ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 8 (6): 515-520, 2009
ISSN 1682-8356

Evaluation of Nupro® Yeast Product in Diets for Broilers[1]

Z. Wang, S. Cerrate, C. Coto, P. Sacakli[2], F. Yan, F.G.P. Costa[3] and P.W. Waldroup[4]
Department of Poultry Science, University of Arkansas, Fayetteville AR 72701, USA

Abstract: Two trials with identical experimental design were conducted approximately 20 months apart to evaluate the response of broiler chickens to the addition of NuPro®, a yeast product rich in nucleotides. In both trials, four dietary treatments were compared. The first treatment contained no NuPro®. For the second treatment, the diet with 2% NuPro® was fed only the first 7 days of life while for the third treatment, 2% NuPro® was fed for the first 14 d. For the fourth treatment, 2% NuPro® was fed for the first 7 days and also during the finisher period of 35-42 d of age. In both studies, each treatment was fed to six replicate groups of 60 male broilers of a commercial strain. Response to the addition of NuPro® varied between the two experiments. In the first study, addition of 2% NuPro® to the diet resulted in improvement in feed conversion. Response varied by age of bird and time during which the NuPro® was fed. At 7 d of age, there were no significant differences between birds that had been fed NuPro® and those fed the negative control diet. At 14 d of age, there were no significant differences in feed conversion among birds fed the various treatments, but feed conversion was numerically better for those birds that had been fed NuPro® for the first 7 or 14 d. At 35 d, birds that had been fed NuPro® for the first 7 d had significantly better feed conversion than those fed the control diet with birds fed NuPro® for the first 14 d being intermediate between these two groups. At 42 d, birds fed diets with 2% NuPro® for the first 7 d or for the first 7 d followed by feeding from 35-42 d had significantly lower feed conversion than those fed the control, with those fed NuPro® for the first 14 d being intermediate between these groups. However, in the second trial there was no significant effect of inclusion of NuPro on any of the parameters evaluated. There may be nutritional differences between batches of the product that influence the response of chicks.

Key words: Yeast byproducts, nucleotides, broilers, prestarter diets

INTRODUCTION

Considerable interest is developing in the use of specialized diets to be fed for the first 7-10 days post hatch, during which time it is assumed that the digestive tract of the chicken may not be developed as well as later in life (Sklan, 2001). In addition, the inevitable loss of the use of antibiotic growth promoters, by government regulation or consumer pressure, has stimulated the search for products that would enhance performance in the absence of AGP. NuPro® (Alltech, Nicholasville KY) is a protein source derived from yeast. The present study was designed to evaluate the use of this product in broiler diets formulated to current industry nutrient standards, when included in the diet at different stages of production.

MATERIALS AND METHODS

Two trials with identical experimental design were conducted. The first trial was initiated on March 20, 2006 with the second trial beginning November 1, 2007, approximately 20 months later. In the first trial, diets were formulated for starter (0-14 d), grower (14-35 d), and finisher (35-42 d) periods based on nutrient composition of the average grower in an agricultural survey (Agri-Stats, Fort Wayne IN). In the second study, diets were formulated for starter (0-14 d), grower (15-35 d) and finisher (36-42 d) periods based on nutrient specifications by a major breeder (Aviagen). Because no information was available on the digestibility of the NuPro, diets in both studies were formulated on total amino acid basis. Corn and soybean meal of known protein and moisture content were used in the formulation with appropriate adjustments made in nutrient composition. Diets were supplemented with complete vitamin and trace mineral mixes obtained from commercial integrators. No antibiotic supplement was used in the diets. NuPro® was added at either 0 or 2% of the diet. The nutrient content of NuPro® provided by the supplier (Table 1) was used in the formulation of the diets. Because of differences in nutrient content of the NuPro®, corn and soybean meal used in the two experiments and differences in nutrient profiles of industry averages and the breeder recommendations, the resulting diets differed slightly in nutrient composition. In Experiment 1, the trace mineral mix used consisted of all inorganic sources while in Experiment 2 a trace mineral mix was used that consisted of all organic sources. Composition and calculated nutrient content of the basal diets are shown in Tables 2 and 3 for Experiments 1 and 2, respectively. Four dietary treatments were compared. The first treatment was considered as the negative control, with

Table 1: Nutrient composition of NuPro® (dry weight basis)[1]

Nutrient	Unit	Experiment 1	Experiment 2
Crude fat	%	0.20	0.45
Crude fiber	%	0.40	1.18
Metabolizable energy	Kcal/lb	1240	1340
Crude protein	%	53.50	50.02
Total nucleic acids	%	5.40	7.00
Lysine	%	2.83	3.40
Alanine	%	2.94	3.13
Arginine	%	1.88	2.14
Aspartic acid	%	3.75	4.45
Cystine	%	0.51	0.63
Glutamic acid	%	8.49	6.76
Glycine	%	1.94	2.21
Histidine	%	0.97	1.13
Isoleucine	%	1.84	1.96
Leucine	%	3.60	3.00
Methionine	%	1.09	0.63
Phenylalanine	%	1.87	1.89
Proline	%	2.11	1.53
Serine	%	1.94	2.10
Threonine	%	2.25	2.21
Tyrosine	%	1.73	1.59
Valine	%	2.46	2.77
Tryptophan	%	0.55	0.56
Total ash	%	5.80	8.84
Sulfur	%	0.46	0.50
Sodium	%	1.68	0.11
Phosphorus	%	1.53	1.63
Potassium	%	1.47	2.02
Magnesium	%	0.32	0.47
Calcium	%	0.05	0.96
Chloride	ppm	442	----

[1]Typically contains 6.0% moisture. Data provided by Alltech, Nicholasville KY

no NuPro® fed during any of the life cycle of the bird. For the second treatment, the diet with 2% NuPro® was fed only the first 7 days of life, similar to "prestarter" diets that are gaining in popularity in many areas. For the third treatment, 2% NuPro® was fed only for the first 14 d, similar to the "starter" period most commonly used in the U.S. poultry industry. For the fourth treatment, 2% NuPro® was fed for the first 7 days and also during the finisher period of 35-42 d of age. Each of the four treatments was assigned to six replicate groups. All diets were pelleted with steam; starter diets were fed as crumbles.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated *in ovo* for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Sixty chicks were placed in each of 24 pens (50 ft^2) in a house of commercial design. Previously used softwood shavings over concrete floors served as litter. Care and management of the birds followed recommended guidelines (FASS, 1999).

Mean body weight by pen was obtained at 1, 7, 14, 35, and 42 d of age. Feed consumption during the same periods was determined. Birds were checked twice daily for mortality with weight of dead birds used to adjust feed conversion. At the conclusion of the study, six birds per pen were randomly selected for processing to determine dressing percentage and parts yield as described by Fritts and Waldroup (2006).

Data were subjected to ANOVA using the General Linear Models procedure of SAS (SAS Institute, 1991). Pen means served as the experimental unit. Mortality data were transformed to square root of n + 1; data are presented as natural numbers.

RESULTS

Some noticeable differences were noted in the nutrient composition of the two different samples of NuPro® used in the studies (Table 1). The product used in Experiment 2 was higher in metabolizable energy and total nucleic acids but much lower in crude protein than the sample used in Experiment 1. The sample used in Experiment 2 was much higher in the essential amino acids lysine and arginine, considerably lower in methionine and similar in threonine and tryptophan content. Diets in Experiment 2 were lower in metabolizable energy and crude protein than those in Experiment 1 (Tables 2 and 3), reflecting changes in average composition of diets in the poultry industry during the 20 month time interval between trials.

Experiment 1: There was a significant difference in body weight only at 14 d; at this time birds that had been fed the NuPro® only during the first 7 d were significantly lighter than those fed the negative control or those that had been fed the NuPro® for the first 14 d (Table 4). However, at 35 and 42 d of age there was no significant difference in body weight among the various treatments. Inclusion of 2% NuPro® to the diet resulted in improvement in feed conversion ratio (Table 5). Response to the NuPro® varied by age of bird and time during which the NuPro® was fed. At 7 d of age, there were no significant differences between birds that had been fed NuPro® and those fed the negative control diet, although feed conversion was numerically improved. At 14 d of age, there were no significant differences in feed conversion among birds fed the various treatments, but feed conversion was numerically better for those birds that had been fed NuPro® for the first 7 or 14 d. At 35 d, birds that had been fed NuPro® for the first 7 d had significantly better feed conversion than those fed the control diet with birds fed NuPro® for the first 14 d being intermediate between these two groups. At 42 d, birds fed diets with 2% NuPro® for the first 7 d or for the first 7 d followed by feeding from 35-42 d had significantly lower feed conversion than those fed the control, with those fed NuPro® for the first 14 d being intermediate between these groups.

Effects of NuPro® inclusion on processing characteristics is shown in Table 7. There were no

Table 2: Composition (g/kg) and calculated analysis of broiler diets (Experiment 1)

	Starter (0-14 d)		Grower (14-35 d)	Finisher (35-42 d)	
Ingredients	-	+	-	-	+
NuPro®	0.00	20.00	0.00	0.00	20.00
Yellow corn	569.36	575.21	624.40	674.02	678.43
Soybean meal, dehulled	348.74	326.14	290.05	243.18	220.89
Poultry oil	30.36	28.13	38.40	38.53	36.80
Limestone	12.91	13.79	10.84	10.83	11.70
Dicalcium phosphate	17.44	16.10	16.09	15.17	13.83
Salt	5.65	5.00	5.00	5.00	5.00
MHA-84	3.28	3.26	3.32	2.92	2.90
L-Threonine	0.91	0.88	0.65	0.55	0.51
L-Lysine HCl	2.10	2.24	2.00	1.30	1.44
Broiler premix[1]	5.00	5.00	5.00	5.00	5.00
Trace mineral mix[2]	1.00	1.00	1.00	1.00	1.00
Coban 60[3]	0.75	0.75	0.75	0.00	0.00
Pel-Stik[4]	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/lb	1400.00	1400.00	1450.00	1475.00	1475.00
Crude protein %	22.50	22.50	20.00	18.00	18.00
Calcium %	0.99	0.99	0.87	0.84	0.84
Total P %	0.69	0.69	0.64	0.61	0.60
Available P %	0.45	0.45	0.42	0.39	0.39
Met %	0.60	0.60	0.58	0.52	0.53
Lys %	1.38	1.38	1.21	1.02	1.02
Trp %	0.27	0.26	0.23	0.21	0.20
Thr %	0.94	0.94	0.82	0.74	0.74
TSAA %	0.99	0.99	0.93	0.84	0.84
Sodium %	0.25	0.26	0.23	0.22	0.25

[1]Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.15 mg. [2]Provides per kg of diet: Mn (from $MnSO_4 \cdot H_20$) 100 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 100 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 50 mg; Cu (from $CuSO_4 \cdot 5H_20$) 10 mg; I from $Ca(IO_3)_2 \cdot H_20$), 1 mg. [3]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825. [4]Uniscope Inc., Johnstown CO 80534

significant differences among the various treatments for dressing percentage or yield of various carcass components, expressed either as total weight or as percentage of carcass weight.

Experiment 2: The inclusion of 2% NuPro® had no significant effect on body weight at any time during this experiment (Table 8). In contrast to the results of Experiment 1, there were no significant differences among the different dietary treatments for feed conversion at any age (Table 9). As in the previous study, there were no significant differences in mortality (Table 10) or processing characteristics (Table 11) between birds fed the various dietary treatments.

DISCUSSION

Few previous studies have been reported regarding the use of NuPro® in poultry feeds. Rutz *et al.* (2004) reported that broilers fed NuPro® from 1-7 d of age showed higher feed intake up to 31 d of age, but this effect was significant only up to 14 d of age. They suggested that the yeast extract stimulated feed intake only in the early stage of chick development. Inclusion of NuPro® in broiler diets from 1-7 d and from 38-42 d of age resulted in improvement in growth performance of the birds. However, feeding NuPro® only from 1-7 d resulted in a lower magnitude of growth performance. Birds fed NuPro® from 1-7 d and from 38-42 d showed numerically better feed conversion at 42 d than control birds or those fed NuPro® only for the first 7 d, but the differences were not statistically significant. Rutz *et al.* (2004) also noted numerically higher carcass yield, drumstick, thigh, wing and breast weight for birds fed NuPro® but the differences were not statistically significant. Swamy and Groenewegen (2008) reviewed a broiler study conducted in India in which birds were fed a control diet or diets supplemented with 2% NuPro® for 7, 14, or 42 d. Nutrient composition of the diets was not indicated. There was no significant effect of NuPro® on feed intake of birds during the first week; however feeding the yeast product for 14 d resulted in a significant increase in feed intake compared to the control birds. Body weight was consistently improved at all times during the study by feeding diets with 2% NuPro® with weights improving the longer the yeast product was fed.

In the present study, differences were noted in response to the NuPro® product in the two experiments.

Table 3: Composition (g/kg) and calculated analysis of broiler diets (Experiment 2)

	Starter (0-14 d)		Grower (14-35 d)	Finisher (35-42 d)	
Ingredients	-	+	-	-	+
NuPro®	0.00	20.00	0.00	0.00	20.00
Yellow corn	530.78	539.67	604.03	657.38	649.16
Soybean meal, dehulled	397.67	371.40	322.94	271.81	260.83
Poultry oil	29.65	27.24	34.16	33.41	33.64
Limestone	5.58	6.46	5.46	5.64	6.58
Defluorinated phosphate	20.45	19.01	18.19	16.85	15.31
Salt	3.33	3.46	2.87	2.54	2.67
MHA-84	2.30	2.40	1.77	1.52	1.45
L-Threonine	0.00	0.00	0.00	0.11	0.00
L-Lysine HCl	0.99	1.11	1.33	1.49	1.11
Broiler premix[1]	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[2]	1.00	1.00	1.00	1.00	1.00
Coban 60[1]	0.75	0.75	0.75	0.75	0.75
Pel-Stik	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/lb	1380.00	1380.00	1425.00	1450.00	1450.00
Crude protein %	24.25	23.96	21.13	19.05	19.33
Calcium %	1.00	1.00	0.90	0.85	0.85
Total P %	0.76	0.75	0.68	0.65	0.64
Available P %	0.50	0.50	0.45	0.42	0.42
Met %	0.57	0.58	0.50	0.46	0.45
Lys %	1.35	1.35	1.18	1.06	1.06
Trp %	0.28	0.27	0.24	0.21	0.21
Thr %	0.87	0.87	0.76	0.70	0.71
Ile%	0.95	0.93	0.82	0.73	0.74
Val %	1.04	1.04	0.91	0.82	0.85
Arg %	1.54	1.50	1.31	1.16	1.16
TSAA %	0.97	0.97	0.85	0.78	0.78
Sodium %	0.25	0.25	0.22	0.20	0.20

[1]As given in Table 2. [2]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg. Novus International, St. Louis MO

Table 4: Effect of inclusion of NuPro® on body weight (Experiment 1). Means of six pens of 60 male broilers

% NuPro®				Body weight (kg)			
1-7 d	7-14 d	14-35 d	35-42 d	7 d	14 d	35 d	42 d
0	0	0	0	0.170	0.430[a]	2.135	2.823
2	0	0	0	0.162	0.416[b]	2.129	2.813
2	2	0	0	---	0.434[a]	2.166	2.870
2	0	0	2	---	----	----	2.831
			SEM				
			CV	5.28	2.83	3.00	1.88
			P diff	0.079	0.017	0.51	0.30

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$)

Table 5: Effect of inclusion of NuPro® on feed conversion (Experiment 1). Means of six pens of 60 male broilers

% NuPro®				Feed:Gain Ratio			
1-7 d	7-14 d	14-35 d	35-42 d	0-7 d	0-14 d	0-35 d	0-42 d
0	0	0	0	1.246	1.390	1.661[a]	1.763[a]
2	0	0	0	1.200	1.369	1.619[b]	1.724[b]
2	2	0	0	----	1.384	1.631[ab]	1.738[ab]
2	0	0	2	----	----	------	1.716[b]
			SEM				
			CV	4.68	3.17	1.98	1.49
			P diff	0.12	0.61	0.05	0.02

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$)

Table 6: Effect of inclusion of NuPro® on mortality (Experiment 1). Means of six pens of 60 male broilers

% NuPro®				Mortality (%)			
1-7 d	7-14 d	14-35 d	35-42 d	0-7 d	0-14 d	0-35 d	0-42 d
0	0	0	0	0.46	0.69	5.00	6.95
2	0	0	0	0.28	0.49	3.47	4.72
2	2	0	0	----	0.97	6.39	7.50
2	0	0	2	---	----	----	
			SEM				
			CV*	0.45	0.29	1.14	1.36
			P diff	0.66	0.27	0.07	0.19

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$). *CV of transformed means

Table 7: Effect of NuPro® on carcass composition of 42 d old broilers (Experiment 1), Means of six pens of six broilers

	NuPro® Addition					
Items	NNNN	YNNN	YYNN	YNNY	CV (%)	P-value
Dressing percentage, %	72.82	73.25	72.58	72.97	2.20	0.3948
Breast weight, kg	0.555	0.581	0.588	0.570	11.83	0.2192
Breast % of live weight	19.27	20.09	19.69	19.88	8.93	0.3074
Breast % of carcass weight	26.45	27.41	27.12	27.24	8.31	0.3610
Wings, kg	0.236	0.234	0.240	0.232	6.66	0.1651
Wings % of live weight	8.23	8.09	8.07	8.10	5.09	0.4190
Wings % of carcass weight	11.30	11.05	11.12	11.11	5.51	0.4187
Leg quarters, kg	0.642	0.652	0.651	0.654	9.52	0.8673
Leg quarters % of live weight	22.34	22.57	21.84	22.76	7.18	0.1063
Leg quarters% of carcass weight	30.69	30.80	30.11	31.19	6.90	0.2179

NNNN-No NuPro® supplementation for the whole 42 days. YNNN-2% NuPro® supplementation only for the first 7 days. YYNN-2% NuPro® supplementation only for the first 14 days. YNNY-2% NuPro® supplementation for the first 7 days and finishing phase (d 35-42)

Table 8: Effect of inclusion of NuPro® on body weight (Experiment 2). Means of six pens of 60 male broilers

% NuPro®				Body weight (kg)			
1-7 d	7-14 d	14-35 d	35-42 d	7 d	14 d	35 d	42 d
0	0	0	0	0.186	0.509	2.405	2.888
2	0	0	0	0.187	0.508	2.407	2.889
2	2	0	0	----	0.509	2.408	2.904
2	0	0	2	----	-----	----	2.867
			SEM	0.0008	0.003	0.023	0.025
			CV	1.10	1.50	2.29	2.14
			P diff	0.20	0.99	0.99	0.74

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$)

Table 9: Effect of inclusion of NuPro® on feed conversion (Experiment 2). Means of six pens of 60 male broilers

% NuPro®				Feed:Gain Ratio			
1-7 d	7-14 d	14-35 d	35-42 d	0-7 d	0-14 d	0-35 d	0-42 d
0	0	0	0	1.233	1.296	1.556	1.738
2	0	0	0	1.214	1.308	1.559	1.737
2	2	0	0	----	1.291	1.550	1.729
2	0	0	2	----	----	----	1.744
			SEM	0.017	0.01	0.01	0.01
			CV	3.46	2.30	1.63	1.40
			P diff	0.34	0.38	0.78	0.77

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$)

Improvements in feed conversion were noted in the first experiment when the product was fed from 1-7 d followed by feeding from 38-42 d, but not when the product was fed only from 1-7 d. No significant improvement in body weight or in processing characteristics was noted in either experiment in the present study. This may have been due to differences in nutrient composition of the products used in the two different studies.

Yeast proteins are nutritious feed ingredients and are readily utilized by poultry (Waldroup *et al*., 1971; Waldroup, 1981). Nucleotides are essential nutrients involved in gut development and repair, skeletal muscle development, heart function and immune response (Grimble and Westwood, 2000). A general review of how nucleotides may stimulate development of broiler gastrointestinal tract, muscle tissue and immune system was provided by Rutz *et al*. (2007). Whether a

Table 10: Effect of inclusion of NuPro® on mortality (Experiment 2). Means of six pens of 60 male broilers

% NuPro®				Mortality (%)			
1-7 d	7-14 d	14-35 d	35-42 d	0-7 d	0-14 d	0-35 d	0-42 d
0	0	0	0	0.00	2.50	3.61	4.72
2	0	0	0	0.65	2.36	4.31	4.72
2	2	0	0	----	2.50	5.28	6.67
2	0	0	2	----	----	----	5.56
			SEM	0.30	0.91	1.13	1.31
			CV*	0.37	1.09	1.33	1.53
			P diff	0.075	0.98	0.59	0.70

[ab]Means with common superscripts do not differ significantly ($p \leq 0.05$), *CV of transformed means

Table 11: Effect of NuPro® on carcass composition of 42 d old broilers (Experiment 2). Means of six pens of six broilers

	NuPro®						
Items	NNNN	YNNN	YYNN	YNNY	SEM	CV (%)	P-value
Dressing percentage, %	73.68	73.77	73.17	73.84	0.311	2.02	0.381
Breast weight, kg	0.624	0.658	0.627	0.626	0.014	10.25	0.141
Breast % of live weight	21.55	22.11	21.52	21.64	0.338	7.47	0.486
Breast % of carcass weight	29.23	29.96	29.40	29.29	0.399	6.50	0.437
Wings, kg	0.228	0.235	0.230	0.233	0.003	5.50	0.161
Wings % of live weight	7.88	7.91	7.91	8.06	0.064	3.84	0.089
Wings % of carcass weight	10.71	10.72	10.82	10.91	0.094	4.16	0.209
Leg quarters, kg	0.622	0.634	0.616	0.609	0.009	6.88	0.136
Leg quarters % of live weight	21.49	21.30	21.16	21.07	0.209	4.71	0.357
Leg quarters% of carcass weight	29.18	28.88	28.93	28.55	0.302	5.01	0.357

NNNN-No NuPro® supplementation for the whole 42 days. YNNN - NuPro® supplementation only for the first 7 days . YYNN - 2% NuPro® supplementation for the first 14 days. YNNY - 2% NuPro® supplementation for the first 7 days and finishing phase (d 35-42)

source of nucleotides such as NuPro® can consistently improve performance in young broiler chicks needs to be evaluated in further studies.

REFERENCES

FASS, 1999. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 1st Rev. Ed. Federation of Animal Science Societies, Savoy IL.

Fritts, C.A. and P.W. Waldroup, 2006. Modified phosphorus program for broilers based on commercial feeding intervals to sustain live performance and reduce total and water-soluble phosphorus in litter. J. App. Poult. Res., 15: 207-218.

Grimble, G.K. and M.R. Westwood, 2000. Nucleotides. In: Nutrition and Immunology: Principles and Practice. M.E. Gershwin, J.B. German and C.L. Keen, Eds. Humana Press, Totowa NJ., pp: 135-144.

Rutz, F., M.A. Anciuti, J.L. Rech, F.M. Goncalves, A.D. Delgado, E.R. Rosa, N. Zauk, C.L.G. Ribeiro and R.R. Da Silva, 2004. Performance and carcass traits of broilers fed diets containing yeast extract (NuPro®™). Pages 77-79 in: Proc. Aust. Poult. Symp., Sydney, NSW, Australia.

Rutz, F., E.G. Xavier, M.A. Anciuti, V.F.B. Roll and P. Rossi, 2007. The role of nucleotides in improving broiler prestarter diets: the Brazilian experience. Pages 175-181 in: Nutritional Biotechnology in the Feed and Food Industries. Proc. Alltech 23rd Ann. Symp. The New Energy Crisis: Food, Feed, or Fuel? T. P. Lyons, K.A. Jacques and J.M. Hower, Ed.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 Edn. SAS Institute Inc., Cary, NC.

Sklan, D., 2001. Development of the digestive tract of poultry. World's Poult. Sci., 57: 415-428.

Swamy, H.V.L.N. and Paul Groenewegen, 2008. Diet Design. Yeast-derived proteins give nutritional boost. http://www.feedmanagement-digital.com/feedmanagement/2008. Downloaded 11/21/2008.

Waldroup, P.W., 1981. Microorganisms as Feed and Food Protein. pp: 205-252 in New Protein Foods. A. A. Altshul and H. W. Wilcke, Ed. Academic Press, New York, NY.

Waldroup, P.W., C.M. Hillard and R.J. Mitchell, 1971. Value of Yeast Grown on Hydrocarbon Fractions for Broiler Chicks. Poult. Sci., 50: 1022-1029.

[1]Published with approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville AR 72701. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable.

[2]Visiting Scientist, Ankara University Faculty of Veterinary Medicine, Department of Animal Nutrition. Supported by funds from The Scientific and Technical Research Council of Turkey.

[3]Visiting Professor, Federal University of Paraiba, Areia-PB – Brazil – Capes Fellowship.

[4]To whom correspondence should be addressed. Waldroup@uark.edu.