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QUALITY CONTROL OF COMMERCIAL FULL-FAT SOYBEANS

by

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INTRODUCTION

Considerable knowledge has been accumulated over the years to quantify the need and the effects of heat treatment in soybean meal (SBM) for animal feeding (Carvens and Sipos, 1958; Liener, 1958; Balloun, 1980). Although full-fat soybeans (FFSB) as an animal feed ingredient may appear fairly related to SBM, in practice FFSB is a different ingredient with different nutritional composition, and processing conditions than SBM. Therefore, in the quality control (QC) of FFSB processing, not necessarily the same parameters used to estimate optimum SBM quality apply to FFSB.

European workers (Matrai *et al.,* 1996; Waaijenberg, 1996) have reported practical QC parameters for FFSB which are specified according to the intended animal species and age of feeding. However, limited information is available correlating specific QC, or laboratory estimators with actual performance of broiler chickens to market age. Therefore, the objective of this presentation is to correlate laboratory determinations conducted on representative samples of commercial FFSB lots with the actual performance data derived from feeding trials using the same FFSB lots with broiler chickens.

EXPERIMENTS

Two different experiments were conducted at the National University of Colombia (South America) to determine the optimum processing conditions to produce commercial FFSB by two different methods: wet-extrusion and dry toasting. In both experiments, treatments consisted of raw soybeans processed at different temperatures and lengths of time, formulated in a single broiler feed and fed to broiler chickens from day-old to 42 days. The design, results and conclusions for each of these experiments are published elsewhere (Perilla *et al.,* 1997; Ordonez and Palencia, 1998). Representative samples of the FFSB used in each treatment for the two experiments were obtained to run laboratory testing and correlate these results with the published performance of broilers at 42 days of age. Additionally, results of *in vivo* amino acid digestibility conducted for each FFSB sample are also discussed in the context of the performance data.

In Experiment 1 (Perilla *et al.,* 1997), FFSB were wet-extruded in an Anderson Expander-Extruder-Cooker (Anderson International Corp., Cleveland, Ohio, U.S.) at 118°, 120°, 122°, 126°, and 140°C. Mean residence time was 20 seconds. Diets containing raw FFSB and solvent extracted SBM were also included in this experiment as negative and positive controls, respectively.

In Experiment 2 (Ordonez and Palencia, 1998), FFSB were toasted in a Thermal Processor for FFSB and Cereals designed and installed at Soyagro Ltd. (Mario Tovar & Arturo Watemberg, Barranquilla, Colombia) at 113°, 120°, 130°, 135°, and 150°C. In this specific toaster, the residence time is adjusted to each temperature by modifying the inclination of the toasting chamber. Residence times were 3.0, 4.5, 6.5, 7.0, and

9.5 minutes, respectively. A diet containing raw FFSB was also included in this experiment as a negative control.

The laboratory analyses conducted to evaluate the quality of FFSB were: urease activity by the pH rise method (AOCS, 1980a), Soy-Chek (LSB products, Kansas, U.S.); trypsin inhibitor activity (AOCS, 1980b); protein solubility in KOH (Dale *et al.*, 1987)

All samples were analyzed at the University of Illinois for true digestible amino acids according to the method of Sibbald (1979) as described by Anderson-Hafermann *et al.* (1992). All amino acid analyses were conducted at the Amino Acid Laboratory of Degussa-Huls Corporation, using AOAC method 994.12 (Llames and Fontaine, 1994).

RESULTS AND DISCUSSION

Proximate composition for FFSB and SBM samples are presented in Table 1. The growth data from Perilla and co-workers (1997) show that body weight gain (Table 2) between eight and 42 days was not significantly different for the 122°, 126°, and 140°C treatments. The body weights obtained with these three treatments were not significantly different than for the SBM treatment. However, feed conversion was more efficient in the SBM treatment. The raw soybeans treatment was significantly different than the 118°C and 120°C treatments confirming the improvement in animal performance due to heating of soybeans. The body weight and feed conversion data indicate that performance was maximized for treatments 122°, 126°, and 140°C.

Trypsin inhibitor (TI) activity dropped smoothly from raw FFSB at 50,800 to 4,700 TI units/gram as temperature treatment increased (Table 2). The 17,700-4,700 range for treatments 122°, 126°, and 140°C appears consistent with the 14,000 to 7,000 TI units/gram range considered typical in the United States (McBride, personal communication) for adequately processed FFSB.

Urease activity (UA) as measured by the pH rise method is another test widely used by industry to assess the adequacy of heat treatment of SBM and FFSB. Raw soybeans, and treatments 118°, and 120°C had the highest UA values, which corresponded to sub-optimal bird performance (Table 2). In this experiment, the range of pH values that corresponded with maximum performance was 0.07-0.03 pH units for treatments 122°, 126°, and 140°, respectively.

Soy-Chek (a trade mark for a ready-to-use color test) was included as another lab test because it is fairly correlated to pH rise and because it is a very quick and simple test to run. The data for Soy-Chek in (Table 2) indicate that this quick method clearly differentiated the under-processed FFSB treatments from the adequate ones. The Soy-Chek manufacturer indicates that the product is applicable to both SBM and FFSB however, for FFSB, the time to evaluate results is 10 minutes as oppose to SBM for which the time is five minutes. It is possible that the fat content in FFSB slows the wetting of the sample by the reagent.

All of the above lab tests are valid to detect under-processing, that is, insufficient heating of SBM or FFSB. The results for TI and UA in (Table 2) follow similar trends as those reported by Perilla *et al.* (1997) on different samples of the same treatments and conducted at a different laboratory.

The KOH protein solubility (KOHPS) test has been suggested as a method to evaluate over-processing, that is, excess of heat treatment of SBM [11, 19, 20] and other oilseed meals. With the exception of the report by Perilla and co-workers (1997), we are not aware of specific publications evaluating the value of the KOHPS test to predict over-processing for FFSB.

The data for KOHPS in (Table 2) show that solubility was above 90% for raw soybeans which is in agreement with the data of Anderson-Hafermann *et al.* (1992). For the heat treatments, all values were in the upper eighties with only the treatment of 140°C at 79%. The KOHPS data (Table 2) do not agree with the data reported by Perilla *et al.* (1997) on different samples of the same treatments since they reported KOHPS values as low as 72% and 67% for treatments 126°, and 140°C, respectively. However, it is important to emphasize that a major limitation of the solubility test is that it is very empirical with various factors such as the particle size of SBM (Whittle and Araba, 1992) or FFSB, and agitation intensity (Ruiz, 1996) among other factors affecting the inter-laboratory variability for the test. For the FFSB samples used for this report, the average particle size expressed as the average geometric diameter ranged from 480 to 650 microns while for the SBM sample it was 250 microns. FFSB samples do not grind very well in lab mills because of its oil content.

Total amino acid (TAA) values standardized at 88% DM are presented in (Table 3). Although one single analysis was run for each sample, it should be noticed that the FFSB treatments were all derived from the same original raw soybeans lot. Except when over-processing conditions occur, TAA values are normally not affected by processing. Therefore, for practical purposes, the TAA values for the different treatments are six replicated analyses.

As temperature increased during wet-extrusion, the digestible amino acid (DAA) coefficients (Table 4) increased indicating the gradual destruction of trypsin inhibitors and other anti-nutritional factors that may affect amino acid absorption. The highest numerical values for DAA coefficients were obtained at 126°C. However, because each DAA coefficient was determined only once per sample, there is no variability data to statistically differentiate treatments 122°, 126°, and 140°C as far as DAA coefficients are concerned. Nevertheless, the performance data from Perilla and co-workers (1997) and shown in (Table 2) as already discussed were not statistically different for these three treatments, and consequently it is possible to infer that the small variation among the DAA coefficients for these three treatments was not enough to change performance.

Although in general there was a small decrease in the DAA coefficients for the 140°C treatment relative to the 126°C treatment, performance data do not support the concept of over-processing in the experiment of Perilla *et. al.* (1997). The effects of over-processed SBM on broiler performance are well-documented (Dale *et al.*, 1987; Araba and Dale, 1990; Parsons *et al.*, 1991), being digestible lysine the single most damaged amino acid (Parsons, *et al.*, 1992; Aburto *et al.*, 1998). However, an additional indication of over-processing is the net destruction of total lysine (Parsons, *et al.*, 1992) which could also be expected to occur in over-processed FFSB and it is not observed in Table 3 for treatment 140°C.

The growth data in Experiment 2 are from Ordonez and Palencia (1998) which show that the body weights at 42 days of age (Table 5) were not significantly different for the 120°, 130°, 135°, and 150°C treatments. The body weights for the raw soybean and 113°C treatments were significantly different (P<0.05). The highest numerical body weight at 42 days was for the 130°C treatment, followed by the 120°C treatment.

TI activity dropped dramatically from raw FFSB to the 113° treatment, that is, from 58,300 to 8,850 TI units/g (Table 5).

Thereafter, additional heating (higher temperatures and longer residence times) resulted in a smooth decrease of the TI activity.

UA also dropped dramatically from 2.01 to 0.03 pH units at the 113°C treatment, and Soy-Chek also reflected the large drop at 113°C (Table 5). Soy-Chek data were consistent with pH-rise data.

KOHPS data in (Table 5) show a smooth decrease from 94% in raw FFSB to 69% at the 150°C treatment.

All of the laboratory data changes corresponded with an improvement in the body weights of broilers at 42 days up to the 130°C treatment. However, as discussed in the next paragraphs, the growth data for the 113° treatment cannot be explained with the lab data obtained for the corresponding FFSB sample for such treatment.

TAA values standardized at 88% DM are presented in Table 6. As in the case of Experiment 1, one TAA analysis was conducted per sample, but because the six samples of this experiment are derived from the same original raw soybeans lot, the TAA values in (Table 6) are very similar demonstrating that there was no damaged to any of the nine analyzed TAAs as a consequence of dry toasting.

As temperature and retention time increased during dry toasting the DAA coefficients (Table 7) of FFSB increased to reach a numerical maximum at the 130°C treatment with very slight changes for the 135° and 150°C treatments. As already indicated and shown in Table 5, the maximum performance in the experiment of Ordonez and Palencia (1998) was obtained with the 130°C treatment. Therefore, the growth data parallel with the increased DAA coefficients as a consequence of toasting.

Did the lab data predict live performance of broilers fed FFSB in these two experiments?

We have to divide the answer to this question in two: under-processing, that is, the detection of insufficient heating, and over-processing, that is, excess heat treatment.

UNDER-PROCESSING EFFECTS

The growth data of the two experiments analyzed here were correlated with the in vitro analyses conducted on samples of the original FFSB used in the dietary treatments. In Experiment 1, TI activity below 18,000 TI units/g correlated with a pH rise below 0.10 pH units. The performance data for broilers at 42 days for the122°, 126°, and 140°C treatments were not significantly different among them, and not significantly different than the SBM positive control. Soy-Chek correlated with pH rise as indicated by the manufacturer in the label.

In Experiment 2, the lab data for the 113°C treatment do not predict the significantly lower body weight of broilers at 42 days since TI activity was only 8,850 TI units/g, and pH rise was not higher than 0.03 pH units. However, a review of the DAA coefficients (Table 7) suggest that indeed the FFSB dry toasted at 113°C show a pattern of overall lower digestibilities typical of under-processed FFSB. In other words, the DAA coefficients data help to explain the sub-optimal performance of broilers fed FFSB dry toasted at 113°C. We do not have an explanation for this inconsistency. Otherwise, the concept of TI activity of less than 18,000 TI units/g and a UA activity lower than 0.10 pH units also applies to dry toasting of FFSB to maximize performance.

OVER-PROCESSING EFFECTS

The only analytical criteria used in the evaluation of the FFSB samples for the two experiments was the protein solubility in KOH. However, neither the growth data nor the *in vivo* DAA coefficients support the concept that over-processing of FFSB occurred in any of the two experiments. Yet the solubility coefficients dropped, particularly in Experiment 2, as a consequence of the increasing heat treatment of FFSB.

This is an unexpected finding because of the widespread use of KOHPS to assess the over-processing status of SBM and although the validity of KOHPS has been documented mostly in laboratory models, it has been tested with commercial SBMs having different KOHPS values. Kang and co-workers (1993) fed broilers to three weeks with commercial SBMs with differences of up to 12 points in KOHPS values. The body weights at 21 days showed a difference of 5.75% between the highest and the lowest solubilities. A controlled experiment conducted by Lee and co-workers (1991) with a commercially over-processed SBM demonstrated that a 10 point drop in solubility resulted in a significant growth depression of about 170 grams in growing turkeys at nine weeks of age. Therefore, there is sufficient evidence on the value of KOHPS to detect over-processed SBM, but the results of the two experiments analyzed here suggest that KOHPS is not necessarily a good predictor of over-processing of FFSB even though there was a drop in solubility of 10 points in Experiment 1 (89% vs. 79%), and 16 points in Experiment 2 (85% vs. 69%).

It is also possible that the value of protein solubility at which it becomes correlated with over-processing of FFSB is much lower than in SBM. For instance, Anderson-Hafermann *et al.* (1993) found that processing of canola seeds to generate canola meal may result in canola meals displaying a wide range of KOHPS values from 80 to 40%, but only solubilities below 40% are correlated with over-processing. A similar effect was reported by Jensen *et al.* (1995) in rapeseed meals.

The relevance of the data from these two experiments with FFSB is that in both experiments, each FFSB processor (the Anderson Expander, and the Thermal Processor) were used beyond their normal operating conditions to generate the highest temperature treatment in each experiment. Therefore, this is a suggestion that over-processing of commercial FFSB may be a difficult task. However, over-heating of raw, or processed soybeans may occur as a consequence of internal combustion under improper storage conditions.

CONCLUSIONS

1- The results of the two experiments analyzed here allowed to conclude that in the quality control of commercial FFSB less than 18,000 trypsin inhibitor units/g, or less than 0.10 pH units of urease activity are adequate to generate FFSB of optimum quality as reflected by broiler chicken performance.

2- Although the solubility coefficients of protein in KOH did drop as a consequence of the increasing heat treatment of FFSB in two commercially available processors, no evidence of over-processing was found *in vivo*.

3- The above two conclusions indicate that the quality control parameters to evaluate FFSB for poultry feeding are considerably different than the parameters applicable to SBM.

Table 1. Proximate analysis of raw soybeans[1] used in Experiments 1 and 2, and SBM in Experiment 1.

	Raw soybeans Experiment 1	Soybean meal Experiment 1	Raw soybeans Experiment 2
Dry matter, %	91.6	89.6	91.1
Ether extract, %	20.5	1.0	19.5
Crude protein, %	36.9	46.3	37.9
Crude fiber, %	6.1	6.1	4.4
Ash, %	4.9	6.2	5.3

[1] The moisture content of each treatment is displayed in Table 2 for Experiment 1, and in Table 5 for experiment 2.

Table 2. ***In vitro*** **analyses of wet-extruded FFSB and SBM, and comparison with broiler performance data per Perilla** ***et al.*** **[6], Experiment 1.**

Treatment[o] EC	Moisture %	Urease activity pH units	Soy-Chek score[5]	Trypsin Inhibitor activity TI units/g	KOH Protein Solubility %	Body Weight gain, 8-42 days, grams	Feed Conversion Ratio
Raw	8.39	1.99	1	80,800	98	1,502[c]	2.53
118	8.01	1.69	1	29,400	87	1,890[b]	1.91
120	7.97	1.11	1	26,000	89	1,897[b]	1.87
122	7.91	0.07	4.5	17,700	89	2,056[a]	1.71
126	8.15	0.08	5	12,200	88	2,067[a]	1.73
140	7.97	0.03	4.5	4,700	79	1,987[ab]	1.71
SBM	10.45	0.08	4.5	3,00	82	2,028[a]	1.65

[o] Wet-extrusion conducted in an Anderson Expander-Extruder-Cooker.

[5] Soy-Chek score per table of interpretation provided in each bottle of the reagent. These scores for FFSB were obtained at 10 minutes after the addition of the reagent. For SBM the reaction time was 5 minutes. According to LSB Products a score of 1 correlates with pH rise of approx. 2.0. A score of 2 correlates with pH rise = 0.3-0.5 . A score of 3 correlates with pH rise = 0.1-0.25 . A score of 4 correlates with pH rise = 0.05-0.10. A score of 4.5 correlates with pH rise = 0.02-0.05, and a score of 5 correlates with pH rise = 0.0. The score values shown above do not correspond exactly with LSB indications, but scores between 4.5 and 5 correlated well with maximum performance.

[a, b, c] Means in columns with different superscript are significantly different ($P<0.05$)

Table 3. Total amino acid values (per cents at 88% DM) in FFSB and SBM samples, Experiment 1.

Treatment EC	Threonine	Cystine	Valine	Methionine	Isoleucine	Leucine	Lysine	Arginine	Tryptophan
Raw	1.39	0.59	1.77	0.51	1.61	2.66	2.06	2.55	0.49
118	1.45	0.61	1.82	0.53	1.62	2.66	2.15	2.67	0.44
120	1.35	0.59	1.81	0.51	1.66	2.63	2.08	2.53	0.38
122	1.42	0.60	1.85	0.52	1.69	2.74	2.13	2.65	0.48
126	1.45	0.60	1.87	0.52	1.68	2.77	2.16	2.70	0.49
140	1.44	0.59	1.81	0.52	1.66	2.76	2.12	2.69	0.47
SBM	1.78	0.75	2.29	0.64	2.06	3.37	2.60	3.27	0.58

Table 4. Digestible amino acid coefficients (%) for FFSB and SBM samples, Experiment 1.

Treatment EC	Threonine	Cystine	Valine	Methionine	Isoleucine	Leucine	Lysine	Argnine	Tryptophan
Raw	73	69	73	72	75	77	73	78	68
118	76	68	79	79	81	81	81	81	68
120	77	67	80	82	83	82	85	81	78
122	85	80	86	88	86	89	87	88	82
126	90	81	88	91	93	93	94	90	91
140	87	80	85	92	90	91	84	88	92
SBM	90	87	89	93	94	94	91	87	91

Table 5. ***In vitro*** **analyses of dried toasted FFSB, and comparison with broiler performance data per Ordonez and Palencia [7], Experiment 2.**

Treatment[o] EC and ret. time (min)	Moisture %	Urease activity pH units	Soy-Chek score[5]	Trypsin Inhibitor activity TI units/g	KOH Protein Solubility %	Body Weight at 42 days, grams	Feed Conversion Ratio
Raw	8.94	2.01	1	56,300	94	1,118[c]	-
113 3.0 min.	6.66	0.03	4.5	8,850	89	1,802[b]	1.81
120 4.5 min.	6.78	0.03	5	6,300	85	1,972[a]	1.80
130 6.5 min.	6.00	0.00	5	5,000	86	2,030[a]	1.71
135 7.0 min.	6.44	0.00	4.5	4,200	79	1,946[b]	1.79
150 9.5 min.	6.22	0.00	5	2,100	69	1,943[b]	1.78

[o] Dry toasting conducted in a Thermal Processor for FFSB and Cereals toaster.
[5] Soy-Chek score as described in Table 2.
[a, b, c] Means in columns with different superscript are significantly different ($P<0.05$).

Table 6. Total amino acid values (per cents at 88%DM) in FFSB samples, Experiment 2.

Treatment EC	Threonine	Cystine	Valine	Methionine	Isoleucine	Leucine	Lysine	Arginine	Tryptophan
Raw	1.40	0.59	1.64	0.48	1.48	2.59	2.18	2.63	0.52
113	1.43	0.60	1.68	0.47	1.51	2.65	2.21	2.70	0.52
120	1.41	0.58	1.68	0.49	1.52	2.64	2.17	2.68	0.47
130	1.41	0.58	1.64	0.44	1.46	2.60	2.15	2.64	0.46
135	1.40	0.55	1.64	0.48	1.48	2.59	2.13	2.64	0.53
150	1.40	0.54	1.66	0.46	1.48	2.60	2.06	2.63	0.43

Table 7. Digestible amino acid coefficients (%) for FFSB samples, Experiment 2.

Treatment EC	Threonine	Cystine	Valine	Methionine	Isoleucine	Leucine	Lysine	Arginine	Tryptophan
Raw	61	46	63	57	67	69	77	72	68
113	77	74	75	78	82	82	84	82	75
120	79	77	77	80	83	82	85	82	73
130	88	81	87	88	92	92	92	90	88
135	88	81	87	85	91	91	91	89	-
150	85	72	87	88	90	90	86	86	94

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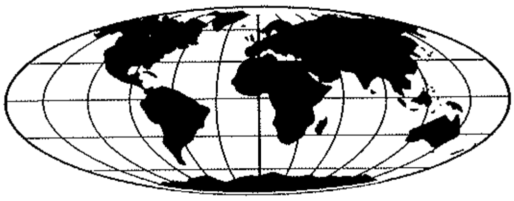

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