Nutritional value of soybean meal: Influence of origin and opportunities for improvement

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High protein SBM, 47% CP

Energy content, poultry

Institution	Year	CP (%)	AMEn (Mcal/kg)
NRC	1994	48.5	2.44
INRA	2002	47.2	2.32
Japan	2009	47.1	2.47
Fedna	2010	47.5	2.38
CVB	2011	47.5	2.22
Brazil	2011	48.1	2.30

SBM, 47% CP

Proximal analyses, %

	NRC (1994)	INRA (2002)	Japan (2009)	Fedna (2010)	Braz (2011)	CVB (2011)
MOI	10.0	12.4	11.0	12.0	10.8	12.6
CP	48.5	47.2	47.0	47.0	48.1	47.5
EE	1.0	1.5	1.6	1.9	1.5	1.8
Ash	6.3	6.3	6.4	6.2	5.7	6.5
NDF	8.5	8.9	11.1	9.1	14.9	8.2
Σ	74.3	76.3	77.1	76.2	81.0	76.6

What is missing?

AMEn content of SBM[1]

European tables

AMEn = 37.5 x CP + 46.4 x EE + 14.9 x NFE

- ✓ Digestibility of the CP fraction?
  - × 83-93%
- ✓ How ether extract is determined?
  - × 1.0 *vs.* 2.2% EE content (HCl hydrolisis?)
- ✓ What is the composition of the NFE fraction?
  - × Sucrose (4 to 9%) *vs.* pectins *vs.* lignin

[1] Jansen, 1989 (kcal/kg)

Objectives

- ✓ To test the effects of origin of the beans on chemical characteristics and nutritive value of commercial SBM
- ✓ To verify the need of using different matrixes of chemical composition and nutritive value for SBM according to the origin of the beans

SBM survey, Spain
Laboratory studies

- ✓ Samples collected from 2007 to 2013
  - × Country of origin (63%) and European ports (37%)
- ✓ Analysis conducted in duplicate
  - × Proximal, AA, sugars, and minerals
  - × Amino acids (NIR)
  - × TIA, KOH, PDI, urease, HDI (AminoRed)
- ✓ Same lab, same technician

EU survey, 2007-2013

Origin of the samples

n = 491

SBM survey

Chemical composition[1], 88% DM

	n	CP	CF	NDF	EE
ARG	158	45.5^{c}	4.7^{b}	9.1^{b}	1.7^{ab}
BRA[1]	148	46.7^{b}	5.5^{a}	10.5^{a}	1.8^{a}
USA[2]	185	47.2^{a}	3.8^{c}	7.8^{c}	1.6^{b}
SEM		0.13	0.08	0.14	0.04
P		***	***	***	**

[1]SBM, 48% CP and profat
[2]Mississippi river and East Cost procedure

SBM survey

Mineral and sugars, 88% DM

	n	Ash	P	Fe	Sucrose	Oligo.[1]
ARG	128	6.6[a]	0.66[b]	109[b]	6.7[b]	6.1[b]
BRA	136	6.3[b]	0.62[c]	168[a]	5.7[c]	6.0[b]
USA	168	6.6[a]	0.69[a]	113[b]	7.3[a]	6.6[a]
SEM		0.04	0.005	4.3	0.08	0.05
P		***	***	***	***	***

[1]Stachyose+raffinose. Brazil higher raffinose content

SBM survey

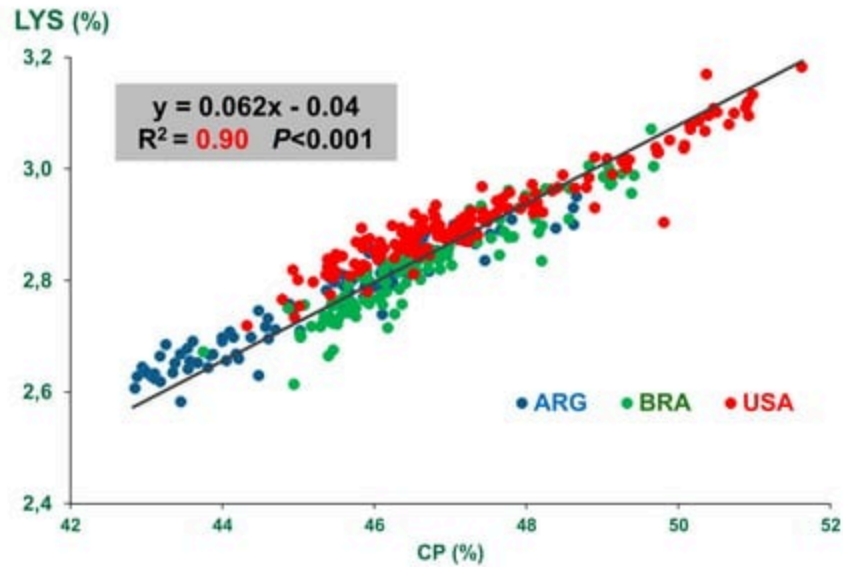
Amino acid profile, % CP

	n	Lys	TSAA	Thr	Trp
ARG	141	6.10[b]	2.87[a]	3.93[a]	1.37[a]
BRA	144	6.05[c]	2.81[b]	3.88[b]	1.34[c]
USA	183	6.16[a]	2.87[a]	3.91[a]	1.36[b]
SEM		0.005	0.005	0.002	0.001
P		***	***	***	***

n = 451

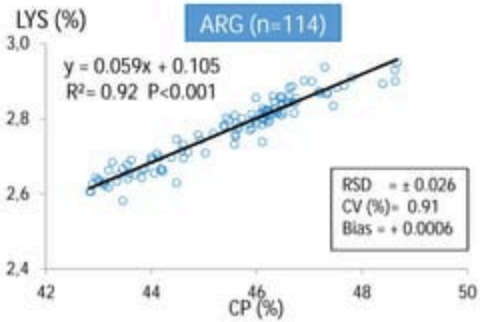
SBM, all origins (n=403)

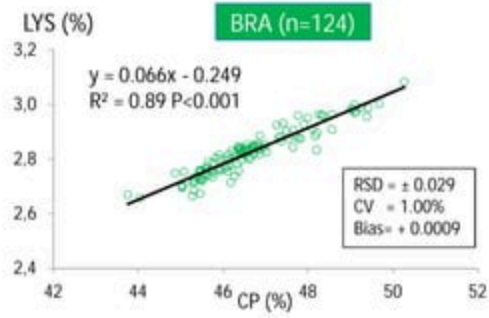
LYS:CP ratio

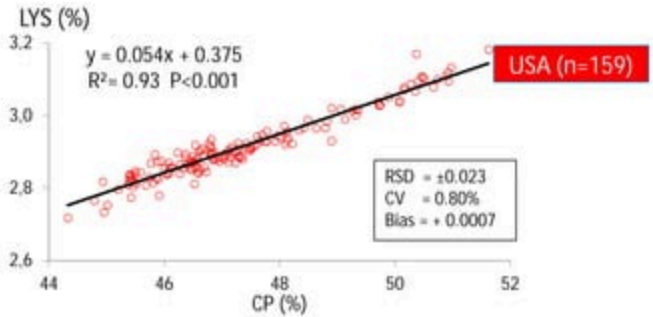


SBM by origin

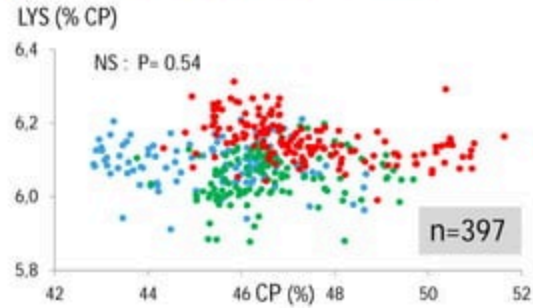
CP vs. Lys content



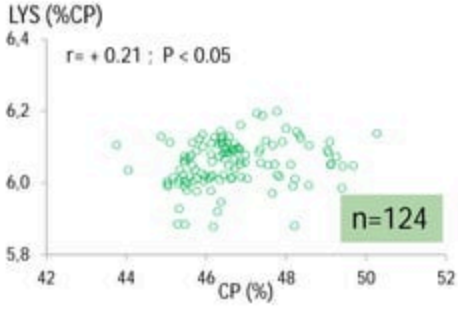




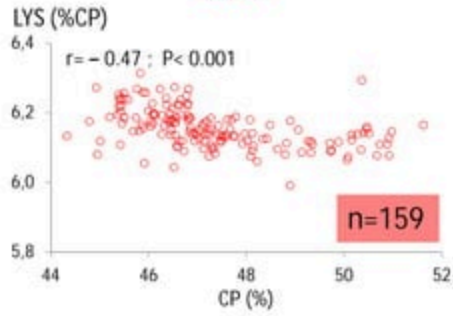
SBM by origin vs. Lys profile



BRA



USA



SBM protein quality
Industry standards

▪ KOH solubility, %:	75-85
▪ PD index, %:	15-30
▪ Urease activity, mg N/g:	0.00-0.10
▪ TI activity, mg/g:	< 2.2-3.5

"Poor agreement between Research Institutions and Industry for suitable values for protein quality of SBM"

SBM protein quality

Survey

	n	TIA (mg/g)	PDI (%)	KOH (%)	HDI AminoRed[2]
ARG	135	2.5[b]	16.3[b]	81.5[c]	12.5[b]
BRA	135	2.6[b]	15.3[c]	82.6[b]	15.6[a]
USA	170	3.1[a]	19.5[a]	86.4[a]	9.0[c]
SEM		0.05	0.34	0.33	0.38
P		***	***	***	***

[1] Urease < 0.03 mg N/g for all origins ($P < 0.01$)
[2] Evonik-Degussa

SBM quality
Length of storage

Item	Storage (d)					SEM (n = 8)
	0	30	60	90	120	
Urease activity[1]	0.00	0.00	0.00	0.00	0.00	0.00
PDI[2] (%)	21.9[a]	21.5[a]	20.1[b]	18.8[c]	17.7[d]	0.21
KOH solubi.(%)	83.8	83.6	83.2	83.8	83.8	0.47
TIA[3]	3.0	3.1	3.0	3.0	3.0	0.072

[1]mg N/g x min
[2]Linear effect, P < 0.001
[3]mg/g SBM

JAPR, 2013

SBM survey
AminoRed (HDI[1])

	Year	ARG	BRA	USA
Evonik[2]	2007	14.6	14.3	6.9
	2008	13.1	12.6	9.7
	2009	11.9	13.9	7.3
	2010	13.3	13.7	9.6
	2011	13.6	15.5	9.5
	2012	11.8	15.4	3.1
	2013	12.9	11.6	4.5
UP Madrid	n	96	113	150
		12.7[b]	15.5[a]	9.0[c]

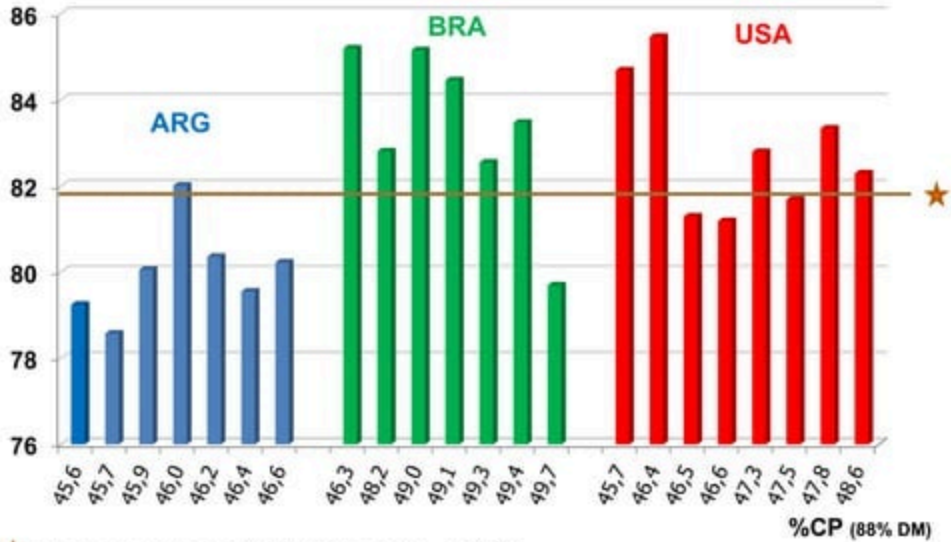
[1]Heat Damage Indicator
[2]n > 2,500 to 2011 and > 4,800 in 2013
[3]n = 359 (P<0.001), SEM = 0.42 (2007 a 2013)

Soybeans storage Argentina

Soybeans storage Argentina

SBM

SID (%) of Cys



★ Adapted from FEDNA (2010) for SBM, 47%CP

Anim. FST, 2012

SBM, all origins[1]

SID of CP *vs.* quality indexes

Variable	*r*	*P*
Crude protein	+ 0.51	0.05
Reactive lys	+ 0.56	0.01
KOH solubility	+ 0.70	0.001
TI activity	+ 0.54	0.01

[1] Broiler trial (n = 22 SBM of 3 origins) Frikha *et al.*, 2012

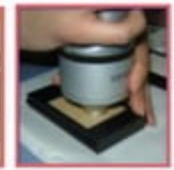
Soybean meal color

- ✓ Heating and processing

- ✓ Particle size

- ✓ Country of origin

Soybean meal colour[1]



	n	Lightness L*	Redness a*	Yellowness b*
ARG	87	67.2[b]	6.5[b]	25.2[b]
BRA	95	65.0[c]	7.6[a]	24.6[c]
USA	148	70.7[a]	6.0[c]	26.3[a]
SEM		0.28	0.10	0.14
P		***	***	***

[1] Minolta (ground at 1mm)

SBM correlations (r, P <)

Protein quality vs. color variables

All origins[1,2]	PDI	KOH	UA	TIA
Lightness L*	63***	52***	14*	56***
Redness a*	- 67***	- 50***	- 23***	-56***
Yellowness b*	12***	31***	- 18**	NS

[1] n = 347
[2] Ground at 1 mm

SBM[1]

TIA vs. color variables (r, P<)

	ARG	BRA	USA	All
n	89	102	156	347
L*	58***	27**	55***	56***
a*	- 49***	- 26**	- 65***	- 56***
b*	ns	ns	- 17*	ns

[1] Ground at 1 mm

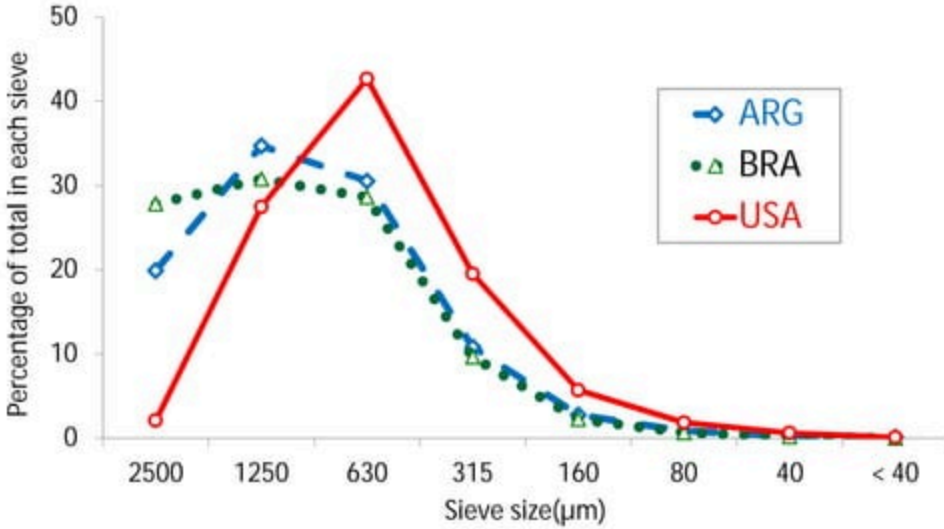
Average particle size

SBM origin

	n	GMD[1]	SD
ARG	91	1,363[b]	472
BRA	92	1,522[a]	474
USA	85	856[c]	168
SEM		50.4	
P		* * *	

[1]GMD: Geometric mean diameter.
7 Sieves (µm) : 2500, 1250, 660, 330, 80, 40 and residue

Particle size distribution in SBM by origin[1]



[1]n=268

Soybean meal
Qualitative analysis (NIRS)

324 samples

NIRS 5000 (1,100-2,500 nm)

As received

n = 255

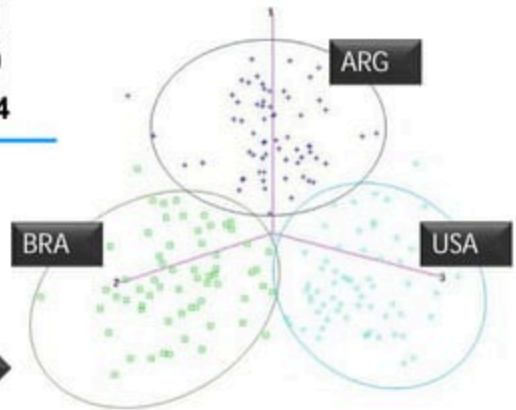
n = 69

Training set 2/3 of samples origins

Validation set 1/3 of samples

Soybean meal validation set (NIRS)

Origin	n	ARG	BRA	USA
ARG	20	19	0	1
BRA	13	0	13	0
USA	36	2	0	34



Correctly classified = 96%

Validation SBM survey
Main findings (88% DM)

	Argentina		Brazil		USA	
	5 y[1]	12/13	5 y[1]	12/13	5 y[1]	12/13
n	130	22	112	27	148	26
CP	45.4	45.9	46.5	47.1	47.5	46.0
NDF	9.4	7.7	10.5	10.2	7.8	8.0
Sucrose	6.7	7.3	5.8	5.6	7.2	8.2
Total P	0.65	0.76	0.61	0.63	0.69	0.68
Fe	1126	116	1936	171	1176	101
Lys (% CP)	0.09	6.14	0.05	6.04	0.15	6.14

[1]2007-2011

Validation SBM survey
Protein quality

	Argentina		Brazil		USA	
	5 y[1]	2012	5 y[1]	2012	5 y[1]	2012
n	112	17	109	27	148	20
PDI (%)	17.1	13.2	15.2	15.8	19.9	18.1
KOH sol. (%)	82.5	75.0	83.6	77.7	87.3	82.0
HDI (Evonik)	13.2	8.9	16.2	12.7	9.7	3.9
TIA (mg/g)	2.5	2.3	2.5	2.7	3.2	2.7

[1]2007-2011
[2]Kakade, method (88% DM)

SID (%) of SBM in broilers

New Zealand, Exp. 1

	USA (n = 3)	ARG (n = 4)	BRA (n = 3)	IND (n = 4)
Lys	91.0[a]	90.9[a]	89.9[a]	87.4[b]
Met	89.5[ab]	89.7[a]	89.9[a]	87.2[b]
Cys	76.3[a]	71.4[ab]	70.6[ab]	62.9[b]
Thr	83.3[a]	83.4[a]	83.1[a]	79.8[b]
Avge AA	87.0	86.6	86.1	83.2
AMEn[1]	2,146[a]	2,112[a]	2,128[a]	1,861[b]

[1]Kcal/kg, as fed

Ravindran and Bootwalla, 2011

SID (%) of SBM in broilers

New Zealand, Exp. 2

	USA (n = 7)	ARG (n = 6)	BRA (n = 3)	IND (n = 4)
CP	85.7	84.7	83.2	78.2
Lys	87.8	86.8	85.1	80.1
Cys	74.6	69.8	67.9	57.3
Met	88.5	87.6	85.6	82.8
Thr	82.5	81.1	78.4	73.8
Avge AA	85.6	84.3	82.5	77.9

Ravindran, 2013

SID (%) of Lys of SBM (range)
Broilers (New Zealand, Exp. 2)

	USA (n = 7)	ARG (n = 6)	BRA (n = 3)	IND (n = 4)
Total Lys (% CP)	4.94 6.61	5.30 6.39	5.52 5.77	4.79 6.39
SID Lys (%)	84.4 90.6	82.0 88.5	82.7 88.2	76.3 83.3
React. Lys (%)	96.4	90.5	93.5	89.7

Ravindran, 2013

Experimental diets

Assumptions

- ✓ HP-SBM had 100 kcal more AMEn than R-SBM
- ✓ Determined AA content
  - ✗ Same availability for all AA
- ✓ Three ratios Lys:ME for each SBM
  - ✗ Low: 380
  - ✗ Medium: 415
  - ✗ High: 450

De Coca *et al.*, 2010

SBM quality

Broiler performance

	R-SBM	HP-SBM
CP, %	46.3	48.6
Total Lys, %	2.75	3.04
Sucrose, %	5.8	6.7
NDF, %	10.2	7.0
TIA, mg/kg	4.8	1.8
KOH sol., %	80.7	84.3
AMEn	2,200	2,300

De Coca *et al.*, 2010

Broiler performance, 1-10 d

Main effects[1]

	ADG (g)	FCR (g/g)
SBM type		
R-SBM	22.3[b]	1.225[a]
HP-SBM	23.5[a]	1.168[b]
SEM (n = 30)	0.24	0.005
Lys:ME ratio		
Low	21.3[c]	1.275[a]
Medium	23.0[b]	1.181[b]
High	24.3[a]	1.133[a]
SEM (n = 20)	0.30	0.006

[1] Interaction ($P < 0.01$): Higher positive response of the use of HP-SBM at the low CP level of the diet

De Coca *et al.*, 2010

Improvement in digestibility

Soybean meal

- ✓ Processing conditions
  - × TIA vs. Maillard reactions
- ✓ Origin of the beans
  - × Growing, storage conditions
- ✓ Gastrointestinal conditions in the bird
  - × Gizzard function and pH
  - × Pepsine activity
- ✓ Use of enzymes
  - × Proteases

Classification of proteases

- ✓ Origin
  - ✖ Bacteria, fungi (fermentation)
  - ✖ Animal and plants (extraction)
- ✓ pH range
  - ✖ Acid, neutral, alkaline
- ✓ Bond specificity
  - ✖ Endo- and exopeptidases
  - ✖ Specific (AA) protease

Angel, 2012

Bond specifity

Serine proteases

- ✓ Examples
  - × Trypsin and ch**ymotrhypsin**
  - × Elastase
  - × Enteroquinase
- ✓ PROACT
  - × Bacterial
  - × Alkaline
  - × Serine protease

Protease and fullfat soybeans

AID of amino acids, %

	Control	Protease 200 mg/T	P
Arg	81.9	86.0	**
Lys	82.5	84.0	+
Cys	48.8	59.5	**
Met	80.7	85.0	**
Thr	63.2	69.8	**

Rostagno et al., 2009

General comments
USA SBM vs. others

- ✓ Brazil
  - × Less sucrose and P and more fiber and Fe
  - × Less indispensable AA per unit of CP
  - × Lower KOH, PDI, and HDI (lower AA digestibility)
- ✓ Argentina
  - × Less CP
  - × Lower KOH, PDI, and HDI (lower AA digestibility)
- ✓ India
  - × More ash, crude fiber, and Fe (less energy)
  - × Less fat, sucrose, and indispensable AA per unit ofCP
  - × Lower KOH (lower AA digestibility)

General conclusions

- ✓ Current methods used by the industry to evaluate protein quality are not capable of detecting existing differences among SBM
- ✓ The composition and the protein quality of SBM vary with the origin of the bean
- ✓ Different matrixes should be used for SBM of different origins, NIR technology might help
- ✓ Proteases might improve the uniformity and nutritive value of SBM batches



Thanks