UTILIZATION OF FULL FAT SOYBEAN IN POULTRY DIETS
Ⅱ. BROILER

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Summary

The efficient use as a protein source for poultry of full fat soybean (FFSB) treated under various processes, i. e. steaming under pressure 40 lbs/sq. inch for 5, 10 or 15 minutes or roasting in a baking oven at 180℃ for 20, 30 or 40 minutes or extruding was compared with that of soybean meal. Eight hundred straight run broiler chicks (AA 707) were randomly allotted into 8 treatments of 4 replicates, fed with rations containing either kind of the above mentioned FFSB for 6 weeks (Wks 1-7). The protein content of the diets for chicks during 1-3, 3-6 and 6-7 weeks of age was 21, 19 and 17% respectively. The result revealed that steaming can destroy 76-92% of the trypsin inhibitor activity (TIA) in soybean, particularly that at 15 minutes, while roasting can get rid of only 13-28% TIA. Chicks fed roasted FFSB had an enlarged pancreas and showed inferior performances to the steaming and the extruding products. Steaming should be at least 10-15 minutes in order to obtain the comparable performances to those of the extrusion or of the soybean meal. The extruded FFSB showed the best feed conversion ratio. This might be due to the very fine particle of the product.
(**Key Words** : Soybean Seed, Full Fat Soybean, Trypsin Inhibitor, Broiler, Organ Weight)

Introduction

The insufficient production of soybean seed to cover the demand for food and feed in Thailand creates a problem which the government has to take care of by guaranteeing the price to the farmers. At the same time the oil price is controlled in order to avoid the impact on food cost. This strain leads to the higher price of soybean meal which effects the cost of animal production. A simple treatment of soybean seed without being processed by an oil extraction plant might alleviate feed cost. Heat treatment is necessary for the destruction of anti-nutritive factors particularly trypsin inhibitor activity (TIA) which is abundant in raw soybean seed (74 mg/g air dry; Tangtaweewipat and Cheva-Isarakul, 1989). However, the method, time and temperature used should be optimized since under-processing is ineffective in getting rid of TIA while over-heating causes the unavailability of some essential amino acids, e.g. methionine and lysine (Hayward et al., 1936; Renner et al., 1953).

Dry roasted soybean seed at 118℃ for 8.5 min can reduce TIA to 3.9 mg/g sample which can be incorporated in pullet and layer diets at 15% and 20%, respectively (Leeson et al., 1989). On the other hand, Porter and Britton (1974) found that the performances of broilers fed soybean seed extruded at 133℃ were inferior to those of soybean meal plus tallow. This might be due to the insufficient heat to destroy TIA and to promote the efficient use of oil in the seed (Carew et al., 1961).

Moist heat as well as pH can lessen the treating time and temperature (McNaughton and Reece, 1980; McNaughton et al., 1981; Hafez et al., 1983). Steaming at 99℃ with the pH of 6.6 for 1 hr could reduce TIA to 7.6 % and showed the highest protein efficiency ratio (PER). However at pH 9.5 it needed only 2.5 min to obtain the similar protein quality (Johnson et al., 1980). Boiling prior to or after grinding, or boiling followed by alkali treatment could be used efficiently in swine creep feed (Euchiewchankit, 1975; Poowadolpirojana, 1982). Biological treatment with microorganisms or digesting with pepsin are still unapplicable (Setapukdee, 1977).

Although these methods seemed to be effective in inactivating TIA, they are rather unappropiate for commercial farms. The purpose of this study is to investigate the simple method and equipment available locally to diminish TIA in soybean seed in order to make

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direct use of the seed in broiler diets. The methods are roasting and steaming at different time followed by drying.

Materials and Methods

Processing methods

Full fat soybean seed (FFSB) of grade 3, generally culled for oil extraction, was brought from the local market. It was subjected to heat treatments to destroy trypsin inhibitor activity (TIA) by steaming or roasting. Steaming was carried out in the locally made wooden tub, which had the lower half installed with an aluminium sieve to allow steam to penetrate inside thoroughly. The tub was covered with an aluminium lid. In each batch 50 kg of soybean seed was steamed under pressure of 40 lbs/sq inch for 5, 10 or 15 min which raised the temperature of the seed to 83, 95 and 105℃, respectively. The steamed product was dried in a big hot pan for 2-3 min before keeping in a sac and ground through 3 mm sieve before use.

Roasted FFSB was done by spreading, in each batch, 8.5 kg of the seed onto the 20 × 28 inch iron tray to about 1 inch high. Two trays were inserted simultaneously into a gas baking oven in which the temperature was controlled to be constant at 180℃. Baking time was 20, 30 or 40 min during which no stirring of the seed was performed. The temperature of the final product was 60, 81 and 100℃, respectively. It was cooled at room temperature and ground through a 3 mm sieve prior to feed mixing.

Extruded FFSB was produced commercially through the dry extrusion in which the temperature of the product was raised to about 150℃ for 30 seconds. It was then dried and aerated at room temperature. The final product had a very fine texture.

TABLE 1. COMPOSITION AND NUTRIENT CONTENT OF BROILER DIETS

Ingredients	Age of birds (wk)					
	1 – 3		3 – 6		6 – 7	
	SBM	FFSB[1]	SBM	FFSB[1]	SBM	FFSB[1]
Yellow corn	61.19	57.54	66.06	62.72	70.58	68.08
Rice bran	7.00	7.00	7.00	7.00	8.00	8.00
Soybean meal, SBM (44% CP)	19.10	–	17.30	–	12.80	–
Full fat soybean, FFSB (38.3% CP)	–	22.75	–	20.64	–	15.30
Fish meal (55% CP)	11.50	11.50	8.50	8.50	7.50	7.50
Oyster shell	0.60	0.60	0.60	0.60	0.60	0.60
DL-Methionine	0.11	0.11	0.04	0.04	0.02	0.02
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin-mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated chemical composition, (% Air dry basis)						
Crude protein	21.00	21.00	19.00	19.00	17.00	17.00
Metabolizable energy (kcal/g)	3.00	3.20	3.05	3.23	3.10	3.23
Crude fiber	4.70	4.35	4.66	4.34	4.55	4.32
Ether extract	4.05	7.40	3.99	7.03	4.16	6.41
Calcium	1.17	1.17	0.94	0.94	0.85	0.85
Avai. phosphorus	0.54	0.54	0.43	0.43	0.39	0.39
Lysine	1.20	1.20	1.00	1.00	0.85	0.85
Methionine (Meth)	0.50	0.50	0.38	0.38	0.32	0.32
Meth + cystine	0.85	0.85	0.72	0.72	0.60	0.60

[1] FFSB in each diet was a steam heated (5, 10 or 15 min), dry heated (20, 30 or 40 min) or extruded soybeans.

[2] Vitamin and mineral premix provided in milligrams per kilogram of diet (except as noted): Vit. A 15,000 IU; Vit. D_3 3,750 IU; Vit. E_{50} 15; Vit. K_3 2; Vit. B_1 3; Vit. B_2 10; Vit. B_6 6; Vit. B_{12} 0.01; Nicotinic acid 40; Pantothenic acid 15; Folic acid 0.7; Biotin 75 μg; Choline chloride 300; Iron 40; Copper 5; Manganese 60; Zinc 60; Cobalt 1; Iodine 0.5; Selenium 0.15; Coccidiostat 1,000 and Antioxidant 50.

Laboratory analysis and broiler feeding trail

All kinds of FFSB (wet or dry heated or extruded) were ground through a 1 mm sieve before being analysed for chemical composition (A.O.A.C., 1980) and TIA (Kakade et al., 1974).

Eight hundred straight run (AA 707) broilers were randomly apportioned to 8 treatments, each of 4 replicates and being raised in a floor pen where feed and water are freely accessed. After the first week of feeding with commercial pelleted diet (21% CP), they were fed with mash form experimental diets containing 21, 19 and 17% CP for the age of 1-3, 3-6 and 6-7 weeks, respectively. The diets of all treatments were isonitrogenous while those containing FFSB contained higher metabolizable energy (ME, 3.2 vs 3.0-3.1 kcal/kg) than the control group (soybean meal, SBM) due to the higher fat content of the products. The ME value of the FFSB used for ration formulation was 3.8 kcal/g (Wiseman, 1987). The composition and nutrient content of the experimental diets containing 5, 10 or 15 min steamed FFSB or 20, 30 or 40 min roasted FFSB, as compared to the extruded FFSB and SBM, are shown in table 1.

The feeding trial lasted 7 weeks from April to June 1993. Growth rate, feed conversion ratio (FCR) and mortality was recorded, and one bird of each sex per replicate was slaughtered at the end of the experiment. The weight of liver, pancreas and abdominal plus visceral fat was determined. All data were subjected to the analysis of variance and Duncan new multiple range test (Steel and Torrie, 1984), respectively.

Results and Discussions

Chemical composition and TIA in FFSB treated by various processes

The CP content of steamed and roasted FFSB was 3% lower than that of the extruded FFSB (table 2). This might be owing to the inferior quality of the initial product which was under graded seed while that of the extruded was mixed grade. The other nutrient composition of the 3 products was comparable. However, they contained 3-6% lower CP and 2% lower CF than SBM while their fat content was much higher, thus causing the higher ME value (3.8 vs 2.2 kcal/g). This seems to be an advantage

TABLE 2. CHEMICAL COMPOSITION OF FULL-FAT SOYBEAN (FFSB) COMPARED TO SOYBEAN MEAL

Compostion (% Air-dry basis)	Type of FFSB			Soybean meal (NRC, 1984)
	Steam heated[1] (10 min)	Dry heated[2] (30 min)	Extruder	
Dry matter	91.7	91.5	93.0	89.0
Crude protein	37.5	37.9	41.5	44.0
Ether extract	20.9	19.5	19.1	0.8
Crude fiber	5.6	5.4	5.2	7.3
Nitrogen free extract	22.7	23.9	22.2	29.1
Ash	5.0	4.8	5.0	7.8
ME (kcal/g)	NA	NA	3.8[3]	2.2
Essential amino acid				
Lysine	NA	NA	2.35[3]	2.93
Methionine	NA	NA	0.52[3]	0.65
Cystine	NA	NA	0.63[3]	0.69
Tryptophan	NA	NA	0.48[3]	0.62
Threonine	NA	NA	1.44[3]	1.81
Leucine	NA	NA	2.85[3]	3.52
Isoleucine	NA	NA	1.78[3]	2.39
Valine	NA	NA	1.77[3]	2.34
Histidine	NA	NA	0.91[3]	1.15
Phenylalanine + tyrosine	NA	NA	3.20[3]	3.55

NA = Data not available.

[1] Heated under pressure 40 lbs/squar inch.

[2] Roasted in bakery oven at 180℃.

[3] Wiseman (1987).

of FFSB as a good source of energy and protein feed.

Steaming was superior in the destruction of TIA to roasting (table 3). The longer the heat treating period, the lower TIA remained in the product. Steam heating for 15 min was as efficient as extrusion in getting rid of TIA. The low destructive effect (13-29%) of roasting in this experiment might be due to the overthickness of the seed layer spreading on the tray (1 inch thick), and the unstirring of the seed during roasting which obstructed the heat penetration into the core of the sample.

Leeson et al. (1989) reported that TIA could be destroyed nearly absolutely when soybean seed was heated to 118℃ for 8.5 min. The reported temperature was higher than the core temperature of the sample in this experiment (60-100℃). The more effectiveness with shorter time and lower temperature of the moist heat treatment was attributed to the pressure of steam which can penetrate thoroughly to each seed. The result was in agreement with McNaughton and Reece (1980) and McNaughton et al. (1981).

TABLE 3. EFFECT OF HEATING ON TRYPSIN INHIBITOR ACTIVITY (TIA)

Type of full-fat soybean	TIA (mg / g sample)	Destroy (%)
Raw	55.4	–
Steam heated, 5 min[1]	13.2	76.2
Steam heated, 10 min	10.3	81.4
Steam heated, 15 min	4.5	91.9
Dry heated, 20 min[2]	49.0	13.1
Dry heated, 30 min	45.4	18.1
Dry heated, 40 min	39.6	28.5
Extruder	3.1	94.4

[1,2] see table 2.

Feeding trial

a. Weight gain and feed conversion ratio

Growth rate, feed intake and FCR or birds fed FFSB steamed for 10 or 15 min were similar to those of the control group (SBM), while those fed with FFSB steamed for only 5 min or roasted 20-40 min were significantly inferior ($p < 0.05$, table 4). This might be due to the high amount of TIA remaining in the products. The results were in agreement with those fed raw or undercooked FFSB (Mitchell et al., 1972: Porter and Britton, 1974). However FCR of the group fed FFSB steamed for 5 min was similar to the control group but superior to the roasted FFSB groups. This might be attributed to a smaller amount of TIA (13.2 vs 39.6-49.0 mg/g sample, table 3) which caused the lower TIA intake (9.9 vs 28.7-35.3 g/bird for the whole experimental period, table 5).

TABLE 4. PRODUCTION PERFORMANCE OF 7 WEEK-OLD BROILERS FED DIETS CONTAINING DIFFERENT PROCESSED SOYBEAN

Diets	Live weight gain (kg)	Feed intake (kg)	FCR (Feed / gain)	Mortality (%)
Basal (soybean meal)	2.04[a]	4.15[a]	2.03[bc]	6.0[a]
Extruder	2.11[a]	4.04[ab]	1.91[d]	2.0[a]
Steam heated, 5 min[1]	1.92[b]	3.93[bc]	2.05[bc]	1.0[a]
Steam heated, 10 min	2.04[a]	4.09[ab]	2.01[c]	5.0[a]
Steam heated, 15 min	2.06[a]	4.16[a]	2.02[c]	5.0[a]
Dry heated, 20 min[2]	1.77[c]	3.78[c]	2.13[a]	8.0[a]
Dry heated, 30 min	1.75[c]	3.75[c]	2.15[a]	4.0[a]
Dry heated, 40 min	1.81[c]	3.80[c]	2.10[ab]	8.0[a]
CV (%)	3.47	2.98	2.42	98.0

[a,b,c] Values within a column with no common superscripts are significantly different ($p < 0.05$)

[1,2] see table 2.

TABLE 5. AMOUNT OF TRYPSIN INHIBITOR ACTIVITY (TIA) IN DIET AND THE INTAKE OF BROILERS FED DIETS CONTAINING DIFFERENT PROCESSED SOYBEAN

Diets	TIA in diet (%)			TIA intake[1] (g / bird)
	1 – 3 wk	3 – 6 wk	6 – 7 wk	
Basal (soybean meal)	NA			NA
Extruder	0.07	0.06	0.05	2.4
Steam heated, 5 min[2]	0.30	0.27	0.20	9.9
Steam heated, 10 min	0.23	0.21	0.16	8.1
Steam heated, 15 min	0.10	0.09	0.07	3.6
Dry heated, 20 min[3]	1.11	1.01	0.75	35.3
Dry heated, 30 min	1.03	0.94	0.69	32.5
Dry heated, 40 min	0.90	0.82	0.61	28.7

NA = Data not available.

[1] The whole experimental period (7 wks).

[2,3] see [1,2] in table 2.

Extruded FFSB provided similar weight gain and feed intake to the 10-15 min steamed FFSB but had the best FCR (1.91 vs 2.01-2.15; table 4). This should be the result of the proper heating which might also improve the digestibility of carbohydrate in the seed. Mitchell et al. (1972) reported on FFSB treated with Roast-a-tron at 122-125℃ that the finer the particles, the better the digestibility of fat. However, the advantage of steamed and roasted FFSB is their longer shelf-life due to the unexposure to the air of fat in the seed which was protected by its seed coat, while the extruded FFSB seemed to be more sensitive to rancidity.

No significant difference among groups was reported on mortality rate although those fed roasted FFSB consumed a high amount of TIA. The result agreed with those fed raw or underheated FFSB or Kunitz inhibitor-free soybean (Bijjalieh et al., 1980; Zhang et al., 1991; Han et al., 1991).

TABLE 6. PERCENTAGE OF LIVER, PANCREAS, AND FAT OF 7 WEEK-OLD BROILERS FED DIETS CONTATINING DIFFERENT PROCESSED SOYBEAN

Diets	Liver	Pancreas	Fat[1]
	⟨·····% Live weight·····⟩		
Basal (soybean meal)	2.07[b]	0.148[b]	2.00[a]
Extruder	2.12[b]	0.182[b]	2.32[a]
Steam heated, 5 min[2]	2.21[ab]	0.192[b]	2.59[a]
Steam heated, 10 min	2.15[b]	0.182[b]	2.25[a]
Steam heated, 15 min	1.99[b]	0.146[b]	2.13[a]
Dry heated, 20 min[3]	2.44[a]	0.279[a]	2.49[a]
Dry heated, 30 min	2.16[b]	0.266[a]	2.74[a]
Dry heated, 40 min	2.23[ab]	0.259[a]	2.57[a]
CV (%)	2.17	16.77	19.36
Males, $\bar{x} \pm SE$[4]	2.13 ±0.18	0.205 ±0.055	2.31 ±0.34
Females, $\bar{x} \pm SE$[4]	2.21 ±0.16	0.209 ±0.055	2.45 ±0.39

[ab] Values within a column with no common superscripts are significantly different ($p < 0.05$).
[1] Abdominal plus visceral fat.
[2,3] See [1,2] in table 2.
[4] No significant difference.

b. Liver, pancreas and abdominal plus visceral fat

Pancreas weight of chicks fed roasted FFSB was significantly higher than the other groups (0.259-0.277 vs 0.146-0.192% LW, table 6). This might be the result of the compensatory effect of pancreas in producing proteolytic enzyme which was inhibited by high TIA intake (table 5). It was in agreement with Featherston and Rogler (1966), McNaughton and Reece (1980) and Anderson-Hafermann et al. (1992) in broilers as well as Kakade et al. (1971) in rats fed high TIA Navy bean or synthetic TIA (p-aminobenzamidine). The latter reported that the supplement of methionine and/or cystine could mitigate the enlargement.

Although pancreas weight of the groups fed extruded FFSB and of those fed 5-10 min steamed FFSB tended to be higher than that of the control group (SBM) but the difference was not significant.

No significant differences were recorded among groups on the liver weight or the abdominal plus visceral fat with the exception of the group fed 20 min roasted FFSB which had the highest liver weight.

The high amount of abdominal plus visceral fat of the groups fed FFSB should be attributed to the high fat (energy) content of FFSB compared to SBM (table 2). This led to the surplus fat being accumulated in the internal organs (Kubena et al., 1974), although no significant difference was found.

No effect of sex was observed on the weight of liver, pancreas and abdominal plus visceral fat (table 6).

c. Cost of production.

Feed cost of chicks fed from 1 to 7 weeks (42 days) was calculated according to the market price of each ingredient (table 7). The processing cost of roasting as well as steaming was estimated to be 1 Bt/kg. Thus the cost of these 2 FFSB products was equal to 9.50 Bt, while the price of the extruded FFSB was 12.50 Bt. Birds fed FFSB had higher feed cost than SBM due to the lower protein content and the processing cost of FFSB. Extruded FFSB cost the highest feed price which led to the higher feed cost/kg liveweight gain than SBM and steamed FFSB but lower than the group fed roasted FFSB.

However if the steaming period is extended to be long enough to destroy all TIA or if soybean seed is finer ground (1 mm) to improve nutrient absorption (Mitchel et al., 1972), the performances of the birds should be comparable to the extruded FFSB. At the same time, feed cost is expected to be reduced due to the simple equipment and the low processing cost. Thus it should be appropriated to those farms which perform feed mixing for their own consumption.

TABLE 7. PERFORMANCE AND COST OF PRODUCTION OF 7 WEEK-OLD BROILERS FED DIETS CONTAINING DIFFERENT PROCESSED SOYBEAN

Diets	Live weight gain (kg)	FCR	Cost of feed per[1]	
			kg. feed	kg. wt. gain
			〈··· (Bt) ···〉	
Basal (soybean meal)	2.04	2.03	5.87	11.92
Extruder	2.11	1.91	6.61	12.63
Steam heated, 5 min[2]	1.92	2.05	6.02	12.34
Steam heated, 10 min	2.04	2.01	6.02	12.10
Steam heated, 15 min	2.06	2.02	6.02	12.16
Dry heated, 20 min[3]	1.77	2.13	6.02	12.82
Dry heated, 30 min	1.75	2.15	6.02	12.94
Dry heated, 40 min	1.81	2.10	6.02	12.64

[1] Ingredient prices (Bt/kg) : yellow corn 3.50, rice bran 4.30, fish meal 13.50, oyster shell 1.50, DL-methionine 100.00, salt 2.00, vitamin-mineral premix 150, soybean meal 9.75, and full-fat soybean 12.50 for extruder, 9.50 for steam & dry heated.

[2,3] see [1,2] in table 2.

Conclusions

Steaming of soybean seed under 40 lb pressure/sq inch for 5, 10 or 15 min or roasting at 180℃ in a baking oven for 20, 30 and 40 min elevated the temperature of the seed to be 83, 95, 105℃ and 60, 81 and 100℃, respectively. The products were used to substitute SBM in broiler rations from 1-7 weeks of age compared to SBM and extruded FFSB. It was concluded that

1. Steaming was more effective than roasting in inactivation TIA. More than 90% of TIA was destroyed by steaming for 15 min or by extrusion. The time and temperature used for roasting in this experiment was insufficient for this purpose, thus leading to only 13-29% destruction of TIA.

2. Steamed FFSB could be efficiently used for broilers without detrimental effect, with the exception of 5 min which caused the lower growth.

3. Roasted FFSB is inappropriate for broiler ration due to the low performances and the enlarged pancreas of the chicks.

4. Extruded FFSB gave the best FCR, while the other performances were not different from those of the steamed products.

5. The abdominal plus visceral fat content of the groups fed FFSB tended to be higher than that of SBM.

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