ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 7 (12): 1138-1146, 2008
ISSN 1682-8356

Effect of Pellet Diameter in Broiler Prestarter Diets on Subsequent Performance[1,2]

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Abstract: Different size pellet dies and two levels of dietary energy density were used in prestarter broiler diets formulated to meet typical commercial standards. In the first experiment, birds reared in battery brooders were offered diets containing either 0.5 or 2.5% poultry oil from 0 to 14 days. Each group of diets was assigned different feed forms such as mash continuously through the study or mash, pellet diameters of 1.59, 2.38 and 3.17 mm dies or crumbled diets from 0-7 days followed by crumbled diets to 14 days and pelleted diets to 35 days. In the second experiment, birds reared in floor litter were assigned the same treatments as the previous study except the 2 levels of poultry oil were supplied from 0-42 days of age. During the first seven days birds fed the 1.59 and 2.38 mm diameter die or crumble diets had higher body weight than did birds fed the other feed forms; however, this positive effect was dissipated as the birds grew older. The feed intake kept almost the same tendency as the body weight. The feed conversion at 7 days was improved as pellet size was reduced. It is thought that this was due in large part to better nutritive value since, birds fed crumbled and pelleted diets have almost the same feed intake but different feed conversion. Birds given the mash feed during the whole period had lower body intake and feed intake than those birds fed other feed forms. The body weights and feed conversions at 35 and 42 days were improved as the level of poultry oil increased. Improvement in feed conversion by birds fed diets with 2.38 and 3.17 mm diameter die or crumble diets at 7 days and mash or 3.17 mm diameter die diets at 42 days was observed as the dietary energy level increased. These data indicate that pellet diameters of 1.59 or 2.38 mm can be beneficial during the prestarter period and can be more useful with 2.5% poultry oil.

Key words: Pellets, broilers, feed density, prestarter diets

INTRODUCTION

Broiler diets fed during the first few weeks after hatch are typically fed either as mash or more frequently by crumbling a large pellet (crumbles). It has been suggested that feeding a smaller intact pellet during the initial feeding period (prestarter diets) may be beneficial in enhancing early growth rates and subsequent performance. The beneficial effects of pelleted feeds have been demonstrated by numerous studies where the body weight gain and feed conversion are improved (Calet, 1965). This positive effect can be more pronounced when the pellets are introduced from the youngest age (Hinds and Scott, 1958). However, mash or crumble starter diets followed by pellet or crumble feed have had the same performance in some studies (Choi *et al*., 1986; Scott, 2002).

It has been postulated that birds select an appropriate feed size according to variation of their oral cavity (Moran, 1989). Moreover, younger birds prefer a smaller particle size while older ones select a bigger particle size (Portella *et al*., 1988). According to these observations, birds fed a smaller pellet size could feel comfortable eating and consequently these birds could spend less energy for eating. Thus, birds fed pelleted diets increase the net energy value due to increasing resting behavior and decreasing time eating (Savory, 1974; Nir *et al*., 1994; McKinney and Teeter, 2004; Skinner-Noble *et al*., 2005). Chicks reared in battery brooders have less activity since they are confined to a smaller space, thus the response of pellets might not be as great as observed in practical conditions in litter floor pens. One study has pointed out that the feed form effects (crumb) are less noticeable when the birds are reared in battery groups (Robertson, 1950). On the other hand, reducing the pellet size can improve the quality of nutrients as observed by Heffner and Pfost (1973).

It has been observed that when the dietary energy density is increased by increasing fat levels from 0-2.5%, the positive pellet effect is not reduced (Combs, 1959; Allred *et al*., 1957; Pesti *et al*., 1983; McNaughton and Reece, 1984; Reece *et al*., 1984; Bertechini *et al*., 1991). However, the positive pellet effects on performance are reduced as the fat or oil levels increased above this level (Allred *et al*., 1957; Pepper *et al*., 1960; McNaughton and Reece, 1984) possibly because both fat and pellet increase the density of the diet (Calet, 1965) or the pellet quality is declined by the addition of fat (Richardson and Day, 1976; Plavnik *et al*., 1997; Brigg *et al*., 1999).

Because some studies (Renner and Hill, 1960; Sell *et al*., 1986) have demonstrated that the young chick or poult does not digest fats as well as do older chickens or turkeys, some have recommended that prestarter diets for young chicks do not contain supplemental fats.

However, in these cited studies, it was noted that saturated fats such as tallow were poorly digested while more unsaturated fats such as corn oil were digested almost as well by the young chick or poult as by the older bird. As poultry oil is rather highly unsaturated, it may be a satisfactory fat source for prestarter diets giving the benefit of increased dietary energy. The objectives of the present study were to compare the performance of chicks fed diets using different size pellet dies in the prestarter period (0-7 days) and the effect of pelleting as influenced by dietary energy on subsequent performance.

MATERIALS AND METHODS

In Experiment 1, diets were formulated for starter (0-14 days), grower (14-35 days) and finisher (35-42 days) periods based on nutrient content of the top 5 broiler companies in an agricultural survey (Agri-Stats, Fort Wayne IN). Two starter diets were formulated, one with 0.5% poultry oil (Diet A, Table 1) and one with 2.5% poultry oil (Diet B, Table 1) with energy and other nutrients adjusted accordingly. This was followed by a common grower diet containing 2.5% poultry oil to 35 days (Diet C, Table 1).

During the prestarter period, from 0-7 days of age, each of the 2 diets was subjected to five different treatments including: No pelleting (mash), Pelleted with 1.59 mm die, Pelleted with 2.38 mm die, Pelleted with 3.17 mm die and Pelleted with 4.76 mm die and crumbled. From 7-14 days of age these birds were fed diets with the respective levels of poultry oil that had been pelleted with 4.76 mm die and crumbled. From 14-35 days of age these birds were fed the common grower diet that had been pelleted with a 4.76 mm die. Further, a negative control group consisted of one group of birds from the 0.5 and 2.5% poultry oil treatments that were fed mash feed continuously through the study.

In Experiment 2, two diets were formulated for each age period, one with 0.5% poultry oil (Diet A, C and E, Table 2) and one with 2.5% poultry oil (Diet B, D and F, Table 2) with energy and other nutrients adjusted accordingly. As in the first trial, each of the two diets was subjected to 5 different treatments including: No pelleting (mash), pelleted with 1.59 mm die, pelleted with 2.38 mm die, pelleted with 3.17 mm die, pelleted with 4.76 mm die and crumbled. From 7-14 days of age these birds were fed diets with the respective levels of poultry oil that had been pelleted with 4.76 mm die and crumbled. From 14-35 days of age these birds were fed the common grower diet that had been pelleted with a 4.76 mm die. Further, a negative control group consisted of one group of birds from the 0.5 and 2.5% poultry oil treatments that were fed mash feed continuously through the study.

In Experiment 1, each of the twelve treatments was fed to six replicate pens of 5 male chicks housed in electrically heated battery brooders with raised wise floors. In Experiment 2, each of the twelve treatments was fed to four replicate pens of 60 male chicks housed in a floor pen scale.

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. In Experiment 1, 5 birds were randomly assigned to each of 72 pens (0.34 M^2) of electrically heated battery brooders from 0 to 14 d of age and then transferred to 72 pens (0.52 M^2) from 14-35 days of age. Each of these pens had one trough drinker and one trough feeder per pen. In Experiment 2, sixty birds were randomly assigned to each of 24 pens (5.2 M^2) located in a broiler house of a floor pen scale. These pens were equipped with 2 tube feeders and one automatic water font. Previously used pine wood shavings over a concrete floor served as litter. Thermostatically controlled gas brooders, ventilation fans and sidewall curtains controlled temperature and airflow. Incandescent lamps supplemented natural light to provide 23 h light daily. Care and management of the birds followed recommended guidelines (FASS, 1999).

Body weight and feed consumption by pen were determined at 1, 14, 35, or 42 days of age. Mortality was checked twice daily and birds that died were weighed for adjustment of feed conversion. Data were subjected to analysis of variance using the General Linear Models of SAS (SAS Institute, 1991). Pens means served as an experimental unit for statistical analysis. Significant differences among or between means were separated by repeated t-tests using the LSMEANS option of SAS. Mortality data were transformed to square root of n + 1 prior to analysis. All results are presented as natural numbers.

RESULTS

Experiment 1: The effects of pellet diameter and level of poultry oil in prestarter diets is shown in Table 3. Because there were only two significant interactions, only main effects are presented in this table. Feed form had a significant effect on body weight at 7 days, with bird fed the crumbled diet or birds fed the diet pelleted with a 1.59 mm die having significantly higher body weights than birds fed the mash diet. Birds fed the diets pelleted with 2.38 or 3.17 mm diet did not differ in body weight from that of birds fed the mash diet. At 14 days, there were no significant differences in body weight among the birds fed the diets with different feed forms from 0-7 days of age. At 35 days, the negative control birds that had been fed mash continuously were significantly smaller than birds that had been fed the mash diet from 0-7 days followed by crumbled and pelleted feed, birds that had been given the diets with 1.50 mm pellets from 0-7 days followed by crumbled and pelleted feed, or birds that had been given crumbled feed from 0-14 days followed by pelleted feed. The negative control birds did not differ significantly in 35 days body weight from those birds that had been given diets pelleted with 2.38 or 3.17 mm dies from 0-7 days followed by crumbled and pelleted feed.

The feed form significantly influenced feed intake (Table 3). Birds fed the crumbled diet or the diet pelleted with the 1.59 mm die consumed the greatest amount of feed during the 0-7 days period while those fed the diet pelleted with the 3.17 mm die consumed the least feed. Birds fed the diet pelleted with the 2.38 mm die consumed approximately the same amount of feed from 0-7 days as those fed the mash diets. At 14 days, after all birds except the negative control had been feed crumbled diets from 7-14 days, feed intake was, for most groups, significantly greater than that of birds on the negative control that had been fed mash diets continuously. This same trend continued to 35 days of age. Birds that had been fed crumbled diets or diets pelleted with the 1.59 mm die from 0-7 days had higher overall feed intake from 0-35 days than birds fed the negative control mash diets or birds that had been fed diets pelleted with 2.38 or 3.17 mm dies during the period of 0-7 days.

Feed form significantly affected feed conversion only at 7 days (Table 3). Birds fed the diets pelleted with 2.38 or 3.17 mm dies had the lowest feed conversion during this time. At 14 and 35 days, however, there were no significant differences in feed conversion among the various dietary treatments. There was no significant effect of feed form on mortality.

Birds fed the diets with 2.5% added poultry oil from 0-14 days did not differ in body weight from those fed diets with 0.5% poultry oil at any time during the study. However, birds fed the diets with 2.5% poultry oil from 0-14 days consumed significantly less feed from 0-7 days and had significantly better feed conversion at 7 and 14 days than those given diets with 0.5% poultry oil from 0-14 days. At 35 days, after all birds had been on a common diet with 2.5% poultry oil from 14 days, there was no significant difference in feed intake or in feed conversion between the two groups of birds. There was no significant effect of level of poultry oil fed 0-14 days on mortality.

There were only 2 significant interactions of level of poultry oil fed 0- 14 days and feed form of diets during this experiment. In diets with 3.17 mm diameter die or crumble diets, feed intake decreased as dietary energy level increased, while in the other diets, no increment in feed intake was noted as dietary energy level increased (Fig, 1). In diets with 2.38 mm diameter die, 3.17 mm diameter die, or crumble diets, feed conversion improved as dietary energy levels increased while in diets with 1.59 mm diameter die or mash diets, no

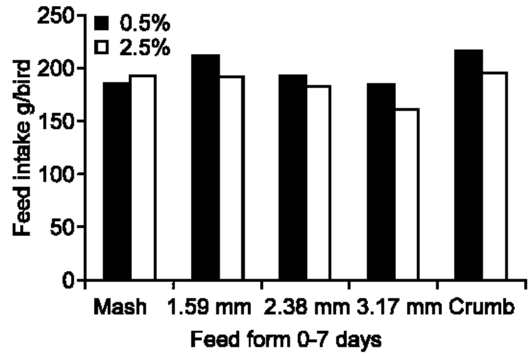

Fig. 1: Interaction of feed form and level of supplemental poultry oil (PO) on 0 to 7 d feed intake

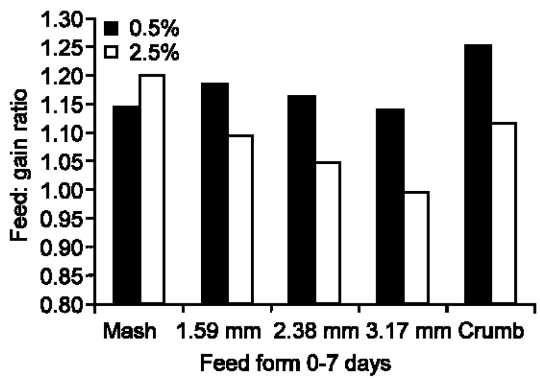

Fig. 2: Interaction of feed form and level of supplemental poultry oil (PO) on 0 to 7 d feed conversion

improvement in feed conversion was noted as dietary energy level increased (Fig. 2).

Experiment 2: The effects of pellet diameter in prestarter diets and dietary energy on performance are shown in Table 4. Feed form had a significant effect on body weight at every age during this study. At 7 days, birds that had been fed pelleted or crumbled diets were all significantly heavier than birds fed the mash diet, with birds fed diets pelleted with 1.59 and 2.38 mm dies having the greatest body weight, followed by those fed the crumbled diet or the diets pelleted with a 3.17 mm die. At 14 days of age, the birds fed 2.38 mm diameter die diet had greater body weight than did birds fed the other diets except crumble in the prestarter period. At 35 days of age, birds fed the 2.38 mm diameter die diet had greater body weight than did birds fed the 1.59 mm diameter die and mash during the whole period. In this period the body weight was similar for birds fed the mash in prestarter period, 2.38, 3.17 mm diameter die, or crumble feed. At 42 days of age the body weight of birds fed the mash feed continuously through the study was significantly less than that of birds fed the other

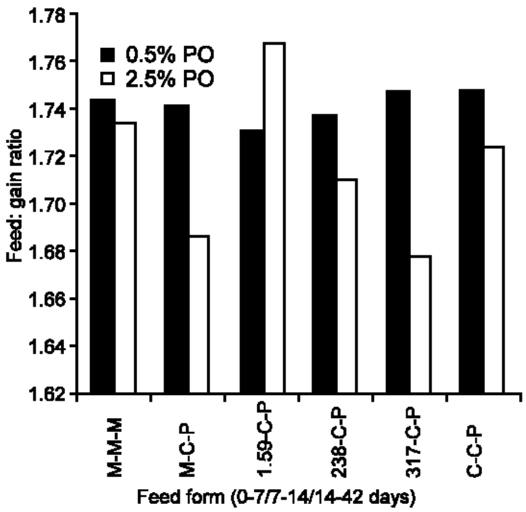

Fig. 3: Interaction of feed form and level of supplemental poultry oil (PO) on 0 to 42 d feed conversion

feeds. Body weight at 42 days did not differ among birds fed the other diets during the prestarter period of 0-7 days. There were no significant interactions of feed form and level of poultry oil on body weight at any age.

During the first 7 days, birds fed the pelleted with the 2.38 mm die diet had higher feed consumption than did birds fed mash, 1.59 mm diameter die, or 3.17 mm diameter die diets but the feed intake was similar when birds fed either 2.38 mm diameter die diet or crumble diet. Over the first 14 days birds fed 2.38 mm diameter die diet had higher feed consumption than did birds fed mash continuously and mash and 1.59 mm diameter die diet during the prestarter period. Birds fed the mash feed from 0-14 days of age had the lowest feed intake. At 35 and 42 days, feed intake by birds given the mash continuously through the study was lower than birds fed the other diets. There was no interaction for feed intake of energy dietary level and pellet diameter in prestarter diets at any age.

Feed conversion at 7 days of age was significantly affected by the pellet diameter in prestarter diets. The feed conversion improved as the pellet size was reduced. Birds fed the diets pelleted with the 1.59 mm die had a better feed conversion than did birds the other feeds except for the 2.38 mm diameter die feed. Feed conversion by birds given the mash feed was worse than that of birds fed the other four feed forms. There were no significant differences in feed conversion among the birds fed the various feed forms in the prestarter diet at 14, 35 and 42 days of age. There was a significant interaction for feed conversion of energy dietary level and pellet diameter in prestarter diets at 42 days of age (Fig. 3). At 7 days, birds fed mash diets or diets pelleted with the 3.17 mm die had improved feed conversion as level of poultry oil increased, while in the other diets, no improvement in feed conversion was noted as dietary energy level increased.

Table 1: Composition (g/kg) and nutrient content of diets (Experiment 1)

Ingredient	A	B	C
Poultry oil	5.00	25.00	25.00
Pro-Pak[1]	50.00	50.00	50.00
Yellow corn	612.53	584.37	649.80
Soybean meal	277.03	280.00	220.38
Limestone	10.30	10.70	8.49
Dicalcium phosphate	9.24	10.01	8.31
Salt	4.95	4.96	5.00
L-Threonine	0.81	1.10	0.70
L-Lysine HCl	2.10	2.56	2.23
Alimet 10% premix	19.04	22.30	21.09
Broiler premix[2]	5.00	5.00	5.00
Trace mineral mix[3]	1.00	1.00	1.00
Pel-Stik	2.50	2.50	2.50
Penicillin	0.50	0.50	0.50
TOTAL	1000.00	1000.00	1000.00
ME kcal/lb	1387.00	1426.00	1458.60
ME kcal/kg	3056.96	3142.90	3214.75
CP	22.50	22.50	20.00
Calcium	0.98	1.01	0.88
Nonphytate P	0.44	0.46	0.42
Met	0.57	0.60	0.56
Lys	1.37	1.41	1.22
Thr	0.93	0.96	0.83
TSAA	0.98	1.01	0.93
Dig Met	0.45	0.48	0.45
Dig Lys	1.07	1.11	0.93
Dig Thr	0.72	0.74	0.62
Dig TSAA	0.74	0.77	0.70
Sodium	0.25	0.25	0.25
Chloride	0.37	0.38	0.38

[1]H. J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Provides per kg of diet: vitamin A (from vitamin A acetate) 7714 IU; cholecalciferol 2204 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 1040 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.1 mg.
[3]Provides per kg of diet: Mn (from $MnSO_4 \cdot H_2O$) 100 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 100 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 50 mg; Cu (from $CuSO_4 \cdot 5H_2O$) 10 mg; I from $Ca(IO_3)_2 \cdot H_2O$), 1 mg.

DISCUSSION

The difference of body weight in experiment 1 and 2 was most marked at 7 days, with the best body weight with 1.59 or 2.38 mm diameter die feeds. This positive response can be accounted for a better pellet size to the oral cavity of the birds (Moran, 1989) and therefore less activity during eating and resting behaviors (Savory, 1974; Nir *et al.*, 1994; McKinney and Teeter, 2004; Skinner-Noble *et al.*, 2005). Otherwise, the nutritive value may be improved as the pellet die is reduced because of increasing the gelatinization in the pellet process (Heffner and Pfost, 1973). Although, the Metabolizable

Table 2: Composition (g/kg) and nutrient content of diets for floor pen pellet study (Experiment 2)

	0-14 days		14-35 days		35-42 days	
Ingredient	A	B	C	D	E	F
Poultry oil	5.02	25.03	5.00	24.95	5.04	24.98
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00
Yellow corn	628.51	603.50	692.80	667.92	742.52	717.68
Soybean meal	277.96	280.81	218.10	221.17	171.05	174.29
Limestone	9.66	9.82	7.56	7.67	7.55	7.66
Dicalcium phosphate	9.14	9.94	7.52	8.24	6.63	7.31
Salt	5.00	5.00	5.00	5.00	5.00	5.00
L-Threonine	0.76	1.06	0.41	0.67	0.34	0.56
L-Lysine HCl	1.99	2.48	1.76	2.16	1.13	1.45
MHA-84	2.21	2.61	2.10	2.47	1.74	2.07
Broiler premix[2]	5.00	5.00	5.00	5.00	5.00	5.00
Trace mineral mix[3]	1.00	1.00	1.00	1.00	1.00	1.00
Pel-Stik	2.50	2.50	2.50	2.50	2.50	2.50
BMD-50	0.50	0.50	0.50	0.50	0.50	0.50
Coban-60	0.75	0.75	0.75	0.75	0.00	0.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/lb	1380.50	1421.20	1412.80	1453.70	1437.50	1478.50
ME kcal/kg	3042.65	3132.28	3113.82	3203.93	3168.27	3258.62
CP	22.50	22.50	20.00	20.00	18.00	18.00
Calcium	0.98	1.00	0.85	0.87	0.81	0.84
Nonphytate P	0.44	0.45	0.41	0.42	0.38	0.39
Met	0.57	0.60	0.53	0.56	0.48	0.50
Lys	1.36	1.40	1.18	1.21	1.00	1.03
Thr	0.93	0.96	0.80	0.82	0.72	0.74
TSAA	0.98	1.00	0.90	0.93	0.82	0.85
Dig Met	0.53	0.56	0.49	0.52	0.44	0.47
Dig Lys	1.23	1.27	1.06	1.10	0.89	0.92
Dig Thr	0.82	0.85	0.70	0.72	0.63	0.65
Dig TSAA	0.87	0.89	0.80	0.82	0.73	0.75
Sodium	0.25	0.25	0.25	0.25	0.25	0.25
Chloride	0.37	0.38	0.37	0.38	0.36	0.36

[1]H.J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Provides per kg of diet: vitamin A (from vitamin A acetate) 7714 IU; cholecalciferol 2204 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 1040 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.1 mg. [3]Provides per kg of diet: Mn (from $MnSO_4•H_20$) 100 mg; Zn (from $ZnSO_4•7H_2O$) 100 mg; Fe (from $FeSO_4•7H_2O$) 50 mg; Cu (from $CuSO_4•5H_20$) 10 mg; I from $Ca(IO_3)_2•H_20$), 1 mg

Energy values (ME) are the same between pellet and mash feed (Hussar and Robblee, 1962; Reddy *et al.*, 1962; McIntosh *et al.*, 1962; Blackely *et al.* 1963; Sibbald, 1977; Brue and Latshaw, 1981), this similitude of ME was not demonstrated in different pellet diameter diets. The similar body weight at 35 or 42 days but not at 7 days between mash feed supplied in the prestarter period and processed feeds can be due to compensatory growth; moreover, this similar result has been observed earlier (Choi *et al.*, 1986; Scott, 2002) which birds fed either mash or crumble up to 14 or 21 days followed by processed feed had similar performance. The lowest body weight by birds fed the mash feed continuously through the study compared to processed feeds is in agreement with previous observations (Arscott *et al.*, 1957; Runnels *et al.*, 1976; Mastika and Cumming, 1981; Choi *et al.*, 1986; Douglas *et al.*, 1990; Kilburn and Edwards, 2001; Engberg *et al.*, 2002; Maiorka *et al.*, 2005; Jahan *et al.*, 2006; Salari *et al.*, 2006).

The feed intake in both experiments had almost the same pattern as body weight. Generally, the treatments with higher body weight were also accompanied by higher feed intake. The highest feed consumption at 7 days was found between birds fed 1.59 or 2.38 mm diameter die diets and crumble diets shows that pellet size of these feeds are the most suitable for this period. During the whole period it was observed that pelleting increased the feed intake compared to mash feed. Several studies are in agreement with this result (Hamm and Stephenson, 1959; Hussar and Robblee, 1962; Olsson and Lagervall, 1962; Mastika and Cumming, 1981; Choi *et al.*, 1986; Nir *et al.*, 1995; Engberg *et al.*, 2002; Maiorka *et al.*, 2005; Jahan *et al.*, 2006; Salari *et al.*, 2006); however, some studies have not found difference in feed intake between mash and pellet feed (Jensen *et al.*, 1962; Douglas *et al.*, 1990; Greenwood *et al.*, 2004) due to possibly a lack of considerable

Table 3: Effects of pellet diameter and level of poultry oil in prestarter diets on performance of male broilers (Experiment 1)

Feed form[1]	Added poultry oil[2] %	Body weight (kg days) 7	14	35	Feed intake (kg/bird days) 0-7	0-14	0-35	Feed conversion (kg feed/kg gain days) 0-7	0-14	0-35	Mortality days (%) 0-7	0-14	0-35
M-M-M			0.432	2.049[c]		0.527[b]	3.151[c]		1.214	1.539		0.00	5.00
M-C-4.76		0.160[b]	0.455	2.160[ab]	0.189[b]	0.563[a]	3.309[ab]	1.174[a]	1.237	1.534	0.83	3.33	6.66
1.59-C-4.76		0.175[a]	0.459	2.194[a]	0.201[ab]	0.569[a]	3.359[a]	1.142[ab]	1.242	1.532	6.66	6.66	11.66
2.38-C-4.76		0.165[ab]	0.440	2.099[bc]	0.188[b]	0.557[ab]	3.212[bc]	1.107[b]	1.270	1.530	5.00	6.66	10.00
3.17-C-4.76		0.161[b]	0.445	2.096[bc]	0.172[c]	0.558[ab]	3.251[abc]	1.071[b]	1.242	1.551	0.00	2.00	10.00
C-C-4.76		0.174[a]	0.461	2.191[a]	0.206[a]	0.587[a]	3.352[a]	1.185[a]	1.265	1.530	0.00	1.66	5.00
	0.5	0.168	0.443	2.132	0.197[a]	0.564	3.273	1.179[a]	1.265[a]	1.536	3.00	3.33	6.88
	2.5	0.167	0.454	2.131	0.185[b]	0.556	3.272	1.093[b]	1.225[b]	1.536	2.00	3.44	9.22
Prob > F													
Poultry Oil (PO)		0.718	0.168	0.951	0.002	0.410	0.977	0.0003	0.042	0.983	0.58	0.93	0.45
Feed Form (FF)		0.012	0.168	0.002	<0.0001	0.031	0.004	0.008	0.608	0.892	0.05	0.29	0.71
PO x FF		0.957	0.926	0.806	0.043	0.765	0.305	0.005	0.452	0.162	0.53	0.72	0.74
CV		8.43	6.91	4.52	7.7	7.07	4.36	7.37	6.32	2.89	3.27*	3.91*	5.81*

[1] Form of feed given 0-7, 7-14, 14-35 d; M = mash; C = crumb; Numerals indicate pellet die diameter in millimeters. [2]Amount of poultry oil fed 0-14 d. From 14 to 35 d all diets contained 2.5% poultry oil. *CV of transformed means. [abcde]Means with common letters do not differ significantly ($P \leq 0.05$)

difference in bulk density (Greenwood *et al.*, 2004) or a low pellet quality.

Although, the feed conversion was improved among the three pellet diameters (1.59, 2.38 and 3.17 mm) in the first study, this positive effect was only observed between 1.59 and 2.38 mm diameters in the second study. Therefore, this discrepancy is possibly due to the condition of rearing such as litter floor or batteries. Robertson (1950) has pointed out that the feed form effects (crumb) are less accentuated when the birds are reared in battery groups. The best feed conversion at 7 days observed in birds fed the smallest diameter die diets may be accounted for by a greater nutritive value of the feed and this positive effect can be accentuated for a better net energy due to less activity for eating. This more available energy or net energy by pellet feed compared to mash feed (Reddy *et al.,* 1961; 1962) improves the feed conversion and also the protein utilization (Cheng *et al.*, 1997). Furthermore, the fact that birds fed crumble diets in prestarter period had better or equal feed intake but higher feed conversion than did birds fed 2.38 mm diameter diets shows that probably there is an improvement of gelatinization or nutritive value as the pellet diameter is reduced as demonstrated by Heffner and Pfost (1973). Whereas the effects of pellets on feed intake and body weigh have been well-documented, the results on feed conversion are more controversial due to possibly the difference of nutrient composition or the precedence of chicks from younger or older breeder flock. Suboptimal protein levels lead to similar feed conversion between pellet and mash feed (Bayley *et al.*, 1968; Greenwood *et al.*, 2005) and this effect can be more marked with low energy levels (Reece *et al.*, 1984). Further, the positive pellet effect on feed conversion can be observed with infra red cooked and extruded soybeans but not with solvent extracted soybean meal (Hull *et al.*, 1968). Moreover, the feed conversion was similar when birds from younger dams fed pellet or mash feed but birds from older dams fed pellet feed had improved the feed conversion compared to mash feed (Auckland and Fulton, 1972). This effect was also, demonstrated for the first 4 weeks of feeding by Nir *et al.* (1995). Thus earlier experiments and the studies reported herein have not found a significant difference in feed conversion between pellet and mash feed (Blackely *et al.*, 1963; Wenk and van Es, 1979; Salmon, 1985; Choi *et al.*, 1986; Chang *et al.*, 1986; Bertechini *et al.*, 1991). On the other hand, many studies have observed that pelleted feed improves the feed conversion in comparison to mash feed (Pepper *et al.*, 1960; Hussar and Robblee, 1962; Yule, 1972; Proudfoot and Sefton, 1978; Mastika and Cumming, 1981; Reece *et al.*, 1985; Douglas *et al.*, 1990; Deaton, 1992; Mendes *et al.*, 1995; Kilburn and Edwards, 2001; Engberg *et al.*, 2002; Maiorka *et al.*, 2005; Salari *et al.*, 2006; Jahan *et al.*, 2006).

The positive pellet effects were not reduced when the dietary energy was increased; it appears that 2.5% poultry oil does not affect the pellet quality. Moreover, in diets with 2.38 and 3.17 mm and crumble diets at 7 days, the feed conversions were improved as the dietary energy was increased. This positive interaction was maintained at 42 days of age for birds fed 3.17 mm diameter die diets. These observations are congruent with the earlier findings which found that the positive pellet effect are not reduced as dietary energy is increased by fat levels from 0 to 2.5% (Combs, 1959; Allred *et al.*, 1957; Pesti *et al.*, 1983; McNaughton and Reece, 1984; Reece *et al.*, 1984; Bertechini *et al.*, 1991); however, as fat levels increased up to 5% or more in pellet diets the favorable performance is reduced as compared to those in mash feed (Combs, 1959; Pesti *et al.*, 1983; McNaughton and Reece, 1984; Reece *et al.*, 1984). This effect may be associated more to fat per se rather than to the increasing nutrient density because the fat negatively affects the pellet quality. Thus, pelleted broiler diets with 5% fat had reduced pellet effects but diets pelleted with fat levels below 2.5% had no impact

Table 4: Effects of pellet diameter in prestarter diets and dietary energy on performance of male broilers (Experiment 2)

Feed form[1]	Aded poultry oil[2] %	Body weight			
		7 d	14 d	35d	42d
	0.5%	0.165	0.416	2.077[b]	2.687[b]
	2.5%	0.164	0.422	2.116[a]	2.748[a]
M-M-M			0.388[d]	1.937[c]	2.536[b]
M- C-4.76		0.155[c]	0.413[c]	2.133[ab]	2.775[a]
1.59- C-4.76		0.167[ab]	0.420[c]	2.088[b]	2.697[a]
2.38- C-4.76		0.172[a]	0.438[a]	2.157[a]	2.769[a]
3.17- C-4.76		0.163[b]	0.421[bc]	2.129[ab]	2.775[a]
C- C-4.76		0.166[b]	0.434[ab]	2.136[ab]	2.753[a]
Prob > F					
Poultry oil (PO)		0.613	0.074	0.032	0.014
Feed form (FF)		<0.0001	<0.0001	<0.0001	<0.0001
PO x FF		0.237	0.450	0.536	0.075
CV		2.91	2.97	2.92	2.98
Feed form[1]	Aded poultry oil[2] %	Feed intake (kg/bird)			
		0-7d	0-14d	0-35d	0-42d
	0.5%	0.134	0.497	3.308	4.594
	2.5%	0.136	0.504	3.306	4.632
M-M-M			0.459[d]	3.066[b]	4.325[b]
M- C-4.76		0.132[c]	0.499[c]	3.354[a]	4.672[a]
1.59- C-4.76		0.131[c]	0.502[bc]	3.333[a]	4.630[a]
2.38- C-4.76		0.141[a]	0.520[a]	3.394[a]	4.691[a]
3.17- C-4.76		0.134[bc]	0.509[abc]	3.335[a]	4.668[a]
C- C-4.76		0.136[ab]	0.513[ab]	3.361[a]	4.694[a]
Prob > F					
Poultry oil (PO)		0.141	0.098	0.92	0.259
Feed form (FF)		0.0002	<0.0001	<0.0001	<0.0001
PO x FF		0.347	0.071	0.434	0.625
CV		3.17	2.56	2.38	2.54
Feed form[1]	Aded poultry oil[2] %	Feed conversion (kg feed/kg gain)			
		0-7d	0-14d	0-35d	0-42d
	0.5%	1.132[b]	1.342	1.630[a]	1.741[a]
	2.5%	1.161[a]	1.343	1.598[b]	1.717[b]
M-M-M			1.35	1.623	1.739
M- C-4.76		1.226[a]	1.362	1.608	1.714
1.59- C-4.76		1.087[c]	1.344	1.634	1.749
2.38- C-4.76		1.122[bc]	1.33	1.609	1.723
3.17- C-4.76		1.151[b]	1.34	1.602	1.712
C- C-4.76		1.147[b]	1.328	1.609	1.736
Prob > F					
Poultry oil (PO)		0.025	0.939	0.0007	0.014
Feed form (FF)		<0.0001	0.127	0.307	0.182
PO x FF		0.502	0.759	0.79	0.043
CV		3.3	1.96	1.84	1.88
Feed form[1]	Aded poultry oil[2] %	Mortality (%)			
		0-7d	0-14d	0-35d	0-42d
	0.5%	0.793	1.737	4.653	5.833
	2.5%	0.709	1.528	4.097	4.722
M-M-M			1.25	3.75	4.375
M- C-4.76		0.625	1.043	4.165	4.581
1.59- C-4.76		0.625	1.459	4.165	5.209
2.38- C-4.76		0.417	1.876	5.624	6.25
3.17- C-4.76		1.043	2.291	5.209	5.833
C- C-4.76		1.044	1.878	3.335	5.416
Prob > F					
Poultry oil (PO)		0.812	0.674	0.414	0.112
Feed form (FF)		0.746	0.695	0.361	0.59
PO x FF		0.947	0.796	0.148	0.105
CV		0.59*	0.83*	1.11*	1.11*

[1] Form of feed given 0-7, 7-14, 14-42 d; M = mash; C = crumb; Numerals indicate pellet die diameter in millimeters.
[2]Level of poultry oil added from 0 to 42 d.
*CV of transformed means.
[abcd]Means with common letters do not differ significantly ($P \leq 0.05$).

on positive pellet effect even though both groups of diets had almost similar metabolizable energy (Allred *et al*., 1957; Pepper *et al*., 1960; Reece *et al*., 1984; Pesti *et al*., 1983; McNaughton and Reece, 1984; Bertechini *et al*., 1991).

The improvement of body weight related to increased dietary nutrient density observed in Experiment 2 but not in Experiment 1 was because of the short time of feeding the different energy levels (0-14 days). In Experiment 2 the improved body weight and feed conversion at 35 and 42 days in diets with more poultry oil are consistent with the results obtained by Saleh *et al*. (2004).

The results of these studies showed that pellet diameter in prestarter diets can improve the performance at 7 days as the diameter die is reduced but these effects are not kept up to 42 days of age. These positive effects may be more accentuated as the dietary energy density is increased especially for feed conversion. Crumbling of a larger diameter pellet appears to be as effective as providing a smaller intact pellet.

ACKNOWLEDGEMENTS

This study was supported in part by the Novus International-Walton Foundation Endowed Professorship.

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[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]Supported in part by the Novus International-Walton Foundation Endowed Professorship.

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