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The Effect of Steam Pelleting Feed Ingredients on Chick Performance: Effect on Phosphorus Availability, Metabolizable Energy Value and Carcass Composition

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THE performance of growing chicks on a diet containing no added inorganic phosphate (42% corn and 40% soybean meal) was markedly increased when the diet was steam pelleted. The ash content of the bones of chicks receiving the diet in the mash form was low but when the ration had been steam pelleted the ash content of the bones was normal (Cisneros, 1966). It would appear that in a corn, soybean meal diet the availability of the organic phosphorus to the young chick is increased by steam pelleting. Summers *et al.* (1967) found that this was also true for rations containing wheat bran.

In the present study the effect of steam pelleting the ingredients of a corn soybean meal diet, separately and in combination, on the response of growing chicks to supplemental inorganic phosphorus, was investigated. An experiment designed to show the effects of exploiting increased nutrient availability as a result of steam pelleting is also described.

EXPERIMENTAL

The rations and ingredients were pelleted using a 60 H.P. California 'Hy-Flo' pellet machine in which the feed passed through a conditioning chamber where it was subjected to steam, injected at a pressure of 55 pounds per square inch (150°C.). Feed remained in the conditioning chamber between three and five seconds and the rate of steam addition was regulated to heat the feed to approximately 90°C. The feed was extruded through 3/16 inch dies and the pellets were cooled with a forced air draught.

Groups of twenty hybrid meat type chicks were assigned to cages in electrically-heated tiered brooders. Female chicks were used in experiment 1 and males in experiment 2. The chicks received the experimental diets from day of age for 23 days. Feed intake and excreta produced in two consecutive two day periods between the 18th and 22nd days were recorded and the excreta was freeze-dried and ground for gross energy determinations. Total feed consumption and gain were recorded and at the end of the experiment all the birds were killed with chloroform. One leg was removed from ten randomly selected birds in each pen and the remaining birds were frozen for carcass analysis. Bone ash determinations were made on the dry, fat free tibiae by the A.O.A.C. (1960) method. The frozen carcasses were ground in a meat grinder, freeze-dried and ground fine with dry ice in a Wiley mill. Nitrogen was determined by the Kjeldahl method, fat by extraction with diethyl ether in soxhlet apparatus, phosphorus by the A.O.A.C. (1960) method, and gross energy values by combustion in a Parr oxygen bomb calorimeter.

Analyses of variance of the results and analysis of covariance between them and feed consumption were carried out as described by Steel and Torrie (1960). The gains were adjusted to equal feed intake by covariance analysis to indicate the nutritional value of the feed, freed from the effects of variation in feed intake. The five percent level of probability was used as the basis for statistical significance.

EXPERIMENT 1

The experiment was designed as a three by four factorial with each treatment replicated four times. The replicates were blocked in tiers. The factors were: level of inorganic phosphate added (0, 0.2 and 0.3%) and ingredient processed (none, complete diet, corn only and soybean meal only). The details of the rations are shown in Table 1. Kaolin was used to maintain the level of inorganic material constant in the three rations. All the diets were fed in the form of mash. Analyses and metabolizable energy determinations were only carried out on the birds receiving the rations with the highest level of added phosphorus.

TABLE 1.—*Diets used in experiment 1*

	% inclusion		
corn	59.2	59.2	59.2
soybean meal (50% protein)	34.0	34.0	34.0
stabilized tallow	3.0	3.0	3.0
iodized salt	0.3	0.3	0.3
vitamin and trace mineral supplement[1]	0.8	0.8	0.8
dicalcium phosphate (22% Ca, 20% P)	0.0	1.0	1.5
ground limestone (38% Ca)	2.0	1.5	1.2
kaolin	0.7	0.2	0.0
	Nutrient level (%)		
(Calculated) protein (%N×6.25)		22.3	
lysine		1.24	
methionine		0.34	
cystine		0.36	
calcium		0.85	
"available" phosphorus (calculated by assuming 30% of plant phosphorus is inorganic)	0.12	0.32	0.42
total phosphorus	0.34	0.52	0.68

[1] The vitamin and trace mineral mixtures used supplied the following levels of nutrients per kg. of diet: vitamin A, 3,400 U.S.P. units, vitamin D_3, 1,300 I.C.U., riboflavin, 55 mg., *d* calcium pantothenate, 10 mg., vitamin B_{12}, 7 mcg., niacin, 11 mg., choline chloride, 290 mg., menadione sodium bisulphite, 450 mcg., ethoxyquin (Monsanto) 250 mg., manganese, 53 mg., zinc, 50 mg., copper 9 mg., iron, 19 mg.

TABLE 2.—*Treatment means for experiment 1*

Processing treatment	Added phosphate % 0.0	0.20	0.30
	gain (g./bird)		
unprocessed	229	371	369
all pelleted and ground	330	376	364
corn pelleted and ground	217	380	378
soy pelleted and ground	200	358	357
	feed consumed (g./bird)		
unprocessed	452	641	644
all pelleted and ground	576	669	626
corn pelleted and ground	429	618	637
soy pelleted and ground	449	655	652
	gain (adjusted to equal feed intake, g./bird)[1]		
unprocessed	273	354	350
all pelleted and ground	335	349	350
corn pelleted and ground	269	370	362
soy pelleted and ground	245	336	336
	feed:gain ratio		
unprocessed	1.99	1.73	1.75
all pelleted and ground	1.74	1.78	1.73
corn pelleted and ground	1.99	1.64	1.69
soy pelleted and ground	2.26	1.83	1.83
	bone ash (% of dry fat free tibia)		
unprocessed	30.7	44.1	45.2
all pelleted and ground	39.6	45.4	44.6
corn pelleted and ground	31.4	43.6	45.0
soy pelleted and ground	30.9	44.1	46.1

[1] Correlation of gain and feed=0.33.

Results and Discussion. The results of experiment 1 are shown in Table 2.

The interaction between level of inorganic phosphorus and processing treatment was significant for all the parameters studied. Pelleting the complete ration which contained no supplemental inorganic phosphorus was the only treatment which significantly increased feed consumption and gain. The adjusted gains would suggest that this effect was not due to a difference in feed intake. It should be noted that pelleting either the corn or the soybean alone did not have the same beneficial effect as pelleting the complete diet. Comparison of the effects of the different processing treatments on the diets with the two higher levels of phosphate indicate no improvement in adjusted gain when the whole ration was pelleted; however, there was a slight, but non-significant improvement if the corn was pelleted alone. Pelleting the soybean meal alone reduced the adjusted gains significantly. The feed:gain ratios showed the same pattern as the adjusted gains and were highest for the two rations with added phosphorus which contained the separately pelleted soybean meal. A similar effect was reported by Allred *et al.* (1957) and from this laboratory by Bayley *et al.* (1968a) and confirms the view that pelleting soybean meal alone reduced its nutritional value.

The bone ash values show that pelleting the complete ration improved calcification on the low phosphorus diet, but that pelleting either ingredient alone had no effect. However, the ash content of the bones for the birds on the low phosphorus ration which had been pelleted was less than for those which had received supplementary phosphorus. The metabolizable energy values and the carcass composition of the birds for the rations with the highest level of phosphorus are shown in Table 3. The metabolizable energy values were higher for the ration which had been pelleted and for the ration containing the reground pelleted soybean meal than for the ration containing the reground pelleted corn and the unprocessed ration. The processing conditions did not significantly affect carcass composition.

EXPERIMENT 2

This experiment was designed to study the feasibility of exploiting the increases in the availability of protein, energy and phosphorus which have been shown to occur when diets containing wheat bran are steam pelleted. If these increases do occur the level of available phosphorus, protein and metabolizable energy, calculated from the results of feeding diets in mash form to young chicks, could be reduced for rations which are steam pelleted before feeding. The N.R.C. (1966) suggests that available phorphorus be calculated on the basis that only 30% of the plant phosphorus is available but Summers *et al.* (1967) suggest that a substantial portion of the phosphorus in bran is made available by steam pelleting. Olsen (1967) showed that the availability of the protein in wheat bran was increased by steam pelleting. Cave *et al.* (1965) showed that the metabolizable en-

TABLE 3.—*Experiment 1. Metabolizable energy value and carcass composition of birds receiving diets with 0.3% added phosphate*

	Metabolizable energy value (kcal./g.)	Carcass composition (% of fresh carcass)		
		Water	Fat	Protein (%N×6.25)
unprocessed	3.05 a[1]	66	9.2	23.0
whole ration pelleted and reground	3.16 b	65	9.0	23.6
corn pelleted and reground	3.06 a	66	8.5	23.6
soy pelleted and reground	3.14 b	63	10.5	24.5

[1] Values followed by the same subscript do not differ at the 5% level of probability.

TABLE 4.—*Diets used in experiment 2*

Ingredient	Control	Nutrient lowered: Protein	Energy	Phosphorus	Protein, energy and phosphorus
	% inclusion				
wheat bran	30	30	30	30	30
corn	31.4	26.4	31.4	31.4	26.4
soybean meal (50% protein)	31	26	31	31	26
stabilized tallow	4	2	2	4	2
corn starch		11.5			11.5
solca floc		0.5	2		0.5
iodized salt	0.3	0.3	0.3	0.3	0.3
ground limestone (38% Ca)	1.2	1.2	1.2	2.0	2.0
dicalcium phosphate (22% P, 20% Ca)	1.3	1.3	1.3	0	0
kaolin	0	0	0	0.5	0.5
vitamin and trace mineral supplement[1]	0.8	0.8	0.8	0.8	0.8
	nutrient level (%)				
calculated protein	23	20	23	23	20
determined protein (%N×6.25)	22.5	19.0	21.0	21.5	18.0
(Calculated amino acid levels)					
lysine	1.44	1.09	1.44	1.44	1.09
methionine	0.32	0.28	0.32	0.32	0.28
cystine	0.38	0.34	0.38	0.38	0.34
calcium	0.8	0.8	0.8	0.8	0.8
available phosphorus (calculated by assuming 30% of plant phosphorus is inorganic)	0.5	0.5	0.5	0.2	0.2
total phosphorus (determined)	0.93	0.90	0.94	0.65	0.63
calculated metabolizable energy value (kcal./g.)	2.56	2.56	2.40	2.56	2.40

[1] See footnote to Table 1 for composition of vitamin, trace mineral supplement.

ergy value of wheat bran was 30% higher when it was fed in a pelleted diet than as mash.

The experiment was designed as a three by five factorial with four replicates. The replicates were blocked in tiers. The factors were: form of feed (mash, crumbles and reground crumbles) and nutrient lowered (control, protein, metabolizable energy value, available phosphate and all three nutrients lowered together).

Details of the rations are shown in Table 4. All the rations contained 30% of wheat bran. The first diet was a control, there were three diets formulated to contain lower levels of protein, metabolizable energy or phosphorus, and a fifth diet formulated to contain reduced levels of all three nutrients. A portion of the five diets was crumbled and part of this was reground. The mash, crumbles and reground crumbles were fed from day of age to 23 days. Feed intake and excreta output were measured for two consecutive two day periods between the 19th and 23rd days. The carcasses for all treatment groups were analyzed.

Results and Discussion. The performance of the birds and the classical metabolizable energy values of the diets (Sibbald and Slinger, 1962) are shown in Table 5. The main effect of feed form showed that the birds consumed more crumbles than mash

TABLE 5.—*Treatment means for experiment 2*

Form	Control	Nutrient lowered: Protein	Energy	Phosphorus	Protein, energy and phosphorus	Form mean
		gain (g./bird)				
unprocessed mash	302	307	294	279	267	290
crumbles	339	346	352	345	302	337
reground crumbles	330	295	289	292	256	292
nutrient mean	324	316	312	305	275	
		feed consumed (g./bird)				
unprocessed mash	559	566	558	504	508	539
crumbles	613	639	673	601	573	620
reground crumbles	556	568	539	532	495	538
nutrient mean	576	591	590	546	525	
		gain (adjusted to equal feed intake, g./bird)[1]				
unprocessed mash	306	306	297	301	290	300
crumbles	319	315	301	330	299	313
reground crumbles	334	294	300	301	285	301
nutrient mean	320	300	299	310	291	
		feed:gain ratio				
unprocessed mash	1.85	1.84	1.90	1.80	1.90	1.86
crumbles	1.76	1.84	1.89	1.74	1.84	1.81
reground crumbles	1.69	1.92	1.91	1.82	1.94	1.86
nutrient mean	1.77	1.87	1.90	1.79	1.89	
		metabolizable energy value (kcal./g.)				
unprocessed mash	2.63	2.69	2.57	2.63	2.68	2.64
crumbles	2.73	2.69	2.68	2.68	2.78	2.71
reground crumbles	2.79	2.65	2.69	2.67	2.87	2.74
nutrient mean	2.72	2.68	2.65	2.66	2.78	

[1] Correlation of gain and feed = 0.42.

and that regrinding the crumbles reduced feed consumption and gain to the level of the mash diets. Adjusting the gains to equal feed intake considerably reduced the effect of form on gain and although there was an apparent difference between means for crumbles and mash it was not significant.

An examination of the effect of form on the five different diets showed that for the control diet the birds consumed more feed and gained more on crumbles than on mash. Regrinding the crumbles reduced feed consumption to the level of the mash diet but the gains on the reground crumbles were almost as great as for the crumbles, indicating a considerable increase in the nutritional value of a unit weight of food. The adjusted gains and feed:gain ratios emphasize this point. However, the control diet was the only one for which the beneficial effect of crumbling on gain was still apparent after the crumbles had been reground and so the gains on this ration were significantly greater than for the other four rations fed as reground crumbles. Comparison of the results for the rations with lowered nutrient levels with the control showed that neither feed consumption nor gain was significantly reduced when the protein content was reduced for the mash and crumbles; however reducing the metabolizable energy value of the diet significantly increased feed consumption in the crumbled form and although the gain on this diet was greater than on the control it was due merely to the increased feed intake as shown by the adjusted gain and feed:gain ratio. Reducing the level of phosphorus in the mash diet resulted in a significant reduction in feed consumption and the reduction in gain was almost significant; however, for the crumbles, feed consumption was not significantly affected and there was no difference between the gains. Altering the diet to reduce the level of all three nutrients at the same time caused significant reductions in feed intake and gain and these were not overcome by steam pelleting and crumbling.

The metabolizable energy value determined for the control diet in the mash form agrees with the calculated value and was increased by crumbling. Crumbling the diet with the lowered protein content did not affect its metabolizable energy value. The metabolizable energy value of the diet calculated to contain a reduced level of metabolizable energy was increased when the diet was steam pelleted. However, the diet calculated to contain reduced levels of protein, metabolizable energy and phosphorus, in fact, had a higher metabolizable energy value than the control diet. This is difficult to explain, but the combined effects of the low levels of all three nutrients could have led to more efficient absorption. Steam pelleting this diet also increased its metabolizable energy value.

The ash content of the bones and the moisture, fat and protein contents of the carcasses are shown in Table 6. The bone ash levels were reduced by crumbling the three diets with adequate levels of phosphorus, whereas the bone ash levels were increased by crumbling the diet with the reduced phosphorus level. This interaction between crumbling and nutrient level was statistically significant for this comparison. However, crumbling the diet with the levels of all three nutrients reduced had no effect on bone ash. Alteration of the nutrient levels in the diets affected the water and protein contents of the carcasses inconsistently but reducing the protein level of the diet, either alone or in combination with the other nutrients significantly increased the fat content of the carcass but alteration of the levels of the other two nutrients exerted no effect. The diet with the reduced level of protein still allowed the birds to grow as well as those on the control diet but the difference in the composition of the carcasses shows that the protein level was marginal and in fact on each diet with lowered nutrient levels crumbling the diet increased the level of carcass protein perhaps indicating an increase in the availability of the protein. The calculated reduction in metabolizable energy value of the diet was not achieved but crumbling the diet did cause an increase in metabolizable energy of about four percent. If the increase was confined to the bran portion of the diet this corresponds to a 12 percent increase in the availability of the energy yielding components of the diet as a result of steam pelleting, considerably lower than the 30 percent increase reported by Cave *et al.* (1965) for a ration containing 50 percent bran and even lower than the 20 percent increase reported by Bayley *et al.* (1968b) for wheat bran pelleted alone.

The bones of birds receiving the mash diets with the lowered phosphorus levels were soft and misshapen and contained less

TABLE 6.—*Experiment 2. Bone ash and carcass composition*

Form	Control	Nutrient lowered: Protein	Energy	Phosphorus	Protein, energy and phosphorus	Form mean
		bone ash (%)				
unprocessed mash	42.3	42.5	42.7	37.8	36.7	40.4
crumbles	41.0	40.9	41.3	40.2	37.0	40.1
reground crumbles	42.5	41.3	41.3	39.4	35.3	40.0
nutrient mean	41.9	41.6	41.8	39.1	36.3	
		carcass composition: % water				
unprocessed mash	72.9	71.9	73.6	73.3	72.3	72.8
crumbles	72.7	71.4	72.2	72.7	70.8	72.0
reground crumbles	72.0	71.2	72.7	72.6	70.1	71.7
nutrient mean	72.5	71.5	72.8	72.9	71.1	
		% fat				
unprocessed mash	4.2	5.7	3.8	4.6	5.6	4.8
crumbles	4.8	6.1	5.2	5.1	7.4	5.7
reground crumbles	5.2	6.3	4.6	5.1	7.4	5.7
nutrient mean	4.8	6.1	4.6	5.0	6.8	
		% protein (%N×6.25)				
unprocessed mash	20.1	20.4	19.2	19.8	20.9	20.1
crumbles	20.7	21.5	20.7	20.6	21.9	21.1
reground crumbles	21.2	21.6	19.5	20.4	22.1	21.0
nutrient mean	20.7	21.1	19.8	20.3	21.7	

ash than those of the birds on the control ration. Steam pelleting and crumbling the diet with the lowered phosphorus level resulted in bones of more normal appearance and a higher ash content. However, the beneficial effect of steam pelleting was not noted for the ration with reduced levels of all three nutrients, probably due to the reduction in the level of soybean meal which contained 0.7% phosphorus much of it phytin phosphorus.

The second experiment confirms the observation in the first that phosphorus availability can be increased by steam pelleting, however the effect of steam pelleting on the availability of the protein and energy in the bran was less marked than expected since the protein in the diet with the reduced protein level was adequate for the birds to gain at the same rate as those on the control. The substitution of cellulose for tallow did not result in the calculated decrease in metabolizable energy of the whole ration. Taken overall there was a four percent increase in metabolizable energy value of the rations as a result of steam pelleting, and for the ration with the lowered energy content the birds consumed so much more of it in the crumbled form that the greatest gains in the experiment were recorded on this treatment.

GENERAL DISCUSSION

The results of the two experiments show that steam pelleting corn, soybean meal diets as well as diets containing wheat bran increased the availability of the phosphorus in the plant material. This suggests that the recommendation of the N.R.C. (1966) that 30% of plant phosphorus is available, is too low for some feeds which have been steam pelleted. The performance and bone ash results suggest that the addition of 0.2% of phosphate phosphorus is adequate for chicks fed on a corn, soybean meal mash and even less than this if the feed is steam pelleted.

However pelleting the corn or soybean meal alone had no effect on either performance or bone ash on the low phosphorus diet, suggesting that the increased availability of the plant phosphorus was a result of at least two factors; liberation of phosphate from phytin and destruction of organic compounds which chelate the phosphorus.

The addition of less inorganic phosphate to the bran diets in the second experiment resulted in decreased bone ash levels but this reduction could be partially overcome by steam pelleting in the case of the ration in which only the level of phosphorus was reduced. Steam pelleting the control bran ration and those with lowered protein or energy levels resulted in a reduction in bone ash. These observations suggest steam pelleting increases the availability of the plant phosphorus and may even cause an imbalance in the levels of available calcium and phosphorus and thus interfere with calcium absorption.

These results suggest that a reappraisal of the appropriate levels of calcium and phosphorus supplementation for diets which are to be steam pelleted should be made.

SUMMARY

A corn, soybean meal ration with either 0, 0.2 or 0.3% added inorganic phosphorus was fed to young growing chicks as mash or after the ingredients had been steam pelleted and reground. Growth and bone development was poor on the mash with no added phosphorus, but were improved by steam pelleting. However, steam pelleting and regrinding either the corn or the soybean meal alone before incorporation into the diet had no effect on growth or bone development.

A second experiment showed that with a diet containing 30% of wheat bran the beneficial effects of steam pelleting compensated a reduction in the level of either protein, metabolizable energy or phosphorus when the level of each nutrient was reduced alone but not when the levels of all three were reduced together.

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Photoperiodism as a Factor in Feeding Rhythms of Broiler Chickens

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BROILERS exposed to continuous light at a single intensity during the growing period are heavier than those exposed to either varying intensities or intermittent light and dark periods (*e.g.* Moore, 1957; Shutze *et al.*, 1960; Krueger *et al.*, 1963; Beane *et al.*, 1962, 1965). Observations indicate that under continuous illumination growth is more rapid at low than at higher intensities (Skoglund and Palmer, 1961; Cherry and Barwick, 1962; Beane *et al.*, 1965).

The diurnal feeding patterns of broilers have been studied by Siegel and Guhl (1956) and Siegel *et al.* (1962). They found that the percentage of birds feeding was highest at the beginning and at the end of the daily light period suggesting that the birds have become conditioned to the dark periods.

The experiment reported there was designed to determine feeding rhythms, growth, feed efficiency, and endocrine responses of broilers maintained under several light regimes.

EXPERIMENTAL PROCEDURE

Four hundred and eighty cockerels from each of two commercial broiler crosses, were used in the experiment. Sixty males from each stock were wingbanded and placed in replicated floor pens of 4 different lighting regimes. The light regimes were: (1) Continuous illumination at a high light intensity (H), (2) Continuous illumination at a low intensity (L), (3) Continuous illumination with 8 hours at the high intensity followed by 16 hours at the low intensity (HL), and (4) Eight hours of continuous illumination at the high intensity followed by 16 hours of darkness (HD).

All pens were darkened to prevent natural light from entering. The high intensity was the same in all pens where it was employed, and the low intensity was the same in those pens where it was used. Since the source of light was located on the ceiling in the center of the pen, intensity was not constant throughout, and the measurements of it were made at several locations. Illumination in luxes, within a pen, ranged from