Chemical composition of commercial soybean meals according to the origin of the beans

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Muestras comerciales de harina de soja de Argentina (ARG; n = 50), Brasil (BRA; n = 26) y USA (n = 32) se recogieron en Europa para estudiar el efecto del origen del haba de soja sobre la composición química de la harina de soja. En materia seca, las harinas de BRA tuvieron más proteína bruta (PB) que las harinas de USA y ARG (P < 0.001). El contenido en Lys por unidad de proteína fue mayor (P < 0.001) en las harinas de USA que en las harinas de BRA y ARG. Las harinas de soja de USA tuvieron más (P < 0.001) sacarosa y estaquiosa pero menos (P < 0.05) fibra neutro detergente y rafinosa que las harinas de BRA y ARG. El extracto etéreo fue mayor en las harinas de USA (P < 0.01) pero las diferencias fueron cuantitativamente de escaso valor. Las harinas BRA contenían más Fe (P < 0.001) y menos Ca, P y Na (P < 0.01) que las harinas USA. El PDI (índice de dispersibilidad de la proteína), la solubilidad en KOH y la actividad de los inhibidores de tripsina fueron mayores (P < 0.001) en las harinas USA que en las ARG. El HDI (indicador de daño de la proteína por calor; Evonik, Hanau, Alemania) fue menor (P < 0.001) en las harinas USA que en las ARG y menor en ambas que en las harinas BRA. Los datos muestran que la composición química, la calidad de la proteína y el valor nutricional de las harinas de soja dependen del origen de las habas. Consecuentemente, los nutricionistas deberían usar diferentes matrices para las harinas de soja en función del origen del haba.

Palabras claves: perfil de aminoácidos; solubilidad en KOH; indicadores de calidad de proteínas; origen de la soja

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Commercial samples of soybean meals (SBM) from Argentina (ARG; n = 50), Brazil (BRA; n = 26), and USA (n = 32) were collected in Europe to study the effect of origin of the beans on chemical composition of the SBM. The two samples from India were not used in the statistical evaluation. On dry matter basis, the BRA meals had more CP than the USA and ARG meals (P < 0.001). Lys content per unit of CP was higher (P < 0.001) in the USA than in the South American meals. The USA meals had more sucrose and stachyose (P < 0.001) and less (P < 0.05) neutral detergent fiber and raffinose than the BRA and ARG meals. Ether extract was highest for the USA meals (P < 0.01). The BRA meals had more Fe (P < 0.001) but less Ca, P, and Na (P < 0.01) than the USA meals. Protein dispersability index, KOH solubility, and trypsin inhibitor activity were higher (P < 0.001) for the USA meals than for the ARG meals. Heat damage index (HDI), an indirect measurement of the incidence of Maillard reactions (Evonik, Hanau, Germany) was lower (P < 0.001) for the USA than for the ARG meals and lower for both than for the BRA meals. The data show that the chemical composition, protein quality and nutritive value of the SBM depend on the origin of the beans. Consequently, nutritionists should use different matrixes for the commercial SBM according to the origin of the beans.

Keywords: amino acid profile; KOH solubility; protein quality indicators; soybean origin

Introduction

Soybean meal (SBM) is the main protein source in non-ruminant diets. The meal is characterized by its high crude protein (CP) content and excellent amino acid (AA) profile and availability (Ravindran et al., 2014). Argentina (ARG), Brazil (BRA), and USA are the three main exporter countries for this ingredient. Most nutritionist analyze moisture, crude fiber (CF), CP,and urease activity (UA) for estimating the nutritive value of the SBM but little attention is paid to the influence of the origin of the bean on the characteristics and nutrient content of the meals. However, factors such as bean genotype, planting production area, type of soil, agricultural practices, and environmental conditions during the growing season and storage affect the chemical composition and nutritive value of the soybeans and SBM (Westage et al., 2000; Karr-Lilienthal et al., 2004; García-Rebollar et al. 2016). The most important antinutrional factors present in raw beans are the trypsin inhibitors (TI) which are inactivated by heat. However, an excess of heat increases the incidence of Maillard reactions, reducing its nutritive value (Fontaine et al., 2007). The determination of TI and Maillard reactions is difficult and expensive. Urease activity, protein dispersibility index (PDI) and protein solubility in KOH are the main methods used by the industry to evaluate the quality of the SBM. The objective of this research was to study the influence of the origin of the beans (ARG, BRA, ID and USA) on chemical composition of soybean meal.

Materials and methods

Representative samples (1-3 kg) of SBM from ARG (n = 50), BRA (n = 26), and USA (n = 32) were collected for two consecutive years by specialized quality control personnel at the arrival of the vessels to Europe or at the exit of the European crushing plant for SBM precedent of beans of known origin.

At arrival to the laboratory, samples were stored in hermetic plastic containers until analyses. The samples were ground using a hammer mill (Model Z-I, Retsch, Stuttgart, Germany) fitted with a 0.50 mm screen and analyzed for moisture by oven-drying (method 930.15), ash with a muffle furnace (method 942.05), and nitrogen (N) by Kjeldahl (method 988.05) as described by the AOAC International (2005). Crude protein content was calculated as N x 6.25. Ether extract (EE) was analyzed by Soxhlet after 3N HCl hydrolysis (method 4.b) as described by Boletín Oficial del Estado (1995). Sucrose and oligosaccharides (stachyose and raffinose) were determined as indicated by de Coca-Sinova et al. (2008). Crude fiber content was determined by sequential extraction with diluted acid and alkali (method 962.09; AOAC International, 2005) and the neutral detergent fiber (NDF) as described by van Soest et al. (1991). All samples were analyzed in duplicate in the same lab by the same technician. Macrominerals and trace elements were analyzed as described by Hermida et al. (2006). The contents in indispensable AA and Cys, were determined by NIRS (Fontaine et al., 2001). Urease activity (mg N/g) was determined as indicated by Boletín Oficial del Estado (1995) and KOH as described by Araba and Dale (1990). The PDI was measured according to method Ba 10-65 of the AOCS (2000) using a Hamilton blender (Model G936, VOS Instrument, Zaltbommel, The Netherlands), and TI activity (TIA), expressed in mg/g DM, according to the method of Hamerstrand et al. (1981). The HDI was determined using the AMINORED method as proposed by Evonik (2010).

Data were analysed as a completely randomized design using the GLM procedure of SAS (SAS Institute Inc., 1990). The main effect of the model was the country of origin of the SBM. When the model was significant, the Tukey test was used to make pairwise comparisons between treatment means. India meals were not included in the model because the number of samples was not representative.

Results and discussion

On DM basis, CP was higher ($P < 0.001$) for the BRA than for the USA meals with the ARG meals being intermediate (*Table 1*). Most available studies (Thakur and Hurburgh, 2007; Frikha et al., 2012; Ravindran et al., 2014), reported that BRA SBM had more CP than USA SBM, in agreement with the data of the current research. However, Park and Hurburgh (2002) reported that CP content was higher for USA beans than for BRA and ARG beans. The discrepancies reported among authors might be

related to differences in the genotype and planting area of the beans, as well as to the proportion of hulls added to the meal after oil extraction. Ether extract, sucrose, and stachyose were higher ($P < 0.01$) and raffinose and NDF lower ($P < 0.05$), for the USA than for the BRA and ARG meals, in agreement with data reported by García-Rebollar et al. (2016). The data show that fiber content of the SBM depends not only on the amount of hulls added to the meal but also on the geographical area of planting, the latitude and day length and the growing season.

Table 1 Chemical composition (%) of the soybean meals[*] (on dry matter basis)

	ARG	BRA	USA	Standard deviation	P-value[**]
Dry matter	88.3	88.7	88.6	0.777	0.078
Ash	7.94[a]	7.91[a]	7.70[b]	0.316	0.004
Crude protein	52.7[b]	54.4[a]	52.6[b]	1.220	<0.001
Ether extract	1.67[b]	1.65[b]	1.96[a]	0.434	0.007
Sucrose	7.38[b]	6.24[c]	8.29[a]	0.837	<0.001
Stachyose	5.02[b]	4.79[b]	5.68[a]	0.598	<0.001
Raffinose	1.41[b]	1.64[a]	1.21[c]	0.218	<0.001
Crude fiber	4.82	4.88	4.83	0.806	0.958
Neutral detergent fiber	10.8[a]	10.0[a]	9.76[b]	1.936	0.039

[a, b, c] Within a row, means without a common superscripts differ ($P < 0.05$).
[*] n = 50, 26, and 32 Argentina (ARG), Brazil (BRA), and USA soybean meals, respectively.
[**] Statistical analysis corresponds to the USA, BRA, and ARG meals, exclusively.

Calcium and Na contents were higher ($P < 0.01$) and Fe content lower ($P < 0.001$) for the USA than for the BRA and ARG meals (*Table 2*). The differences in content reported for most minerals, were due probably to differences in soil characteristics, fertilization rate used, and the availability to the plant (Westage et al., 2000).

Table 2 Macromineral (%) and trace mineral (mg/kg) content of the soybean meals[*] (on dry matter basis)

	ARG	BRA	USA	Standard deviation	P-value[**]
Macrominerals					
Ca	0.43[b]	0.42[b]	0.38[a]	0.061	0.001
P	0.78[a]	0.74[b]	0.77[a]	0.037	<0.001
K	2.56[a]	2.44[b]	2.46[b]	0.101	<0.001
Mg	0.35[b]	0.38[a]	0.34[b]	0.024	<0.001
Na	0.071[ab]	0.067[b]	0.079[a]	0.014	0.006
Trace minerals					
Zn	49.5[c]	57.7[a]	54.6[b]	4.75	<0.001
Mn	52.8[a]	41.9[b]	38.0[b]	7.97	<0.001
Fe	117[b]	178[a]	117[b]	38.2	<0.001
Cu	17.3	16.6	17.1	1.79	0.262

[a, b, c] Within a row, means without a common superscripts differ ($P < 0.05$).
[*] n = 50, 26, and 32 Argentina (ARG), Brazil (BRA), and USA soybean meals, respectively.
[**] Statistical analysis corresponds to the USA, BRA, and ARG meals, exclusively.

The AA profile of the SBM varied with the origin of the beans (*Table 3*). On CP bases, Arg and Lys contents were higher ($P < 0.001$) for the USA that for the BRA and ARG meals. Similarly, total sulfur AA and Trp concentrations were greater ($P < 0.001$) for the USA than for the BRA and ARG meals. As a result, the concentration of the five critical AA (Lys, Met+Cys, Thr, and Trp) in the protein fraction was higher for the USA meals than for the BRA and ARG meals, in agreement with data of García-Rebollar et al. (2016).

Table 3 Amino acid (AA) profile (% crude protein) of the soybean meals*

	ARG	BRA	USA	Standard deviation	P-value**
Indispensable AA					
Arg	7.202[b]	7.211[b]	7.273[a]	0.054	<0.001
His	2.583[a]	2.569[b]	2.576[ab]	0.016	0.001
Iso	4.547[b]	4.594[a]	4.516[c]	0.030	<0.001
Leu	7.619[b]	7.650[a]	7.602[b]	0.043	<0.001
Lys	6.098[b]	6.079[b]	6.127[a]	0.044	<0.001
Met	1.336[b]	1.318[c]	1.351[a]	0.016	<0.001
Phe	5.087[b]	5.134[a]	5.063[c]	0.016	0.001
Thr	3.884[a]	3.865[b]	3.874[ab]	0.024	0.004
Trp	1.352[b]	1.356[b]	1.368[a]	0.011	<0.001
Val	4.753[a]	4.743[ab]	4.731[b]	0.023	<0.001
Dispensable AA					
Cys	1.422[b]	1.430[b]	1.462[a]	0.021	<0.001
∑ Five key AA		14.05[b]	14.09[b]	0.089	<0.000
∑ Ten key AA		45.95	45.88	0.161	0.115

[a, b, c] Within a row, means without a common superscripts differ (P < 0.05).
* n = 50, 26, and 32 Argentina (ARG), Brazil (BRA), and USA soybean meals, respectively.
** Statistical analysis corresponds to the USA, BRA, and ARG meals, exclusively.

Protein quality indicators differed among SBM (*Table 5*). The PDI was higher for the USA (P < 0.001) than for the BRA and ARG meals. KOH solubility and TIA were higher for the USA and BRA meals (P < 0.001) than for the ARG meals. However, HDI was lower (P < 0.001) for the USA than for the ARG meals and lower for both than for the BRA meals.

Table 4 Protein quality indicators of the soybean meals*

	ARG	BRA	USA	Standar deviation	P-value
Urease activity, mg N/g	0.004	0.006	0.009	0.012	0.274
Protein dispersability index (%)	10.3[c]	12.7[b]	14.3[a]	2.230	<0.001
KOH protein solubility (%)	71.9[b]	79.0[a]	80.4[a]	4.486	<0.001
Trypsin inhibitor activity (mg/g DM)	1.91[b]	2.83[a]	3.04[a]	0.623	<0.001
Heat damage index+	15.3[b]	18.4[a]	12.3[c]	4.079	<0.001

[a, b, c] Within a row, means without a common superscripts differ (P < 0.05).
* n = 50, 26, and 32 Argentina (ARG), Brazil (BRA), and USA soybean meals, respectively.
** Statistical analysis corresponds to the USA, BRA, and ARG meals, exclusively.
+ Values varied from 0 (lowest damage of crude protein) to 40 (highest damage of crude protein).

It is concluded that the chemical characteristics, protein quality, and nutritive value of the soybean meal differ according to the country of origin of the original meals. Consequently, it is recommended to use different matrixes for soybean meals of different origins in feed formulation.

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