Feeding Value of High-oil Corn for Taiwan Country Chicken

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ABSTRACT : The feeding value of high-oil corn fed to Taiwan Country (TC) chicken was examined by measuring apparent metabolizable energy (AME), growth performance, sexual maturity, carcass characteristics, and plasma pigmentation. In a completely randomized design, 870 sex-intermingled one-wk-old chicks were assigned to one of 30 floor pens, 29 birds per pen, and each pen randomly assigned to one of five dietary treatments. The experiment was ended when birds were 16 wk of age. The five dietary treatments varied in main fat sources, which were corn oil (CO), high-oil corn (HOC), lard (LRD), whole soybean (WSB) and yellow corn (YC), respectively. All the diets were formulated isonitrogenously, isocalorically, and of equal lysine and methionine contents except YC, in which equal amounts of YC replaced HOC. The results indicated that feed conversion in HOC was 8% higher ($p<0.05$) than YC whereas the calculated AME of HOC was only 3.5% to 4.0% higher than that of YC. No significant differences were observed in body weight, body weight gain, feed consumption, feed conversion ratio and ME efficiency for body weight gain among CO, HOC, LRD, and WSB. No significant differences existed in both skin and muscle pigmentation of breast among the five dietary treatments. No significance differences existed in plasma carotenoid content measured at various ages among the five dietary treatments except that birds fed with HOC had less ($p<0.05$) plasma carotenoids at 16 wk-old. The results indicate that if the price of high-oil corn is no more than 1.05 times that of yellow corn, the dietary cost per kg of body weight gain for TC chickens fed diets containing high-oil corn will be less, although their body weight may be lighter compared to chickens fed diets formulated with other fat sources. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 9 : 1348-1354)***

Key Words : High-oil Corn, Dietary Fat, Taiwan Country Chicken, Growth Performance, Pigmentation

INTRODUCTION

In Taiwan, the diets of chickens are mainly based on corn and soybean meal. Other nutrients such as oil or fat, methionine and lysine, choline, minerals and vitamins are used to complete the diet formulations. In order to enhance the nutritional value of corn, new strains of corn containing high methionine, lysine or oil have been developed.

The feeding value of high-oil corn for raising egg-type chickens, (Han et al., 1987; Parsons et al., 1998) and broilers (Han et al., 1987; Adams et al., 1994; Bartov and Barzur, 1995; Benitez et al., 1999; Kim and Allee, 2003) has been well documented. In these previous studies, it was concluded that high-oil corn had greater nutritional value in comparison with yellow corn.

The TC chicken is one of the three main varieties of chicken marketed in Taiwan. Although preferred by the Taiwanese consumer the chicken, in comparison with broilers, is characterized by slower growing performance and less efficient in utilizing feed. The birds are marketed at sexual maturity between 15 and 16 wk, with typical body weights of 1,800-2,000 g in males and 1,400-1,500 g in females.

The energy, protein and amino acid contents of the diet are major factors determining feed efficiency and body composition of birds. For broilers, diets of high energy content promote rapid growth, so ME contents are generally not less than 12.5 MJ/kg (Whitehead, 2002). Diets supplemented fats and oils are, therefore, widely used in practice to achieve the high dietary ME values.

There are no data regarding the nutritional value of high-oil corn for feeding TC chickens. This study was, therefore, designed to investigate the feeding value of HOC for TC chicken in comparison with yellow corn or other feedstuffs, which are typically included in the diets of TC chickens. The comparisons provided the information valuable in the substitution of high-oil corn as a fat source for yellow corn, corn oil, lard or whole soybean in the diets of TC chickens. The feeding value of all dietary treatments was evaluated by chemical analyses of nutrient concentrated diets, feed efficiency and cost analysis.

MATERIALS AND METHODS

Experimental design and animal diets

Eight hundreds and seventy chicks of 1 week of age (Line SDL_2 of TC chicken, bred by National Chung Hsing University) were randomly grouped into 30 floor pens with 29 birds per pen. Care of the birds followed the Regulations of the Laboratory Animal Management Committee of the university. Each was randomly allotted to one of five dietary treatments. The growing periods of the birds were

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Table 1. Diets for Taiwan Country chickens from 1 to 4 wk of age (g/kg)

Main source of fat	YC	HOC	WSB	CO	LRD
Ingredients					
Yellow corn	608	-	580	572	567
High-oil corn	-	608	-	-	-
Soybean meal	287	287	193	324	324
Whole soybean, heat processed	28.0	28.0	150	-	-
Lard	-	-	-	-	32.0
Corn oil	-	-	-	27.0	-
Fish meal, 60 %	50.0	50.0	50.0	50.0	50.0
DL-methionine	1.90	1.90	2.00	2.00	2.00
Choline chloride, 50 %	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	9.50	9.50	9.50	9.50	9.50
Limestone	8.60	8.60	8.50	8.50	8.50
Salt	2.50	2.50	2.50	2.50	2.50
Vitamin premix	1.00	1.00	1.00	1.00	1.00
Mineral premix	1.00	1.00	1.00	1.00	1.00
Coxistac-6%	1.00	1.00	1.00	1.00	1.00
Aurofac-100	0.110	0.110	0.110	0.110	0.110
Total	1,000	1,000	1,000	1,000	1,000
Calculated values					
Protein, %	21.7	22.0	22.0	22.0	22.0
AME, MJ/kg	12.3	12.8	12.8	12.8	12.8
Fat, %	3.18	5.00	5.23	5.25	5.73
Lysine, %	1.38	1.41	1.41	1.41	1.41
Methionine, %	0.584	0.596	0.595	0.596	0.595
Methionine+cysteine, %	0.921	0.945	0.929	0.936	0.934
Analyzed values					
Gross energy, MJ/kg	16.2	16.7	16.6	16.8	16.7
Protein, %	21.1	21.8	21.9	21.7	21.6
Fat, %	3.15	5.25	5.39	5.54	5.90

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. Vitamin premix provided vitamins A 10,000 IU, D_3 1,000 IU, E 20 mg, B_1 2 mg, B_2 4 mg, B_6 3 mg, B_{12} 15 μg, biotin 60 μg, K_3 1.5 mg, d-calcium pantothenate 15 mg, folic acid 1 mg, and nicotinic acid 35 mg in each kg of diet. Mineral premix provided Cu 5.0 mg, Fe 40 mg, Zn 60 mg, Mn 80 mg, Co 0.1 mg, Se 0.3 mg, and I 0.4 mg in each kg of diet. Coxistac-6% provided sodium salinomycin, a coccidiostat, 60 ppm in the diets. Aurofac-100 provided aureomycin, a chlorotetracycline, 24.2 ppm in the diets.

divided into three periods, 1 to 4, 5 to 8 and 9 to 16 wk of ages. The 5 dietary treatments for the birds in each period of growth contained corn oil (CO), yellow corn (YC), high-oil corn (HOC), lard (LRD) and whole soybean (WSB) as their major fat sources. Yellow corn and HOC replaced each other in their respective treatment diets; hence, the apparent metabolizable energy (AME) and protein content was lower in the YC dietary treatment. Except for YC, the other diets were isonitrogenous and isocalorious in the same growing periods. The essential amino acids, lysine and methionine, were also formulated of equal concentration in HOC, WSB, CO and LRD in the same growing periods. The formulas of the diets for all periods were shown in Table 1 to 3.

Gross analyses of the diet, such as fat, protein, calcium, phosphorus, ash, and moisture were determined according to the AOAC (1980). Gross energy content was measured using an Adiabatic Bomb Calorimeter (Mode 1241; Parr Instrument Co., 1970). The analyzed composition of high-oil corn and yellow corn is shown in Table 4. The AME was measured using 40 roosters of TC chicken fed with 30 and 50 g of either high-oil corn or yellow corn in 32 h during 18 to 22 wk of age according to the modified method of Sibbald (1975).

Bird housing and inoculations

The birds were provided with continuous lighting and the average of ambient temperatures in the house was 28.2°C. The diets were fed in mash form and water was provided *ad libitum*. At day 1, chicks were administered with vaccines against Marek's Disease subcutaneously and Newcastle Disease B_1 strain plus Infectious Bronchitis (ND B_1+IB) ocularly. At 7 days old, the birds were vaccinated against Infectious Bursal Disease (IBD) ocularly and Fowl Pox via wing-web puncturing. Booster inoculations of ND B_1+IB ocularly, ND La Sota strain ocularly, and inactivated ND vaccine intramuscularly at 14 d, 21 d, and 7 wk, respectively.

Growth, performance and carcass composition

The body weights and feed consumption of the birds were recorded at 1, 4, 8, 12, and 16 wk of ages. At 4 wk of age, 3 birds in each floor pen were randomly selected for

Table 2. Diets for Taiwan Country chickens from 5 to 8 wk of age (g/kg)

Main source of fat	YC	HOC	WSB	CO	LRD
Ingredients					
Yellow corn	671.8	-	641.1	636	628.1
High-oil corn	-	671.8	-	-	-
Soybean meal	254	254	157	267	270
Whole soybean, heat processed	-	-	127.5	-	-
Lard	-	-	-	-	27.5
Corn oil	-	-	-	22.6	-
Fish meal, 60 %	50.0	50.0	50.0	50.0	50.0
DL-methionine	0.100	0.100	0.400	0.300	0.400
Choline chloride, 50 %	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	9.10	9.10	9.00	9.10	9.00
Limestone	8.00	8.00	8.00	8.00	8.00
Salt	2.50	2.50	2.50	2.50	2.50
Vitamin premix	1.00	1.00	1.00	1.00	1.00
Mineral premix	1.00	1.00	1.00	1.00	1.00
Coxistac-6%	1.00	1.00	1.00	1.00	1.00
Aurofac-100	0.110	0.110	0.110	0.110	0.110
Total	1,000	1,000	1,000	1,000	1,000
Calculated values					
Protein, %	19.6	20.0	20.0	20.0	20.0
AME, MJ/kg	12.5	13.0	13.0	13.0	13.0
Fat, %	2.88	4.89	5.02	5.01	5.47
Lysine, %	1.24	1.26	1.26	1.26	1.27
Methionine, %	0.386	0.409	0.415	0.407	0.417
Methionine+cysteine, %	0.697	0.724	0.726	0.720	0.731
Analyzed values					
Gross energy, MJ/kg	16.1	16.5	16.7	16.6	16.7
Protein, %	18.9	19.9	19.8	19.5	19.4
Fat, %	2.89	4.92	5.25	5.27	5.42

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. Vitamin premix provided vitamins A 10,000 IU, D_3 1,000 IU, E 20 mg, B_1 2 mg, B_2 4 mg, B_6 3 mg, B_{12} 15 μg, biotin 60 μg, K_3 1.5 mg, d-calcium pantothenate 15 mg, folic acid 1 mg, and nicotinic acid 35 mg in each kg of diet. Mineral premix provided Cu 5.0 mg, Fe 40 mg, Zn 60 mg, Mn 80 mg, Co 0.1 mg, Se 0.3 mg, and I 0.4 mg in each kg of diet. Coxistac-6% provided sodium salinomycin, a coccidiostat, 60 ppm in the diets. Aurofac-100 provided aureomycin, a chlorotetracycline, 24.2 ppm in the diets.

blood sampling via cardiac puncture (3 to 4 mL sample) with heparinized syringes and again at 8, 12 and 16 wk via wing vein (4 to 5 mL sample). Blood samples were centrifuged at 280×g for 15 min and plasma stored at -20°C for further analyses.

One hundred and twenty birds, 2 males and 2 females with body weights close to the median for each pen at the designated ages, were sacrificed at 12 and 16 wk. The feed-deprived body weights (FDBW) of the birds were measured after deprivation of feeds, but not drinking water, for 18 h. The carcass weight was defined as FDBW minus the weight of blood, feather, abdominal fat pad and viscera but included the kidneys.

Determination of tissue pigmentation

The pigmentations of breast skin and breast muscle were measured using a hand colorimeter (NR-3000, Nippon Denshoku Ind. Co., Ltd.) with light source C/2° and standard white plate at X=92.29, Y=94.17 and Z=108.97. The readings of L, positive a, negative a, positive b, and negative b were defined as light (L), red light spectra (a+), green light spectra (a-), yellow light spectra (b+) and blue light spectra (b-), respectively. Chroma was calculated according to Lai and Lin (1993) as: Chroma=$\sqrt{a^2+b^2}$. The greater the chroma value was the more intense the pigmentation in a tissue.

L, a, and b values of the skin on both right- and left-side breast of the carcasses were determined at 12 and 16 wk of ages. The eviscerated and skinned carcasses were stored in freezer at -20°C until determination of breast-muscle weight, and thigh-muscle weight as well as the L, a and b values of both right- and left-side breast muscle after skin removal.

Determination of plasma pigmentation

Determination of the optical density of the plasma, an indicator of the extent of pigmentation, was determined by a modification of the methods of Wilson (1956) and Ruff et al. (1974). Briefly, 0.5 ML of plasma after being thawed for 10 h at 4°C was added to 4.5 mL acetone to precipitate the protein followed by centrifuging at 720×g for 12 min. The optical density of the supernatant fluid was measured with a spectrophotometer (Hitachi U-2000) at 445 nm.

Table 3. Diets for Taiwan Country chickens from 9 to 16 wk of age (g/kg)

Main source of fat	YC	HOC	WSB	CO	LRD
Ingredients					
Yellow corn	716.1	-	683.46	675.68	669.4
High-oil corn	-	716.1	-	-	-
Soybean meal	228.6	228.6	119	243.5	244.58
Whole soybean, heat processed	-	-	142.5	-	-
Lard	-	-	-	-	30.8
Corn oil	-	-	-	25.6	-
Fish meal, 60 %	30.0	30.0	30.0	30.0	30.0
DL-methionine	-	-	0.140	0.120	0.120
Choline chloride, 50 %	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	8.60	8.60	8.40	8.60	8.60
Limestone	9.70	9.70	9.50	9.50	9.50
Salt	2.50	2.50	2.50	2.50	2.50
Vitamin premix	1.00	1.00	1.00	1.00	1.00
Mineral premix	1.00	1.00	1.00	1.00	1.00
Coxistac-6%	1.00	1.00	1.00	1.00	1.00
Aurofac-100	0.110	0.110	0.110	0.110	0.110
Total	1,000	1,000	1,000	1,000	1,000
Calculated values					
Protein, %	17.7	18.0	18.0	18.0	18.0
AME, MJ/kg	12.7	13.2	13.2	13.2	13.2
Fat, %	2.86	5.01	5.26	5.27	5.77
Lysine, %	1.04	1.07	1.06	1.07	1.08
Methionine, %	0.331	0.346	0.345	0.345	0.345
Methionine+cysteine, %	0.625	0.654	0.638	0.642	0.641
Analyzed values (mean±SD, n=7)					
Gross energy, MJ/kg	16.1±0.11	16.7±0.13	16.5±0.11	16.6±0.07	16.7±0.12
Protein, %	17.5±0.32	18.0±0.49	17.8±0.35	17.8±0.40	17.8±0.42
Fat, %	2.66±0.24	5.24±0.52	5.43±0.52	5.40±0.58	5.74±0.69

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. Vitamin premix provided vitamins A 10,000 IU, D_3 1,000 IU, E 20 mg, B_1 2 mg, B_2 4 mg, B_6 3 mg, B_{12} 15 μg, biotin 60 μg, K_3 1.5 mg, d-calcium pantothenate 15 mg, folic acid 1 mg, and nicotinic acid 35 mg in each kg of diet. Mineral premix provided Cu 5.0 mg, Fe 40 mg, Zn 60 mg, Mn 80 mg, Co 0.1 mg, Se 0.3 mg, and I 0.4 mg in each kg of diet. Coxistac-6% provided sodium salinomycin, a coccidiostat, 60 ppm in the diets. Aurofac-100 provided aureomycin, a chlorotetracycline, 24.2 ppm in the diets.

Table 4. The analyzed composition of high-oil corn and yellow corn

Composition	High-oil corn	Yellow corn
Gross energy, MJ/kg	17.1	16.2
AME[1], MJ/kg	14.0	13.2
Protein, %	8.61±0.64	7.75±0.24
Fat, %	6.56±0.42	3.89±0.01
Ash, %	1.06±0.01	1.03±0.02
Calcium, %	0.095±0.002	0.063±0.062
Total phosphorus, %	0.260±0.045	0.298±0.007
Moisture, %	14.4±0.62	14.4±1.01

[1] The apparent metabolizable energy, AME, was measured using 20 roosters of TC chicken fed with 30 and 50 g of high-oil corn or yellow corn in 32 h during 18 to 22 wk of age following the modified method of Sibbald (1975); n=2 for gross analysis of the composition.

Statistical analyses

The data obtained were statistically analyzed with the General Linear Model Procedure of SAS (1988). The predetermined level of significance was $p<0.05$. The least-square means of the treatments were compared with each other to test the significance of the differences. The variables which exhibited overall significant differences among the 5 treatments were further compared using predetermined orthogonal contrasts.

RESULTS AND DISCUSSION

Growth performance and feed consumption

The results indicated that birds consuming high oil corn containing diets were not significantly different from those consuming yellow corn containing diets in terms of body weight gain, feed consumption, and ME efficiency for body weight gain between 1 and 16 weeks of age (Table 5). The HOC birds, however, exhibited an 8% improvement in feed conversion ratio compared to the YC birds ($p<0.05$) during the period. There were no significant differences in body weight gain, feed consumption, feed conversion ratio, and ME efficiency for body weight gain among HOC, WSB, CO, and LRD which were fed on an isocaloric and isonitrogenous basis. Similar results have been reported in broilers (Han et al., 1987; Bartov and Barzur, 1995) and single-comb Leghorn layers (Han et al., 1987).

Table 5. Growth and performance of Taiwan Country chickens during 1 to 16 wk of age[1]

wk	Diet					SEM	P value
	YC	HOC	WSB	CO	LRD		
Initial body weight, g/bird							
1	65.4	65.0	63.9	65.4	65.8	1.57	0.9281
Body weight gain, g/bird							
1-4	205	215	200	214	218	5.29	0.1321
5-8	415[b]	433[b]	483[a]	420[b]	424[b]	14.6	0.0202
9-12	371[a]	402[a]	313[b]	409[a]	404[a]	19.6	0.0102
13-16	387[b]	373[b]	438[a]	391[b]	408[ab]	14.8	0.0459
1-16	1,379	1,423	1,434	1,434	1,454	30.0	0.4912
Feed consumption, g/bird							
1-4	404	393	397	400	400	6.94	0.8552
5-8	1,185	1,134	1,211	1,171	1,141	19.6	0.0593
9-12	1,587	1,517	1,576	1,524	1,521	45.8	0.7107
13-16	2,047	1,945	2,041	1,988	1,960	49.0	0.4813
1-16	5,223	4,990	5,226	5,083	5,022	91.3	0.2405
Feed conversion ratio, g feed/g gain							
1-4	1.97[a]	1.83[b]	1.99[a]	1.87[b]	1.84[b]	0.028	0.0006
5-8	2.86[a]	2.62[bc]	2.54[c]	2.79[ab]	2.70[abc]	0.062	0.0088
9-12	4.31[b]	3.80[b]	5.38[a]	3.73[b]	3.77[b]	0.359	0.0149
13-16	5.35	5.25	4.67	5.10	4.84	0.204	0.1320
1-16	3.80[a]	3.51[b]	3.64[ab]	3.54[b]	3.46[b]	0.072	0.0186
ME efficiency for body weight gain, g gain/MJ AME							
1-4	41.3[a]	42.6[a]	39.4[b]	41.8[a]	42.5[a]	0.616	0.0061
5-8	28.0	29.4	30.6	27.6	28.5	0.795	0.0839
9-12	18.4[a]	20.1[a]	15.1[b]	20.5[a]	20.1[a]	0.931	0.0019
13-16	15.0	14.5	16.3	14.9	15.8	0.559	0.1936
1-16	20.9	21.7	20.9	21.6	22.1	0.409	0.2244

[1]Values are means of 6 pens, each with 29 birds at 1 wk of age. YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. SEM=Standard error of the mean. AME=Apparent metabolizable energy. [a, b, c] Means in the same row without the common superscripts differ ($p<0.05$).

The birds were not significantly different among the five dietary treatments in body weight gain, feed consumption, and ME efficiency for body weight gain during over all period, say 1 to 16 wk-old, though they did have different growth performances in some intervals of the entire experimental period. No proper explanation for the inconsistent and drifting outcomes.

There was great variation in the body weight gain, feed conversion ratio, and ME efficiency for body weight gain of birds fed a diet containing heat processed whole soybean, WSB, from one growing period to another. Since the whole soybean used was a heat processed one, thus, anti-nutritional factors, for instance soybean trypsin inhibitor, should not be the first priority to suspect that they would be the main causes to result in the wide variation of growth from one period to another. One explanation could be that whole soybeans contained approximately 18% fat (Dale, 1995), of which unsaturated fatty acids are the main components. If these unsaturated fatty acids undergo peroxidation during storage, they could exert adversely effect on the growth and performance of the chickens as proposed by Anjum et al. (2002). This is especially true under a hot and humid climate like Taiwan has. In contrast, birds fed with diets containing high-oil corn had less variation in growth performance, which could be attributed to less fat content (6%) and a greater vitamin E content of the feedstuff per se (Weber, 1984).

Plasma carotenoid content and tissue pigmentation

The pigmentation of breast skin and muscle is in Table 6. At the very beginning and during the processes of breeding TC chickens, most of the birds selected were white-skinned. Results indicated that the breast skin of TC chickens has a slightly green light spectra regardless of the diets fed to the birds. This suggests that the breast skin of TC chickens does not have the capacity to accumulate carotenoids, regardless of how much pigment is absorbed in the diet.

The plasma carotenoid content expressed as optical density value is shown in Table 7. The plasma carotenoid contents among the five treatments were not different at 4, 8, and 12 wk-old. Birds fed with high-oil corn containing diet comparing to those fed with the other diets had significantly lower carotenoid content in plasma at 16 wk-old. Han et al. (1987), however, reported that broilers fed diets containing high-oil corn instead of equal amounts of yellow corn had significantly greater plasma carotenoid content. The storage sites of absorbed total carotenoids could be liver, plasma, skin, leg or unabsorbed egg yolk in chicks (Wilson, 1956; Ruff et al., 1974; Allen, 1987; Allen, 1992; Haq and Bailey, 1996).

Table 6. The pigmentation of breast skin and muscle of Taiwan Country chickens (n=24/treatment and n=60/sex) at 12 and 16 wk of ages

wk	Breast	Diet					Sex		MS
		YC	HOC	WSB	CO	LRD	Female	Male	
Lightness									
12	Skin	50.9	55.5	54.4	56.3	58.8	56.4	53.9	463
12	Muscle	58.2	58.4	60.6	57.5	57.6	57.8	59.1	53.1
16	Skin	64.7	66.0	65.8	65.0	65.5	65.8	65.1	13.1
16	Muscle	53.7	56.6	55.0	55.8	56.6	54.8	56.3	36.7
Redness									
12	Skin	-0.465	-0.504	-3.28	-0.233	-3.36	-1.69	-1.44	62.5
12	Muscle	-2.69	-2.28	-2.84	-3.20	-1.66	-2.75	-2.31	36.9
16	Skin	-7.44	-6.51	-9.29	-6.00	-5.41	-8.22^{B}	-5.63^{A}	28.2
16	Muscle	0.710	-4.12	-1.94	-4.37	-3.02	-4.08	-1.01	104
Yellowness									
12	Skin	2.55	3.17	3.24	3.06	4.86	3.83	2.92	39.2
12	Muscle	3.19	2.58	3.67	3.36	2.38	3.26	2.81	13.1
16	Skin	6.84	7.42	7.58	7.22	7.28	7.71	6.83	11.8
16	Muscle	1.12	1.74	2.72	1.89	2.16	3.02^{A}	0.83^{B}	11.3
Chroma									
12	Skin	9.47	8.94	9.52	7.23	9.02	8.12	9.55	35.8
12	Muscle	7.52	6.53	6.97	6.71	5.26	6.29	6.91	20.5
16	Skin	11.2	10.7	12.5	10.4	9.81	11.8^{x}	10.1^{y}	22.9
16	Muscle	7.05	7.78	7.98	8.63	11.9	9.93^{x}	7.43^{y}	49.9

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. MS = mean square of error (df = 115).
$^{A, B}$ Means in the same row between sexes without the common superscripts differ very significantly ($p<0.01$).
$^{x, y}$ Means in the same row between sexes without the common superscripts tend to differ ($p<0.10$).

Table 7. The plasma carotenoid content expressed as optical density value of Taiwan Country chickens at 4, 8, 12 and 16 wk of age

wk	Diet					Sex		MS
	YC	HOC	WSB	CO	LRD	Female	Male	
Optical density value at 445 nm×1,000								
4	75.9	77.4	80.4	70.2	80.1	74.6	78.9	304
	(14)	(16)	(17)	(18)	(14)	(39)	(40)	
8	69.3	76.5	73.5	60.1	68.6	70.3	68.9	825
	(18)	(18)	(18)	(18)	(18)	(39)	(51)	
12	109	102	114	108	115	107	112	482
	(18)	(18)	(18)	(18)	(18)	(35)	(55)	
16	131^{a}	99.9^{b}	127^{a}	132^{a}	134^{a}	128	122	1,107
	(18)	(18)	(18)	(18)	(18)	(40)	(50)	

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard. MS=mean square of error (df=25).
^{ab} Means in the same row under diet without the common superscripts differ ($p<0.05$). ( ): Figure in the parentheses is the sample size.

Table 8. Dietary costs for body weight gain of Taiwan Country chickens during 1 to 16 wk of age

wk	Diet					HOC[2]	HOC[3]	HOC[4]
	YC	HOC[1]	WSB	CO	LRD			
Cost of feed, NT$/bird								
1-4	4.01	3.91	4.03	4.56	4.13	3.99	4.04	4.08
1-8	15.3	14.7	15.8	17.2	15.4	15.1	15.2	15.4
1-12	29.6	28.4	30.5	33.2	29.8	29.2	29.5	30.0
1-16	48.1	46.0	49.5	54.0	48.4	47.3	47.9	48.5
Dietary cost of body weight gain, NT$/kg								
1-4	19.6	18.2	20.2	21.3	18.9	18.6	18.8	19.0
1-8	24.4	22.6	22.8	26.8	23.9	23.2	23.3	23.7
1-12	29.5	26.9	30.1	31.5	28.3	27.7	28.0	28.5
1-16	35.0	32.3	34.5	37.7	33.3	33.2	33.7	34.1

YC: yellow corn. HOC: high-oil corn. WSB: whole soybean. CO: corn oil. LRD: lard.
[1]Assuming that the price of high-oil corn was equal to that of yellow corn. which was 7.2 NTS /kg in this study.
[2] Basing on that the price of high-oil corn was 5 % higher than that of yellow corn. [3] Basing on that the price of high-oil corn was 8 % higher than that of yellow corn. [4] Basing on that the price of high-oil corn was 10 % higher than that of yellow corn.

Dietary cost for body weight gain

According to the previously described growth performance of TC chickens, taking the variables, such as the body weight gain, and feed consumption, as well as the prices of the various experimental diets together, the costs of experimental diets for all the periods were able to calculate. The costs for each kg of body weight gain calculated are shown in Table 8.

High-oil corn is not a popular feedstuff in Taiwan. If the price of high-oil corn stays below 1.05 times of that of yellow corn, our data suggest diets containing high-oil corn would represent a least cost formulation, although HOC diets may not result in the greatest body weight gain.

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REFERENCES

Adams, K. L., S. E. Watkins, A. L. Waloroup and P. W. Waldroup. 1994. Utilization of high-oil corn in diets for broiler chickens. J. Appl. Poult. Res. 3:146-156.

Allen, P. C. 1987. Physiological responses of chicken gut tissue to coccidial infection: Comparative effects of *Eimeria acervulina* and *Eimeria mitis* on mucosal, carotenoid content, and brush border enzyme activity. Poult. Sci. 66:1306-1315.

Allen, P. C. 1992. Effect of coccidiosis on the distribution of dietary lutein in the chick. Poult. Sci. 71:1457-1463.

Anjum, M. I., M. Z. Alam and I. H. Mirga. 2002. Effect of non-oxidized and oxidized soybeab oil supplemented with two levels of Antioxidant on broiler performance. Asian-Aust. J. Anim. Sci. 15:713-720.

AOAC. 1980. Official Methods of Analysis. 13th ed. Association of Official Analytical Chemists. Washington, DC.

Bartov, I. and A. Bar-zur. 1995. The nutritive value of high-oil corn for broiler chicks. Poult. Sci. 74:517-522.

Benitez, J. A., A. G. Gernat, J. G. Murillo and M. Araba. 1999. The use of high oil corn in broiler diets. Poult. Sci. 78:861-865.

Dale, N. 1995. Ingredient analysis table: 1995 ed. of Yearbook. Feedstuffs.

Han, Y., C. M. Parsons and D. E. Alexander. 1987. Nutritive value of high oil corn for poultry. Poult. Sci. 66:103-111.

Haq, A.-U. and C. A. Bailey. 1996. Time course evaluation of carotenoid and retinol concentdiets in posthatch chick tissue. Poult. Sci. 75:1258-1260.

Kim, I. B. and G. L. Allee. 2003. The use of high-oil corn in young broiler chicken diets. Asian-Aust. J. Anim. Sci. 16:880-883.

Lai, Kung-Ming and Liang-chuan Lin. 1993. Response surface model to study meat color in frozen ground pork with sodium erythorbate and sodium tripolyphosphate. J. Chin. Soc. Anim. Sci. 22:323-337. (Taiwan).

Parr Instrument Co. 1970. Instruction for 1241 and 1242 adiabatic calorimeters. Parr Instrument Co. (Moline, IL) Manual No. 142.

Parsons, C. M., Y. Zhang and M. Araba. 1998. Availability of amino acids in high-oil corn. Poult. Sci. 77:1016-1019.

Ruff, M. D., W. M. Reid and J. K. Johnson. 1974. Lowered blood carotenoid levels in chickens infected with coccidia. Poult. Sci. 53:1801-1809.

SAS. 1988. SAS User's Guide:Ststistics. SAS Inst. Inc., Cary, NC.

Sibbald, I. R. 1975. The effect of level of feed intake on metabolizable energy values measured with adult roosters. Poult. Sci. 54:1990-1997.

Weber, E. J. 1984. High-performance liquid chromatography of the tocols in corn grain. J. Am. Oil Chem. Soc. 61:1231-1234.

Wilson, W. O. 1956. Identifying non-laying chicken hens. Poult. Sci. 35:226-227.

Whitehead, C. C. 2002. Nutrition and poultry welfare. World's Poult. Sci. J. 58:349-356.