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Nutritional and Physiological Effects of Different Levels of Canola Meal in Broiler Chick Diets

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ABSTRACT

This study was undertaken to evaluate the effect of different dietary levels of Canola Meal (CM) on growth performance and histological responses of broiler chicks. Cobb-500 day-old chicks were randomly distributed to five equal treatments, each of three replications. Ten starter and grower CM-diets (0.0, 10, 12.5, 15 and 20%) were formulated and used for 6 weeks. The chicks were kept in brooding and rearing batteries and fed their respective experimental diets. All chicks were managed similarly. The criteria of response were performance, carcass traits, plasma thyroid hormones and histological characteristics of liver and thyroid. Feeding CM-containing diets (up to 15%) did not adversely affect growth performance or carcass traits but relative weight of thyroid was significantly increased. Increasing dietary CM level up to 20% caused significant increases in feed intake, percentages of abdominal fat and thyroid gland but negatively affected weight gain, feed conversion ratio, bursa relative weight and plasma thyroxine concentration compared with the control chicks. Plasma level of triiodothyronine and activity of alanine aminotransferase were not affected by dietary treatments. Activity of plasma aspartate aminotransferase was significantly increased in chicks fed the highest two levels of CM compared with the control ones. The chicks fed the 20% canola meal diets exhibited progressive changes in the liver architecture and thyroid structure. Taking the histological feature of liver and thyroid, plasma thyroid hormones and growth performance into account, it could be concluded that canola meal can safely be included in broiler diets at a level of 15%.

Key words: Dietary canola meal, broiler performance, carcass traits, thyroid hormones, histology

INTRODUCTION

In developing countries, nutritionists and poultry producers are usually interested in compounding the poultry feeds based on the least-cost feed formulation program. Although soybean meal is an expensive protein source, it still the major plant protein component of poultry diets worldwide but when its purchasing prices become considerably high, the economic aspect dictates to look for other cheaper plant proteins. New cultivars of rape seed (so-called double-zero varieties) that contain low glucosinolates or low erucic acid have been developed in Canada, during the last few decades (Elkin, 2002). The by-product derived from such new cultivars after oil extraction is termed Canola Meal (CM). Because the oil from these special cultivars was low in erucic acid, Canadian producers coined the term canola (for Canadian oil low acid) (Cheeke, 1998). In this

respect, Bell (1993) reported that canola is the registered name for rapeseed containing less than 2% of the total fatty acids in the oil as erucic acid and less than 30 μmol of alkenyl glucosinolates per gram of oil-free dry matter of the seed.

As regards the nutritive value of CM, various publications in the literature indicated that its crude protein content is lower than that of soybean meal (34.8-40% vs. 44 or 48%) and although canola meal also contains less lysine per unit of dietary protein, it is relatively richer in methionine than soybean meal (NRC., 1994; Elkin, 2002; Khajali and Slominski, 2012). On the other hand, the limited use of double zero, low-glucosinolate and low-erucic acid varieties of rapeseed meal in the nutrition of monogastric animals is due to the low available energy content and the presence of antinutritional factors, including glucosinolates, sinapine and phytate (Mawson *et al.*, 1994, 1995) and dietary fiber components, such as tannins or non-starch polysaccharides (Slominski and Campbell, 1990; Kocher *et al.*, 2000; Khajali and Slominski, 2012).

In an early study, Summers *et al.* (1992) observed no significant differences in weight gain or feed conversion ratio of 6 weeks old male broiler chickens fed a practical type corn-soybean meal diet or a similar diet containing 25% canola meal but feed intake was negatively affected in birds fed the CM-supplemented diets. In addition, Figueiredo *et al.* (2003) investigated the response of broiler chicks to feeding diets containing various levels of CM during the starter period and concluded that it is possible to include up to 20% of CM without adverse effects on growth performance. Moreover, Khajali and Slominski (2012) reviewed that canola meal can be incorporated to diets of broiler chickens and laying hens up to 20%, without producing any adverse effects. Recently, Zdunczyk *et al.* (2013) reported that inclusion of low-glucosinolate rapeseed meal up to 18% in diets of male turkey poults did not affect the growth performance of turkeys. More recently, Gopinger *et al.* (2014) evaluated the effects of dietary inclusion of CM on growth performance of broiler chicks and concluded that canola meal can be added up to 16.7% in diets for broilers with no deleterious effect on their growth performance.

It is interesting to note that the glucosinolate content of the currently-produced CM is only about one-twelfth (10 vs. 120 $\mu\text{mol g}^{-1}$) of that of the older high glucosinolate rapeseed, as demonstrated by Khajali and Slominski (2012). They also stated that since CM contains more methionine and cysteine but less lysine than soybean meal, both meals tend to complement each other when used together in poultry diets.

Therefore, the aim of this study was to investigate the effect of including canola meal in broilers' diets on their growth performance, certain carcass traits, plasma thyroid hormones and histological responses of liver and thyroid gland.

MATERIALS AND METHODS

The field work of this study was carried out at the Poultry Research Unit; Kalabsho Agricultural Researches and Experiments Center, Faculty of Agriculture, Mansoura University, El-Mansoura, Egypt, during October and November, 2014. However, the blood analyses and tissue histological examinations were undertaken at the Laboratory of Poultry Physiology, Faculty of Agriculture, Ain Shams University, Egypt.

Experimental diets: Five starter and five grower experimental diets containing graded levels of CM (0.0, 10.0, 12.5, 15.0 and 20.0%, equivalent to 40, 50, 60 and 80% from soybean meal) were formulated to meet the nutrient requirements of broiler chicks, as recommended by NRC (1994). Canola seed (*Brassica napus* L.) meal, evaluated herein, was purchased from the local market and

Table 1: Composition and calculated analysis of the experimental starter and grower diets used in the present study

Ingredients	CM levels in starter diets (%)					CM levels in grower diets (%)				
	0.0	10	12.5	15	20	0.0	10	12.5	15	20
Yellow corn	55.88	54.38	54.12	54.07	53.30	61.25	60.45	60.33	60.00	59.23
Soybean meal (44%)	25.00	15.00	12.50	10.00	5.00	25.00	15.00	12.50	10.00	5.00
Corn gluten meal	11.70	13.00	13.25	13.52	14.20	6.20	7.30	7.60	7.86	8.50
Canola meal (CM)	0.00	10.00	12.50	15.00	20.00	0.00	10.00	12.50	15.00	20.00
Ground limestone	1.57	1.52	1.60	1.59	1.60	1.55	1.50	1.47	1.47	1.47
Dicalcium phosphate	1.50	1.38	1.31	1.20	1.20	1.30	1.10	1.00	1.02	1.02
Premix [†]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sunflower oil	3.40	3.65	3.67	3.67	3.75	3.65	3.74	3.75	3.80	3.93
Common salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.10	0.12	0.10	0.10	0.10	0.10	0.11	0.00	0.00	0.00
Lysine-HCl	0.20	0.30	0.30	0.20	0.20	0.30	0.15	0.20	0.20	0.20
Calculated analysis										
ME (kcal kg ⁻¹)	3204.00	3208.00	3204.00	3203.00	3198.00	3207.00	3202.00	3202.00	3200.00	3199.00
Crude protein (%)	23.25	23.11	23.00	22.84	22.74	20.39	19.95	19.88	19.78	19.65
Ether extract (%)	6.02	6.54	6.63	6.71	6.93	6.33	6.72	6.81	6.93	7.19
Crude fiber (%)	3.13	3.11	3.74	3.87	4.11	3.18	3.67	3.80	3.92	4.16
Calcium (%)	1.01	0.99	1.02	1.00	1.02	0.95	0.93	0.90	0.92	0.94
Available P (%)	0.41	0.39	0.38	0.36	0.36	0.37	0.33	0.32	0.32	0.42
Lysine (%)	1.09	1.11	1.09	1.00	0.96	1.13	0.95	0.97	0.95	0.92
Methionine (%)	0.53	0.57	0.56	0.57	0.58	0.46	0.49	0.39	0.39	0.41
Meth+cyst. (%)	0.92	1.00	1.00	1.01	1.00	0.80	0.87	0.77	0.78	0.81

[†]Each 3 kg premix contains, Vit. A: 12,000,000 IU, Vit. D₃: 3,000,000 IU, Vit. E: 10,000 mg, Vit. K₃: 3,000 mg, Vit. B₁: 200 mg, Vit. B₂: 5,000 mg, Vit. B₆: 3,000 mg, Vit. B₁₂: 15 mg, Biotin: 50 mg, Folic acid: 1,000 mg, Nicotinic acid: 35,000 mg, Pantothenic acid: 10,000 mg, Mn: 80 g, Cu: 8.8 g, Zn: 70 g, Fe: 35 g, I: 1.0 g, Co: 0.15 g and Se: 0.3 g

added to the basal diets mainly at the expense of soybean meal with slight modifications in dietary levels of yellow corn and corn gluten meal. All the experimental diets were isocaloric and isonitrogenous and their ingredient compositions and calculated analyses are shown in Table 1.

Birds and management: One hundred and eighty, day-old Cubb-500 broiler chicks were randomly divided into five equal experimental groups, each composed of three equal replications. Chicks of each replicate group were kept at a separate compartment of wire-floored brooding battery and fed their respective starter diet until the chicks were three weeks of age; then, they were transferred to two compartments (with one feeder) of wire-floored rearing battery and fed their respective grower diet from 3-6 weeks of age. All chicks were managed similarly; had free access to feed and water and subjected to a daily photoperiod of 22 h. The chicks were vaccinated against New Castle disease, infectious bursal disease and avian influenza viruses.

Growth performance of broiler chicks: Growth performance of chicks was evaluated as Live Body Weight (LBW), Body Weight Gain (BWG), Feed Intake (FI) and Feed Conversion Ratio (FCR). Records on weekly FI and LBW of birds on a replicate group basis for both the starter and grower phases of the fattening period were maintained and thus, BWG and FCR (g feed consumed: g BWG) were calculated throughout the whole experimental period (1-42 days of age). Mortality of birds, however, was monitored and recorded daily.

Carcass traits and vital internal organs/glands: At the end of the experimental period, six birds from each dietary treatment were randomly chosen, weighed and slaughtered. Just after complete bleeding, their carcasses were scalded, feather plucked and immediately processed. Relative weights (% of LBW of bird at slaughter) of carcass dressing-out (i.e., total edible parts), abdominal fat and vital internal organs (i.e., liver, thymus, spleen and bursa of Fabricius) and thyroid glands were estimated.

Blood parameters of broiler chicks: During slaughtering, six blood samples per treatment were collected in heparinized tubes. Blood samples were immediately centrifuged for 10 min at 4000 rpm, then blood plasma was decanted and stored at -20°C until later analyses. Activity of blood plasma transaminases [alanine aminotransferase (ALT) and aspartate aminotransferase (AST)] was measured by using available commercial kits according to Reitman and Frankel (1957). Plasma concentrations of thyroxine (T4) and triiodothyronine (T3) were determined by radioimmunoassay technique using commercial radioimmunoassay kits, as reported by Akiba *et al.* (1982). The T3/T4 ratio was also calculated.

Histological examination of liver and thyroid gland: Representative tissue samples (from liver and thyroid gland) were taken during slaughtering and immediately fixed in 10% formalin-saline solution for 24 h before preparing the histological sections by using Paraffin method technique. All the excised sections were stained with hematoxylin and eosin stain, examined under light microscopes (X40) and then photographed by using Canon digital camera.

Experimental design and statistical analysis: A completely randomized design was used. The statistical processing of data was performed by using one-way analysis of variance of the Statistical Analysis System (SAS., 2006). The significant differences among means of the different variables were identified by Duncan's new multiple range test (Duncan, 1955) at $p \leq 0.05$.

RESULTS AND DISCUSSION

Growth performance of broiler chicks: The effects of feeding diets containing different levels of Canola Meal (CM) on growth performance of broiler chicks from 1 day-old to 6 weeks of age are given in Table 2. It was observed that Body Weight Gain (BWG) of chicks was negatively affected ($p \leq 0.05$) due to increasing dietary CM up to 20% during the starter (1-21 days old) and grower (21-42 days old) periods. Live Body Weight (LBW) responded similarly during both the starter and grower phases of the fattening period. Feeding the CM-containing diets adversely affected ($p \leq 0.05$) feed conversion ratio (FCR) only when CM level reached 20% during both the starter and the whole experimental period (1-42 days of age) but FCR was not affected by dietary CM during the grower period. Increasing dietary CM level up to 20% did not affect Feed Intake (FI) during the starter period but feeding the CM-containing diets resulted in significant increases ($p \leq 0.05$) in FI during both the grower and the whole experimental period compared with the control birds. It is important to note that no deaths occurred during the course of this study.

The above results indicate that when the dietary inclusion level of CM increased to 20% BWG and FCR were negatively affected. The reduced growth performance of broilers fed the 20% CM-containing diets, observed in the present study, may be related to the anti-nutrients or toxic substances that may be present in CM, such as glucosinolates, sinapine, non-starch polysaccharides and phytate which can interfere with digestion and bioavailability of nutrients (El-Wardany and Mohamed, 1995; Kermanshahi and Abbasi Pour, 2006; Gopinger *et al.*, 2014). The high crude fiber content of canola meal (12%), as indicated by NRC (1994), is also involved, at least partly, in the

Table 2: Effect of different dietary levels of canola meal (CM) on growth performance of broiler chicks from day-old to 6 weeks of age

Dietary treatments	LBW (g)			BWG (g)		
	Day-old	3 weeks old	6 weeks old	1-21 days old	21-42 days old	1-42 days old
Control	43.8±2.2	736.9±12.4 ^a	1998.6±46.3 ^b	693±10.8 ^a	1261±23.9 ^a	1998±39.5 ^a
10% CM	43.3±1.4	729.5±10.6 ^a	2018.2±32.4 ^a	684±15.2 ^a	1289±18.9 ^{ab}	1974±35.4 ^a
12.5% CM	44.2±1.1	725.8±16.5 ^a	2030.4±50.5 ^a	681±14.9 ^a	1305±23.7 ^{ab}	1986±41.2 ^{ab}
15% CM	43.7±1.2	716.6±12.8 ^a	2015.6±42.8 ^a	672±18.5 ^a	1299±21.8 ^{ab}	1971±48.5 ^{ab}
20% CM	43.8±1.3	670.4±14.3 ^b	1910.5±38.5 ^c	626±14.8 ^b	1240±18.1 ^b	1867±45.3 ^b
Significance	NS	*	*	*	**	**
Dietary treatments	FI (g)			FCR (g feed: g gain)		
	1-21 days old	21-42 days old	1-42 days old	1-21 days old	21-42 days old	1-42 days old
Control	9980±15.8	2683±20.7 ^c	3682±39.8 ^b	1.42±0.02 ^b	2.13±0.08	1.88±0.02 ^b
10% CM	1008±20.3	2702±31.2 ^b	3709±52.6 ^b	1.48±0.03 ^b	2.10±0.04	1.87±0.07 ^{ab}
12.5% CM	1004±26.0	2829±41.6 ^a	3834±66.8 ^a	1.47±0.06 ^{ab}	2.16±0.08	1.93±0.10 ^{ab}
15% CM	1005±18.2	2851±50.6 ^a	3857±86.4 ^a	1.49±0.10 ^b	2.20±0.11	1.96±0.14 ^{ab}
20% CM	9870±24.6	2744±48.5 ^b	3732±56.4 ^b	1.58±0.11 ^a	2.22±0.14	2.01±0.10 ^a
Significance	NS	*	*	*	NS	*

^{a,b}For each variable, means within the same column bearing different superscripts differ significantly ($p \leq 0.05$), NS: Not significant, SE: Standard error. *Significant at $p \leq 0.05$, **Significant at $p \leq 0.01$, LBW: Live body weight, BWG: Body weight gain, FI: Feed intake, FCR: Feed conversion ratio. Results are taken as Mean±SE

poor growth performance of broilers fed the 20% CM-containing diets which can impair the efficiency of energy utilization in these diets (NRC., 1994).

In harmony with the present results, Payvastegan *et al.* (2013) investigated the effects of different dietary levels of CM (0, 10, 20%) on growth performance of broiler chicks and found that body weight gain and feed conversion ratio were significantly impaired when 20% canola meal was added in the diets between 1-21 days of age but feed intake was not affected. The present results are also in line with the findings of Min *et al.* (2009), who reported that body weight gain of broilers declined dramatically with increasing inclusion of CM from 0.0-25% of diet during 1-18 days of age, while FCR was not affected. In addition, Woyengo *et al.* (2011) studied the effect of including expeller-extracted CM in broilers' diets on their growth performance and found that increasing dietary level of CM from 0-40% resulted in a linear decrease in feed intake by 4.8 g/21 days period for each 1% increase in CM and in body weight gain by 6.0 g/21 days period for each 1% increase in CM. However, Ahmad *et al.* (2007) reported that CM could be used at up to 20% of diets fed from 1-28 days of age without any adverse effects on broiler performance. Similar results were obtained by Zdunczyk *et al.* (2013), who observed no significant differences in the feed conversion ratio and body weight of growing turkeys fed diets containing 0, 6, 12 or 18% rapeseed meal. The contradictions in the literature on the responsiveness of animals to dietary rapeseed/canola meal is reasonable to be attributed to many factors such as genotype and age of animal, rapeseed cultivar, agronomic practices, climatic conditions, diet composition and feed processing treatments (Tripathi and Mishra, 2007).

Carcass traits and vital internal organs/glands: The effects of feeding diets containing different levels of CM on carcass traits and vital internal organs/glands of 6-week-old broiler chicks are presented in Table 3. Feeding the 20% CM-containing diets adversely affected ($p \leq 0.05$) relative weights of abdominal fat, thyroid gland and bursa of Fabricius compared with the control chicks

Table 3: Effect of different dietary levels of canola meal (CM) on carcass traits and vital internal organs/glands of 6-week-old broiler chicks

Vital organs and glands (%)	Dietary treatments					Significance
	Control	10% CM	12.5% CM	15% CM	20% CM	
Dressing-out	72.590±2.35	72.950±2.60	72.880±2.34	71.800±2.19	70.620±1.66	NS
Abdominal fat	2.420±0.24 ^b	2.500±0.32 ^b	2.620±0.33 ^b	2.750±0.39 ^b	3.430±0.44 ^a	*
Liver	2.100±0.20	2.880±0.25	2.630±0.14	2.850±0.24	2.910±0.32	NS
Thyroid	0.013±0.00 ^c	0.015±0.00 ^b	0.016±0.00 ^b	0.022±0.00 ^b	0.029±0.00 ^a	*
Thymus	0.890±0.22	0.820±0.19	0.800±0.25	0.900±0.27	0.850±0.31	NS
Bursa	0.190±0.06 ^b	0.220±0.05 ^b	0.200±0.06 ^b	0.190±0.08 ^b	0.250±0.05 ^a	*
Spleen	0.120±0.01	0.140±0.01	0.120±0.02	0.150±0.03	0.130±0.03	NS

^{a,b,c} Means within the same row bearing different superscripts differ significantly ($p \leq 0.05$), NS: Not significant, SE: Standard error,

*Significant at $p \leq 0.05$. Results are taken as Mean±SE

but lower levels of CM had no effect. The percentages of dressing-out carcass, liver, thymus and spleen were not affected by dietary treatments.

The lack of significant differences in most carcass traits and internal organs, measured in the present study, in response to feeding the CM-containing diets up to a level of 15% is an indication that such level is tolerable by the broiler chicks. The increased relative weight of thyroid gland due to feeding the CM-containing diets, observed herein, may be due to the glucosinolate derivatives of CM that have a goitrogenic effect on the thyroid gland. These goitrogens have been found to depress thyroid gland activity (El-Wardany and Mohamed, 1995; Tripathi and Mishra, 2007; Khajali and Slominski, 2012). This result is in harmony with those reported by Nassar and Arscott (1986) and Slominski and Campbell (1990), who demonstrated that the high dietary levels of canola meal can cause enlargement of thyroid gland follicles. These authors attributed this thyroidal enlargement to the presence of glucosinolates in CM which leads to hypothyroidism and changes in the ratio between T3 and T4 in the blood.

In accordance with the present results, Ahmad *et al.* (2007) observed no significant effect of dietary CM (up to 20%) on carcass weight, breast and thigh yields or abdominal fat but gizzard weight as percentage of carcass weight increased linearly as dietary level of CM increased. In partial agreement with the present results, Payvastegan *et al.* (2013) found that relative weights of liver, thyroid glands, gizzard and pancreas were significantly increased when dietary CM level reached 20% but the percentage of carcass yield was not affected. Similarly, Kermanshahi and Abbasi Pour (2006) evaluated the partial replacement of soybean meal with rapeseed meal (at dietary levels of 0.0, 15 and 30%) on carcass traits of broiler chicks. They found that dietary rapeseed meal caused significant increases in the weights of liver, proventriculus and abdominal fat pad. However, Woyengo *et al.* (2011) reported that feeding CM-containing diets (up to 40%) did not significantly affect the relative weights (% of LBW) of kidney, heart or thyroid gland but relative weight of liver was linearly increased as dietary CM level increased.

Plasma thyroid hormones and liver enzymes: Blood plasma concentrations of thyroid hormones (T3 and T4) and the T3/T4 ratio of broiler chicks as influenced by feeding graded levels of dietary CM are presented in Table 4. The obtained results indicated that the high dietary level of CM (20%) decreased significantly ($p \leq 0.05$) the plasma thyroxine (T4) level compared with the other dietary treatments. The same trend of response was also observed for the plasma triiodothyronine (T3) level, however, the differences were not significant. The T3/T4 ratios showed also insignificant differences indicative of a slight depressive effect of CM on the rate of T4 turnover

Table 4: Effect of different dietary levels of Canola Meal (CM) on plasma thyroid hormones concentrations and liver enzymes activity of 6 weeks old broiler chicks

Dietary treatments	Thyroid hormone level (ng dL ⁻¹)			Liver enzyme activity (U L ⁻¹)	
	T3	T4	T3/T4 ratio	AST	ALT
Control	3.42±0.78	16.33±2.85 ^a	0.21±0.03	76.22±6.90 ^b	18.28±2.41
10% CM	3.68±0.86	18.54±1.94 ^a	0.20±0.04	75.18±8.56 ^b	20.56±2.14
12.5% CM	3.55±0.65	18.62±2.10 ^a	0.21±0.03	81.42±6.88 ^b	18.94±2.65
15% CM	3.34±0.59	18.16±3.21 ^a	0.19±0.03	89.96±9.45 ^a	21.15±3.47
20% CM	2.98±0.25	13.44±1.70 ^b	0.18±0.02	96.48±8.72 ^a	23.32±3.95
Significance	NS	*	NS	*	NS

^{a,b}Means within the same column bearing different superscripts differ significantly ($p \leq 0.05$), NS: Not significant, SE: Standard error, Results are taken as Mean±SE

to T3. The T3/T4 ratio in plasma was reported by many researchers as a good indicator of euthyroid status and hence better performance (El-Wardany and Mohamed, 1995; Kermanshahi and Abbasi Pour, 2006; Maroufyan and Kermanshahi, 2006).

Regarding the transaminases activity (AST and ALT), the present results revealed that AST activity but not ALT, was significantly increased ($p \leq 0.05$) in chicks fed the diets containing 15 and 20% CM compared with the other dietary treatments. It is well known that increased AST activity is related to degeneration of hepatic cells which was also supported by the histological observations where necrotic areas were present, especially in the 15 and 20% CM-fed groups. These results are in close agreement with the data reported in the scientific literature which support the evidence that some goitrogenic compounds and hepatotoxic agents are still present in the double-zero canola meal (Butler *et al.*, 1982; El-Wardany and Mohamed, 1995; Maroufyan and Kermanshahi, 2006). Consequently, the dietary inclusion level of canola meal for broiler chicks should be around 15%.

Histological observations: The histological structure of livers from different experimental groups fed the CM-containing diets is illustrated in Fig. 1a-e. It is clear from Fig. 1a that the hepatocytes of the control chicks are normal with some dark-stained eosinophilic cells surrounding the central vein. This structural appearance of hepatocytes was also observed in hepatic sections of birds fed the diets containing 10 and 12.5% CM and to a little extent, in those fed the 15% CM-diets (Fig. 1b-d, respectively). However, there are some congested areas, moderate hypertrophy of hepatocytes, some necrotic areas and infiltrable fluids could be seen in all sections. The severity of these observations is dependent on the dietary inclusion level of CM. Progressive changes in the liver architecture could be seen in Fig. 1e, where chicks were fed the 20% CM diets. There are many focal sinusoids in/between many compressed hepatic cords accompanied with necrotic areas, infiltrable fluids and dilated central vein engorged with blood. These observations are supported by the microscopic examination of livers, where they were greatly enlarged in birds fed the higher levels of CM (15 and 20%). At autopsy (6 weeks of age), some livers were enlarged, friable and variable in color from tan to pale yellow in the 20% CM-fed group. This observation coincided with the significant increase in plasma activity of AST of birds fed the 15 and 20% CM diets (Table 4), indicative of some damage in liver cells. The enlarged livers were also observed as for their relative weights in these treatment groups (15 and 20% CM) which recorded insignificantly higher values than other experimental groups (Table 3). The previously mentioned changes in the liver histology may be due, in part, to the increase in the metabolic rate associated with the high growth rate of broiler chicks, in general. Since liver is the main metabolic organ in the body, some histological and

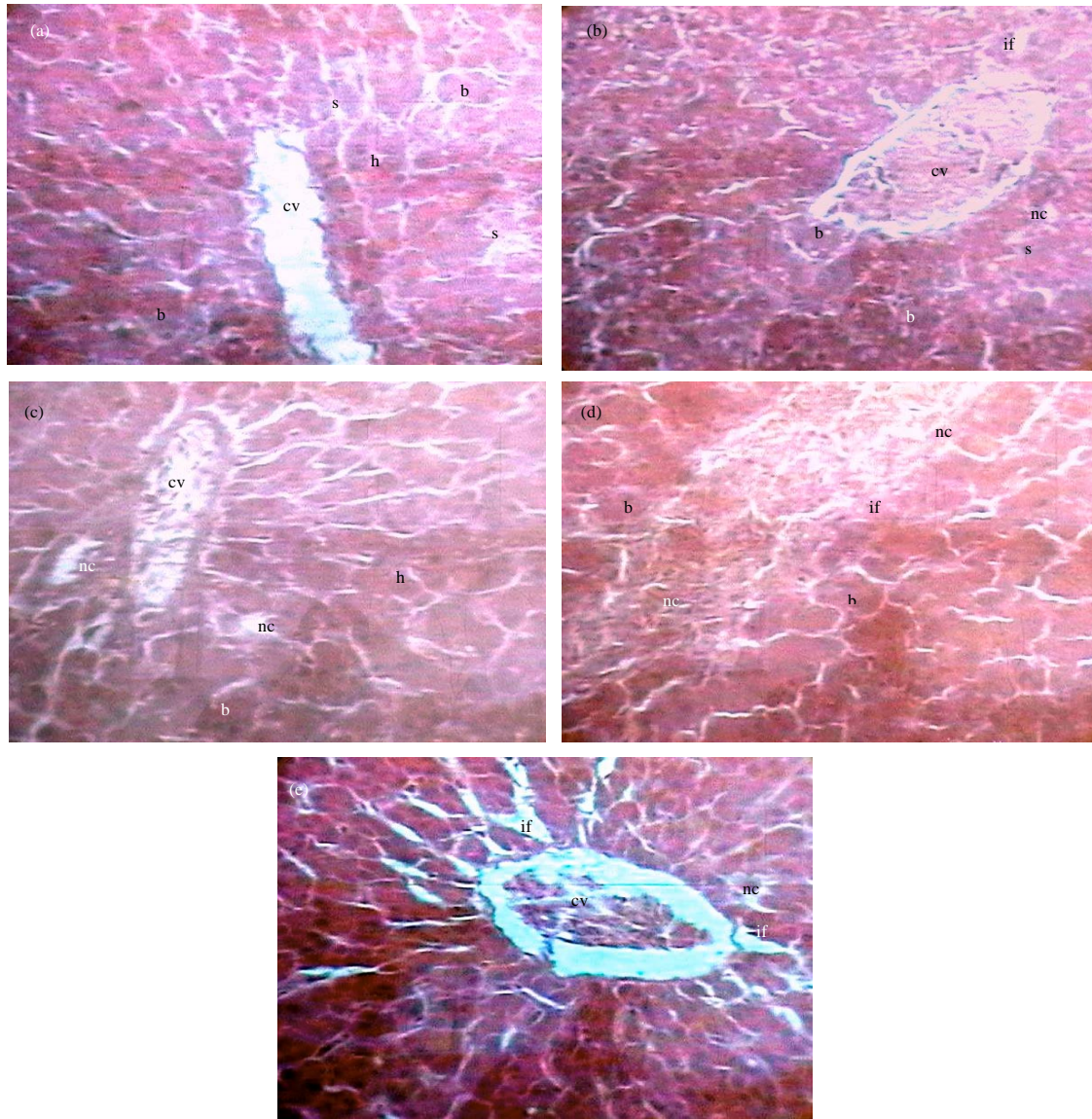


Fig. 1(a-e): Cross section in the liver tissue of broiler chicks received different dietary levels of canola meal, T.S in the liver of broiler chicks receiving (a) Control diet, (b) 10, (c) 12.5, (d) 15 and (e) 20% CM (H and E×40), respectively cv: Central vein, h: Hepatocytes, s: Blood sinusoids, if: Infiltrable fluids, nc: Necrotic area and b: Bile duct

anatomical lesions should be expected. These changes did not affect the performance of broilers in the present study but some growth depression was noticed in the 20% CM-fed group.

Concerning the effect of feeding various levels of CM on thyroid gland histology, the microscopic examination showed an obvious increase in the number of thyroid follicles (per microscopic field), especially in Fig. 2a-b. This is concomitant with the larger amount of colloid within the follicular lumen. The epithelial lining of the follicles tended to be high cuboidal or columnar, indicative of

a possible hyperactivity of the gland. On the other hand, the thyroid gland sections from chicks that were fed the diets containing 12.5 and 15% CM (Fig. 2c-d) exhibited moderate changes including low amounts of colloid and an enlargement in some follicles, especially in the 15% CM-fed chicks. There are also dense connective tissue septa that are separating the follicles and giving them a polyhedral appearance in the 20% CM-fed chicks. It is also of great interest to observe that the epithelial lining of thyroid follicles (Fig. 2e) became low cuboidal or squamous in its appearance with little colloidal material in the follicles, indicative of hypothyroid activity.

The previous results indicate that the negative effect of dietary CM was primarily observed beyond the inclusion level of 15%. Although, the effects of feeding CM-diets up to 15% were not

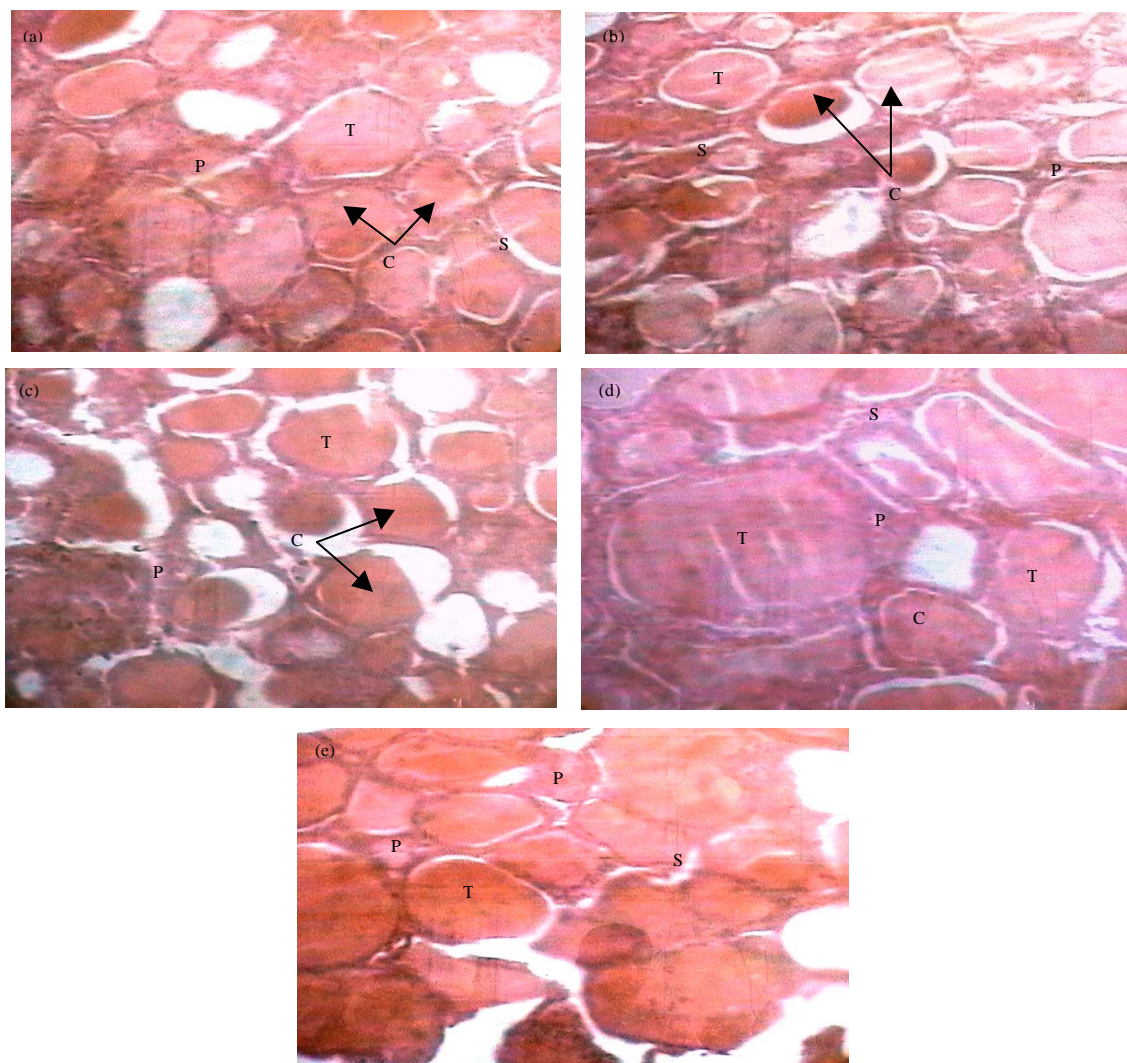


Fig. 2(a-e): Cross section in the thyroid glands of broiler chicks received different dietary levels of canola meal, T.S in the thyroid gland of broiler chicks receiving (a) Control diet, (b) 10, (c) 12.5, (d) 15 and (e) 20% CM (H and E×40), respectively. T: Thyroid follicles, P: Parafollicular cells, C: Colloid and S: Septa

severe enough to depress the growth performance of broiler chicks but there is no doubt that some goitrogenic substances still present in the canola meal. The presence of antinutritional factors in CM, particularly glucosinolates and erucic acid, has been reported to be less than 2% erucic acid of the total fatty acids in the oil and less than 30 μmol of alkenyl glucosinolates per gram of oil-free dry matter of the seed (Bell, 1993); however, they still exert a detrimental effect on thyroid gland function, especially when high level of CM is included in broiler diets. It is evident that the birds can compensate for the goitrogenic effect by increasing thyroidal mass to supply extra-thyroid hormones. This is accompanied by enlargement of follicles as a result of the excessive secretion of the thyroid stimulating hormone from the pituitary gland which causes thyroidal hypertrophy and enlarged follicles.

The present observations are in close agreement with the earlier findings by Van Etten (1969) and Nassar and Arscott (1986), who found that the thyroid gland enlargement is due to rapeseed glucosinolates which are hydrolyzed by the enzyme myrosinase and yield some compounds such as thiocyanates, isothiocyanates, goitrin and nitriles that interfere with the function of thyroid gland and adversely affect the growth performance of monogastric animals (Fenwick, 1982; McCurdy, 1990; Tripathi and Mishra, 2007). These compounds block the iodine uptake by the thyroid gland, causing hypothyroidism without any damage to the follicles. It appears that the extraction and refining processes of canola seed oil can be effective to isolate most but not all, goitrogens present in canola meal.

CONCLUSION

Summarizing, taking the previous histological characterization of liver and thyroid gland, plasma levels of thyroid hormones and growth performance of broilers into account, it could be concluded that canola meal can safely be included at up to 15% in broiler chicks' diets.

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