RUNNING TITLE: DIETARY ENERGY VS. BOVANS AND DEKALB

TITLE: Influences of Dietary Energy on Performance and Egg Composition of Bovans White and Dekalb White in Phase I

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SPECIFIC SECTION: METABOLISM AND NUTRITION

Abstract: A 4 × 2 factorial experiment with four dietary energy levels (2719, 2798, 2877 and 2959 kcal/kg) and two strains (Bovans White and Dekalb White) was conducted to determine the influence of dietary energy on reproductive performance, egg composition, and profits of two strains of commercial leghorns. This experiment lasted 16 weeks. Bovans White hens (n = 768) and Dekalb White hens (n = 768) in Phase I (21 weeks of age) were randomly divided into 8 treatments (16 replicates of 12 birds per treatment). Bovans White had significant higher feed intake, egg production, egg mass, body weight, percent egg yolk, and Yolk/Albumen ratio than Dekalb White, while Bovans White had significant lower feed conversion, egg weight, egg specific gravity, percentage of albumen weight, percentage of shell weight, and Haugh unit than Dekalb White. When dietary energy level increased from 2719 to 2956 kcal/kg, hens adjusted feed intake from 107.6 to 101.1 g/hen/day so that the same amount of dietary energy (5.8 kcal) was used to produce one gram egg. Increasing dietary energy by the addition of poultry oil increased early egg weight, which appeared to be due to increased yolk weight. Increasing dietary energy by the addition of poultry oil significantly decreased feed conversion and egg specific gravity, but had no effect on egg production, egg mass, body weight and mortality. Therefore, increasing dietary energy by the addition of poultry oil had positive effects on performance in both Bovans White and Dekalb White fed the corn-soy diets in Phase 1. Based on egg weight, increasing dietary energy by the addition of poultry oil at a 282 energy/lysine ratio had maximum performance of laying hens in Phase 1, but may not get optimal profits because egg price and poultry oil price are variable.

Key words: strains, energy, egg composition, egg weight, feed intake

INTRODUCTION

A number of studies have been conducted to investigate dietary energy effects on feed intake of commercial leghorns. Grobas et al. (1999) reported that an increase in dietary energy from 2680 to 2810 kcal/kg decreased feed intake by 4%. Harms et al. (2000) showed that hens fed the diets containing 2519 kcal/kg had 8.5% more feed intake than hens fed the diets containing 2798 kcal/kg, and hens fed the diets containing 3078 kcal/kg had 3.0% less feed intake than hens fed the diets containing 2798 kcal/kg.

Many researchers have studied the effect of dietary energy on early egg weight. Harms et al. (2000), Bohnsack et al. (2002), Keshavarz (1995), and Keshavarz and Nakajima (1995) reported that increasing dietary energy by the addition of corn oil or poultry oil increased early egg weight. However, Summers and Leeson (1983) reported that egg weight was not changed by increasing dietary energy or supplementing with fat.

There is a wide range of energy contents currently being used in layer diets. However, few papers if any papers have suggested an ideal dietary energy level for optimal performance and profits of commercial leghorn in Phase I. Feed intake can affect cost of production, and early egg weight can significantly affect profits. With sharp increase in energy prices that occurred during past year, it is even more important to have more information concerning the effect of dietary energy on profit returns. In addition, while shell egg consumption decreases, processed egg consumption such as liquid egg product and dried egg solid has steadily increased. No studies have been conducted to investigate the dietary energy effect on egg components of current strain of Bovans White and Dekalb White.

The objective of this study was to determine the influence of dietary energy on performance, egg composition, and profits in Bovans White and Dekalb White hens in Phase I.

MATERIAL AND METHODS

A 4 × 2 factorial experiment with four dietary energy levels (2719, 2798, 2877 and 2959 kcal/kg) and two strains (Bovans White and Dekalb White) was conducted for 16 weeks. Ingredients and nutrient composition of experimental diets were showed in Table 1.

In the present experiment, Bovans White hens (n = 768) and Dekalb White hens (n = 768) in Phase I (21 weeks of age) were randomly divided into 8 treatments (16 replicates of 12 birds per treatment). Replicates were equally distributed into upper and lower cage content to minimize cage level effect. Three hens were housed in a 40.6 cm × 45.7 cm cage and five adjoining cages consisted of a group. All hens were housed in an environmentally controlled house with temperature maintained at approximately 25.6°C. The house has controlled ventilation and lighting (16 hr/day). All hens were supplied with feed and water *ad libitum*. Egg production was recorded daily, feed consumption and egg weight were recorded weekly, and egg specific gravity was recorded monthly. Egg weight and egg specific gravity were measured using all eggs produced during two consecutive days. Egg specific gravity was determined using 11 gradient saline solutions varying in specific gravity from 1.060 to 1.100 incremented by 0.005-unit increments (Holder and Bradford, 1979). Mortality was determined daily and the feed consumption was adjusted accordingly. Body weight was obtained by weighing 3 hens per group at the end of the experiment. Egg mass and feed conversion (g feed/g egg) were calculated from egg production, egg weight and feed consumption.

Egg component were measured using all eggs (n = 341) from four replicates of each treatment in the middle of experiment and all eggs (n = 301) from four replicates of each treatment at the end of experiment. Eggs were weighed and then broken. The yolks were separated from the albumen. Before determining the yolk weight, the chalazae was removed by forceps. Then, each yolk was rolled on a paper towel to remove adhering albumen. The shell were carefully cleaned of any adhering albumen and dried for 5 days. Albumen weight was calculated by subtracting the weight of yolk and shell from the whole egg weight.

Three eggs from each replicate were collected at the end of experiment for measuring total solid. The yolk and albumen were mixed completely and 5-6 gram homogenate was pipetted into aluminum dish with weight recorded to 0.001 gram. The sample was dried in an oven for 24 h at 105 C (AOAC, 1990), and then weighed. Three eggs per treatment were used to analyze yolk and albumen solid. After separating, albumen and yolk were mixed separately. The procedure for analyzing albumen and yolk solid was the same as the procedure for total egg solid content. Yolk color and Haugh units were measured using 3 eggs of each replicate at the end of experiment.

Data was analyzed by 4×2 factorial design in the General Linear Models (GLM) procedure of Statistical Analysis System (V 8.2, SAS Institute Inc. Cary, North Carolina, USA). If differences in treatment means were detected by ANOVA, Duncan's Multiple Range Test was applied to separate means. Statements of statistical significance are based on a probability of ($P \leq 0.05$). Contrast statements were utilized to test for linear or quadratic energy effects.

RESULTS AND DISCUSSION

Feed consumption

There was no interaction between dietary energy and strain on feed intake (Table 2). Dietary energy had a significant negative effect on overall average feed intake (Table 2). Feed intakes at four energy contents were significantly different from each other. With increasing dietary energy levels feed intake linearly decreased from 107.6 to 101.1 g/hen/day, resulting in a net decrease of 6.5 g/hen/day or 6.0% of feed intake. Therefore, increasing dietary energy contents by the addition of poultry oil linearly decreased feed intake. An increase of 39 kcal/kg dietary energy decreased feed intake by 1%. Calculations from the results of Grobas (1999) indicated that an increase of 33 kcal/kg dietary energy decreased feed intake by 1%, which was very similar to our result. There were no significant differences in dietary energy required to produce one gram egg among hens fed four dietary energy levels (Table 4). When dietary energy level increased from 2719 to 2956 kcal/kg, hens adjusted feed intake from 107.6 to 101.1 g/hen/day so that the same amount of dietary energy (5.8 kcal) was used to produce one gram egg. Strain significantly affected overall average feed intake (Table 2). Dekalb White hens had significantly lower feed intake than Bovans White hens. Feed intake decrease curve in Dekalb White hens was similar to that in Bovans White hens (Figure 1).

Egg production and egg mass

There was no interaction between protein and dietary energy on egg production and egg mass (Table 2). Strain had a significant effect on egg production and egg mass (Table 2). Bovans White hens had significant higher egg production and egg mass than Dekalb White hens at all four energy levels. There was no significant dietary energy effect on egg production and egg mass (Table 2). This result was consistent with that of Harms et al. (2000) who reported that egg production was not affected by dietary energy.

Egg weight

There was no interaction between strain and dietary energy on egg weight (Table 3). Strain had a significant effect on egg weight. Dekalb White hens had significant higher egg weight than Bovans White hens from 25 week of age (Table 3). Dietary energy had a significant positive liner effect on egg weight during week 25 to 26, week 31 to 32, week 35 to 36, and overall average (Table 3). Therefore, increasing dietary energy by the addition of poultry oil increased early egg weight. This result was in agreement with that of Harms et al. (2000), Bohnsack et al. (2002) and Sohail et al. (2003) who observed that increasing dietary energy by the addition of corn oil or poultry oil had positive effect on early egg weight. With dietary energy levels increasing from 2719 to 2877 kcal/kg egg weight linearly increased from 60.85 to 61.47 g. However, increasing dietary energy levels from 2877 to 2956 kcal/kg had no influence on egg weight (Table 3). As dietary energy level increased, feed intake linearly decreased. Because nutrient contents except energy in all four diets were the same, nutrients such as protein, TSAA intake, and lysine used to produce one gram egg linearly decreased (Table 4). The decrease of nutrient intake might explain why increasing dietary energy levels from 2877 to 2956 kcal/kg had no effect on egg weight.

Feed conversion

There was no interaction between protein and dietary energy on feed conversion (Table 2). Strain had a significant effect on feed conversion (Table 2). Feed conversion of Bovans White hens was significantly lower than that of Dekalb White hens. Dietary energy had a significant linear effect on feed conversion. As dietary energy content increased from 2719 to 2956 kcal/kg, feed conversion linearly decreased from 2.14 to 1.97 (g feed/g egg), resulting in a net decrease of 7.94%.

Egg specific gravity, final body weight, and mortality

There were no interactions between protein and added lysine on egg specific gravity, body weight, and mortality (Table 2). Strain had a significant effect on egg specific gravity. Egg specific gravity of Dekalb White hens was significantly higher than that of Bovans White at all four energy contents. Dietary energy had a significant effect on egg specific gravity (Table 2). Egg specific gravity in hens fed diets containing 2719 and 2798 kcal/kg dietary energy was significantly lower than that in hens fed diets with 2877 and 2956 kcal/kg dietary energy. Bovans White hens had significantly higher body weight than Dekalb White hens. There was no dietary energy effect on hen body weight. Strain and dietary energy had no effect on mortality (Table 2).

Egg component, Egg solid, Haugh unit, and yolk color

Strain had significant effects on albumen weight, shell weight, percentage of yolk, percentage of albumen, percentage of shell, and Yolk/Albumen ratio (Yolk weight/Albumen weight) (Table 5). Dekalb White hens had significant higher albumen weight, shell weight, percentage of albumen, and percentage of shell than Bovans White hens. Bovans White hens had significant higher percentage of yolk and Yolk/Albumen ratio than Dekalb White hens. These results suggest that eggs from some strains may be more desirable for further processing. Dietary energy had a significant linear effect on yolk weight (Table 4). As energy content increased from 2719 to 2956 kcal/kg, egg yolk increased from 15.95 to 16.39 g. These results suggest that the increase of egg weight might be mainly due to increased yolk weight. Shell et al. (1987) hypothesized that because hepatic synthesis of lipoprotein by hens during early egg production is insufficient, exogenous fat might supply more lipids for egg yolk development. Dekalb White hens had significant higher Haugh unit than Bovans White hens. Dietary energy had a linear significant negative effect on Haugh unit (Table 6).

Economics

Economic feeding and management program developed by Roland et al. (1998; 2000) was used to calculate profits of different dietary energy level at different poultry oil prices. When poultry oil price was 10 cents/lb, the highest profits per dozen eggs were gained in hens fed the diets containing 2956 kcal/kg dietary energy at three different egg prices respectively. However, when poultry oil price increased to 18 cents/100lb, the best profits were gained in hens fed the diets containing 2798 kcal/kg at three different egg prices respectively. Because feed ingredient prices and egg price often change, the economics of dietary energy levels may change.

In conclusion, Bovans White had significant higher feed intake, egg production, body weight, percent of egg yolk, and Yolk/Albumen ratio than Dekalb White, while Bovans White had significant lower egg weight, feed conversion, egg specific gravity, percentage of albumen weight, percentage of shell weight, and Haugh unit than Dekalb White. When dietary energy level increased from 2719 to 2956 kcal/kg, hens adjusted feed intake from 107.6 to 101.1 g/hen/day so that the same dietary energy (5.8 kcal) was used to produce one gram egg. Increasing dietary energy by the addition of poultry oil increased early egg weight, which appeared to be due to increased yolk weight. Increasing dietary energy by the addition of poultry oil significantly decreased feed conversion and egg specific gravity, but had no effect on egg production, egg mass, body weight and mortality. Therefore, increasing dietary energy by the addition of poultry oil had positive effects on performance in Bovans White and Dekalb White fed corn-soy diets in Phase 1. Based on egg weight, increasing dietary energy by the addition of poultry oil at a 282 energy/lysine ratio had maximum performance of laying hens in Phase 1, but may not get optimal profits because egg price and poultry oil price are variable.

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TABLE 1. Ingredients and nutrient composition of experimental diets

Ingredient (%)	Diet 1	Diet 2	Diet 3	Diet 4
Corn	59.03	57.21	55.36	53.52
Soybean meal	29.28	29.43	29.57	29.72
$CaCO_3$	6.98	6.98	6.97	6.97
Hardshell[1]	2.00	2.00	2.00	2.00
Dicalcium phosphate	1.68	1.69	1.70	1.71
Poultry oil	0.00	1.68	3.36	5.05
NaCl	0.38	0.39	0.39	0.39
Vitamin Premix[2]	0.25	0.25	0.25	0.25
Mineral premix[3]	0.25	0.25	0.25	0.25
DL-Methionine	0.135	0.140	0.145	0.149
Calculated analysis (%)				
CP	18.85	18.78	18.71	18.63
ME (kcal/kg)	2719	2798	2877	2956
Ca	4.00	4.00	4.00	4.00
Available phosphorus	0.42	0.42	0.42	0.42
Methionine	0.44	0.44	0.44	0.44
Metionine+Cystine	0.76	0.76	0.76	0.76
Lysine	1.02	1.02	1.02	1.02

[1]Hardshell = large particle (passing US mesh #4 and retained by US mesh #6) $CaCO_3$ supplied by Franklin Industrial Minerals, Lowell, Florida.

[2]Provided per kilogram of diet: vitamin A (as retinyl acetate), 8,000 IU; cholecalciferol, 2,200 ICU; vitamin E (as DL-α-tocopheryl acetate), 8 IU; vitamin B_{12}, 0.02 mg; riboflavin, 5.5 mg; D-calcium pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; folic acid, 0.5 mg; vitamin B_1 (thiamin mononitrate), 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; vitamin K (menadione sodium bisulfate complex), 2 mg.

[3]Provided per kilogram of diet: manganese, 65 mg; iodine, 1 mg; ferrous carbonate, 55 mg; copper oxide, 6 mg; zinc oxide, 55 mg; sodium selenium, 0.3 mg.

TABLE 2. Influence of dietary energy on performance of Bovans White and Dekalb White (21 to 36 wk of age)

Factor		Feed intake (g/hen/day)	Egg production (%)	Egg mass (g egg/h/d)	Feed conversion (g feed/g egg)	Egg specific gravity (unit)	Body weight (kg)	Mortality (%)
Strain	Bovans	105.6^{a}	85.84^{a}	52.18^{a}	2.02^{b}	1.0887^{b}	1.43^{a}	0.076
	Dekalb	103.0^{b}	80.22^{b}	49.38^{b}	2.09^{a}	1.0909^{a}	1.30^{b}	0.086
Dietary energy (Kcal/kg)	2719	107.6^{a}	82.53	50.22	2.14^{a}	1.0903^{a}	1.30	0.086
	2798	105.4^{b}	83.25	50.75	2.08^{b}	1.0902^{a}	1.30	0.086
	2877	103.2^{c}	82.79	50.87	2.03^{c}	1.0894^{b}	1.82	0.086
	2956	101.1^{d}	83.54	51.29	1.97^{d}	1.0894^{b}	1.04	0.065
Pooled SEM		0.97	2.76	0.80	0.02	0.0004	0.06	0.0027
Two-way ANOVA		-------------------------	-------------------------	-------------------------	Probability	-------------------------	-------------------------	-------------------------
Main effects and interactions								
Strain		0.0005	0.0001	0.0001	0.0001	0.0001	0.0117	0.8325
Dietary energy		0.0001	0.7396	0.6137	0.0001	0.0007	0.3087	0.8365
Strain × Energy		0.6614	0.6805	0.9390	0.8345	0.8392	0.9536	0.9199
Contrasts								
Energy linear		0.0001	0.4197	0.1939	0.0001	0.0002	0.0521	0.9247
Energy quadratic		0.9591	0.9893	0.9230	0.4348	0.9686	0.9447	0.5084

$^{a-d}$ Means within a column and under each main effect with no common superscripts differ significantly

TABLE 3. Influence of dietary energy on egg weight in Bovans White and Dekalb White

Factor		Egg weight (g)								
		21-22 wk	23-24 wk	25-26 wk	27-28 wk	29-30 wk	31-32 wk	33-34 wk	35-36 wk	Overall
Strain	Bovans	51.76	56.82	58.95^{b}	60.59^{b}	62.44^{b}	63.26^{b}	63.14^{b}	62.85^{b}	60.80^{b}
	Dekalb	51.96	56.59	59.34^{a}	61.31^{a}	63.13^{a}	64.24^{a}	64.30^{a}	64.30^{a}	61.55^{a}
Dietary energy (Kcal/kg)	2719	51.72	56.65	58.95^{ab}	60.78	62.52	63.26^{c}	63.29	62.97^{b}	60.85^{c}
	2798	51.86	56.39	58.72^{b}	60.68	62.50	63.50^{bc}	63.76	63.56^{ab}	60.98^{bc}
	2877	51.72	56.94	59.47^{a}	61.26	63.15	64.22^{a}	63.89	63.81^{a}	61.47^{a}
	2956	52.01	56.82	59.43^{a}	61.09	62.96	64.03^{ab}	63.94	63.95^{a}	61.40^{ab}
Pooled SEM		0.71	0.45	0.38	0.36	0.42	0.41	0.47	0.46	0.35
Two-way ANOVA		--Probability--								
Main effects and interactions										
Strain		0.6787	0.3077	0.0389	0.0001	0.0016	0.0001	0.0001	0.0001	0.0001
Dietary energy		0.9310	0.3420	0.0117	0.0838	0.0770	0.0040	0.1869	0.0187	0.0286
Strain × Energy		0.9834	0.3092	0.3150	0.3046	0.7553	0.5541	0.6369	0.1856	0.6570
Contrasts										
Energy linear		0.6469	0.2966	0.0105	0.0585	0.0397	0.0015	0.0486	0.0027	0.0067
Energy quadratic		0.8351	0.7609	0.5901	0.8626	0.6974	0.2974	0.3604	0.3331	0.5762

$^{a\text{-}c}$ Means within a column and under each main effect with no common superscripts differ significantly

TABLE 4. Influence of dietary energy on nutrient intake for one gram egg of Bovans White and Dekalb White

Factor		Energy/lysine ratio (kcal/g)	Nutrients used to produce one gram egg			
			Dietary energy (Kcal)	Protein (g)	TSAA (mg)	Lysine (mg)
Strain	Bovans	278	5.7[b]	0.38[b]	15.39[b]	20.65[b]
	Dekalb	278	5.9[a]	0.39[a]	15.88[a]	21.31[a]
Dietary energy (Kcal/kg)	2719	267	5.8	0.40[a]	16.29[a]	21.87[a]
	2798	274	5.8	0.39[b]	15.80[b]	21.20[b]
	2877	282	5.8	0.38[c]	15.44[c]	20.72[c]
	2956	290	5.8	0.37[d]	15.00[d]	20.12[d]
Pooled SEM			0.054	0.004	0.158	0.212
Two-way ANOVA			----------Probability----------			
Main effects and interactions						
Strain			0.0001	0.0001	0.0001	0.0001
Dietary energy			0.9748	0.0001	0.0001	0.0001
Strain × Energy			0.6101	05619	0.5603	0.5614
Contrasts						
Energy linear			0.8347	0.0001	0.0001	0.0001
Energy quadratic			0.9743	0.9147	0.8110	0.8117

[a-c] Means within a column and under each main effect with no common superscripts differ significantly

TABLE 5. Influence of dietary on egg component in Bovans White and Dekalb White

Factor		Egg component weight (g)				% of egg components			Yolk:Albumen ratio
		Egg weight	Yolk weight	Albumen weight	Shell weight	Yolk	Albumen	Shell	
Strain	Bovans	62.71^{b}	16.31	40.64^{b}	5.76^{b}	26.05^{a}	64.76^{b}	9.20^{b}	0.404^{a}
	Dekalb	64.49^{a}	16.11	42.29^{a}	6.13^{a}	25.00^{b}	65.48^{a}	9.52^{a}	0.383^{b}
Dietary energy	2719	63.48	15.95^{b}	41.58	5.95	25.15	65.46	9.39	0.386
(Kcal/kg)	2798	63.11	16.09^{ab}	41.07	5.96	25.54	65.02	9.44	0.394
	2877	63.70	16.41^{a}	41.34	5.94	25.82	64.85	9.33	0.400
	2956	64.11	16.39^{a}	41.78	5.94	25.59	65.14	9.27	0.394
Pooled SEM		0.84	0.25	0.69	0.11	0.37	0.41	0.13	0.008
Two-way ANOVA		----------Probability----------							
Main effects and interactions									
Strain		0.0007	0.1362	0.0003	0.0001	0.0001	0.0026	0.0001	0.0001
Dietary energy		0.4261	0.0524	0.5173	0.9973	0.1218	0.2236	0.2923	0.1562
Strain × Energy		0.2022	0.4279	0.1840	0.2364	0.1647	0.3645	0.5364	0.1929
Contrasts									
Energy linear		0.2083	0.0110	0.5827	0.8847	0.0715	0.2309	0.1169	0.1127
Energy quadratic		0.3667	0.5330	0.1882	0.9304	0.1142	0.0893	0.3824	0.1042

[a-b] Means within a column and under each main effect with no common superscripts differ significantly

TABLE 6. Influence of dietary energy on egg solid, haugh units, and yolk color in Bovans White and Dekalb White

Factor		% of solid			Haugh unit	Yolk color
		Whole egg	Albumen	Yolk		
Strain	Bovans	24.60	12.61	49.48	80.98^{b}	6.85
	Dekalb	23.53	12.57	49.20	83.49^{a}	7.02
Dietary	2719	23.58	12.68	49.06	84.36^{a}	6.73
energy	2798	23.87	12.64	49.67	82.73^{ab}	7.23
(Kcal/kg)	2877	23.95	12.54	49.52	80.37^{c}	6.83
	2956	24.87	12.49	49.13	81.46^{bc}	6.96
Yeast	0	23.74	12.62	49.39	82.58	6.99
culture	0.1%	24.39	12.55	49.30	81.88	6.89
Pooled SEM		0.19	0.24	0.11	1.96	0.34
ANOVA		---Probability---				
Main effects and interactions						
Strain		0.0609	0.6636	0.4800	0.0020	0.2339
Dietary energy		0.4059	0.4131	0.6474	0.0040	0.0703
Strain × Energy		0.5086	0.0896	0.0176	0.7106	0.5540
Contrasts						
Energy linear		0.1213	0.0980	0.9667	0.0023	0.6407
Energy quadratic		0.5745	0.9100	0.2131	0.0900	0.1808

[a-c] Means within a column and under each main effect with no common superscripts differ significantly

TABLE 7. Influence of dietary energy levels and poultry oil price on profits

Returns[1] (cents/doz)	Dietary energy content (kcal/kg)			
	2719	2798	2877	2956
High fat price (18 cent/lbs)				
High egg price	57.1	57.6	57.3	57.4
Moderate egg price	10.9	11.4	11.2	11.3
Low egg price	-14.3	-13.7	-13.8	-13.8
High fat price (10 cent/lbs)				
High egg price	57.1	57.8	58.1	58.6
Moderate egg price	11.0	11.6	12.0	12.5
Low egg price	-14.2	-13.5	-13.1	-12.5

[1]Returns (R) were calculated using the equation: R = UBEP - NR -PC - FdC, where UBEP = Urner Barry Egg Price, NR = nest run into package product delivered, PC = production cost, and FdC = feed cost, as described by Roland et al. (1998; 2000).

Figure 1. Dietary energy effect on feed intake in Bovans White and Dekalb White