ORIGINAL ARTICLE

The use of mustard meal as a protein source in broiler diets

Suchon Tangtaweewipat[1], Boonlom Cheva-Isarakul[2], and Piched Sangsrijun[3]

Abstract

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Mustard meal (MM) from an essential oil extraction plant was dried under the sun or in a gas-heated pan. Its crude protein, ether extract and fiber contents on dry matter (DM) basis were 30-32, 19-22 and 12-13%, respectively. The metabolizable energy values of the sun dried and the gas dried meals were 2.89 and 2.44 kcal/g DM, respectively. The meal obtained from either the sun or the gas drying process was incorporated into broiler diets at 0, 10, 20 or 30% through the whole 6 weeks of experimental period. It was found that body weight gain, feed intake and feed efficiency decreased with the increasing levels of MM. The overall performance indicated that MM could be incorporated in broiler diet at 10% during 2-7 weeks of age without any adverse effects. Since older chicks can tolerate higher level of fiber and toxic substances from MM, the incorporation of MM to the diet fed only during week 7 can be up to 20%, which is corresponding to the substitution of 62% soybean meal. No significant differences among groups on carcass quality (i.e. dressing percentage and the weight of liver, pancreas and abdominal fat) were observed. However, the thyroid gland was found to enlarge with the increasing levels of MM.

Key words : mustard meal, plant protein, visceral organ, thyroid gland, broiler

[1]Ph.D.(Poultry Nutrition), Assoc. Prof., [2]Dr.sci.agr.(Animal Nutrition), Assoc. Prof., [3]M.Sc. (Animal Science), Department of Animal Science, Faculty of Agriculture, Chiang Mai University, 50200, Thailand.
Corresponding e-mail: agani002@chiangmai.ac.th
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บทคัดย่อ

สุชน ตั้งทวีวิพัฒน์, บุญล้อม ชีวะอิสระกุล และ พิเชษฐ แสงศรีจันทร์
การใช้กากมัสตาร์ดเป็นแหล่งโปรตีนในอาหารไก่เนื้อ
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กากมัสตาร์ดจากโรงงานผลิตน้ำมันหอมระเหย ชนิดที่ทำให้แห้งด้วยการตากแดดและคั่วในกระทะขนาดใหญ่ที่ใช้แก๊ส มีปริมาณโปรตีน ไขมัน และเยื่อใยเท่ากับ 30-32, 19-22 และ 12-13% ของวัตถุแห้ง (DM) ตามลำดับ ส่วน ME ของกากทั้งสองชนิดดังกล่าวมีค่าเท่ากับ 2.89 และ 2.44 kcal/g. DM เมื่อนำไปใช้เป็นแหล่งโปรตีนในอาหารไก่เนื้อที่ระดับ 0, 10, 20 หรือ 30% คงที่ตลอดระยะการทดลองเป็นเวลา 6 สัปดาห์ ปรากฏว่า น้ำหนักตัว ปริมาณอาหารที่กินได้ และประสิทธิภาพการใช้อาหารด้อยลงตามการเพิ่มระดับกากมัสตาร์ดในสูตรอาหาร การใช้กากมัสตาร์ดจากทั้งสองกรรมวิธีที่ระดับ 10% ในช่วงไก่อายุ 2-7 สัปดาห์ หรือเท่ากับแทนที่กากถั่วเหลือง 21-31% ให้ผลไม่แตกต่างจากลุ่มควบคุม อย่างไรก็ดี ในสัปดาห์สุดท้ายของการเจริญเติบโต (อายุไก่ 43-49 วัน) สามารถใช้กากมัสตาร์ดในสูตรอาหารได้สูงถึง 20% หรือเท่ากับแทนที่กากถั่วเหลืองที่ระดับ 62% สำหรับผลด้านคุณภาพซาก (%ซาก น้ำหนักตับ ตับอ่อน และไขมันในช่องท้อง) ให้ผลไม่แตกต่างกัน ยกเว้นต่อมไทรอยด์มีขนาดโตขึ้นตามระดับของกากมัสตาร์ดที่เพิ่มขึ้นในสูตรอาหาร

ภาควิชาสัตวศาสตร์ คณะเกษตรศาสตร์ มหาวิทยาลัยเชียงใหม่ อำเภอเมือง จังหวัดเชียงใหม่ 50200

The investigation on the potential use of agro-industrial residues and by-products to substitute conventional feed is useful for the reduction of feed cost. In Thailand, mustard meal (MM) is an interesting by-product from oil extraction process of the seed because of its high nutrient content and the availability of around 4,000 tons of fresh matter a year. Since mustard (*Brassica juncea*) is in the same genus as rapeseed (*B. napus* or *B. compestris*), it contains similar toxic substances i.e. glucosinolate, erucic acid, sinapine, tannin and some anti-nutrient factors. The substances induce unpalatability, growth retardation, thyroid gland enlargement, low feed efficiency and reproductive problem, particularly when the seed is incorporated in the diet at high level. Bhattacharjee *et al*. (1995) found that MM could substitute peanut meal at 30% in Japanese quail diet during 2-8 weeks of age without adverse effect. The substitution level over 50% reduced body weight, protein bound iodine and thyroxin (T4) in blood serum while thyroid gland and serum cholesterol increased. Das and Ali (1993) reported that undetoxicated MM could substitute 50% of sesame meal. At the higher level it reduced egg size and feed intake. Marangos and Hill (1976) found no deleterious effect on egg performance when MM was incorporated in layer diet at 12%. However, fishy flavor was observed in eggs.

Newkirk *et al*. (1997) reported that MM had higher metabolizable energy (ME) and apparent ileal crude protein (CP) digestibility than rape seed meal, thus gave slightly better performance of broilers although its glucosinolate content was higher (34.3 vs 21.8-25.5 μmole/g). Blair (1984) found that MM which containing 45.7% CP, 1.69% ether extract (EE) and 6.5% crude fiber (CF) can incorporated in broiler diet at 10% without any adverse effect on growth but the weight of thyroid gland increased significantly ($P<0.05$). However, when the meal was treated with ammonia and supplemented with lysine, the incorporated level could be increased to 20%. Begum *et al*. (1997) found no deleterious effect when MM was sub-stituted for peanut meal at 30% in broiler diet. At over 50%, however, body weight decreased. Göhl (1981) suggested that MM should not incorporate in poultry diet higher than 9%.

The objective of this experiment was to investigate the optimum level of 2 types of MM,

i.e. sun dry and gas dry, in broiler diets.

Materials and Methods

One thousand and fifty one day old broilers (Arbor Acre 707) were fed a commercial pellet diet containing 21% CP during the first week of birds' age. After that they were randomly divided to 7 groups, each with 3 replicates (50 birds per replicate). The ratio of male and female chicks was estimated to be varied between 0.8-1.2 : 1.0. Feed and water were provided *ad libitum*. Experimental diets were in mash form containing either type of MM, i.e. sun dry or gas dry. These MM contained on dry matter (DM) basis: 30-32% CP, 19-22% EE and 12-13% CF. Apparent ME of the sun dry meal was 2.89 kcal/g DM and gas dry meal was 2.44 kcal/g DM (Cheva-Isarakul *et al*., 2003). The incorporation levels of MM were 10, 20 or 30% of the diet, which were equal to the substitution of

Table 1. Feed formulation and nutrient composition of broiler diets for 8-21 days (week 2-3) of age

Type of MM		**Sun dried meal**			**Gas dried meal**		
In diet (%)	**0**	**10**	**20**	**30**	**10**	**20**	**30**
Substituted SBM (%)	**0**	**21**	**42**	**64**	**21**	**42**	**64**
Ingredients:							
Corn (8.5% CP)	49.31	45.48	41.69	37.86	44.74	40.18	35.61
SBM (44% CP)	27.25	21.46	15.66	9.86	21.47	15.69	9.91
MM[1/]	-	10.00	20.00	30.00	10.00	20.00	30.00
Crude rice bran oil	4.72	4.55	4.37	4.20	5.28	5.84	6.39
DCP	0.79	0.73	0.66	0.60	0.73	0.67	0.61
Oyster shell	1.09	0.99	0.90	0.81	0.99	0.90	0.81
DL-Methionine	0.16	0.15	0.13	0.12	0.15	0.13	0.12
L-Lysine	0.18	0.14	0.09	0.05	0.14	0.09	0.05
Constant[2/]	16.50	16.50	16.50	16.50	16.50	16.50	16.50
Total	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***
Calculated chemical composition *(% air dry basis)*							
CP	21.00	21.00	21.00	21.00	21.00	21.00	21.00
ME (kcal/g)	3.15	3.15	3.15	3.15	3.15	3.15	3.15
CF	5.17	5.70	6.24	6.78	5.70	6.23	6.77
EE	8.44	9.78	11.12	12.46	10.78	13.13	15.47
Ca	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P, available	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Lys	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Met	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Met + Cys	0.78	0.77	0.77	0.76	0.77	0.77	0.76

MM = Mustard meal, SBM = Soybean meal, DCP = Dicalcium phosphate (18% P).

[1/] CP, EE, CF (%) and ME (kcal/g) of sun dried mustard meal were 28.90, 17.07, 11.34 and 2.724, while those of gas dried meal were 29.50, 20.04, 11.56 and 2.328, respectively. The amino acid content of MM was according to Bell *et al.* (1984).

[2/] The other ingredients were incorporated in all diets at a constant percentage, i.e., rice bran 10.00, fish meal (57% CP) 6.00, salt 0.25 and vitamin-mineral premix[3/] 0.25.

[3/] mg/kg feed unless otherwise noted: Vitamins; A 15,000 IU, D_3 3,750 IU, E 15, K_3 2, B_1 3, B_2 10, B_6 6, B_{12} 0.01, Nicotinic acid 40, Pantothenic acid 15, Folic acid 0.7, Biotin 0.075, Choline chloride 300; Minerals: Fe 40, Cu 5, Mn 60, Zn 60, I 1, Se 0.5; Favoring agent 25 and preservative 6.25.

Table 2. Feed formulation and nutrient composition of broiler diets for 22-42 days (week 4-6) of age

Type of MM		Sun dried meal			Gas dried meal		
In diet (%)	0	10	20	30	10	20	30
Substituted SBM (%)	0	26	52	78	26	52	78
Ingredients:							
Corn (8.5% CP)	54.53	50.74	64.90	43.12	49.97	45.40	40.84
SBM (44% CP)	22.40	16.60	10.81	5.00	16.62	10.84	5.06
MM[1/]	-	10.00	20.00	30.00	10.00	20.00	30.00
Crude rice bran oil	3.62	3.44	3.27	3.08	4.18	4.73	5.29
DCP	0.70	0.63	0.57	0.51	0.64	0.58	0.52
Oyster shell	1.05	0.95	0.86	0.76	0.95	0.86	0.76
DL-Methionine	0.08	0.06	0.05	0.03	0.06	0.05	0.03
L-Lysine	0.12	0.08	0.04	-	0.08	0.04	-
Constant[2/]	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Total	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***
Calculated chemical composition *(% air dry basis)*							
CP	19.00	19.00	19.00	19.00	19.00	19.00	19.00
ME (kcal/g)	3.15	3.15	3.15	3.15	3.15	3.15	3.15
CF	5.17	5.71	6.24	6.78	5.70	6.24	6.77
EE	7.66	9.00	10.34	11.67	10.01	12.35	14.69
Ca	0.90	0.90	0.90	0.90	0.90	0.90	0.90
P, available	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Lys	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Met	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Met + Cys	0.64	0.63	0.62	0.62	0.63	0.62	0.61

MM = Mustard meal, SBM = Soybean meal, DCP = Dicalcium phosphate (18% P).
[1/, 3/] See Table 1.
[2/] The other ingredients were incorporated in all diets at a constant percentage, i. e., rice bran 12.00, fish meal (57% CP) 5.00, salt 0.25 and vitamin-mineral premix[3/] 0.25.

soybean meal (SBM) at the levels of 21, 42, 64%; 26, 52, 78% and 31, 62, 94% during 2-3, 4-6 and 7 week of age, respectively. The other diet was the control (without MM). All diets (Table 1-3) contained equal ME at 3.15 kcal/g air dry throughout the experimental period. However, CP content of the diets was varied with birds' age (21, 19 and 17% during week 2-3, 4-6 and 7, respectively). Body weight and feed intake were recorded at the end of week 3, 6 and 7 of age. At the end of the experiment, 2 birds (one male and one female from each replicate) were randomly slaughtered. Dressing percentage and weight of liver, pancreas, abdominal plus visceral fat and thyroid gland were recorded. All data were analyzed by ANOVA according to completely randomized design. The difference between groups was investigated using Duncan's new multiple range test (Steel and Torrie, 1984). The work has been done at Chiang Mai University farm.

Results and Discussion

Production performance

The overall body weight gain, feed intake and feed efficiency (feed conversion ratio, FCR) of broilers decreased with the increasing levels of MM, particularly at the levels beyond 10%. There-

Table 3. Feed formulation and nutrient composition of broiler diets for 43-49 days (week 7) of age

Type of MM		**Sun dried meal**			**Gas dried meal**		
In diet (%)	**0**	**10**	**20**	**30**	**10**	**20**	**30**
Substituted SBM (%)	**0**	**31**	**62**	**94**	**31**	**62**	**94**
Ingredients:							
Corn (8.5% CP)	60.96	57.14	53.33	49.50	56.39	51.84	47.26
SBM (44% CP)	18.50	12.70	6.91	1.11	12.72	6.94	1.16
MM[1/]	-	10.00	20.00	30.00	10.00	20.00	30.00
Crude rice bran oil	2.66	2.49	2.32	2.15	3.22	3.78	4.34
DCP	0.69	0.63	0.56	0.50	0.63	0.56	0.50
Oyster shell	1.02	0.92	0.83	0.73	0.92	0.83	0.73
DL-Methionine	0.05	0.04	0.02	0.01	0.04	0.02	0.01
L-Lysine	0.12	0.08	0.03	-	0.08	0.03	-
Constant[2/]	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Total	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***
Calculated chemical composition *(% air dry basis)*							
CP	17.00	17.00	17.00	17.00	17.00	17.00	17.00
ME (kcal/g)	3.15	3.15	3.15	3.15	3.15	3.15	3.15
CF	5.05	5.59	6.12	6.66	5.59	6.12	6.65
EE	6.79	8.12	9.47	10.82	9.13	11.48	13.82
Ca	0.80	0.80	0.80	0.80	0.80	0.80	0.80
P, available	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Lys	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Met	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Met + Cys	0.56	0.55	0.55	0.54	0.55	0.55	0.54

MM = Mustard meal, SBM = Soybean meal, DCP = Dicalcium phosphate (18% P).
[1/, 3/] See Table 1.
[2/] The other ingredients were incorporated in all diets at a constant percentage, i. e., rice bran 12.00, fish meal (57% CP) 3.50, salt 0.25 and vitamin-mineral premix[3/] 0.25.

fore, the use of MM in broiler diets during 2-7 weeks of birds' age should not exceed 10% of the diet, which was equal to the substitution of SBM at 21, 26 and 31% during week 2-3, 4-6 and 7 of birds' age, respectively. The results of this study were in agreement with Göhl (1981), Blair (1984) and Bhattacharjee *et al*. (1995). However, when the growth of each period was taken into consideration it was found that young chick (less than 6 weeks of age) was sensitive to the toxic substance of MM. On the other hand, older chickens seemed to be more tolerate to the higher levels of both fiber and toxic substances in MM. Therefore, 20% MM could be incorporated in the diet during week 7 of broilers' age without any adverse effect (Table 4).

No significant difference was observed on mortality rate, although the high rate of 13% in broilers fed sun dried MM was noticed. It might be due to heat stress during the last week of the experimental period in which the temperature was up to 37-40ºC.

Carcass quality

There were no significant differences among groups on dressing percentage and the weight of liver, pancreas, and abdominal plus visceral fat. However, thyroid gland increased with the in-

Table 4. Performances of broilers fed diets containing varying levels of sun dried and gas dried mustard meals (MM) during 2-7 weeks of age[1/]

MM (%) in diet	Type of MM	BW gain (kg)	Feed intake (kg)	FCR	Mortality (%)
Overall (42 days)					
0	-	2.25^{a}	4.36^{ab}	1.94^{c}	7.3
10	Sun dried[2/]	2.14^{ab}	4.36^{ab}	2.04^{ab}	13.3
10	Gas dried[3/]	2.16^{a}	4.34^{ab}	2.01^{bc}	6.0
20	Sun dried	2.04^{b}	4.30^{ab}	2.13^{a}	3.3
20	Gas dried	2.04^{b}	4.18^{b}	2.11^{ab}	3.3
30	Sun dried	1.85^{c}	3.94^{c}	2.13^{a}	4.7
30	Gas dried	1.84^{c}	3.81^{c}	2.07^{ab}	3.3
Pooled SEM		0.01	0.02	0.01	1.1
Week 2-3 (14 days)					
0	-	0.52^{a}	0.77^{a}	1.48^{d}	0.7
10	Sun dried	0.49^{b}	0.76^{a}	1.55^{bcd}	0.7
10	Gas dried	0.50^{ab}	0.76^{a}	1.53^{cd}	0
20	Sun dried	0.46^{c}	0.75^{a}	1.64^{a}	0
20	Gas dried	0.46^{c}	0.73^{ab}	1.58^{abc}	0
30	Sun dried	0.42^{d}	0.67^{c}	1.61^{ab}	0.7
30	Gas dried	0.42^{d}	0.68^{c}	1.64^{a}	0
Pooled SEM		0.003	0.005	0.01	-
Week 4-6 (21 days)					
0	-	1.37^{a}	2.54^{a}	1.86^{b}	2.0
10	Sun dried	1.26^{bc}	2.57^{a}	2.04^{a}	4.0
10	Gas dried	1.24^{bc}	2.51^{a}	2.03^{a}	4.7
20	Sun dried	1.17^{cd}	2.50^{a}	2.13^{a}	2.7
20	Gas dried	1.20^{c}	2.45^{a}	2.03^{a}	2.1
30	Sun dried	1.10^{d}	2.29^{b}	2.09^{a}	4.0
30	Gas dried	1.10^{d}	2.22^{b}	2.02^{a}	0.7
Pooled SEM		0.01	0.02	0.01	-
Week 7 (7 days)					
0	-	0.36^{abc}	1.05^{a}	2.96	4.7
10	Sun dried	0.40^{ab}	1.06^{a}	2.70	8.7
10	Gas dried	0.43^{a}	1.07^{a}	2.50	1.4
20	Sun dried	0.40^{ab}	1.05^{a}	2.67	0.7
20	Gas dried	0.38^{abc}	0.99^{ab}	2.64	1.4
30	Sun dried	0.34^{bc}	0.97^{ab}	2.89	0
30	Gas dried	0.32^{c}	0.91^{b}	2.86	2.7
Pooled SEM		0.01	0.01	0.05	-

Values within column with no common superscripts are significantly different (P<0.05).
[1/] In the first week, BW gain and feed intake were 97 and 119 g/bird, respectively.
[2/] 3-days sun dried.
[3/] 8-hrs dried by gas machine.

creasing levels of MM (Table 5). It indicated that although some toxic substances such as allyl isothiocyanate, nitrile and indoles (derivatives of glucosinolate) were extracted from the seed, the remaining in the meal was still high enough to inhibit thyroid function. Tangtaweewipat *et al*.

Table 5. Dressing percentage and relative weight of visceral organs and thyroid gland of broilers fed diets containing various levels of sun dried and gas dried mustard meals (MM) during 2-7 weeks of age.

MM in diet (%)	Type of MM	% Dressing	Liver	Fat[1/] (% BW)	Pancreas	Thyroid (mg/100 g BW)
0	-	88.38	1.85	2.23	0.154	3.26[b]
10	Sun dried[2/]	88.83	1.91	2.43	0.169	3.99[ab]
10	Gas dried[3/]	88.27	1.74	2.37	0.182	3.99[ab]
20	Sun dried	86.91	1.79	2.04	0.152	3.22[ab]
20	Gas dried	88.04	1.75	2.40	0.156	4.46[a]
30	Sun dried	87.45	1.86	2.30	0.165	4.01[ab]
30	Gas dried	88.89	1.83	2.70	0.179	4.65[a]
Pooled SEM		0.21	0.03	0.06	0.003	0.12
Male	***Ave. ± SD***	*87.5±0.6*	*1.77±0.05*	*2.20±0.1*	*0.16±1.0*	*3.51±0.52*
Female	***Ave. ± SD***	*87.5±0.6*	*1.88±0.08*	*2.49±0.3*	*0.17±1.2*	*4.14±0.72*

Values within column with no common superscripts are significantly different (P<0.05).
Ave. = Average. SD = Standard deviation.
Dressing percentage = {(Liveweight - Blood - Feather - Whole visceral organs) × 100}/Liveweight
[1/] Visceral plus abdominal fat.
[2/, 3/] See Table 4.

Table 6. Cost of broiler production fed diets containing various levels of sun dried and gas dried mustard meals (MM) during 2-7 weeks of age

MM in diet (%)	Type of MM	BW gain (kg)	FCR	Production cost[1/]	
				(Bt/bird)	(Bt/kg BW)
0	-	2.25	1.94	33.78	15.01
10	Sun dried[2/]	2.14	2.04	32.53	15.20
10	Gas dried[3/]	2.16	2.01	32.64	15.11
20	Sun dried	2.04	2.13	30.41	14.91
20	Gas dried	2.04	2.11	30.41	14.91
30	Sun dried	1.85	2.13	26.49	14.32
30	Gas dried	1.84	2.07	26.90	14.62

[1/] Price of each ingredients (Bt/kg): Corn 5.60, Rice bran 4.10, SBM 9.10, FM 16.50, Rice bran oil 20.00, DCP 12.00, Oyster shell 2.00, Met 160.00, Lys 75.00, Salt 3.00, Vitamin-mineral premix 120.00 and Mustard meal 5.00. (43 Bt = 1 $ US)
[2/,3/] See Table 4.

(1998) reported the similarity and found enlarged thyroid glands and low blood thyroxin in broilers fed with rape seed meal containing 75.3 µmol/g glucosinolate. Bhattacharjee *et al*. (1995) also reported similar evident in Japanese quail consuming deoiled mustard cake.

Production cost

When the price of MM was calculated base on its CP content compared to SBM, its cost would be 5 Baht (Bt)/kg or around 116 $US/ton (approx. 1 $US = 43 Baht). Since the cost of MM diets were lower than the control and FCR of all groups

were similar, feed cost per kg body weight of the birds fed 30% MM was found to be the lowest (Table 6).

In conclusion, MM can be incorporated in broiler diet at 10% during 2-7 weeks of age or at 20% only in week 7. Carcass quality was not affected by MM with the exception of the enlarged thyroid glands.

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References

Begum, I., Rahman, T. and Bhattachaya, M. 1997. Pathological and histoenzymic studies on the toxic effect of mustard cake (*Brassica juncea*) in broiler chicken. Indian J. Anim. Sci., 67(11): 946-948.

Bell, J.M., Keith, M.O., Blake, J.A. and McGregor, D.I. 1984. A nutritional evaluation of ammoniated mustard meals for use in swine. Canadian J. Anim. Sci., 64: 1023-1033.

Bhattacharjee, S.N., Dalapati, M.R., Bhowmick, M.K. and Samanta, G. 1995. Goitrogenic effect of deoiled mustard-cake (*Brassica juncea*) in Japanese quail. Indian J. Anim. Sci., 67(9): 811-813.

Blair, R. 1984. Nutritional evaluation of ammoniated mustard meal for chicks. Poultry Sci., 63: 754-759.

Cheva-Isarakul, B., Tangtaweewipat, S., Sangsrijun, P. Yamauchi, K. 2003. Chemical composition and metabolizable energy of mustard meal. J. Poultry Sci., 40 (3) : 221-225.

Das, H. and Ali, M.A. 1993. Replacement of sesame oil cake by mustard oil cake in the diet of laying hens. Indian J. Anim. Prod. and Manag., 9(4): 169-173.

Göhl, B. 1981. Tropical Feeds. FAO, Rome, Italy.

Marangos, A.G. and Hill, R. 1976. The use of rape seed meals and mustard seed meal as a protein source in diets for laying pullets. British Poultry Sci., 17(6): 643-653.

Newkirk, R.W., Classen, H.L and Tyler, R.T. 1997. Nutritional evaluation of low glucosinolate mustard meals (*B. juncea*) in broiler diets. Poultry Sci., 76(9): 1272-1277.

Steel, R.G.D. and Torrie, J.H. 1984. Principles and Procedures of Statistics, 2nd ed., McGrow-Hill Book Co. Inc., New York, USA.

Tangtaweewipat, S., Cheva-Isarakal, B. and Paspisanu, P. 1998. The use of rape seed meal in poultry diets. Proc. 6th Asian Pacific Poultry Cong., Nagoya, Japan, June 4-7, 1998: 82-87.