Utilization of Low Glucosinalate and Conventional Mustard Oilseed Cakes in Commercial Broiler Chicken Diets

S. V. Rama Rao*, M. V. L. N. Raju, A. K. Panda and M. Sailaja Shashibindu
Project Directorate on Poultry, Rajendranagar, Hyderabad, 500 030, India

ABSTRACT : An experiment was conducted to study the effect of replacing soyabean meal (SBM) at 50 and 100% with conventional (CMC) and low glucosinalate mustard cakes (LGMC) in *iso-caloric* and *iso-nitrogenous* diets in broiler chickens. All these diets contained 0.1% choline chloride with a purity of 50% (w/w). Another diet was prepared by replacing SBM *in toto* with CMC with no supplemental choline to find out the possible role of supplemental choline in mustard cake (MC) based diets. Two hundred and seventy day-old broiler chicks were distributed randomly in 54 stainless steel battery brooder pens of five chicks in each pen. Each experimental diet was allotted at random to nine battery brooders and offered *ad-libitum* from day 2 through 42 days of age. Body weight gain was significantly depressed by total replacement of SBM with either LGMC or CMC at 21 days of age. Non-supplementation of choline significantly depressed the growth compared to those fed CMC 100% with supplemental choline. However, at 42 days of age, such an effect was seen only with CMC. Replacement of SBM with CMC 100% with or without choline supplementation depressed the body weight gain. The concentrations of cholestorol and tryglicerides in serum and the relative weights of ready to cook yield, giblet and gizzard decreased by incorporation of mustard cakes in broiler diets. The trend in fat and protein contents in breast and thigh muscles and liver was not clearly attributable to the treatment effect. Based on the results, it is concluded that SBM can be replaced *in toto* with LGMC (535.0 and 466.5 g/kg starter and finisher diets, respectively) or up to 50% (215.0 and 186.7 g/kg starter and finisher diets, respectively) with CMC in commercial broiler chicken diets. Choline supplementation at 0.1% level in broiler diets containing CMC was found to be beneficial during starter phase. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 8 : 1157-1163)***

Key Words : Mustard Cake, Broilers, Growth, Feed Efficiency, Carcass Traits, Lipid Profile, Nutrient Excretion

INTRODUCTION

The ever increase in price of poultry feed forces to utilize cost effective alternate feed ingredients in place of conventional energy and protein sources in poultry diets. The high cost of soybean meal (SBM), the traditional source of protein in poultry diet often limits its use in poultry diets due to economic reasons. Therefore, alternate protein sources have to be incorporated in diet to economize the feed cost. Mustard oil cake (MC) is a fairly good source of protein (31 to 39%) and energy (2,200 kcal/kg), low in lysine (1.0 to 2.0%), but rich in methionine (1.01 to 1.57%) compared to SBM (Vaidya et al., 1979). However, utilization of MC in poultry diets is limited due to the presence of certain intrinsic toxic principles (Vaidya et al., 1979; Prasad and Rao, 1982a), which are known to lower the performance of birds when used at higher levels (>10%) in the diets of chicken (Vaidya et al., 1979; Prasad and Rao, 1982a; McNeill and MacLeods, 2001).

Of late, a few varieties of mustard were developed which contain zero/low levels of toxic principles. Information about the utility of LGMC in poultry diets are very limited (Newkirk et al., 1997). Therefore, the present experiment was conducted to study the performance of broiler chickens fed conventional (CMC) and low glucosinalate (LGMC) varieties of MC at 50 and 100% of SBM protein in *isocaloric* and *isonitrogenous* diets. The toxic principles present in the CMC interfere with fat metabolism leading to fat accumulation and enlargement of liver (Prasad and Rao, 1982b; Newkirk and Classen, 2002). The magnitude of fatty liver in the absence of supplemental choline with CMC was also tested to find out the possibility of enhancing the utility of CMC with methyl donors in poultry diets.

MATERIALS AND METHODS

Experimental diets

All the feed ingredients used were analysed for moisture, crude protein (CP), calcium (Ca), phosphorus (P) and ether extract (AOAC, 1995). Amino acid compositions of all feed ingredients were estimated with NIR-Spectroscopy. The metabolizable energy (ME) contents in major feed ingredients were calculated based on their nutrient composition. Standard starter (Table 1) and finisher (Table 2) diets were prepared using SBM as the principal source of protein. The SBM used in the starter (397.1 g/kg) and finisher (344.7 g/kg) diets were replaced with LGMC and CMC at 50 and 100% on nitrogen basis. The CP, lysine, methionine, Ca, available P and ME were maintained uniform in all the diets. Choline chloride (50%) was supplemented to all the diets at the level of 0.10%. Another diet was prepared using CMC as the principal source of

* Corresponding Author: S. V. Rama Rao. E-mail: svramarao1@rediffmail.com
Received September 22, 2004; Accepted February 28, 2005

Table 1. Ingredient and nutrient composition of broiler starter (up to 21 days of age) diets

Ingredient composition (g/kg)	Soya bean meal	Low glucosinalate mustard cake		Conventional mustard cake	
		50%	100%	50%	100
Yellow maize	556.6	477.1	384.9	529.6	502.0
Soybean meal	397.1	214.1	0.0	202.4	0.0
Low glucosinalate mustard cake	0.0	246.9	535.0	0.0	0.0
Conventional mustard cake	0.0	0.0	0.0	215.0	438.0
Vegetable oil	4.67	25.52	49.72	15.70	27.02
Dicalcium phosphate	18.85	16.30	13.34	16.80	14.69
Oyster shell grit	11.32	8.33	4.83	8.59	5.76
Common salt	4.0	4.0	4.0	4.0	4.0
DL-methionine	1.59	1.20	0.75	1.20	0.79
L-lysine·HCl	0.0	0.69	1.70	0.93	2.08
Vitamin premix[1]	0.40	0.40	0.40	0.40	0.40
Choline chloride (50%)	1.00	1.00	1.00	1.00	1.00
Toxin binder	2.00	2.00	2.00	2.00	2.00
Trace mineral mix[2]	1.20	1.20	1.20	1.20	1.20
Antioxidant	0.20	0.20	0.20	0.20	0.20
Antimicrobial[3]	0.50	0.50	0.50	0.50	0.50
Coccidiostat[4]	0.50	0.50	0.50	0.50	0.50
Nutrient composition					
ME (kcal/kg)	2,807	2,807	2,807	2,807	2,807
Protein (%)	221.5	221.5	221.5	221.5	221.5
Lysine (%)	13.16	13.00	13.00	13.00	13.00
Methionine (%)	5.2	5.2	5.2	5.2	5.2
Total sulfur amino acids (%)	9.03	8.9	8.9	8.9	8.9
Calcium (%)	8.0	8.0	8.0	8.0	8.0
Non-phytate phosphorus (%)	4.0	4.0	4.0	4.0	4.0
Crude fibre (%)	37.2	56.6	78.7	52.7	68.7

[1] Vitamin premix provided (mg/kg diet): thiamin 1; pyridodine, 2; cyanocobalamani, 0.01; niacin, 1.5; pantothenic acid, 10. Tocopherol, 10; riboflavin, 5; menadione, 1; retinal, acetate, 8,250 IU and cholecalciferol, 1,200 ICU.
[2] Trace mineral premix provided: $ZnSO_4$ 60; $MnSO_4$, 60; $FeSO_4$, 30; $CuSO_4$, 4.3 g/100 kg.
[3] Furazolidone, 22.4% W/W. [4] Coban TM (monensin sodium 10 w/w).

protein (CMC 100%) without supplemental choline. The total glucosinalate concentration in MC was estimated using titration method suggested by McGhee et al. (1965).

Birds and management

Two hundred seventy day-old commercial broiler chicks were distributed randomly in 54 stainless steel battery brooder pens with 5 chicks in each pen (24×30×18”). Ground maize was provided *ad libitum* on day one followed by the respective experimental diet up to 42 d of age. Each experimental diet was fed *ad libitum* to 9 replicate groups (pens) randomly from day 2 to 42 days of age. Required temperature in brooders was provided using incandescent bulbs.

Traits measured

Body weight and feed intake were recorded weekly intervals. Three milliliters of blood were collected from one bird from each replicate on 21st and 42nd day of age to study the serum concentrations of different cholesterol fractions [total cholesterol (Enzymatic method, product number 72181/72191), HDL cholesterol (PTA Precipitation method, product number 72201)], triglycerides (Glycerol Phosphate Oxidase method, product number 72381/72261/72271) and protein (TSP, 0500 CH) using diagnostic kits from M/s Qualigens Fine Chemicals, Mumbai, India. On 43 days of age, one bird from each replicate was selected at random and slaughtered to study the ready to cook (RTC) yield, relative weights of liver, abdominal fat, giblet, gizzard and lymphoid organs (bursa and spleen). Breast and thigh muscle and liver samples were analysed for protein and fat (AOAC, 1995) contents.

Statistical analysis

The data were subjected to one-way analysis of variance (Snedecor and Cochran, 1989), and the differences among treatment means were tested with Duncan Multiple Range Test (1955). Significance was considered at $p \leq 0.05$.

RESULTS AND DISCUSSION

Nutrient composition of feed ingredients

Low glucosinalate mustard cake contained lower CP and glucosinalates compared to the CMC (Table 3). The residual oil contents in LGMC and CMC were very similar. The concentrations of methionine and total sulfur-

Table 2. Ingredient and nutrient composition of broiler finisher (22 to 42 days of age) diets

Ingredient composition (g/kg)	Soya bean meal	Low glucosinalate mustard cake		Conventional mustard cake	
		50%	100%	50%	100%
Yellow maize	584.4	514.0	433.2	559.5	535.3
Soybean meal	344.7	187.36	0.0	177.2	0.0
Low glucosinalate mustard cake	0.0	214.4	466.5	0.0	0.0
Conventional mustard cake	0.0	0.0	0.0	186.7	381.9
Vegetable oil	30.2	48.68	69.86	40.16	50.07
Dicalcium phosphate	17.98	15.76	13.16	16.20	14.34
Oyster shell grit	11.27	8.67	5.61	8.90	6.42
Common salt	4.0	4.0	4.0	4.0	4.0
DL-methionine	1.69	1.35	0.95	1.34	0.99
L-lysine·HCl	0.0	0.0	0.89	0.21	1.21
Vitamin premix[1]	0.20	0.20	0.20	0.20	0.20
Choline chloride (50%)	1.00	1.00	1.00	1.00	1.00
Toxin binder	2.00	2.00	2.00	2.00	2.00
Trace mineral mix[2]	1.20	1.20	1.20	1.20	1.20
Antioxidant	0.20	0.20	0.20	0.20	0.20
Antimicrobial[3]	0.50	0.50	0.50	0.50	0.50
Coccidiostat[4]	0.50	0.50	0.50	0.50	0.50
Nutrient composition					
ME (kcal/kg)	3,006	3,006	3,006	3,006	3,006
Protein (%)	201.5	201.5	201.5	201.5	201.5
Lysine (%)	11.68	11.00	11.00	11.00	11.00
Methionine (%)	5.0	5.0	5.0	5.0	5.0
Total sulfur amino acids (%)	8.5	8.5	8.5	8.5	8.5
Calcium (%)	7.8	7.8	7.8	7.8	7.8
Non phytate phosphorus (%)	3.8	3.8	3.8	3.8	3.8
Crude fibre (%)	34.5	51.5	70.7	48.0	62.0

[1] Vitamin premix provided (mg/kg diet): thiamin 1; pyridodine, 2; cyanocobalamani, 0.01; niacin, 1.5; pantothenic acid, 10. Tocopherol, 10; riboflavin, 5; menadione, 1; retinal, acetate, 8,250 IU and cholecalciferol, 1,200 ICU.
[2] Trace mineral premix provided : $ZnSO_4$ 60; $MnSO_4$, 60; $FeSO_4$, 30; $CuSO_4$, 4.3 g/100 kg.
[3] Furazolidone, 22.4% W/W. [4] Coban TM (monensin sodium 10 w/w).

Table 3. Nutrient composition of feed ingredients

Feed ingredient	Nutrients[1]					
	ME (kcal/kg)	Crude protein	Ether extract	Ca	Total P	Glucosinalates (mM/g)
Yellow maize	3,350	9.54	2.89	0.09	0.26	
Soyabean meal	2,250	44.9	1.04	0.45	0.60	
LGMC[2]	1,988	35.1	4.45	0.62	1.13	30
CMC[3]	2,000	39.9	3.94	0.69	1.21	156
Dicalcium phosphate				20.0	15.4	
Oyster shell grit				33.5		

[1] 88% dry matter basis. [2] Low glucosinalte mustard cake. [3] Conventional mustard cake.

containing amino acids were higher and concentrations of other amino acids were lower in MC compared to SBM (Table 4). The amino acid profile in both varieties of MC was constant in relation to the CP concentration in the cakes.

Weight gain and feed efficiency

The data on body weight gain and efficiency of feed utilization in broilers as influenced by feeding LGMC and CMC at 50 and 100% of SBM are given in Table 5. At 21 days of age, the body weight gain was not affected by replacing SBM with either LGMC or CMC at 50%, but total replacement of SBM with these cakes significantly ($p<0.001$) depressed the growth compared to those fed the SBM reference diet. At 100% level, LGMC -fed broilers gained significantly more weight as compared to the CMC fed birds. However at 42 days of age, body weight gain was not affected by replacing SBM totally with LGMC or CMC at 50%. But replacement of SBM with CMC at 100% significantly depressed growth compared to those fed the other diets.

The growth depression observed in broilers fed 100% LGMC at 21 days of age, but not at 42 days of age indicates the influence of age on tolerance level to LGMC (Rao and Cladinin, 1970; Prasad et al., 1973). These authors reported increased tolerance in birds to higher levels of MC with increase in age. The growth depression in the birds fed

Table 4. Amino acid composition (%) of feed ingredients[1]

Amino acid	Feed ingredients			
	Maize	Soybean meal	LGMC[2]	CMC[3]
Crude protein	9.54	44.88	35.12	39.92
Methionine	0.19	0.57	0.67	0.70
Cystine	0.21	0.65	0.94	1.04
Total sulfur amino acids	0.39	1.22	1.61	1.75
Lysine	0.26	2.67	1.85	2.01
Threonine	0.32	1.70	1.47	1.51
Tryptophan	0.07	0.61	0.50	0.57
Arginine	0.42	3.32	2.19	2.65
Isoleusine	0.30	2.04	1.37	1.47
Leucine	1.16	3.46	2.39	2.58
Valine	0.42	2.13	1.76	1.83

[1] 88% dry matter basis. [2] Low glucosinalate mustard cake.
[3] Conventional mustard cake.

Table 5. Weight gain and feed efficiency of broilers (up to 42 days of age) fed low glucosinalate (LGMC) and conventional mustard cakes (CMC) in place of soybean meal (SBM)

Diet	Body wt gain/g		Feed/gain	
	21 days	42 days	21 days	42 days
SBM	734.9[a]	2,022[a]	1.359[cd]	1.761[b]
LGMC 50%	713.3[a]	1,964[a]	1.333[d]	1.726[b]
LGMC 100%	637.9[b]	1,923[a]	1.284[d]	1.707[b]
CMC 50%	701.3[a]	1,908[a]	1.417[bc]	1.800[b]
CMC 100%	522.8[c]	1,646[b]	1.496[ab]	1.906[a]
CMC 100%*	462.7[d]	1,613[b]	1.561[a]	1.772[b]
P≤	0.001	0.001	0.001	0.001
N	9	9	9	9
SEM±	13.88	24.6	0.0152	0.0129

* No supplemental choline.
[a, b] Means with different superscripts in a column differ significantly (p≤0.05).

100% CMC diet but not in LGMC diet, might be due to the higher concentration of glucosinalates present in the former. The LGMC-based diet contained lower concentration of glucosinalates (16.1 and 14.0 mM/kg in starter and finisher diets, respectively) compared to CMC (68.3 and 59.6 mM/kg starter and finisher diets, respectively). The literature also suggested the lack of ill effects of feeding low glucosinalate cultivars of MC when they were used at higher (15-28%) concentration in broiler diets (Sadagopan et al., 1982; Newkirk et al., 1997; Yaved et al., 1999).

At 21 days of age, the broilers fed CMC at 100% with no supplemental choline gained significantly low body weight compared to those fed choline supplemented diet. Thus the results indicated the possibility of minimizing the ill effects of certain intrinsic toxic principles present in CMC with supplemental choline. The exact role of choline in minimizing the ill effects of feeding higher levels of MC is not known, however, its role as lipotropic factor (Ruitz et al., 1983; Rama Rao et al., 2001) might have contributed to the partial alleviation of deleterious effects of MC. Although, the liver weight was not affected by choline supplementation to CMC 100 diet, the reduction in total cholesterol at 21days of age (Table 6) and fat deposition in liver (Table 8) support the hypothesis. However, such beneficial effects were not observed at 42 days of age. This could be attributed to increasing ability of chick to synthesize choline with age (Leeson and Summers, 2001). The efficiency of feed utilization was not affected by replacing SBM *in toto* with LGMC or CMC up to 50% at either 21 or 42 days of age. However, the efficiency of feed utilization was significantly depressed when CMC was used at 100% both at 21 and 42 days of age compared to those fed the SBM reference diet.

Much of the literature available on MC is based on the work done with traditional MC (i.e. CMC) and few reports are available on the utilization of low glucosinalate MC in poultry diets (Newkirk et al., 1997). The results of the present experiment suggest that CMC could be incorporated up to 21.5 and 18.67% in *isocaloric* and *isonitrogenous* broiler starter and finisher diets, respectively, without affecting growth and feed efficiency, but higher levels (43.8 and 38.19% in starter and finisher diets, respectively) depressed the performance. These findings are in line with the previous reports (Malik et al., 1972; Sadagopan et al., 1982; Newkirk et al., 1997; Yaved et al., 1999). However, growth depression was reported by McNeill and MacLeods

Table 6. Serum biochemical profile of broilers (up to 42 days of age) fed low glucosinalate (LGMC) and conventional mustard cakes (CMC) in place of soybean meal (SBM)

Diet	Protein (%)		Cholesterol, mg/dl		Tryglycerides, mg/dl		HDL cholesterol, mg/dl	
	21 d	42 d	21 d	42 d	21 d	42 d	21 d	42 d
SBM	1.678[a]	2.468[ab]	109[a]	187[a]	22.4[ab]	53.4[a]	107	118[a]
LGMC 50%	1.320[b]	2.258[b]	111[a]	151[b]	17.3[b]	36.7[b]	72.4	94.1[d]
LGMC 100%	1.689[a]	2.433[ab]	116[a]	148[b]	21.0[b]	38.9[b]	90.6	106[bc]
CMC 50%	1.728[a]	2.559[ab]	112[a]	151[b]	20.4[b]	58.3[a]	89.3	105[bc]
CMC 100%	1.753[a]	2.633[a]	90[b]	123[c]	26.3[a]	62.8[a]	65.0	97.1[cd]
CM 100%*	1.784[a]	2.612[a]	108[a]	141[b]	22.4[ab]	57.8[a]	71.1	110[ab]
p≥	0.001	0.028	0.002	0.001	0.001	0.001	NS	0.001
N	9	9	9	9	9	9	9	9
SEM±	0.036	0.037	2.19	2.85	0.62	1.69	4.79	1.57

* No supplemental choline.
[a, b] Means with different superscripts in a column differ significantly (p≤0.05).

(2001) when MC was used even at 10% in the broiler diets.

The growth depression observed in broilers fed 100% CMC might have been due to the higher inclusion levels of CMC in the present study (43.8 and 38.2%, respectively in starter and finisher phase) compared to the maximum levels tested (28 and 32%) in the previous studies (Cilly et al., 1977; Sadagopan et al., 1982). The possible reasons for the lack of uniformity regarding the toxic levels of MC in chicken diet may be due to the cultivar (Kubota et al., 1972), residual oil content (i.e. erucic acid) in MC (Vogtmann et al., 1975, Sadagopan et al., 1981), processing conditions of the cake (Newkirk and Classen, 2002) or the variation in reference protein source used, i.e., SBM or groundnut meal (Mandal and Saxena, 1985; Newkirk et al., 1997; Banday and Verma, 2003).

Serum biochemical profile

The concentrations of protein, total and HDL cholesterol and triglycerides in serum were significantly affected by replacement of SBM with MC (Table 6). At 21 days of age, the concentration of protein in serum of broilers fed 50% LGMC diet decreased significantly as compared to those fed the other diets. However, the serum protein concentration was significantly depressed at 50% LGMC compared to those fed 100% CMC with or without choline supplementation at 42 days of age, while the serum protein concentration in other groups were intermediate.

At 21 days of age, the serum total cholesterol (TC) concentration decreased significantly by replacing SBM *in toto* with CMC, however, the TC concentration increased similar to those fed the SBM reference diet by not supplementing choline to CMC 100% diet. At 42 days of age, the serum TC concentration decreased significantly by incorporation of both varieties of MC in broiler diet. Among varieties of MC, CMC 100% decreased TC compared to broilers fed the other MC based diets. Non-supplementation of choline to CMC 100% diet significantly improved serum TC concentration similar to those fed diets containing CMC 50% or LGMC up to 100%.

The concentration of triglycerides in serum did not show any specific trend at 21 days of age, however, at 42 days of age, the concentration decreased significantly in LGMC diets compared to those fed the SBM reference diet. Incorporation of CMC did not influence the serum triglyceride concentration.

The HDL cholesterol concentration at 21 days of age was not affected by the dietary treatments. However, the concentration decreased by incorporation of both varieties of MC compared to the SBM reference group at 42 days of age. Removal of choline chloride from the CMC 100% diet significantly improved the concentration, which was similar to those fed the SBM reference diet. Reduction in concentrations of total and HDL cholesterol at 42 days of age with both LGMC and CMC levels, triglyceride concentration with LGMC level suggested the possibility of altering the serum lipid profile by replacing SBM with LGMC. The beneficial effects of incorporating MC on serum lipid profile need to be investigated further to produce poultry products with minimum fat/cholesterol concentrations.

Carcass parameters

The relative weights of lymphoid organs and abdominal fat were not affected by replacing SBM with MC (Table 7). However, the relative weights of liver, gizzard, giblet and RTC yield were influenced by the treatments employed in the present study. The liver weight was significantly increased in broilers fed either LGMC 100% or CMC 100% diets without supplemental choline. Athough the liver weight in the other groups fed with MC increased, the difference between MC and SBM groups was not significant (p>0.05). The hepatic enlargement in birds fed MC could be attributed to the erucic acid present in the residual oil present in these cakes (Newkirk and Classen, 2002). The calculated erucic acid concentration in diets based on LGMC and CMC in starter and finisher diets was 1.05, 0.915%, 0.761 and 0.664%, respectively. These levels were marginally lower than the toxic levels of erucic acid reported by Prasad and Rao (1982b). These authors found higher liver weight in broilers fed MC based diets

Table 7. Relative weight of RTC yield and visceral organs (g/kg) in broilers (up to 42 days of age) fed low glucosinalate (LGMC) and conventional mustard cakes (CMC) in place of soybean meal (SBM)

Diet	RTC yield	Giblet	Liver	Gizzard	Bursa	Spleen	Abd. fat
SBM	749.7^{a}	41.35^{b}	21.47^{b}	16.23^{b}	0.493	2.109	14.34
LGMC 50%	732.8^{ab}	44.62^{ab}	23.95^{ab}	16.59^{ab}	0.636	1.482	11.60
LGMC 100%	720.3^{bc}	47.63^{a}	25.80^{a}	17.36^{ab}	0.778	1.769	12.19
CMC 50%	719.9^{bc}	47.43^{a}	23.83^{ab}	18.89^{a}	0.511	1.570	8.60
CMC 100%	714.7^{bc}	47.98^{a}	24.14^{ab}	18.92^{a}	0.476	1.619	11.62
CMC 100%*	706.6^{c}	49.01^{a}	25.23^{a}	18.81^{a}	0.731	1.750	10.77
P≤	0.0001	0.0003	0.0121	0.0414	NS	NS	NS
N	9	9	9	9	9	9	9
SEM±	2.94	0.584	0.371	0.339	0.0484	0.07	0.636

* No supplemental choline.

[a, b] Means with different superscripts in a column differ significantly (p≤0.05).

Table 8. Protein and fat content (%) in thigh muscle, breast muscle and liver of broilers (up to 42 days of age) fed low glucosinalate (LGMC) and conventional mustard cakes (CMC) in place of soybean meal (SBM)

Diet	Fat			Protein		
	Thigh muscle	Breast muscle	Liver	Thigh muscle	Breast muscle	Liver
SBM	10.87	2.112	12.73[ab]	78.64[b]	88.72[ab]	62.04
LGMC 50%	11.74	2.318	12.80[ab]	81.00[ab]	88.13[b]	65.40
LGMC 100%	12.09	3.177	13.00[ab]	80.81[ab]	89.76[a]	67.74
CMC 50%	10.21	2.023	11.57[b]	82.80[a]	88.22[b]	57.42
CMC 100%	11.99	2.429	11.87[b]	75.99[c]	89.19[ab]	64.12
CMC 100%*	13.17	2.770	14.66[a]	75.87[c]	87.80[b]	68.80
p≤	NS	NS	0.0490	0.0001	0.0470	NS
N	9	9	9	9	9	9
SEM±	0.338	0.111	0.303	0.430	0.205	1.335

* No supplemental choline. [a, b] Means with different superscripts in a column differ significantly (p≤ 0.05).

containing 1.21 to 1.82% erucic acid.

The relative weight of giblet increased significantly by replacing SBM with both varieties of MC compared to those fed the SBM based diet except LGMC at 50%, which did not differ with SBM based diet. Similarly, the relative weight of gizzard increased due to incorporation of CMC with or without choline supplementation. Replacement of SBM with LGMC did not alter the gizzard weight. The reasons for increased relative weights of gizzard and giblet may be due to higher levels of fibre (5.27 to 7.87% and 4.8 to 7.07%, respectively in starter and finisher diets) present in diets containing MC compared to those fed the SBM based diets (3.72 and 3.45%, respectively in starter and finisher diets). The higher levels of fibre in diets based on MC might have increased the activity of these organs as an effort to increase its digestibility. Similar hypertrophic effect due to high fibre diets on different visceral organs was also observed in our previous studies (Rama Rao et al., 2000; 2004).

Protein and fat contents in tissue

Incorporation of two varieties of MC in broiler diets significantly affected the protein content in thigh and breast muscle and fat content in the liver (Table 8). The fat content in breast muscle was significantly higher in LGMC 100% fed birds compared to those fed the other except CMC 100% without supplemental choline. In the latter group, the fat content in the breast muscle was similar to those fed LGMC 100%. The fat content in liver was not affected by replacing SBM with both varieties of MC up to 100%. Non supplementation of choline to CMC 100% diet increased the fat content in the liver, suggesting the possibility of alleviating the toxic effects of MC by supplementing methyl donors in diets containing MC. Choline supplementation is known to reduce fat deposition in chicken (Ruiz et al., 1983; Rama Rao et al., 2001). Athough the difference was not significant (p>0.05), choline supplementation reduced the fat contents in both thigh and breast muscles (Table 8). The protein content in thigh muscle increased significantly in broilers fed 50% CMC compared to those fed SBM as the principal source of protein in diet. However, total replacement of SBM with CMC reduced the protein content in thigh muscle. The protein content in thigh muscle was not affected by the incorporation of LGMC in place of SBM. Athough the protein content in breast muscle was significantly influenced, the variation did not show any specific trend.

Based on these results, it is concluded that SBM can be replaced *in toto* with the LGMC and up to 50% with CMC in commercial broiler chicken diet without affecting growth, feed efficiency and slaughter traits. Higher levels of CMC (100% of SBM) significantly reduced growth and feed efficiency compared to those fed SBM. Serum cholesterol (CMC and LGMC) and tryglyceride concentrations (LGMC) decreased significantly due to incorporation of mustard cakes in broiler diets.

ACKNOWLEDGEMENT

This study was supported and financed by the National Agricultural Technology Project (NATP). The authors are thankful to M/S Dugussa AG, Germany for their help in amino acid analysis of feed ingredients.

REFERENCES

AOAC. 1995. Official methods of Analysis. 16th edn. Association of Official Analyticl Chemists, Washington, DC.

Banday, M. T. and S. V. S. Verma. 2003. Influence of chemical treatment of rapeseed meal diets on the performance and nutrient utilization in broiler chicken. Indian J. Anim. Nutr. 20(1):76-82.

Cilly, V. K., G. N. Lodhi and J. S. Ichhoponani. 1977. Mustard cake a substitute for groundnut cake in egg type and meat type chick diets. J. Agric. Sci. Camb. 89:759-765.

Duncan, D. B. 1955. Multiple range and multiple F. tests. Biometrics 11:1-42.

Kubota, D., S. Hijkuro, M. Matsushima, S. Noguchi, I. Mai, M. Ino, K. Hirano and S. Trie. 1972. Nutritive value of rapeseed-meal as a feedstuff for poultry. Poult. Sci. 9:274-80.

Lesson, J. D. and S. Summers. 2001. Scott's Nutrition of Chicken. 4th Edition, International Book Distributing Co., Lucknow,

India.
Malik, N. S., G. N. Lodhi and J. S. Ichhoponani. 1972. Feeding value of mustard oil cake as protein source for chickens. Proc. Second Ann. Poult. Sci. Symp. pp. 26-27. Indian Poult. Sci. Assoc. Ludhiana.
Mandal, A. B. and V. P. Saxena. 1985. Associative efficiency of certain protenic byproducts for broiler production performance. Indian J. Poult. Sci. 20:94-100.
McGhee, J. E., L. D. Kirk and G. G. Mustakas. 1965. Total glucosinalates methods for Brassica species. J. Assoc. Off. Anal. Chem. 42:889-891.
McNeill, L. and M. G. Mac Leods. 2001. Food intake, growth rate and food conversion in broilers fed on diets high in rapeseed meal and pea meal. Br. Poult. Sci. 42:4-5.
Newkirk, R. W., H. L. Classen and R. T. Tyler. 1997. Nutritional evaluation of low glucosinolate mustard meals (*B. juncea*) in broiler diets, Poult. Sci. 76(9):1272-1277.
Newkirk, R. K. and H. L. Classen. 2002. The effects of toasting canola meal on body weight, feed conversion efficiency and mortality in broiler chickens. Poult. Sci. 81:815-825.
Prasad, A. and P. V. Rao. 1982 a. Factors limiting the utilization of mustard cake by chicken. Indian J. Anim. Sci. 52:417-422.
Prasad, A. and P. V. Rao. 1982b. Effect of dietary erucic acid and erucic acid free mustard cake on the performance of starter chicks. Indian J. Anim. Sci. 52:547-551.
Prasad, J., S. B. Misra and O. P. Agarwala. 1973. Study on growth of starter cockerels as affected by partial replacement of protein of groundnut cake with that of mustard cake and fish meal. Indian J. Poult. Sci. 8:273-276.
Rama Rao, S. V., M. R. Reddy, N. K. Praharaj and G. Shyam Sunder. 2000. Laying performance of broiler breeder chicks fed various millets or broken rice as a source of energy at a constant nutrient intake. Tropical Anim. Health Prod. 32:329-338.
Rama Rao, S. V., G. Shyam Sunder, M. R. Reddy, N. K. Praharaj, M. V. L. N. Raju and A. K. Panda. 2001. Effect of supplementary choline on the performance of broiler breeders fed on different energy sources. Br. Poult. Sci. 42:362-367.
Rama Rao, S. V., M. V. L. N. Raju, M. R. Reddy and A. K. Panda. 2004. Replacement of yellow maize with pearl millet (*Pennisetum typhoides*), foxtail millet (*Setaria italica*) or finger millet (*Eleusine coracana*) in broiler chicken diets containing supplemental enzymes. Asian-Aust. J. Anim. Sci. 17(6):836-842.
Rao, P. V. and D. R. Clandinin. 1970. Effect of method of determination on the metabolizabke energy value of rape seed meal. Poult. Sci. 49:1069-1074.
Ruiz, N., R. D. Miles and R. H. Harmes. 1983. Choline, methionine and sulphate interrelationship in poultry nutrition, a review. World's Poult. Sci. J. 39:185-198.
Sadagopan, V. R., V. R. Reddy and T. S. Johri. 1981. Studies on the utilization of mustard oil cake in chicks and layers. Indian Poult. Gaz. 65(4):130-135.
Sadagopan, V. R., H. P. Shrivastava, T. S. Johri and Surendra Chand. 1982. Utilization of solvent extracted mustard oil cake in broilers. Avian Res. 66(3):91-94.
Snedecor, G. W. and W. G. Cochran. 1989. Statistical Methods. Oxford and IBH Publishing Company, New Delhi.
Vaidya, S. V., B. Panda and P. V. Rao. 1979. Studies on nutritive value and utilization of mustard oil cake (MOC) in broilers. Indian Vet. J. 56:875-884.
Vogtmann, H., D. R. Clandinin and R. T. Hardin. 1975. The effect of crude and refined low erucic acid rapeseed-oil in the diet of broiler chicken. Br. Poult. Sci. 16:63-65.
Yaved, M. Y., T. N. Pasha, A. Khalique and A. Mahmud. 1999. Use of different levels of rapeseed meal in broiler diets. Indian J. Anim. Nutr. 16(2):160-163.