Effects of Feeding Diets Containing U.S. Corn Distiller's Dried Grains with Solubles on Growth Performance and Carcass Quality of Domestic Colored Broiler Chickens in Taiwan

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Introduction

Distiller's dried grains with solubles (DDGS) is a by-product of the dry grind process of ethanol production. High quality corn DDGS contains highly digestible amino acids, energy, several metabolites produced in the fermentation process, and is significantly higher in available phosphorus compared to corn and other grains and grain by-products. Xanthophylls are yellow to orange pigments found in corn, which are more concentrated in corn DDGS. Consumers in many Asian countries, including Taiwan, prefer yellow skin of broiler chicken they purchase and consume. Therefore, the use of DDGS as a source xanthophyll pigment in poultry feeds is one of the attractive features for using DDGS in Taiwan.

Domestic colored chickens are popular in Asia. The annual production of colored chickens in Taiwan is about 170 million birds, which is approximately 50% of the total chickens produced. In general, domestic colored chickens grow significantly slower than white broilers with a typical rearing period of 14 to 16 weeks, to reach an average body weight at slaughter of 2.2 to 2.5 kg for males and 1.8 to 2.1 kg for females. The nutrient concentration of diets for domestic colored chickens is lower than diets for white broilers. Research by Noll and Parsons (2003) has shown that the corn DDGS is a good energy source, but its energy value is lower than corn. Therefore, DDGS appears to be a good alternative feedstuff for use in diets of domestic colored chickens. The Taiwan colored chicken market requires specific characteristics that must be met for consumer acceptance including body maturity, red comb with suitable size, glittering feathers, yellow skin, and tender meat (Figure 1). These characteristics are very different from those required of white commercial broilers. To achieve the color requirements of comb and skin, extra artificial pigments are regularly added in the commercial poultry feeds, and cost an additional 300 to 600 NT$ per metric ton of feed. Therefore, the addition of DDGS as a source of pigment could reduce the cost of pigment supplementation while achieving the desired color requirements of domestic colored chickens.

Results from a commercial layer trial conducted in Jalisco, Mexico showed that adding 10% DDGS to sorghum based diets significantly improved the egg yolk color (Shurson et al., 2003). The trial demonstrated that the improvement in egg yolk color was attributed to the increased level of xanthophyll which was provided by DDGS in the diets. However, no studies have been conducted to determine the effects of xanthophylls from DDGS on the carcass quality and skin color of domestic colored chickens.

The objectives of this study were to determine the effect of different dietary inclusion rates of DDGS affects growth performance, skin color and carcass quality of domestic colored chickens.

Material and Methods

1. Facilities and Management

The trial was conducted in the experimental barn of Animal Science Department, at National Chia-Yi University, Taiwan. The facilities contained small, divided pens typically used for small-scale poultry research. Each pen had feed trough and automatic water trough (Figure 1). Experimental diets were mixed and stored in covered plastic tanks in front of each pen. Feed was added manually to feed troughs each day of the trial. A computerized recorder (Watchdog® 450) was installed in the barn to log the temperature and relative humidity during the experiment.

Figure 1. Experimental Facilities Used to House Domestic Colored Chickens.

2. Animals and Feeding Program

Six dietary treatments were used in a three-phase commercial feeding program. Experimental diets for each treatment were formulated to contain the same level of crude protein (CP) and metabolizable energy (ME) within each of the three rearing phases:

Phase 1 (0 to 4 weeks of age): CP 21.0 %, ME 3000 kcal/kg.

Phase 2 (5 to12 weeks of age): CP 19.0 %, ME 2900 kcal/kg.

Phase 3 (13 to16 weeks of age): CP 18.0 %, ME 2900 kcal/kg.

Six hundred twenty-four day-old small type, commercial domestic colored chickens from a local commercial breeder farm were used in the feeding trial. Each of the four replications per treatment utilized 26 chickens (13 male and 13 female) and were fed their respective experimental diets from 0 to 16 weeks of age. The diet composition of experimental diets is shown in Table 1, Table 2, and Table 3. Dietary treatments were as follows:

1) Control diet : corn-soybean meal
2) Control diet + full amount of artificial pigments during phase 2 and 3 without DDGS
3) 10 % DDGS diet
4) 20 % DDGS diet
5) 20 % DDGS + 50% of the amount of artificial pigments during phase 2 and 3
6) Control diet for phase 1 and 20 % DDGS diet during phase 2 and 3

Table 1. Diet Composition for Domestic Colored Chicken Trial (0-4 wks of age).

	Dietary Treatment					
	1	**2**	**3**	**4**	**5**	**6**
Ingredient, %	**Control**	**Control**	**10% DDGS**	**20% DDGS**	**20% DDGS**	**Control**
Corn	473.0	473.0	424.2	373.0	373.0	473.0
Soybean meal	220.0	220.0	174.0	135.0	135.0	220.0
Soybeans, full fat	190.0	190.0	180.0	160.0	160.0	190.0
Wheat middlings	50.0	50.0	50.0	50.0	50.0	50.0
DDGS[1]	0.0	0.0	100.0	200.0	200.0	0.0
Soybean oil	22.0	22.0	28.0	36.8	36.8	22.0
Dical. phosphate	17.0	17.0	16.0	14.5	14.5	17.0
Limestone	13.8	13.8	14.3	15.4	15.4	13.8
Salt, iodized	4.0	4.0	4.0	4.0	4.0	4.0
L-lysine HCl	0.0	0.0	0.4	1.4	1.4	0.0
DL-methionine	1.8	1.8	1.7	1.5	1.5	1.8
Vitamin premix	1.2	1.2	1.2	1.2	1.2	1.2
Mineral premix	1.2	1.2	1.2	1.2	1.2	1.2
Choline chloride, 50%	1.0	1.0	1.0	1.0	1.0	1.0
Premix, OTC	1.0	1.0	1.0	1.0	1.0	1.0
Propionic acid	2.0	2.0	2.0	2.0	2.0	2.0
Zn-bacitracin	1.0	1.0	1.0	1.0	1.0	1.0
Anti-coccidial drug	1.0	1.0	1.0	1.0	1.0	1.0
Pigment, artificial	0.0	0.0	0.0	0.0	0.0	0.0
Calculated Nutrient Content[2]						
Crude protein,%	21.04	21.04	21.08	21.04	21.04	21.04
Ether extract, %	7.61	7.61	8.91	10.31	10.31	7.61
Linoleic acid, %	2.56	2.56	2.82	3.00	3.00	2.56
Crude fiber, %	3.83	3.83	4.26	4.69	4.69	3.83
Ash, %	3.08	3.08	2.78	2.47	2.47	3.08
ME, kcal/kg	3000.3	3000.3	3001.5	3001.4	3001.4	3000.3
Ca, %	1.01	1.01	1.01	1.01	1.01	1.01
Total P, %	0.73	0.73	0.73	0.73	0.73	0.73
Available P, %	0.46	0.46	0.46	0.45	0.45	0.46
Lysine, %	1.16	1.16	1.11	1.10	1.10	1.16
Methionine, %	0.51	0.51	0.51	0.51	0.51	0.51
Met+Cys, %	0.67	0.67	0.69	0.69	0.69	0.67
Choline, mg/kg	1832	1832	1921	2006	2006	1832
Tryptophan, %	0.27	0.27	0.25	0.23	0.23	0.27
Arginine, %	1.41	1.41	1.32	1.22	1.22	1.41
Threonine, %	0.81	0.81	0.79	0.77	0.77	0.81
Histidine, %	0.57	0.57	0.56	0.55	0.55	0.57
Isoleucine, %	0.89	0.89	0.87	0.85	0.85	0.89
Leucine, %	1.79	1.79	1.78	1.76	1.76	1.79
Phenylalanine, %	1.03	1.03	1.01	1.00	1.00	1.03
Phe+Tyr, %	1.86	1.86	1.81	1.74	1.74	1.86
Xanthophylls, mg/kg (Analyzed values)	3.47	3.29	4.75	6.02	5.80	3.42

[1]The analyzed xanthophyll content of DDGS was 21.05mg/kg.
[2]Nutrient content was calculated according to the nutrient composition of feedstuffs in the Nutrient Requirements of Poultry (NRC, 1994).

Table 2. Diet Composition for Domestic Colored Chicken Trial (5-12 wks of age).

	Treatments					
	1	2	3	4	5	6
Ingredient, %	**Control**	**Control + Pigment**	**10% DDGS**	**20% DDGS**	**20%DDGS + 1/2 Pigment**	**20% DDGS**
Corn[1]	579.7	579.7	528.0	475.8	475.8	475.8
Soybean meal	217.0	217.0	189.0	119.0	119.0	119.0
Soybeans, full fat	112.0	112.0	80.0	100.0	100.0	100.0
Wheat middlings	50.0	50.0	50.0	50.0	50.0	50.0
DDGS[1]	0.0	0.0	100.0	200.0	200.0	200.0
Wheat bran	3.0	1.0	3.0	3.0	2.0	3.0
Soybean oil	0.0	0.0	11.0	12.6	12.6	12.6
Dical. phosphate	12.0	12.0	11.1	10.4	10.4	10.4
Limestone	14.5	14.5	15.0	15.4	15.4	15.4
Salt, iodized	4.0	4.0	4.0	4.0	4.0	4.0
L-lysine HCl	0.0	0.0	1.2	2.3	2.3	2.3
DL-methionine	0.8	0.8	0.7	0.5	0.5	0.5
Vitamin premix	1.0	1.0	1.0	1.0	1.0	1.0
Mineral premix	1.0	1.0	1.0	1.0	1.0	1.0
Choline chloride, 50%	1.0	1.0	1.0	1.0	1.0	1.0
Premix, OTC	0.0	0.0	0.0	0.0	0.0	0.0
Propionic acid	2.0	2.0	2.0	2.0	2.0	2.0
Zn-bacitracin	1.0	1.0	1.0	1.0	1.0	1.0
Anti-coccidial drug	1.0	1.0	1.0	1.0	1.0	1.0
Pigments, artificial[2]	0.0	2.0	0.0	0.0	1.0	0.0
Calculated Nutrient Content[3]						
Crude protein, %	19.02	19.02	19.03	19.08	19.08	19.08
Ether extract, %	4.40	4.40	5.81	7.19	7.19	7.19
Linoleic Acid, %	2.09	2.09	2.17	2.68	2.68	2.68
Crude fiber, %	3.69	3.69	4.13	4.53	4.53	4.53
Ash, %	2.89	2.89	2.60	2.28	2.28	2.28
ME, kcal/kg	2900	2900	2900	2900	2900	2900
Ca, %	0.91	0.91	0.90	0.90	0.90	0.90
Total P, %	0.62	0.62	0.63	0.64	0.64	0.64
Available P, %	0.36	0.36	0.36	0.37	0.37	0.37
Lysine, %	1.01	1.01	1.02	1.02	1.02	1.02
Methionine, %	0.38	0.38	0.39	0.39	0.39	0.39
Met+Cys, %	0.63	0.63	0.64	0.65	0.65	0.65
Choline, mg/kg	1686	1686	1771	1865	1865	1865
Tryptophan, %	0.24	0.24	0.22	0.20	0.20	0.20
Arginine, %	1.24	1.24	1.15	1.06	1.06	1.06
Threonine, %	0.73	0.73	0.71	0.69	0.69	0.69
Histidine, %	0.51	0.51	0.50	0.49	0.49	0.49
Isoleucine, %	0.80	0.80	0.78	0.75	0.75	0.75
Leucine, %	1.67	1.67	1.66	1.64	1.64	1.64
Phenylalanine, %	0.92	0.92	0.91	0.89	0.89	0.89
Phe+Tyr, %	1.68	1.68	1.63	1.56	1.56	1.56
Xanthophylls,mg/kg (Analyzed value)	4.62	28.34	5.15	7.66	18.57	6.56

[1]The analyzed xanthophyll content of DDGS and corn were 20.11 and 6.49 mg/kg, respectively.

[2] The artificial pigments used in this feeding trial were obtained from a commercial product and extracted from marigold petals with 10g of xanthophylls per kg of product. The manufacturer recommended supplementation rate was 2 kg of product per metric ton of feed to achieve the desired carcass color. This product cost NT$333 per kg.

[3] Nutrient content was calculated according to the nutrient composition of feedstuffs in the Nutrient Requirements of Poultry (NRC, 1994).

Table 3. Diet Composition of Domestic Colored Chicken Trial (13-16 wks of age).

	Treatments					
	1	2	3	4	5	6
Ingredient, %	Control	Control + Pigment	10% DDGS	20% DDGS	20% DDGS + 1/2 Pigment	20% DDGS
Corn[1]	615.0	615.0	564.5	511.8	511.8	511.8
Soybean meal	217.0	217.0	139.0	114.0	114.0	114.0
Soybeans, full fat	76.0	76.0	104.0	68.0	68.0	68.0
Wheat middlings	50.0	50.0	50.0	50.0	50.0	50.0
DDGS[1]	0.0	0.0	100.0	200.0	200.0	200.0
Wheat bran	6.0	4.0	6.0	6.0	5.0	6.0
Soybean oil	0.0	0.0	0.0	12.0	12.0	12.0
Dical. Phosphate	11.0	11.0	10.0	9.8	9.8	9.8
Limestone	13.5	13.5	14.2	15.0	15.0	15.0
Salt, iodized	4.0	4.0	4.0	4.0	4.0	4.0
L-lysine HCl	0.0	0.0	1.0	2.2	2.2	2.2
DL-methionine	0.5	0.5	0.3	0.2	0.2	0.2
Vitamin premix	1.0	1.0	1.0	1.0	1.0	1.0
Mineral premix	1.0	1.0	1.0	1.0	1.0	1.0
Choline chloride, 50%	1.0	1.0	1.0	1.0	1.0	1.0
Premix, OTC	0.0	0.0	0.0	0.0	0.0	0.0
Propionic acid	2.0	2.0	2.0	2.0	2.0	2.0
Zn-bacitracin	1.0	1.0	1.0	1.0	1.0	1.0
Anti-coccidial drug	1.0	1.0	1.0	1.0	1.0	1.0
Pigments, artificial[2]	0.0	2.0	0.0	0.0	1.0	0.0
Calculated Nutrient Content[3]						
Crude protein, %	18.06	18.06	18.06	18.05	18.05	18.05
Ether extract, %	3.89	3.89	5.25	6.69	6.69	6.69
Linoleic Acid, %	1.86	1.86	2.43	2.47	2.47	2.47
Crude fiber, %	3.62	3.62	4.01	4.45	4.45	4.45
Ash, %	2.80	2.80	2.48	2.18	2.18	2.18
ME, kcal/kg	2900	2900	2900	2900	2900	2900
Ca, %	0.84	0.84	0.84	0.87	0.87	0.87
Total P, %	0.60	0.60	0.60	0.62	0.62	0.62
Available P, %	0.34	0.34	0.34	0.35	0.35	0.35
Lysine, %	0.94	0.94	0.93	0.94	0.94	0.94
Methionine, %	0.34	0.34	0.34	0.35	0.35	0.35
Met+Cys, %	0.60	0.60	0.61	0.63	0.63	0.63
Choline, mg/kg	1618	1618	1709	1793	1793	1793
Tryptophan, %	0.22	0.22	0.20	0.18	0.18	0.18
Arginine, %	1.16	1.16	1.07	0.98	0.98	0.98
Threonine, %	0.69	0.69	0.67	0.65	0.65	0.65
Histidine, %	0.49	0.49	0.48	0.46	0.46	0.46
Isoleucine, %	0.75	0.75	0.73	0.71	0.71	0.71
Leucine, %	1.61	1.61	1.59	1.58	1.58	1.58
Phenylalanine, %	0.87	0.87	0.86	0.84	0.84	0.84
Phe+Tyr, %	1.60	1.60	1.53	1.47	1.47	1.47
Xanthophylls, mg/kg (Analyzed value)	4.35	27.39	5.83	6.75	16.54	7.26

[1]The analyzed xanthophyll content of DDGS and corn were 20.94 and 6.84 mg/kg, respectively.

[2] The artificial pigments used in this feeding trial were obtained from a commercial product and extracted from marigold petals with 10g of xanthophylls per kg of product. The manufacturer recommended supplementation rate was 2 kg of this product per metric ton of feed to achieve the desired carcass color. This product cost NT$333 per kg.

[3] Nutrient content was calculated according to the nutrient composition of feedstuffs in the Nutrient Requirements of Poultry (NRC, 1994).

3. Measurements and Data Collection

Samples of DDGS, corn, and diets for each treatment in each of the three rearing phases were collected and were sent to the Experiment Station Chemical Laboratories of University of Missouri-Columbia for xanthophyll analysis.

Chickens from each treatment were weighed individually every two weeks and feed consumption of each pen was recorded. Growth rate, feed disappearance, and feed efficiency of three rearing phases were calculated.

Eight chickens (4 male and 4 female) were randomly selected and slaughtered from each replication of each treatment at 12, 14, and 16 weeks of age, respectively. Live weight, carcass weight, dressing percentage, amount of abdominal fat pad, and liver weight were measured. The color of abdominal fat pad was determined using Roche color fan. One half of the breast muscle and thigh muscle were sampled and grounded for Hunter's meat color measurements. Using the Hunter's score system, L*, a*, and b* represent the brightness, degree of red color, and degree of yellow color of meat, respectively. The other half of breast and thigh muscle were steam-cooked at 100^{o}C for 10 minutes. The cooked muscle was used for shear force measurements. There was technical difficulty to quantify the skin color of raw carcass. As a result, the carcasses were steam-cooked to show skin color differences between treatments.

Blood samples were collected from the slaughtered chickens. Centrifuged blood samples were analyzed for total protein (TP), albumin (ALB), triglyceride (TG), total cholesterol (CHOL), and creatinine (CREA) to determine the effects of DDGS on chicken protein and lipid metabolism.

4. Data Analysis

Data from the three rearing phases were statistically analyzed using the GLM Procedures of SAS. The accumulated xanthophyll intake (AXI) was estimated by the sum of multiplying dietary xanthophyll content with feed consumption at each rearing phase. The relationship between accumulated xanthophyll intake and the color of abdominal fat pad was tested using linear or non-linear regression model.

Results and Discussion

The feeding trial was conducted during the summer season (Figure 2), where the highest temperature in the daytime was above 36° C. High relative humidity was the other source of heat stress for experimental chickens.

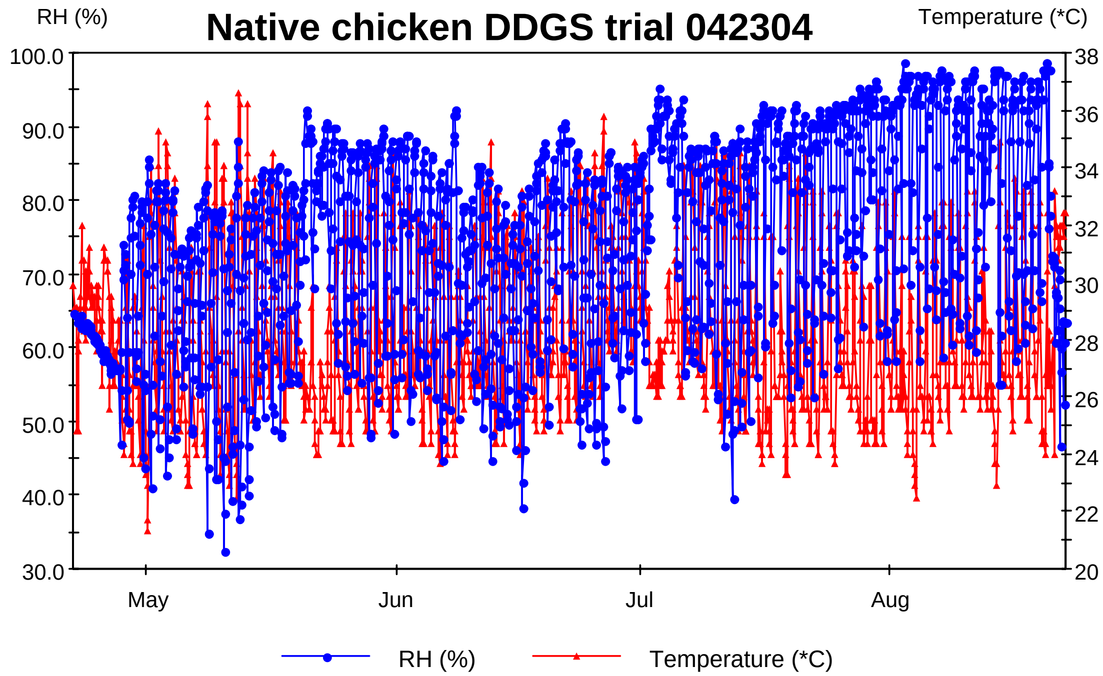

Figure 2. Temperature and Relative Humidity During the Domestic Colored Chicken Feeding Trial.

The DDGS used in this trial was from the same 40 foot container that was imported from U.S. in April 2004. The xanthophyll content of DDGS samples from week 0, 2, 5 and 12 was 20.6, 21.5, 20.1, 20.94 mg/kg, respectively. This indicates that the xanthophyll in DDGS is stable for at least a 12-week storage period in hot and humid climates. The amount of xanthophyll contained in the experimental diets fed during the three rearing phases were as expected when the experiment was originally designed (Figure 3.). Therefore, there was accurate formulation and mixing of the experimental diets. As shown in Figure 3, adding DDGS increased the dietary xanthophyll content. Compared with control diets, the xanthophyll content of the 20% DDGS diets at different rearing phases was increased by about 60 to 70%. Adding the full amount of artificial extracted pigment, however, dramatically increased (about 6 times of the control diets) the xanthophyll content of the diet.

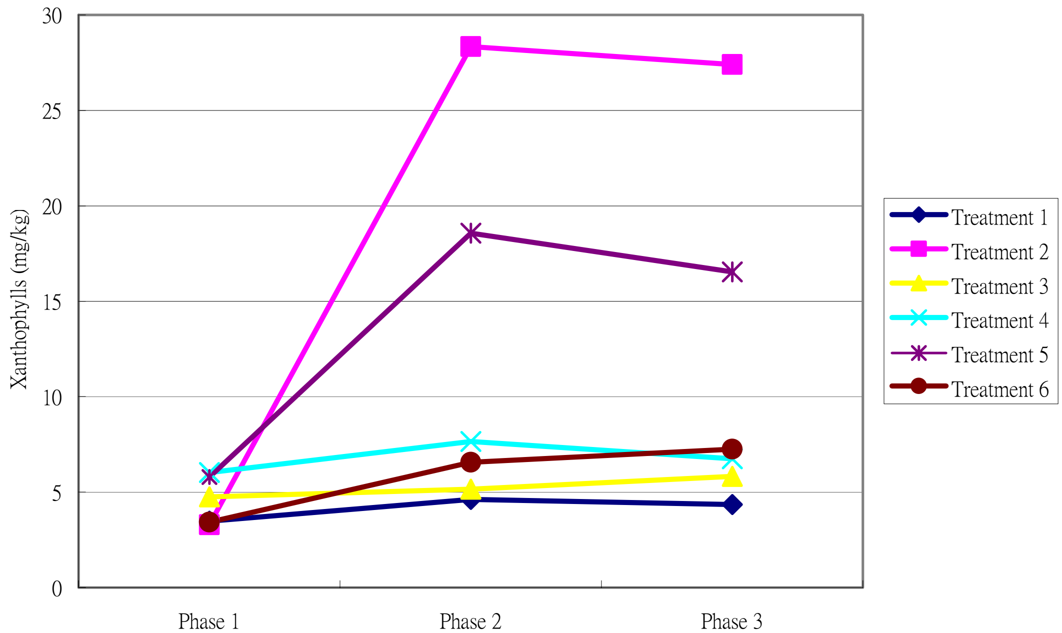

Figure 3. Dietary Xanthophylls Content of Each Treatment at Different Rearing Phases.

Although the fiber content of DDGS is relatively high, the growth performance (weight gain and feed efficiency) of domestic colored chicken was not significantly influenced ($P > .05$) by including 20% of DDGS in the diets (Table 4). When the diets were formulated with the same amount of metabolizable energy and protein, DDGS can be good alternative feedstuffs for domestic native chickens.

The live weight, carcass weight, weight of the abdominal fat pad, and liver weight did not show consistent trend of significant difference between treatments (Table 5, 6, and 7). It appears that some statistically significant differences observed for some of these traits shown in Table 5, 6, and 7 were a result of sampling errors when birds were selected for slaughter.

Table 4. Effects of Feeding Diets Containing DDGS on Growth Performance of Taiwan Domestic Native chickens.

Treatment	Feed consumption g/bird	Weight gain g/bird	Feed/gain
……………………………………0~4 weeks old…………………………………….			
1. Control	585±33	300±28	1.95±0.07
2. Control	613±51	305±45	2.01±0.13
3. 10%DDGS	615±33	309±23	1.99±0.04
4. 20%DDGS	620±28	321±22	1.93±0.05
5. 20%DDGS	613±89	299±35	2.05±0.06
6. Control	622±22	318±13	1.96±0.15
…………………………………5~12 weeks old..……………………………….			
1. Control	3505±258	1115±108	3.14±0.43
2. Control+AP	3930±103	1093±118	3.60±0.59
3. 10%DDGS	3842±168	1166±77	3.30±0.35
4. 20%DDGS	3808±119	1131±58	3.37±0.19
5. 20%DDGS+1/2AP	4023±103	1165±62	3.45±0.36
6. 20%DDGS	3824±209	1189±88	3.22±0.26
.…………………………………13~16 weeks old..……………………………….			
1. Control	3039±762	634±298	4.79±1.79
2. Control+AP	3106±992	709±156	4.38±2.24
3. 10%DDGS	2232±404	518±112	4.31±1.73
4. 20%DDGS	2666±428	619±128	4.31±0.33
5. 20%DDGS+1/2AP	2834±309	719±373	3.94±1.77
6. 20%DDGS	2917±307	601±40	4.85±0.19

AP: artificial extracted pigment
[a, b, c] Means within the same column of different rearing stages without the same superscript are significantly different（$P < 0.05$）

The color of abdominal fat pad was significantly influenced by the dietary treatments (Table 5, 6, and 7). The diets with either the full amount of artificial pigments, or 20% DDGS plus half amount of artificial pigments significantly improved ($P < .05$) the abdominal fat pad color at 12 weeks of age (Table 5), which agreed with the amount of xanthophyll in the diets. The diets containing the full amount of pigment, and the diets containing 20% DDGS plus 1/2 the recommended amount of pigment treatment had abdominal fat pad color scores of 6.5 and 5.0 at the end of trial, respectively. When compared with the control group, abdominal pad fat color of these two treatments was improved by 160% and 100%, respectively (Table 7). Abdominal fat pad color of 10% DDGS and 20% DDGS treatment groups were not significantly different ($P > .05$) compared to the control group at 12 weeks of age (Table 5). Nevertheless, the abdominal fat pad color of these two DDGS treatments continuously improved in Phase 3 (13 to 16 weeks). At the end of feeding trial (16 weeks), the abdominal fat pad color of 10% DDGS and 20% DDGS groups were improved by 20% and 67%, respectively (Table 6 and 7). Treatment 6, which switched from the control diet to the 20% DDGS diet during Phase 2, did not show improvement in abdominal fat pad color up to 16 weeks of age. When accumulated xanthophyll intake (AXI) were estimated and evaluated, feeding 20% DDGS diets during phase 2 and phase 3 (Treatment 6) resulted in an AXI of 48,390 mg/bird, which is higher than the AXI of 10% DDGS group (35,720 mg/bird), and is very close to that of the 20% DDGS group (50,897 mg/bird). This indicates that supplementation of xanthophylls in the early stage of life may be necessary to improve deposition of pigments in the skin and abdominal fat pad of domestic colored chickens. However, birds fed diets containing 100% of the recommended level of artificial pigment (Treatment 2) and 50% of the recommended level of artificial pigment (Treatment 5), did not show this phenomenon. Whether there is a difference on the efficiency of absorption and deposition of xanthophylls from different sources remains unknown. More research is needed to answer this question.

Table 5. Effects of Feeding Diets Containing Artificial Pigment and DDGS on Carcass Traits of Taiwan Domestic Native Chickens at 12 Wks of Age.

	Treatment						
Measure	**Control**	**Control + AP[1]**	**10% DDGS**	**20% DDGS**	**20% DDGS + ½ AP[1]**	**Control Phase 1, 20% DDGS Phase 2 & 3**	**MSE**
Live weight, g	1633.8	1486.4	1548.8	1456.3	1511.3	1482.5	237.3
Carcass weight, g	1288.3	1227.3	1226.0	1118.8	1174.3	1157.3	224.1
Dressing %	78.4	78.4	76.4	76.8	77.5	76.5	4.2
Abdominal fat pad, g	11.7	11.3	33.5	12.0	15.7	12.0	5.9
Liver weight, g	29.3[a]	24.3[ab]	19.0[b]	20.9[b]	21.9[b]	23.0[ab]	6.3
Abdominal fat pad color score	1.0[d]	4.4[b]	1.1[d]	1.5[cd]	5.3[a]	2.0[c]	0.5

[a, b, c, d] Means within the same row without the same superscript are significantly different（P ＜ .05）
[1] AP = artificial pigment

Table 6. Effects of Feeding Diets Containing Artificial Pigment and DDGS on Carcass Traits of Taiwan Domestic Native Chickens at 14 Wks of Age.

	Treatment						
Measure	**Control**	**Control + AP[1]**	**10% DDGS**	**20% DDGS**	**20% DDGS + ½ AP[1]**	**Control Phase 1, 20% DDGS Phase 2 & 3**	**MSE**
Live weight, g	1772.0	1793.3	1900.7	1863.2	1786.8	1968.8	214.0
Carcass weight, g	1347.8	1321.7	1460.7	1421.3	1375.5	1554.0	201.5
Dressing %	75.9^{ab}	73.8^{b}	76.6^{ab}	76.1^{ab}	76.8^{ab}	79.3^{a}	3.9
Abdominal pad fat, g	19.2	26.8	26.0	24.8	11.4	25.3	17.3
Liver weight, g	33.2	37.8	33.7	32.5	33.2	38.7	7.5
Abdominal fat pad color score	2.0^{e}	4.2^{b}	2.7^{d}	3.5^{c}	5.0^{a}	2.0^{e}	0.4

[a, b, c, d, e] Means within the same row without the same superscript are significantly different（$P < .05$）.
[1] AP = artificial pigment

Table 7. Effects of Feeding Diets Containing Artificial Pigment and DDGS on Carcass Traits of Taiwan Domestic Native Chickens at 16 Wks of Age.

	Treatment						
Measure	**Control**	**Control + AP[1]**	**10% DDGS**	**20% DDGS**	**20% DDGS + ½ AP[1]**	**Control Phase 1, 20 % DDGS Phase 2 & 3**	**MSE**
Live weight, g	2150.7^{ab}	2041.3^{ab}	1997.5^{b}	2076.7^{ab}	2146.0^{ab}	2361.0^{a}	263.8
Carcass weight, g	1691.3	1607.0	1555.7	1646.3	1689.5	1839.7	236.9
Dressing %	78.2	78.7	77.7	79.3	78.6	78.0	2.8
Abdominal fat pad, g	26.2	37.5	21.8	43.2	33.7	31.0	30.3
Liver weight, g	30.5	38.2	34.8	37.8	38.0	41.5	9.9
Abdominal fat pad color score	2.5^{d}	6.5^{a}	3.0^{d}	4.2^{c}	5.0^{b}	2.5^{d}	0.4

[a, b, c, d] Means within the same row without the same superscript are significantly different（$P < .05$）.
[1] AP = artificial pigment

As shown in Figure 4, the relationship between abdominal fat pad color and AXI was non-linear. The abdominal pad fat color (y) can be predicted by the following non-linear regression model using AXI (x) as independent variable:

$$y = 2.0036Ln(x) - 18.448 \qquad R^2 = 0.8271$$

The increase in abdominal fat pad color was significant when the AXI increased from 0 to about 50,000 mg/bird. The effects of xanthophyll supplementation on abdominal on increasing fat pad color plateaued when AXI was higher than 100,000 mg/bird. The data points in Figure 4 were grouped by treatments using different colored lines to distinguish between treatments. Data points with AXI higher than 100,000 mg/bird can only be made by the supplementation of artificial pigments. Without artificial pigments, 20% DDGS diets supplied about 50,000 mg/bird of AXI with abdominal fat pad color around 4.5. This information indicates that the xanthophyll in feedstuffs, such as DDGS and corn, may have higher absorption efficiency than the artificial extracted pigments. The other possibility is that artificial pigments were over-supplemented in this trial. According to experience in the field, an abdominal fat pad color score of 5 is acceptable in the Taiwan market. The xanthophyll provided be feeding a diet containing 20% of DDGS plus half of the amount of artificial pigments (Treatment 5) can achieve the color score desired by consumers.

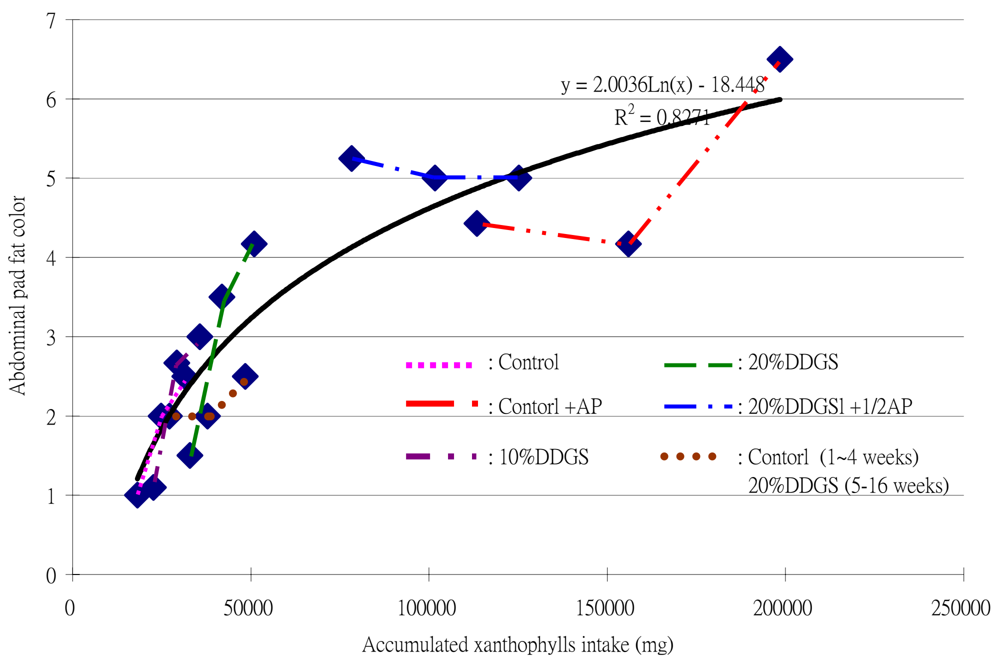

Figure 4. Relationship Between Abdominal Fat Pad Color and Accumulated Xanthophyll Intake (AXI).

The slaughtered chickens were steam-cooked and the skin color of the carcass was assessed as shown in Figure 5. Feeding diets containing the full amount of artificial pigments (Treatment 2) and 20% DDGS plus 1/2 of the recommended level of artificial pigments (Treatment 5) resulted in chickens have a bright yellow skin color which is popular among Taiwan consumers. The skin color of chickens fed the 20% DDGS diet was improved compared to chickens from other groups fed diets without artificial pigment, but was not at a level considered acceptable for the desired skin color.

Figure 5. Skin Color of Steam-Cooked Domestic Colored Chickens Representing the Six Dietary Treatments.

The results of Hunter's muscle color scores and shear force tests are presented in Table 8. Chickens fed diets containing the full amount of artificial pigments (Treatment 2) and diets containing 20% DDGS plus 1/2 of the recommended amount of artificial pigments (Treatment 5) tended to have higher b values for muscle color compared the muscle from chickens fed the other dietary treatments. This indicates that meat from these two dietary treatments had a stronger yellow color. However, the effect of dietary treatment on the other meat color characteristics (lightness or redness of color) was not consistent in different stages. The shear force of meat of the control group was lower than some of the other dietary treatments. The result was not consistent in different stages and was not conclusive. The biochemical composition of blood was not significantly influenced by the dietary treatments in this trial (Table 9).

Table 8. Effects of Feeding Diets Containing Artificial Pigment and DDGS on Breast and Thigh Muscle Traits of Taiwan Domestic Native Chickens at 12,14 and 16 Wks of Age.

	Treatment						
Measure	**Control**	**Control + AP[1]**	**10 % DDGS**	**20 % DDGS**	**20 % DDGS + ½ AP[1]**	**Control Phase 1, 20% DDGS Phase 2 & 3**	**MSE**
			--------------------------- 12 weeks -------------------------				
Breast muscle							
Hunter L*	32.78^{b}	34.47^{ab}	36.22^{a}	33.57^{ab}	33.97^{ab}	35.62^{a}	2.43
Hunter a*	1.59	1.92	1.88	2.08	2.45	2.00	1.44
Hunter b*	7.38^{c}	10.45^{a}	8.64^{b}	8.19^{bc}	10.74^{a}	8.21^{bc}	1.03
Thigh muscle							
Hunter L*	34.31^{b}	34.95^{b}	32.91^{b}	34.18^{b}	38.09^{a}	34.46^{b}	2.56
Hunter a*	5.60^{b}	5.98^{ab}	8.50^{a}	5.76^{b}	4.53^{b}	6.52^{ab}	2.32
Hunter b*	9.20^{b}	11.12^{a}	9.46^{b}	9.39^{b}	11.24^{a}	10.11^{b}	0.94
			--------------------------- 14 weeks -------------------------				
Breast muscle							
Hunter L*	34.44	35.46	33.96	34.23	35.08	36.15	2.01
Hunter a*	1.90	2.69	3.61	2.71	2.48	1.62	1.58
Hunter b*	8.12	10.25	8.44	8.92	9.11	8.08	1.21
Shear force	1.56^{a}	1.52^{a}	1.14^{b}	1.50^{a}	1.26^{ab}	1.36^{ab}	0.29
Thigh muscle							
Hunter L*	34.3	33.72	33.36	32.00	35.26	32.39	2.46
Hunter a*	8.55	8.84	8.67	9.63	8.38	7.86	1.12
Hunter b*	9.92	11.31	9.04	10.03	10.52	8.91	1.09
Shear force	0.93^{d}	1.27^{bc}	1.66^{a}	1.22^{bc}	1.37^{b}	1.12^{cd}	0.29
			--------------------------- 16 weeks -------------------------				
Breast muscle							
Hunter L*	32.80	31.83	32.09	30.73	29.93	31.68	2.59
Hunter a*	1.76	3.58	3.37	2.38	3.66	2.18	1.26
Hunter b*	7.82^{ab}	9.32^{ab}	8.30^{ab}	7.48^{b}	9.55^{a}	8.08^{ab}	1.64
Shear force	0.80^{c}	1.00^{b} c	1.16^{ab}	1.35^{a}	1.02^{ab}	0.89^{bc}	0.31
Thigh muscle							
Hunter L*	28.90	31.56	32.44	28.95	30.30	31.89	2.99
Hunter a*	9.70	7.35	7.41	9.59	8.24	8.23	1.76
Hunter b*	8.93	10.03	9.72	8.82	9.99	9.57	0.97
Shear force	1.00^{b}	1.08^{ab}	1.38^{a}	1.40^{a}	1.12^{ab}	1.40^{a}	0.29

[a, b, c] Means within the same row without the same superscript are significantly different ($P < .05$)

[1] AP = artificial pigment

Table 9. Effects of Feeding Diets Containing Artificial Pigment and DDGS on Blood Biochemical Composition of Taiwan Domestic Native Chickens at 16 Wks of Age.

	Treatment						
	Control	**Control + AP[1]**	**10% DDGS**	**20% DDGS**	**20% DDGS + ½ AP[1]**	**Control Phase 1, 20% DDGS Phase 2 & 3**	**MSE**
TP, g/dl	5.9	5.6	6.7	5.7	5.4	8.4	2.4
ALB, g/dl	2.3	2.5	2.7	2.3	2.3	2.5	0.6
CHOL, mg/dl	189.3	179.8	205.1	168.7	165.5	228.0	38.7
CREA, mg/dl	0.24	0.25	0.25	0.25	0.23	0.32	0.57
TG, mg/dl	22.6	27.0	23.3	23.3	17.3	22.7	4.4

[a, b] Means within the same row without the same superscript are significantly different（P ＜ .05）.
[1] AP = artificial pigment

Summary

Results from this study showed that adding 20% corn DDGS to domestic colored chicken diets had no negative effects on weight gain, feed efficiency, meat quality, protein metabolism and fat metabolism. The xanthophylls in DDGS can be effectively absorbed and deposited in the abdominal fat pad and skin. Distiller’s dried grain with solubles can be stored effectively for up to 12 weeks without losing xanthophylls concentration. Although the xanthophylls in DDGS can not completely replace the artificial pigments to meet the color requirement for the Taiwan market, 20% DDGS plus one-half of the amount of artificial pigments can achieve the desired carcass quality and color of the abdominal fat pad and skin. When the cost of diets without supplementation of artificial pigments are the same between treatments as in this trial, adding 20% DDGS can decrease the supplementation of artificial pigments by 50% and can save about 200 to 300 NT$ per metric ton due to less need for artificial pigment supplementation. These results show that DDGS is a good alternative feedstuff for efficient domestic colored chicken production as its use in diets for domestic colored chickens is encouraged.