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Article

Evaluation of two soybean soapstocks in egg production and quality in Bovans hens

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Abstract:

Crude soybean oil (CSO) is used to increase metabolizable energy (ME) content in diets for laying hens. Also used in human food, its price is consequently high. Oil soapstocks are byproducts of the oil extraction process and therefore cost less. An evaluation was done of the effect of two soybean soapstocks (SS) on egg production, quality and lipid composition, and the cost of 1 kilogram of eggs. Soapstock ME and lipid composition were quantified. An experiment was done using 240 hens in six treatments, with five replicates and eight hens per replicate. Diets were formulated using CSO, or one of the soapstocks, at 2 or 4% concentrations. The evaluated productive variables were feed intake, feed conversion, egg weight, egg mass, laying percentage and egg quality parameters. Egg lipid composition was described and the cost per one kilogram calculated. Replacement of CSO with the soapstocks did not affect poultry production variables (*P*>0.05), but did improve Haugh unit values (*P*<0.05). Egg fatty acids composition changed in response to oil composition (*P*<0.05), and inclusion concentration affected the levels of specific fatty acids. Use of the soapstocks resulted in a lower cost per kilogram of eggs than with CSO (*P*<0.05). Substitution of crude soy oil with the evaluated soapstocks had no effect on productive variables, improved egg quality and lowered overall feed costs.

Key words: Soybean oil, Level, Energy, Fatty acids, Costs.

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Introduction

Concentrated components such as fats and oils are added to poultry diets to meet energy requirements[1]. In laying hens these additives can strongly affect feed costs. Because of its high energy content and unsaturated fatty acids concentration crude soy oil (CSO) is used in poultry feeds[2,3]. These fatty acids are more digestible for poultry than saturated fatty acids (SFA)[4]. However, CSO is expensive since it is also used in human diets. A less costly fatty acids source is soybean soapstock (SS), a byproduct of the oil refining process. This oil contains free fatty acids (58.6%)[1], phospholipids, non-saponifiable chemical ingredients, oxidation compounds, carotenoids and xanthophylls[5,6,7]. Potential use of SS in poultry culture could be limited by two factors. First, its fatty acid content can vary[8] in response to refining method and storage conditions[5]; this is vital since fatty acids content may be the most important factor influencing egg weight (EW) and egg lipids concentration[9]. Second, SS's metabolizable energy (ME) content is lower than that of CSO, a property that depends on free fatty acids content[10]. The present study objective study was to evaluate two SS from different sources in substitution of CSO at two inclusion levels (2% and 4%), and their effects on egg production, quality and lipid composition, and the production cost of one kilo of egg in Bovans White laying hens.

Material and methods

True metabolizable energy (TME)

Oil true metabolizable energy (TME) was analyzed according to Sibbald[11] (Table 1). Experimental animals were twenty-four Bovans White line roosters of 33 weeks of age with an average individual weight per bird of 2.06 ± 0.06 kg. Animals were randomly distributed in three treatments, eight per treatment, with each rooster representing a replicate. Administration of pure oil causes poultry to regurgitate[12], and its liquid state prevents quantification of dry matter (DM)[13]. Due to these physical characteristics, the oils were mixed with ground sorghum at a 90:10 proportion. Sorghum DM was therefore quantified simultaneously with the treatments using six roosters.

Table 1: Oil true metabolizable energy

Oils	**Kcal^{-1}kg**
Crude soy oil (CSO)	8337
Soybean soapstock T (SST)	8296
Soybean soapstock Y(SSY)	8528

Metabolic and endogenous energy were measured. The roosters were allowed to rest for five days and then fasted for 24 hours. Total manure (endogenous and metabolic material) was collected from each animal to ensure that the endogenous portion used in the calculations came from the same animal[14]. Ingredient and excreta gross energy (GE) were measured in two replicates using a isoperibolic calorimetric pump (Parr 1266, model Moline, Illinois, USA).

Production variables and egg quality

A total of 240 Bovans White hens, 30 wk old, were used in this assay. Animals were distributed into six treatments, five replicates per treatment, and eight animals per replicate. Hens were placed two per cage (30 x 45 cm), with linear feeders and automatic drinking troughs in a conventional hut. Photoperiod was 16 h daylight^{-1}, provided by artificial lighting. The experimental period was 16 wk.

Diets were isoenergetic and based on a sorghum-soybean paste (Table 2). They met the laying hen nutritional requirements of the NRC[15] and Cuca *et al*[16]. The diets were kept isoenergetic by varying proportions of sorghum, soybean paste and sand (sterilized in autoclave). Crude soy oil (CSO), soybean soapstock T (SST) and soybean soapstock Y (SSY) were evaluated at two inclusion levels (2 and 4 %), resulting in six treatments: 2%CSO; 4%CSO; 2%SST; 4%SST; 2%SSY; and 4%SSY. During the growth period hens had been vaccinated against newcastle, smallpox, gumboro, bronchitis, encephalomyelitis and infectious coryza. Water and food were freely available.

Table 2: Diet composition and calculated analysis

Ingredients (%)	CSO		SST		SSY	
Oil concentration	2%	4%	2%	4%	2%	4%
Sorghum (8.3% CP)	63.49	57.45	64.08	58.63	64.08	58.63
Soy paste (45.8% CP)	22.32	22.97	22.26	22.84	22.26	22.85
Sand	0.52	3.89	0	2.84	0	2.84
DL- methionine (99%)[1]	0.32	0.33	0.32	0.33	0.32	0.33
Threonine (98.5%)[1]	0.04	0.04	0.04	0.04	0.04	0.04
$CaCO_3$ (38%)[2]	10.05	10.04	10.06	10.04	10.06	10.04
Dicalcium phosphate (18/21)[3]	0.49	0.53	0.49	0.52	0.49	0.52
Vitamins and minerals[4]	0.25	0.25	0.25	0.25	0.25	0.25
Pigment	0.15	0.15	0.15	0.15	0.15	0.15
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Feed cost ($ kg^{-1})[5]	5.02	5.19	4.95	5.06	4.91	4.98
Calculated analysis						
ME, $Kcal^{-1}$ kg	2800	2800	2800	2800	2800	2800
Crude protein, %	15.53	15.23	15.55	15.37	15.55	15.37
Calcium, %	4.00	4.00	4.00	4.00	4.00	4.00
Available phosphorous, %	0.25	0.25	0.25	0.25	0.25	0.25
Lysine, %	0.83	0.83	0.82	0.83	0.82	0.83
Methionine + Cysteine, %	0.78	0.78	0.78	0.78	0.78	0.78
Tryptophan, %	0.19	0.19	0.19	0.19	0.19	0.19
Threonine, %	0.61	0.61	0.61	0.61	0.61	0.61
Linoleic acid, %	1.88	2.90	1.42	1.98	0.94	1.02

[1]Purification percentage.

[2]38%= calcium.

[3]18%= phosphorous; 21%= calcium.

[4]Contents per kilogram feed: vit A, 9000 UI; vit D_3, 2,500 UI; vit E, 20 UI; vit K, 3.0 mg; vit B_2, 8.0 mg; vit B_{12}, 0.015 mg; pantothenic acid, 10 mg; nicotic acid, 60 mg; niacin, 40 mg; folic acid, 0.5 mg; choline, 300 mg; D-biotin, 0.055 mg; thiamin, 2.0 mg; iron, 65.0 mg; zinc, 100 mg; manganese, 100 mg; copper, 9.0 mg; selenium, 0.3 mg; iodine, 0.9 mg.

[5]FND = Financiera Nacional de Desarrollo Agropecuario, Rural, Forestal y Pesquero. Market prices as of 26 August 2016 in Mexico[17].

CSO= crude soy oil; SST= soybean soapstock T; SSY= soybean soapstock Y; ME= metabolizable energy; CP= crude protein.

Data were collected weekly on five production variables: food intake (FI, g/bird/d); laying percentage (LP, %); egg weight (EW, g/d); feed conversion (FC); and egg mass (EM, g). Egg quality was measured using twenty eggs (four per replicate) from each treatment at the beginning of the period and at wk 4, 8 and 12. Four parameters were used to characterize egg quality: albumin height (AH); Haugh units (HU); yolk color (YC) using an Egg Multi Tester (QCM System, Technical Services and Supplies, Dunnington, United Kingdom) which measures yolk color based on the DSM range; and eggshell thickness (ET), taken with a micrometric screw.

Fatty acids analysis

Oil fatty acid profile (Table 3) was analyzed using the AOAC total lipids technique[18]. Egg fatty acids composition was measured using the same eggs used to measure egg quality. These were manually mixed with a blender to create a pooled sample. Lipid extraction was done using the AOAC total lipids technique[19] (923.07), with a gas chromatographer (model 3380 CX, Varian) equipped with a DB23 column (30 m x 0.25 mm id), a CP8400 Autosampler and a flame ionization detector (FID)(USA).

Table 3: Fatty acids profiles in soy oil, soapstocks and experimental diets (%)

	CSO	**SST**	**SSY**	**CSO**		**SST**		**SSY**	
Fatty acids		(%)		2%	4%	2%	4%	2%	4%
Myristic (C14:0)	0.11	0.47	2.78	0.19	0.19	0.20	0.21	0.25	0.30
Palmitic (C16:0)	11.74	11.47	18.22	0.57	0.80	0.57	0.80	0.70	1.06
Stearic (C18:0)	4.17	3.34	19.88	0.81	0.90	0.80	0.86	1.13	1.53
Palmitoleic (C16:1)	0.18	0.33	1.53	0.15	0.16	0.16	0.16	0.18	0.21
Oleic (C18:1)	22.3	43.67	38.88	3.44	3.88	3.86	4.74	3.77	4.55
Linoleic (C18:2)	51.09	28.01	3.95	1.88	2.90	1.42	1.98	0.94	1.02
α-Linolenic (C18:ω3)	7.52	6.59	0.23	0.37	0.52	0.35	0.48	0.22	0.23
Arachidic (C20:0)	0.32	ND	0.51	0.09	0.09	0.08	0.08	0.09	0.10
EPA (C20:5 ω3)	.36	ND	ND	0.02	0.02	0.01	0.01	0.01	0.01
Other fatty acids	0.86	0.94	3.09	0.02	0.03	0.02	0.04	0.06	0.12
Total saturated, %	16.50	16.97	42.49	0.33	0.66	0.34	0.68	0.85	1.70
Total monounsaturated, %	23.67	47.17	49.54	0.47	0.95	0.94	1.89	0.99	1.98
Total polyunsaturated, %	58.97	34.92	4.88	1.18	2.36	0.70	1.40	0.10	0.20

CSO= crude soy oil; SST= soybean soapstock T; SSY= soybean soapstock Y; EPA= eicosapentaenoic acid.

Cost per kilogram of eggs

The cost of each diet was calculated by multiplying the price of each ingredient by the quantity of each in each feed formula. The cost of one kilo of eggs per feed was calculated based on the FI of each treatment and multiplied by the feed cost. Ingredient prices (/kilo) were sorghum, $3.58; soy paste, $7.96; CSO, $16.00; SST, $12.00; SSY, $10.00; DL-methionine, $70.00; threonine, $30.00; $CaCO_3$, $1.50; dicalcium phosphate, $16.00; vitamins, $75.00; minerals, $20.00; salt, $3.50; and pigment, $30.00.

Statistical analyses

Data were analyzed with a completely random design employing a 3x2 factorial arrangement in five replicates: oils (CSO, SST and SSY), and inclusion levels (2 and 4%). Using the SAS statistics package[20], the MIXED procedure was applied and differences between the treatment means compared with a Tukey test ($P<0.05$).

Results and discussion

Values for the productive variables FI, LP, EW, EM and FC did not differ ($P>0.05$) in response to the different oils and levels (Table 4). This coincides with a previous study in which addition of sunflower soapstock did not modify production variables because the diets were isoenergetic and isoproteic[21]. Other studies have also found that inclusion of different oils in laying hen diets does not modify productive variables[22,23].

Table 4. Effect of soy oil and soapstocks on production variables during 16 weeks in Bovans White hens

Oils	FI g/bird/d	LP (%)	EW (g)	EM (g)	FC
CSO	103.04	94.66	59.66	56.41	1.82
SST	102.54	95.35	59.36	56.60	1.81
SSY	101.91	93.83	59.08	55.35	1.82
SE	0.63	0.88	0.25	0.54	0.01
Concentrations (%)					
2	95.04	95.04	59.20	56.20	1.83
4	94.10	94.1	59.53	56.03	1.82
SE	0.72	0.21	0.44	0.52	0.01

FI= feed intake; LP= laying percentage; EW= egg weight; EM= egg mass;
FC= feed conversion (kg feed / kg egg).

CSO= crude soy oil; SST= soybean soapstock T; SSY= soybean soapstock Y.

SE= standard error of the mean.

(P>0.05).

Feed intake (FI) was unaffected because the diets were isoenergetic. Poultry adjust feed intake according to diet energy concentration since they eat to cover energy requirements(24,25). Laying percentage (LP) is also controlled by poultry feed energy content(1). Since all the treatment diets contained 2,800 kcal/kg, LP remained unchanged. Egg weight (EW) did no vary in response to the different concentrations of soybean soapstock, which agrees with a study where substitution of CSO (3.5%) with 25%, 50%, 75% and 100% soybean soapstock had no effect on this variable(26). Addition of oils increases diet energy content and consequently EW(27), which is attributed to the fatty acids, particularly linoleic acid (LA)(28,29). Content of LA in the present diets ranged from 0.94 to 2.9 % (Table 2), which did not affect EW. This coincides with a study in which diets containing from 0.7 to 2.1% LA did not affect EW(30). Egg mass (EM) responds to diet ME(1); the present diets had the same ME levels and therefore did not modify EM. Because FI and EW were unaffected by inclusion of the soybean soapstocks or inclusion levels, feed conversion (FC) did not change between treatments; this coincides with previous reports(26).

Egg quality

Inclusion of both SST and SSY increased HU values (P<0.05), but no differences were observed between different inclusion levels (Table 5). This contrasts with a study in which substitution of CSO (2.6%) with sunflower soapstock (25, 50, 75 and 100%) tended to lower HU values as inclusion level increased(21). However, another study reported that use of soybean soapstock in hen diets had no effect on HU values(26). Neither oil type (CSO, SST, SST) nor level (2 and 4%) affected AH or ST (P>0.05); this agrees with previous studies(21,26).

Table 5: Effect of soy oil and soapstocks on egg quality variables in hens during sixteen weeks

Oils	HU	AH (mm)	ST (mm)	YC (Roche)
CSO	65.65c	5.02	0.36	7.17b
SST	68.82ab	5.24	0.36	7.81a
SSY	68.97a	5.29	0.35	7.07b
SE	0.76	0.09	0.04	0.05
Concentrations (%)				
2	67.89	5.15	3.5	7.30
4	67.73	5.22	0.36	7.40
SE	0.62	0.07	0.03	0.04

HU= Haugh units; AH= albumin height; ST= shell thickness; YC= yolk color (DSM range).

CSO= crude soy oil; SST= soybean soapstock T; SSY= soybean soapstock Y.

SE= standard error of mean.

[abc] Different letters in the same column indicate difference (P<0.05).

Yolk color (YC) was modified by oil type (P<0.05) but not by oil inclusion level. Addition of SST improved yolk color, whereas no changes were observed with the CSO and SSY treatments (Table 5). How an added oil affects YC depends on the xanthophyll content of the seeds from which it was extracted, and the process used to produce the soapstock since bleaching of soybean soapstocks can eliminate xanthophylls[(6)]. The present results coincide with a study in which YC improved in response to replacement of CSO with sunflower soapstock, a phenomenon attributed to oil tocopherol content[(21)]. Soy soapstock is also reported to be an important natural pigment in broilers[(31)]. However, another study found CSO and sunflower soapstock to have no effect on skin pigmentation in chickens[(32)].

Egg fatty acid composition

Fatty acid composition was affected by oil type (P<0.05). Inclusion of SSY increased concentrations of C14:0 and C16:0 (P<0.05) in the egg (Table 6). In contrast, addition of SST lowered C14:0 by 14% and C16:0 by 2%, and CSO lowered C14:0 by 25% and C16:0 by 3%. This is to be expected because these fatty acids were deposited in the egg according to their levels in each oil (Table 3). Neither soybean soapstock modified egg C18:0 levels. Oil diet inclusion levels had no effect on C14:0 or C18:0 levels, but C16:0 (P<0.05) did increase at the 4% level. These results contrast with a previous report in which egg SFA (C14:0, C16:0 and C18:0) composition did not vary between treatments containing different levels of soybean soapstocks[26]. It is yet unclear why some fatty acids are more readily deposited in the egg. Some fatty acids are better metabolized than others, and high SFA content decreases when oils with lower SFA content are added to diets[33].

Table 6: Fatty acid content in eggs in response to oil type and diet inclusion level in Bovans hens

		∑SFA			∑MUFA				∑PUFA								
	14:0	16:0	18:0	16:1	18:1	18:3 LLA α3	20:5 EPA 3	22:6 DHA 3	22:5 DPA 3	18:2 LA 6	18:3 LLA γ6	20:4 ARA 6	∑SFA	∑MUFA	∑PUFA 3	∑PUFA 6	n-6:n-3
CSO	0.33b	25.12b	8.57	2.63b	38.92c	0.74a	0.04	0.93a	0.15a	16.70a	0.24a	1.71b	34.09	41.50	1.87a	18.49a	13.83a
SST	0.38b	25.33ab	7.84	2.76b	41.50b	0.57b	0.07	0.84a	0.11b	12.60b	0.23ab	1.79b	32.13	42.74	1.57b	13.85b	12.58b
SSY	0.44a	25.84a	8.24	3.38a	44.32a	0.29c	0.06	0.60b	0.08c	10.05b	0.10c	1.97a	32.80	45.14	1.00c	11.36c	12.55b
SE	0.01	0.31	0.22	0.06	0.77	0.02	0.03	0.03	0.06	0.55	0.02	0.06	0.88	1.34	0.08	0.40	0.51
Concentration %																	
2	0.37	25.07b	8.23	3.20a	41.80	0.46b	0.06	0.75	0.10b	12.72	0.19	1.89	33.27	43.73	1.38b	14.08b	13.04
4	0.39	25.89a	8.20	2.65b	41.36	0.60a	0.05	0.83	0.12a	13.51	0.19	1.76	32.75	42.52	1.58a	15.03a	12.93
SE	0.01	0.29	0.24	0.04	0.72	0.02	0.02	0.03	0.05	0.58	0.01	0.05	0.70	1.07	0.04	0.32	0.27

SFA= saturated fatty acids; MFA = monounsaturated fatty acids; P= polyunsaturated fatty acids.

CSO= crude soy oil; SST= soybean soapstock T; SSY= soybean soapstock Y; αLLA= α linolenic acid; EPA= eicosapentaenoic acid; DHA= docosahexaenoic acid; DPA= docosapentaenoic acid; LA= linoleic acid; γLLA= γ linolenic acid; ARA= arachidonic acid.

SE= standard error of mean.

abc Different letters in the same column indicate difference (*P*<0.05).

Inclusion of SSY increased concentrations of the monounsaturated fatty acids (MUFA) C16:1 and C18:1 (*P*<0.05). Addition of SST decreased C16:1 by 18% and C18:1 by 6%, while CSO reduced C16:1 by 22% and C18:1 by 12%. Concentrations of C16:1 responded to oil inclusion level since levels were higher at the 2% level (*P*<0.05); C18:1 concentration was unaffected by inclusion level. These results differ somewhat from those of a study in which no changes were observed in C16:1 and C18:1 concentrations in eggs when CSO was substituted by soybean soapstock at 25, 50, 75 and 100%[26].

Content of the polyunsaturated fatty acid (PUFA) C18:3 ω3 was higher (*P*<0.05) with addition of CSO in the diet and decreased with inclusion of SST (23%) and SSY (61%). This is to be expected since yolk PUFA composition, and especially C18:3 ω3, is influenced by feed oil profile[34,35,36]. Levels of C18:3 ω3 increased at the 4% oil inclusion level (*P*<0.05). This is consistent with a reported increase in C18:3 ω3 when diet oil content was raised from 1.5 to 3%[23].

Eicosapentaenoic acid (EPA) levels did not change (*P*>0.05) in response to addition of different oils or inclusion level. However, docosahexaenoic acid (DHA) and docosapentaenoic (DPA) acid levels tended to increase in the egg (*P*<0.05) when CSO and SST were added to the diet, whereas they decreased with addition of SSY. This was probably due to the high C18:3 ω3 content in the CSO and SST (Table 3), which desaturase and elongase enzymes transform into EPA and subsequently DHA and

DPA[37,38]. Soapstock inclusion level had no effect on DHA levels (*P*>0.05), but DPA levels did increase at the 4% level (*P*<0.05).

Levels of the PUFA C18:2 ω6 in the CSO treatment were 25 % higher than with SST and 40 % higher than with SSY (*P*<0.05); this was probably due to the respective contents of this acid in each oil. The content of C18:2 ω6 was not affected by oil inclusion level (*P*>0.05). Addition of CSO and SST reduced (*P*<0.05) C20:4 ω6 content in the egg, but SSY increased it. This may be because the SSY contained 0.23% C18:3 ω3 while the CSO had 7.52 % and the SST 6.59 % (Table 3). High C18:3 ω3 concentrations are known to limit synthesis of C20:4 ω6 since both acids use the Δ-desaturase enzyme[39] due to competition between n-3 and n-6 for the same enzymes for biosynthesis[34,40].

Total egg SFA and MUFA contents were unaffected by oil type and inclusion level (*P*>0.05). This was not true for the PUFA n-3, which decreased 16 % with SST and 47 % with SSY, and n-6, which decreased 27 % with SST and 38 % with SSY (*P*<0.05). Higher oil inclusion level increased (*P*<0.05) both n-3 and n-6 contents (Table 6).

Both n-6 and n-3 fatty acids are important in human nutrition, and maintaining a 4:1 n-6/n-3 ratio is vital to overall human health[41,42]. During gestation n-3 fatty acids function as structural components in the brain and retina, and contribute to normal growth and development in the infant[43]. High levels of n-6 promote cardiovascular diseases, and an adequate n-6/n-3 balance can diminish and prevent obesity[44]. Addition of oils rich in n-3 (e.g. flax seed) to hen diets can raise n-3 levels in the egg and help to improve the n-6/n-3 ratio[33]. Compared to eggs from the CSO treatment, those from the soybean soapstock treatments had a lower n-6/n-3 (*P*<0.05); these eggs had a lower n-3 content as well as a lower n-6 content. Diet oil inclusion level did not influence the n-6/n-3 ratio, which agrees with previous findings of no effect on this ratio in response to addition of CSO (11.90) and soybean soapstock (13.75)[26].

Cost per kilogram of eggs

Compared to the cost per one kilogram of eggs in the CSO treatment, the cost in the SST dropped 2.68% and that in the SSY by 2.03% (*P*<0.05) (Table 7). At the 4% inclusion level the cost per one kilogram increased by 1.8 % over the 2% level (*P*<0.05).

Table 7: Production cost of one kilogram of eggs by oil addition treatment

Oil	**Cost per 1 kg eggs**
CSO	9.32a
SST	9.07b
SSY	9.13b
SE	0.07
Concentrations (%)	
2	9.09b
4	9.26a
SE	0.04

CSO= crude soy oil; SST= soybean soapstock T;
SSY= soybean soapstock Y.
SE= standard error of mean.
[ab] Different letters in the same column indicate significant difference (P<0.05).

Conclusions and implications

The evaluated soybean soapstocks have different fatty acid profiles and metabolizable energy contents. Both can be used in laying hen diets as an alternative metabolizable energy source to costlier crude soy oil. They do not affect productive variables and improve egg quality (Haugh units). The type and concentration of oil added to the diet modified egg fatty acid profile. Inclusion of soybean soapstocks in laying hen diets decreased the production cost of one kilogram of eggs.

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