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DIETARY CALCIUM AND AVAILABLE PHOSPHORUS
REQUIREMENTS OF GROWING AND ADULT
RING-NECKED PHEASANTS

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Major professor

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DIETARY CALCIUM AND AVAILABLE PHOSPHORUS REQUIREMENTS
OF GROWING AND ADULT RING-NECKED PHEASANTS

By

Richard Douglas Reynnells

A DISSERTATION

Submitted to

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ABSTRACT

DIETARY CALCIUM AND AVAILABLE PHOSPHORUS REQUIREMENTS OF GROWING AND ADULT RING-NECKED PHEASANTS

BY

Richard Douglas Reynnells

Factorial-design experiments were conducted to better define the dietary calcium and available phosphorus levels and ratios for the growing and adult pheasant (Phasianus colchicus).

Growing pheasant's dietary calcium levels were: 0.6; 1.2, and 1.8 percent; the available phosphorus levels were: 0.2, 0.4, and 0.6 percent; giving nine treatment combinations. The adult dietary calcium levels were: 1.5, 2.1, 2.7, and 3.3 percent; the available phosphorus levels were: 0.3, 0.4, 0.5, and 0.6 percent; resulting in sixteen dietary treatment combinations. The birds were confined in batteries (growing), individual cages (adults) or on the floor (all ages).

Standard hatching, brooding, growing, and laying house practices were employed. Caged layers were artificially inseminated with approximately 0.025 ml of pooled semen (100×10^6 spermatozoa).

For the growing pheasants, the treatment combinations with 0.2 percent available phosphorus were anorectic, rachitic, and lethal. Changes in chick body weights paralleled their

feed intake. Feed intake of chicks was depressed with 0.4 percent dietary phosphorus and a Ca:P ratio of 3:1 or greater. Maximum tibia mineralization occurred with dietary calcium: available phosphorus ratios of 2:1, 3:1, or 1.5:1 in that order; with adult levels of tibia mineralization being reached between four and eight-weeks of age. The tibia calcium and phosphorus concentrations were not readily changed by the treatment combinations. The lowest mortality of chicks over all levels of calcium was for those consuming the 0.6 percent available phosphorus diets.

No deficiency or excess of available phosphorus was indicated by measurements of adult egg and tibia parameters. However, 1.5 percent dietary calcium was not adequate as indicated by lowered tibia dry fat-free bone and ash, lowered eggshell thickness and eggshell weight as a percentage of total egg weight, and the decline in plasma calcium with higher plasma phosphorus. Only replicate effects were noted for feed consumption and the overall change in body weight of the hens. Mortality of adults fed any treatment was insignificant; while mortality of chicks from the hens consuming these feed treatments was significantly greater ($P \leq 0.05$) for chicks from hens fed the 3.3 percent calcium treatment combinations.

Conclusions were that adult hens housed in cages or on the floor required at least 2.1 but not greater than 2.7 percent dietary calcium; 0.4 percent available phosphorus was adequate. A Ca:P ratio effect was not apparent. For the

Richard Douglas Reynnells

growing birds, the optimum response, as measured by all parameters, was to the treatment combination of 1.2 percent Ca:0.6 percent available phosphorus. Treatment combinations of 1.8 Ca:0.6 P and 0.6 Ca:0.4) also produced favorable results.

TO MY FAMILY AND PARENTS

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TABLE OF CONTENTS

	PAGE
Introduction	1
Literature Review	3
Calcium and Phosphorus Requirements	5
METHODS AND MATERIALS	14
PHEASANT BREEDERS	14
1. Experiment one (E1)	22
2. Experiment Two (E2)	24
3. Experiment Three (E3)	24
STARTER/GROWER PHEASANTS	26
1. Day-old through 16 weeks of age reared on the floor	28
2. Battery-reared chicks (SG I, II, IIIf)	28
RESULTS AND DISCUSSION	29
ADULT DATA	29
Egg apparent Fertility	29
Hatchability	36
Hen-day Percent Egg Production	40
Egg Weight in Grams	50
Eggshell Weight as a Percentage of Total Egg Weight	56
Eggshell Thickness (in mm.)	58
Eggshell Membrane Thickness	69
Blood Calcium and Phosphorus	70
1. Calcium	70
2. Phosphorus	74
Adult Feed Consumption	76
Adult Bone (Tibia)	80
1. Percent dry fat-free bone (dffb); in mg dffb/100 mg tibia	80
2. Percent ash in mg ash/100 mg dffb	82
3. Ash percent calcium in mg Ca/100 mg ash	89
4. Ash percent phosphorus in mg P/ 100 mg ash	93
Adult Body Weight (as the percentage change)	96
F1 Mortality	100
STARTER/GROWER DATA	102
Feed Consumption of Battery-reared Chicks (SG Ic and SG IIc)	102
Comparisons of Starter-, Grower-, and Flight-Aged Bird's Feed Consumption (SG If, and SG IIIf replicates, only)	105

	PAGE
Body Weight (in grams)	111
1. Day-old through four-weeks of age	111
Body Weight through Sixteen-weeks of Age	116
Starter/Grower Bone Determinations	119
1. Two-week-old Pheasant chicks	119
Tibia dry fat-free bone (dfffb)	119
Dry Fat-free bone percentage ash	122
Ash percentage calcium	126
Ash percentage phosphorus	126
2. Two- and four-week old chick bone values for replicates SG If; SG IIIf; SG Ic; and SG IIIc	131
Tibia percentage dry fat-free bone (dfffb)	131
Dry fat-free bone percentage ash (from two- and four-weeks of age chicks)	133
Ash percentage calcium (from two-, and four- weeks of age chicks)	134
Ash percentage phosphorus (from two-, and four-week of age chicks)	136
3. Two-, four-, eight-, and twelve-week old pheasant chick tibiae values for replicates SG If, and SG IIIf	136
Tibia percentage dry fat-free bone (dfffb) (two- through twelve-week data)	139
Dry fat-free bone percentage ash (two- through twelve-week data)	139
Ash percentage calcium	142
Ash percentage phosphorus	147
STARTER/GROWER MORTALITY	147
Day-old through four-weeks of age	147
SUMMARY	154
Adult Pheasants	154
Growing Pheasants	155
CONCLUSIONS	157
Adult Pheasants	157
Starter/Grower Pheasants	157
APPENDIX A	158
APPENDIX B	161
APPENDIX C	170
APPENDIX D	217
BIBLIOGRAPHY	220

LIST OF TABLES

TABLE		PAGE
1	Calcium effect on pheasant egg apparent fertility	31
2	Effect of treatment combinations on pheasant egg apparent fertility	32
3	Effect of time on percent egg fertility and hatchability	35
4	Effect of treatment combinations on pheasant egg hatchability	37
5	Replicate effect on the percent hen-day egg production	41
6	Effect of dietary phosphorus on egg production	43
7	Effect of time on egg production and egg weight	47-48
8	Replicate effect on egg weight	51
9	Effect of dietary calcium on egg weight	52
10	Effect of dietary calcium on percent eggshell	57
11	Effect of time on percent eggshell and eggshell thickness	59
12	Effect of treatment combinations on percent eggshell	60-61
13	Effect of dietary calcium on eggshell thickness	66
14	Effect of treatment combinations on eggshell thickness	67-68
15	Effect of treatment combinations on eggshell membrane thickness	71
16	Effect of dietary calcium on plasma calcium	73
17	Effect of dietary calcium or phosphorus on plasma phosphorus	75
18	Effect of treatment combinations on plasma phosphorus	77
19	Feed consumption of adult males	79
20	Calcium effect on adult dry fat-free bone	81
21	Effect of treatment combinations on adult dry fat-free bone	83-84
22	Calcium effect on adult tibia ash	86
23	Effect of treatment combinations on adult tibia ash	87-88
24	Calcium effect on adult ash percentage calcium	90
25	Effect of treatment combinations on adult ash percentage calcium	91-92
26	Calcium effect on adult tibia percentage phosphorus	94
27	Effect of treatment combinations on ash percentage phosphorus	95
28	Replicate effect on adult body weight change	97

VIII

TABLE		PAGE
29	Effect of treatment combinations on adult body weight change	99
30	Effect of dietary calcium on F1 mortality	101
31	Effect of treatment combinations on feed consumption of pheasant chicks	103
32	Effect of treatment combinations on feed consumption of battery-reared pheasant chicks	104
33	Dietary calcium effect on feed consumption of four-week old growing pheasants	106
34	Effect of treatment combinations on growing pheasants	108
35	Feed consumption by pheasant growth period	109
36	Effect of dietary calcium on growing pheasants body weight	112
37	Dietary calcium by phosphours by period effect on growing pheasant body weight	113
38	Effect of treatment combinations on the growing pheasants body weight	115
39	Body weight averages for pheasant chicks at day-old through sixteen-weeks of age	117
40	Effect of treatment combinations on two-week old pheasant chicks tibia percentage dry fat-free bone	120
41	Effect of dietary phosphorus on two-week old pheasant chick tibia percentage dry fat-free bone	121
42	Dietary calcium by phosphorus interaction effect on the two-week old pheasant chick dry fat-free bone percentage ash	123
43	Effect of treatment combinations on the two-week old pheasant chick tibia dry fat-free bone percentage ash.	124
44	Growing pheasant's tibia ash percentage calcium	127
45	Effect of treatment combinations on two-week old pheasant chick tibia ash calcium	128
46	Dietary calcium by phosphorus interaction effect on two-week old pheasant chick tibia ash percentage phosphorus	129
47	Effect of treatment combinations on the two-week old pheasant chick tibia ash phosphorus	130
48	Effect of treatment combinations on the two- and four-week old pheasant chick tibia percentage dry fat-free bone	132
49	Effect of treatment combinations on the two- and four-week old pheasant chick tibia dry fat-free bone percentage ash	135
50	Effect of treatment combinations on the two- and four-week old pheasant chick tibia ash percentage phosphorus	137

TABLE		PAGE
51	Effect of dietary calcium on two- and four-week old pheasant chick tibia ash percentage phosphorus	138
52	Effect of time on growing pheasant's tibia percentage dry fat-free bone and the dffb percentage ash	140
53	Effect of various dietary calcium and phosphorus combinations on the grower pheasant tibia percentage dry fat-free bone	141
54	Effect of various calcium and phosphorus combinations on the grower pheasant's tibia dry fat-free bone percentage ash	143
55	Dietary calcium by phosphorus interaction effect on grower pheasant chick's tibia dry fat-free bone percentage ash	144
56	Effect of time on growing pheasant chick tibia ash percentages of calcium and phosphorus	145
57	Percentage mortality of starter/grower chicks through four-weeks of age, by replicate	148
58	Effect of dietary calcium on the percentage mortality of pheasant chicks from all replicates through four-weeks of age	150
59	Effect of dietary phosphorus on the percentage mortality of pheasant chicks from all replicates through four-weeks of age	151
60	Effect of treatment combinations on the percentage mortality of pheasant chicks through four-weeks of age	153

APPENDIX A-D LIST OF TABLES

TABLE	PAGE
APPENDIX A	
1. National Research Council Calcium and Phosphorus Requirements	158
2. Summary of total pheasant eggs used for the determination of egg apparent fertility/hatchability	159
3. Percent hen-day egg production of Ring-necked pheasants.	160
APPENDIX B	
1. Ca:P ratios and treatment designations for treatment combinations for adult and growing pheasants	161
2. Feed ingredient analysis restrictions used in the computer formulation of these rations	162
3. Vitamin-trace mineral premixes for pheasants	163
4. Pheasant rations used at M.S.U.	164
5. Starter ration composition used in this study	165
6. Grower ration composition used in this study	166
7. Flight ration composition used in this study	167
8. Breeder ration composition used in this study	168
APPENDIX C	
This appendix consists of the Analysis of Variance Tables which were the basis of the statistical analysis of these studies. They are in the order in which they were discussed in the text, see the Table of Contents for this order.	170
APPENDIX D	
1. Period averages of feed consumption for starter (weeks 1-6), grower (weeks 7-12), and flight-aged (weeks 13-16) pheasants from the floor replicates	217
FIGURE	
1. Expected hen-day egg production for S.C.W.L. laying hens	218

LIST OF FIGURES

FIGURE		PAGE
	Effect of time on pheasant egg apparent fertility and hatchability	38-39
	Effect of time on pheasant hen-day egg production	45-46
	Effect of time on egg weight	54-55
	Effect of time on eggshell weight as a percentage of total egg weight and eggshell thickness	62-64

ABBREVIATIONS AND SYMBOLS

E1	=	Experiment one = Laying Hens, first floor experiment
E2	=	Experiment two = Laying Hens, second floor experiment
E3	=	Experiment three= Laying Hens, caged layer experiment
SC IF	=	Starter/Grower birds, first floor replicate
SG IIF	=	Starter/Grower birds, second floor replicate
SG Ic	=	Starter/Grower birds, first caged replicate
SG IIc	=	Starter/Grower birds, second caged replicate
SG IIIc	=	Starter/Grower birds, third caged replicate
P	=	Dietary available phosphorus
Ca	=	Dietary calcium
dffb	=	Tibia percentage dry fat-free bone
ash	=	dffb percentage ash
Group 1	=	Data of LH c was totaled and considered as a replicate for statistical analysis with the two floor replicates
Group 2	=	The LH c data was statistically analyzed alone, using the existing replication. The same statistical model (the simple ANOVA or the split-plot ANOVA) was used to evaluate data of either Group 1 or Group 2.

All treatment numerical designations are defined in Appendix B, Table 1.

INTRODUCTION

Because of an expanding population and a decline in the number of acres around metropolitan centers which are suitable for pheasant hunting, several states and individual gun clubs have sponsored programs to provide an opportunity for city/suburban dwellers to hunt pheasants. In the state of Michigan this is the Put-and-Take Program, which was started in 1972. During the 1978 season, about 100,000 adult pheasants (Phasianus colchicus) were released in selected areas for Michigan hunters who had purchased special licenses. An undetermined number of pheasants are reared annually in Michigan for private or commercial gun club release. The game bird industry in Michigan and the U.S.A. is a rapidly growing economic enterprise which has need of specific information regarding the nutrient requirements of game birds. Due to a need for increased economic efficiency, it is no longer adequate to assume that pheasant has requirements that are "close enough" to the chicken or turkey so that their rations may be freely substituted for pheasants.

Earlier investigators have noted that excessive levels of calcium in the rations of laying hen pheasants seem to result in depressed egg production (Hinkson et al., 1970; Flegal et al., 1973; Flegal, 1978). The National Research Council (1977) (N.R.C.) guidelines in the Nutrient Requirements of Poultry do

not include phosphorus or calcium requirements for pheasants, with the exception of the starter/growers.

The objective of this work was to add information to the existing knowledge about the calcium and phosphorus requirements of adult pheasants so that acceptable dietary amounts and ratios of these minerals may be provided. In addition, an attempt was made to determine if growing pheasants could be maintained on dietary calcium and phosphorus concentrations somewhat less than the National Research Council recommendations.

Various parameters which may be affected by different amounts of dietary calcium and/or phosphorus were evaluated in adult and growing pheasants. These included: tibia percentage dry fat-free bone (dffb); dffb percentage ash; ash percentage calcium; and ash percentage phosphorus. Mortality, feed consumption and body weight values were also recorded. Hen-day percent egg production, egg apparent fertility and hatchability were also measured as well as the eggshell thickness and the eggshell weight as a percentage of the total egg weight. Adult blood plasma calcium and phosphorus levels were determined.

LITERATURE REVIEW

Hinkson et al. (1970) and Anderson and Stewart (1973) gave Leopold (1931) credit for initiating scientific research on the calcium requirements of pheasants. Leopold suggested that "the distribution of pheasants in the United States may be associated with soils of recent glaciation". Dale and DeWitt, in a paper about the vegetative sources of protein (see Hinkson, 1971), suggested 'that calcium deficiency may be more serious to the pheasant'. Leopold (1933) (see Vance, 1971), and McCann (1939) proposed that grit was a major source of minerals for pheasants and other gallinaceous birds. Jones (1968) (see Vance, 1971) calculated 'that as much as 99 percent of a pheasant's dietary Ca might come from calcitic grit'.

The work of Leopold (1931) apparently stimulated a number of other investigations about the grit (calcium/mineral) requirements of pheasants (Skoglund, 1940; Dale, 1954; Harper, 1963; Harper, 1964; Harper and Labisky, 1964; Korschgan et al., 1965; Kopishke and Nelson, 1966; and Anderson and Stewart, 1973).

Skoglund (1940) may have been the first to define specific calcium and phosphorus requirements for young pheasants (see Hinkson et al., 1971). Callenback et al. (1933) and Norris et al. (1936) were among the first to establish protein requirements for growing Ring-necked pheasant chicks. Sunde and Bird (1956) reported very little data was available about the phosphorus requirements of the young pheasant, that being

Skoglund's work in which he only had two references. Wilcox et al. (1953) did calcium and phosphorus work with turkey poults and included an extensive literature review. Scott et al. (1958a) produced a series of experiments on the nutrition of pheasants which was based on work done by Scott and Reynolds (1949).

Primarily during the early nineteen-seventies, the pheasant was used to determine the effect of various hazardous chemicals on wild populations of these game birds (Scott et al., 1954; Gill et al., 1970; Janda and Bosseova, 1970; Dahlgren and Linder, 1970; Dahlgren et al., 1972a; Dahlgren et al., 1972b; Huckabee et al., 1972; Dahlgren and Linder, 1974; Messick et al., 1974).

An insufficient amount of work has been conducted to warrant the establishment of calcium and phosphorus guidelines by the N.R.C. for pheasant breeders (see Appendix A1). The N.R.C. values are generally considered as the acceptable ones, especially in cases of conflicting evidence (Waibel et al., 1961).

Flegal (1978), based on the work of Flegal et al. (1973), stated that some of his breeder pheasant hens prematurely ceased production of eggs when fed a ration containing calcium at 3.3, and phosphorus at 0.8 percent of the ration. Calcium and/or phosphorus was suspected to be out of the physiological range for these breeder pheasants. For the data available in 1973, and in the 1977 publication, the N.R.C. has not established recommendations of mineral require-

ments for breeder hens.

Calcium and Phosphorus Requirements

Andrews et al. (1972) concluded that a large portion of the total organic phosphorus was available for utilization by turkey poults. Their best treatment was a degerminated corn meal basal diet that contained 0.59 percent total P or 0.32 percent available P.

Nelson et al. (1960) (see Waible et al., 1961) recently reported that after eight weeks of age, calcium and phosphorus levels of 0.5-0.6 percent of the diet each resulted in good turkeys. Waible et al. (1961) stated that excellent turkeys were produced both on range and in confinement, with reduced calcium and phosphorus levels during the growing period. Between 8-14, 14-20, and 20-24 weeks-of-age, the calcium levels were 1.24 percent of the ration (from 1.63 percent), 0.89 percent (from 1.36), and 0.62 percent (from 1.13), and the total phosphorus levels were 0.75 percent (from 0.84), 0.58 percent (from 0.72), and 0.48 percent (from 0.58), respectively.

Balloun and Miller (1964) reported on the calcium requirements of turkey breeder hens but made no recommendations. They found that 2.0 percent dietary calcium was best as measured by egg hatchability but later in the laying season 2.5 percent dietary calcium resulted in the best hatchability. Hatchability was depressed by both the 1.5 and 3.0 percent dietary calcium levels, with the latter being more severe.

In broiler experiments by Lillie et al. (1964), the chicks

fed rations with 0.5 percent total phosphorus and 0.9, 1.0, 1.1, and 1.2 percent calcium, developed rickets by about 3 1/2 weeks into the experiment. The rickets were more pronounced with the higher calcium levels. These authors referenced several papers to support their findings that the dietary energy level had no effect on the calcium and/or phosphorus requirements for growth and feed efficiency of broilers.

Wozniak et al. (1977) used phosphoric acid (assumed to be 100% available) as the reference standard to study the bio-availability of feed phosphates to broiler chicks which were fed a practical diet. These authors confirmed that the chick tibia bone ash assay was a sensitive and reproducible method to determine phosphorus bio-availability from inorganic feed phosphate. They did not make specific recommendations, but the highest ash was from chicks fed diets with 0.73 percent total phosphorus. Calcium was supplied at 1.0 percent of all diets. Dicalcium phosphate produced significantly higher bone ash (42.2 percent) than defluorinated rock phosphate (39.0 percent).

Christmas and Harms (1978), when using three-week old cockerels, reported a strain difference in the phosphorus requirement and stated that these differences should be considered when making recommendations regarding dietary phosphorus levels.

Watts and Davis (1960) concluded that 0.75-1.2 percent dietary calcium levels for broilers produced satisfactory

growth when the total phosphorus was 0.7 percent (0.45 percent inorganic) of the diet. In their study, soft phosphate, dicalcium phosphate, or a mixture of the two were equally effective as a source of phosphorus.

Waldroup et al. (1963) concluded that broiler requirements for either calcium or phosphorus cannot be stated without specifying the level of the other element.

Biely and March (1967) found that calcium could be reduced to 0.75 percent without decreasing broiler growth rate if vitamin D was adequate (600 ICU/Kg diet). Dietary phosphorus levels used were variable. They found no advantage to feeding less than 1.0 percent calcium and that calcium up to 1.3 percent was well tolerated with no indication of growth inhibition or decreased feed efficiency. Tibia calcification decreased with 0.75 or 0.85 percent of the diet as calcium, but was increased at these levels if vitamin D₃ was increased to 600 ICU/Kg diet. Increasing dietary protein and fat reduced tibia calcification.

Atkinson et al. (1967) reported that for breeder turkeys, dietary calcium levels of 1.24-3.95 percent "did not appear to have any particular effect on feed consumption, feed efficiency, body weight loss, mortality, fertility, egg weight or the percentage of broken and soft-shelled eggs". Dietary inorganic (available) phosphorus was 0.64 or 0.78 percent. There was a trend for decreased hatchability with dietary calcium at 3.95 percent. The Broad Breasted Bronze (BBB) hens in cages required at least 1.90, and the Broad Breasted White

(BBW) hens required at least 2.66 percent dietary calcium. Floor-housed BBB hens required a minimum of 1.67 percent dietary calcium. Criteria used for evaluation were egg production, egg fertility, and hatchability. Maximum response was with about 3.0+% dietary calcium.

Balloun and Miller (1964) reported on the calcium requirements of turkey breeder hens but made no recommendations. They found that 2.0 percent dietary calcium was best as measured by egg hatchability but later in the laying season 2.5 percent dietary calcium resulted in the best hatchability. Hatchability was depressed by both the 1.5 and 3.0 percent calcium levels, with the latter being more severe.

Anderson (1967) looked at the effect of chicken pre-lay dietary mineral concentrations on subsequent laying hen performance. He concluded the growing (10-22 week-old) chicken has a changing requirement for dietary Ca and/or Ca:P ratio. These needs were inversely related to the stage of sexual maturity, and directly related to a decreased rate of growth. The 10-14 week-old chicks needed about 0.8%, and the 14-15 week-old chicken needed about 0.6% dietary calcium. He used chick starter with 1.17 percent calcium and 0.5 percent available phosphorus to ten weeks of age. Then the various levels of calcium (0.6, 0.8, 1.0, 1.5, 2.0, and 2.5 percent) with available P at 0.5 percent of the diet were fed to 22 weeks of age. In one experiment with caged hens, he found no significant difference in reproductive performance from feeding pre-laying diets of calcium levels from 0.6-2.6 percent. But in

another experiment he reported a positive reproductive response to increasing pre-lay dietary calcium up to 2.6 percent for caged hens on wire and litter boxes within the cage. He concluded that the reproductive responses of these adult females was influenced not only by the level of pre-laying dietary Ca and/or Ca:P ratio and the type environment, but were also in part dependent on the rate at which growth and endocrine development are proceeding during the pre-laying adaptation period.

In 1937, Titus et al. reported that 4.05 or 5.40 percent dietary calcium adversely affected the hatchability of chicken eggs, and the effect was greater with 0.9 vs. 1.2 percent dietary phosphorus. However, in 1963, Titus et al. (see Atkinson et al., 1967) reported the best reproductive performance of laying chickens was obtained when the diet contained 6.0 percent calcium. They reported that the phosphorus level for the laying chicken appeared to be relatively unimportant as long as it was not too low, with the optimum phosphorus level being approximately 0.75 percent.

Sanford and Alder (1969) implied that the best Ca:P ratio was 3.0:0.7 (in percents), as measured by production parameters of the laying chickens. However, the best specific gravity of eggs was with the 3.0:0.6 (in percents) dietary Ca:P ratio.

Scott et al. (1958a) found the minimum dietary calcium level appeared to lie between 0.93 and 1.33 percent for five-week-old pheasant chicks. There was no (growth) inhibitory effect when 1.6 percent dietary Ca was fed for this time period. They concluded that apparently the calcium requirement of

growing pheasants is not critical and can be met with safety by dietary calcium level within the range of 1.3 to 1.6 percent.

Sturkie (1965) discussed the results of a dietary calcium deficiency for chicken layer-breeders. He stated the final cessation of egg production was due to an inhibition of pituitary gonadotropin secretion. He also stated that there apparently is no relationship between plasma inorganic phosphate and shell production even though several workers have found that levels of plasma inorganic phosphate increased during shell production.

Owings et al. (1977) stated that their results indicated relatively low dietary phosphorus levels can fulfill the chicken laying hen's requirement for egg production provided that about 0.19% or more available phosphorus is present in the ration. To maintain livability, the available phosphorus requirement was thought to be at least 0.28 percent. Part of the available phosphorus should be inorganic in origin. Available phosphorus levels of 0.19, 0.28, or 0.37 percent of the diet supported a high level of egg production during the 140 days of their experiment.

Harms et al. (1965) reported that although high dietary phosphorus (above 0.44 percent Av. P) will depress performance of caged chicken hens, they tolerated high dietary phosphorus better than floor hens. They postulated that the difference is due to a higher phosphorus requirement of caged hens. They used inorganic phosphorus levels of 0.44-1.44 percent of the diet.

Harms and Waldroup (1971) found that levels of calcium up to 5 percent of the diet did not prove to be significantly deleterious to S.C.W.L. laying hens as measured by egg production, weight, or shell thickness, or feed consumption, over a four month period. Dietary phosphorus was 0.80 percent. These hens would even tolerate 10 percent dietary calcium for up to 28 days before the production parameters were affected.

Scott et al. (1958a, b) used growth and calcification of the tibia as criteria for determining the phosphorus requirements for pheasants and Bobwhite quail. Scott et al. (1958b) reported the total phosphorus requirements for the Bobwhite quail to be 0.6 percent for the starting period (0-6 weeks) and no higher than 0.48 percent for the growth period (6-12 weeks of age).

Skoglund (1940) (see Scott and Reynolds, 1949) showed the incidence of perosis was increased markedly when the level of dietary calcium for pheasant chicks was greater than two percent. In one study, 0.87 percent dietary calcium and 0.78 percent dietary phosphorus produced the best results. Skoglund concluded that the best pheasant starter ration calcium and total phosphorus levels were 1.5 and 1.0 percent of the diet, respectively. The former values are slightly higher than the requirements for young chickens (see the NRC pamphlet, or Scott and Reynolds, 1949).

Scott and Reynolds (1949) concluded that except for the protein requirements, which resemble those for the turkey poult, their studies indicated that the nutrition of the

pheasant resembles that of the domestic chicken more than it does that of the turkey poult.

McCann in 1939 stated that adult pheasants seem better able to maintain themselves on grit deficient in calcium than young birds, this is undoubtedly due to their greater reserve of, and smaller demand for calcium. Another point of interest is that experimental birds were found able to select between types of grit, preferring glacial gravel. This latter statement was confirmed by Sadler in 1961, Harper in 1963, and Harper and Labisky in 1964.

Sunde and Bird (1956) implied that a lesser amount of total phosphorus was required for two-week-old vs. four-week-old pheasants (0.86 and 0.96 percent, respectively). They reported the chicks with 0.66% total (about 0.2% available) dietary phosphorus developed leg weaknesses after about one week. Optimal performance was achieved with 0.5% dietary available phosphorus (0.96% total phosphorus). Up to 1.46 total dietary phosphorus did not result in decreased growth or an increase in the evidence of leg disorders. The calculated calcium content for all rations was 1.51 percent. Sunde and Bird stated that apparently the phosphorus requirement of the pheasant chick is high. For this reason, they believed the pheasant chick to be an experimental animal for determining the bio-availability of phosphorus in various types of feedstuffs. Soares et al. (1978) in their literature review stated that some reports have indicated that the chick and turkey poult can utilize various phosphorus (particularly

organic) sources more efficiently with age. Soares et al. (1978) used monobasic sodium phosphates as the reference standard (assumed to be 100% available) for their defluorinated phosphate experiments. They used a dietary Ca:P ratio of 1.25:1 for all their broiler chick experiments.

Labisky and Jackson (1969) measured egg production and egg weights of individual pheasant hens over three years and found that egg production and egg total mass was better for the two-year-old hens, than either the yearling or third year hens.

Dale and DeWitt (1958) (see Greeley, 1962) reported that approximately 1.2 percent of the diet as calcium was sufficient for production of eggs and offspring by penned pheasants if they had not been subjected to a deficiency of calcium or phosphorus during the previous winter.

The re-nesting phenomenon of pheasants was studied by Chambers et al. (1966). They found breeder hens fed a calcium-deficient diet did not produce a second clutch of sufficient size to adequately maintain the population of an area.

In Appendix A, Table 1, are listed the dietary calcium and phosphorus requirements of chickens, turkeys, and pheasants according to the National Research Council.

METHODS AND MATERIALS

Experiments were conducted with adult and growing Ring-necked pheasants in an attempt to determine their dietary calcium and phosphorus requirements, as they related to the levels and ratios of these minerals. The specific experimental designs and other information will be discussed for each experiment separately, after any general comments. The Michigan State University diagnostic clinic performed all necropsies of pheasants to determine their health status.

PHEASANT BREEDERS

Two different management systems were evaluated (floor vs. caged breeder pheasants) for their effect on these dietary mineral requirements, in addition to the 16 dietary treatments which were of primary concern. The numerical designations of all treatment combinations are defined in Appendix B, Table 1. Due to lack of space, the two experiments of the floor-housed laying hens were done in consecutive years (May-August, 1977; and February-May, 1978), and in two different buildings. The second floor experiment and the cage layer experiment were conducted nearly simultaneously. Any differences in numbers per treatment in the floor or caged experiments were due to the availability of pheasants. Obviously, these seasonal constraints tend to increase the uncertainty of valid comparisons between experiments (Anderson, 1967).

For all adult experiments, the allocation of birds to each of the 16 dietary treatments and of treatments to pens or cages was done randomly, with the restriction that all treatments received similar numbers of heavy and light hens. All birds were from stock that was not selected for any of the traits studied except that all birds were from stock selected for increased egg numbers. The source of the adult birds was not the same for all replicates. The floor-housed pheasants used in experiment one were from different genetic experiments here at Michigan State University. The original stock was derived from contributions from a private gamebird farm and the Michigan Department of Natural Resources. The floor-housed adult pheasants of experiment two and all the caged layers and males were progeny of experiment one breeders that were fed rations which were considered adequate in all nutrients.

All adults were weighed before being assigned to a treatment. The birds were also specked (specks are plastic eye-shields to inhibit cannibalism) and wing-clipped at this time. For the pheasants in the first experiment, these operations were completed during the adjustment period, which lasted approximately ten days. The same amount of time was given birds in experiment two for acclimation. No pre-treatment period was allowed birds of any experiment regarding the feed treatments. The duration of all adult experiments was 90 days.

The composition of the vitamin/mineral premix, and a list of the ingredients used in the ration formulation are in different tables in Appendix B. The calculated analyses of pheasant rations currently used at Michigan State University are also listed in Appendix B. The dietary Ca:P ratios, levels, and respective treatment combinations are listed in Appendix B, Table 1.

In addition to the specks for the floor birds, red lights were used to aid in preventing cannibalism. Incandescent 15-watt light bulbs were spray painted red (OSHA Red).

During the production period, lights for all replicates were on 14 hours per day and were increased to 17 hours per day after the peak egg production was reached (Hinkson et al., 1967; Woodard and Snyder, 1978). Sixty-watt incandescent light bulbs were used in the caged layer room.

For all laying hen experiments, eggs were collected once each day. Eggs were recorded as intact, broken, or softshell, and marked to allow specific identification of each egg. All eggs were then individually weighed (in grams) and stored at 60°F (15.6°C) until they were brought to room temperature before being placed in the incubator. Eggs were not fumigated. On the same day once each week, the eggs were broken open, rinsed of albumen and air dried. These dried eggshells were stored for further processing. These eggshells were weighed individually ($\pm$ 0.01 grams), and the eggshell thickness was determined ($\pm$ 0.05 mm.), using a micrometer^{*}. The average of

* Federal brand, model P6I manufactured by Federal Products Corp., 1144 Eddy Street, Providence, RI 02901

two eggshell thickness values taken at the equator of the egg were used for the statistical analysis (Hinkson et al., 1970).

For three consecutive weeks, eggshell membrane thickness was directly determined from the total egg production for one day by using the micrometer that was used for measuring the eggshell thickness. This was done for only the caged layers and replicate two of the floor birds.

For all adults, feed consumption was determined every 28 days and for the final week. The first statistical analysis (Group 1) of feed consumption was performed on the weighted treatment totals for each experiment disregarding the replication within the caged layer treatments. The caged layer treatments were subsequently analyzed as a separate entity (Group 2). Feed consumption data for birds housed on the floor included the feed eaten by the males. Male breeder feed consumption was determined for the 48 individually caged males used for artificial insemination of the caged layers. A single batch of feed was prepared for hens of each treatment of the first floor replicate. A second single batch of feed, according to the treatment ration specifications, was prepared that was sufficient for the caged layers and experiment two of the floor birds.

For all layer/breeders, heparinized blood was collected from each pheasant at the end of the experiment and pooled according to treatment and sex. This plasma was analyzed for calcium and phosphorus by atomic absorption spectroscopy and with a light transmittance spectrophotometer, respectively.

The blood plasma inorganic phosphorus was analyzed using the Gomorri modification of the Fiske and SubbaRow colorimetric technique and calcium via the atomic absorption spectrophotometric technique; both as given in the working laboratory procedures outlined by Ullrey. Artificial composite serum standards were prepared and diluted 1:4 with 12.5% TCA, the same as the plasma samples. The TCA deproteinized the plasma samples. After centrifugation, an aliquot of the supernatant was mixed with an MS (molybdate-sulphuric acid) and elon (p-methyl-amino-phenolsulfate) solution, and read after 45 minutes of incubation at room temperature. For plasma calcium the deproteinized supernatant was diluted 1:2 with 20,000 ppm Sr, and read.

For the breeders of experiment one, no tibia samples were taken. For experiment two (floor birds) two females and one male were killed and frozen for later removal of the tibia. Tibia data of the males were similar to the data of the females so the data were pooled for statistical analysis. For the cages layers (experiment three) one female from each replicate was killed (four per treatment) and one male from each replicate was killed (four per each of the two feed replicates), and likewise stored for later removal of the tibia. The tibiae were removed and processed along with the tibiae from the starter/grower pheasants for tibia percentage dry fat-free bone (dffb), dffb percentage ash; and ash percents calcium and phosphorus.

For all tibiae, the following procedure was used. The bone was placed in boiling water for about two minutes, then the remaining tissue was mechanically removed. The air-dried individual bones were then weighed, wrapped in cheesecloth, tagged, and crushed. These bones were then extracted with absolute ether and then 200 proof ethanol for 24 hours each. The bone packages were air-dried between extractions. After these extractions the bones were considered dry and fat-free and were individually weighed into a tared, pre-ashed crucible. The amounts of dffb and ash were determined by difference. The bones were ashed at about 600°C overnight in a muffle furnace. Weighed portions of the ash were analyzed for calcium and phosphorus by dissolving in 6N HCL, diluting to 100 ml with distilled deionized water, then storing at room temperature. Working standards and sample aliquots of the diluent were diluted with SrCl_2 . The calcium concentrations were then determined using an atomic absorption spectrophotometer. The ash phosphorus concentration was determined by further diluting an aliquot of the previously discussed diluent, plus working standards as described for determinations of plasma phosphorus. The calcium and phosphorus determinations were made using the previously discussed equipment procedures.

At the time of hatch, all chicks of treated adults were banded and kept separated by dam treatment; they were then weighed as a group. Random hatches were collectively brooded for three weeks. For these randomly selected hatches,

mortality records were kept to determine the effect of dam treatment on subsequent liveability of the offspring.

All chicks (including starter/growers) were brooded under gas brooders with supplemental infra-red lamps. These lights were on constantly. Heat was provided as needed, starting at about 90°F (32.2°C). A cardboard brooder ring was used to confine the chicks for the first five to seven days. Depending on the availability of Plasson or other mechanical waterers, chicks were provided with water from the automatic waterers and/or one-gallon waterers for the first seven to ten days. They were then all changed over to 'automatic' waterers. At least one one-gallon waterer was provided for each 50 chicks during those first few days.

During the brooding period, feed was provided in a tube or trough-type feeder, each chick having at least one linear inch (2.54 cm.) of feeder space for the first week, then at least 3 linear inches (7.6 linear cm) throughout the growing period. In the battery brooders the feeder space was at least 1.0 linear inch (2.54 cm) per bird with at least 0.5 linear inches (1.3 cm) water space per bird. Dimensions of the Petersime battery brooder cage were 40" x 28" x 9" (101.6 x 71.1 x 22.9 cm).

Adult data were statistically analyzed in two basic ways. In one, the caged layer experiment totals were considered as a replicate and evaluated along with the data of the two floor experiments (this has been defined as Group 1). In the other analysis the data from the caged females were

analyzed separately (this has been defined as Group 2).

One caged layer replicate (of four) was deleted for the statistical analysis of data from some parameters in an effort to avoid unequal replication at some time periods (egg fertility and hatchability). In those cases where the data in a treatment were complete, the replicates with the largest number of eggs were chosen. If no deletions were necessary all four replicates were used.

The stat4 computer statistical program was used for evaluation of all adult and starter/grower data, except those with unequal replication (e.g. adult body weight percent change), for which a special ANOVA program was used. The stat4 program is a split plot analysis if there are period effects, otherwise it is the regular ANOVA.

All linear, quadratic or cubic effects were determined using orthogonal polynomials. If the averages of any model component were linear, then all the points on the line could be considered significantly different. All statistical tests are described by Gill (1978). Differences between means were determined by using the Bonferroni t-test, unless otherwise stated. Exceptions are the tables where the treatments were ranked according to their degree of influence on a parameter, in which case the significance level was determined using the Tukey test of means. In there was homogenous variance among the means, as determined by the f-max test (S_L^2/S_M^2), the standard error of the mean (SEM) was calculated as $\sqrt{MS_E/\text{No. observations per mean}}$. For the means with

heterogenous variances, the conventional square root of the variance divided by the number of observations per mean was used as the SEM.

The values for all egg fertility and hatchability results are in percentages, as re-transformed from the arcsin. The arcsin transformation (i.e., $\arcsin\sqrt{\text{proportion}}$) of all original egg fertility and hatchability data was used for the statistical analysis of this data. The resulting arcsin mean values were converted back to percentages after statistical evaluation. Conversion of the SEM from arcsin to percentages is not correct statistical procedure.

For each parameter discussed with a statistical analysis, the analysis of variance table is in Appendix C, in the order in which that subject appears in the text.

1. Experiment one (E1)

The pens of this replicate measured 7' x 10' (2.13 x 3.05 meters). There were 14 females and 2 males in each of 16 dietary treatments, each having 4.4 sq. ft. (0.41 meters) floor space. Pine shavings were used as litter for all adult and starter/grower floor birds.

All adults of the first experiment were maintained during the growing period at six hours light per 24 hour period. They were brought into egg production by increasing the light duration in three two-hour steps, which were four days apart, to 14 hours total light. Males were lit about two weeks prior to the females.

Total egg production from six days each week was incubated in 1977 and from five days in 1978. Due to crowded conditions on the incubators, these eggs were candled at 10-12 days incubation in 1977. Apparent infertiles and early deads were removed at this time. Eggs were transferred to the hatching incubator at day 21 of incubation and chicks were removed from this incubator on day 26.

Adult pheasant data that were collected are summarized in outline form:

A. Egg data

1. percent hen-day (intact eggs) egg production by 10-day period
2. egg weight of all eggs except softshell and broken (including non-leaking cracks)
3. eggshell weight and thickness determined once a week
4. apparent fertility and hatchability--for intact eggs from five days each week (10 weeks)
 - a. mortality through three weeks of age for the chicks from these eggs; data were summarized according to the treatment of the dam

B. Body weight percentage change over the 90 day experiment

C. Feed consumption in grams per bird per day

D. Adult blood calcium and phosphorus levels

E. Tibia dry fat-free bone, ash, and ash percents calcium and phosphorus

2. Experiment two (E2)

There were ten females and two males in each treatment of the second experiment. The pens used for the birds of the second experiment measured 10' x 15' (3.05 x 4.58 meters), giving 12.5 sq. ft. (1.16 sq. meters) per bird.

During the maintenance period all pheasants that were used for experiment two and the caged layer experiment were specked and housed in a 38' x 24' (11.6 x 7.3 meter) room. Only four hours light was used during the major portion of this time. Specks were removed from the birds only when they were transferred to cages. These birds also had both wing feathers and tail feathers clipped to aid in the movement within the cage.

Data were collected using the same procedures during the second experiment as in the first experiment. The type data collected in experiment two and the caged-layer experiment were the same as in experiment one with the exception of the additional information for the eggshell membrane thickness and bone data of experiments two and three.

Also, for experiment two, all incubated eggs were only candled at the time of transfer to the hatching incubator. Again, all apparently infertile eggs and early deads were removed and recorded as such.

3. Experiment three (E3)

The caged pheasants were given about six weeks acclimation time. Some pheasants would not adjust to this environment and killed themselves by repeatedly jumping and hitting

the cage top or by not eating.

The caged layers were confined individually in 8" x 14" x 12" (20.3 x 35.6 x 30.5 cm.), numbered cages; giving a space of 112 sq. in. (722.7 sq. cm.) per bird. One inch (2.54 cm.) mesh 14 guage wire was used to construct the cages. These cages had a two inch (5.08 cm.) sloping wire floor and a four inch (10.2 cm.) wide egg tray which was divided according to cage number by a piece of wire. The mono-Flo watering system was used. The cage doors were constructed to swing 'in' for ease of catching and returning the hens or cocks for/after artificial insemination or semen collection. The feeders were attached to the outside of the cage, partially blocking the door. Door fasteners had to be used for a portion of the cages to prevent the pheasant's escape.

All birds were weighed and had the wing feathers clipped before treatments started. Specks were removed from all caged birds. The caged birds had the feathers clipped on both wings and the tail.

There were four hens per replicate and four replicates per treatment, with replicates randomly allocated throughout the room but also ensuring a replicate from each treatment in all sections of the room (two sides and the middle). Forty-eight males were randomly allocated to one of two feed replicates of the same commercial layer breeder ration. The males were used as the source of the semen for the artificial insemination part of the experiments. The secondary purpose of these male feed replicates was to determine the average feed consumption of caged male pheasants.

All males were kept in the center cages, at the end opposite the females of the center section.

For the artificial insemination, a glass tube 'straw' was calibrated to hold approximately 100 million spermatozoa (0.025 ml semen). This was done using a light transmittance spectrophotometer and a standard curve. The sperm count of the standard curve was established with a hemocytometer. Males were lit about three weeks prior to the females and about five weeks before the need for semen (Woodard and Snyder, 1978).

Hens were initially inseminated three times in eight days, and weekly thereafter. Within 15 minutes after collecting the pooled semen in a glass or plastic vial, the semen was deposited at the UV junction of the everted female's oviduct by blowing it through a straw/rubber hose assembly.

STARTER/GROWER PHEASANTS

As for the adults, two types of management systems were evaluated (floor-reared chicks through 16-weeks of age vs. battery-reared chicks through four-weeks of age) for their effect on these dietary mineral requirements. These data were in addition to evaluating the nine dietary treatments, which were of primary concern. Again, differences in numbers per replicate were due to the availability of chicks. The source of chicks was the same for all replicates (from hens of experiment one that were being fed the conventional pheasant rations) except the chicks of the first floor replicate. The chicks from the first floor replicate came

from extra eggs from breeders at the Department of Natural Resources gamebird farm at Mason, Michigan.

Ingredients used and the calculated analyses for the dietary treatments are listed in Appendix B. Enough feed (starter or grower or flight) was mixed at one time so all replicates at a particular age were fed with feed ingredients from the same source.

There were two replicates for the floor-reared chicks and three for the battery-reared chicks. However, there was a problem with one replicate of the battery-reared chicks in that some chicks initially could intermingle to a limited degree between treatments, but not later. Therefore, the only data used from this replicate was for the bone data from chicks in the correct group at four-weeks of age.

The tibiae from the developing pheasant chicks were processed as discussed for the adult bones. Samples were taken at two, four, eight, and twelve-weeks of age. Due to excessive mortality in the 0.2 percent dietary phosphorus treatments, the tibia data were analyzed in three different ways:

1. all floor and caged replicates and using all treatments at two weeks of age
2. two and four week data comparisons for all replicates except SG IIc
3. two, four, eight, and twelve week data for only the floor replicates.

In an effort to decrease experimental error (and to create enough ash for calcium and phosphorus determinations)

both tibiae were combined and processed as one, for the two- and four-week old chicks. Otherwise one tibia, chosen randomly, was used for the various determinations. The now-calcified cartilage cap was included for all eight-week and older birds.

1. Day-old through 16 weeks of age reared on the floor

Replicate one had 52 chicks and replicate two had 45 chicks in each of nine dietary treatments, respectively. Replicate one was conducted from June through September, and replicate two from August through December, 1977.

Data collected from these chicks were:

- A. body weight for day-old through four-, eight-, twelve-, and sixteen-weeks of age
- B. Feed Consumption
 - 1. Starter: day one through six-weeks of age
 - 2. Grower: seven through twelve-weeks of age
 - 3. Flight: thirteen through sixteen-weeks of age
- C. tibia determinations as previously described for the adult tibiae

2. Battery-reared chicks (SG I, II, IIIc)

Replicates one, two, and three had 22, 26, or 25 chicks, respectively, in each of nine dietary treatments. The duration of these experiments was day-old through four-weeks of age.

These replicates were terminated after the 28th day due to the vertical space limitations of the Petersime battery-brooders.

All starter/grower experiments were conducted during July and August, 1977.

RESULTS AND DISCUSSION

Data from the adults will be presented first, then the starter/grower information, and then an overall summary/discussion. Treatment numerical designations are defined in Appendix B, Table 1. Groups 1 and 2 are defined on the Abbreviations and Symbols page.

ADULT DATA

Egg Apparent Fertility

For Group 1 the experiment means for egg apparent fertility were: E1 = 61.2; E2 = 73.7; E3 = 86.8 percent, respectively. All these means significantly differed from each other ($P \leq 0.05$). These levels of fertility are similar to the ones from natural mating experiments as reported by Woodard et al. (1970). The Chukkar Partridge egg fertility averages for four successive production periods was: 77; 74; 83; and 79 percent, respectively. The different pheasant mating systems may be a reason for these differences between means of pheasant egg apparent fertility. The inherent variability of the mass mating system vs. artificial insemination could have had an influence on these values. Also, it should be remembered that the present experiments were done over two years and at different seasons (E1 = May through August, 1977; E2 and E3 = February through May, 1978).

In Group 1, increased concentrations of dietary calcium caused a linear ($P \leq 0.01$) decline in egg apparent fertility ($P \leq 0.035$), see Table 1. Only the extremes of this range of means were significantly different from each other ($P \leq 0.05$), even though the relationship of increasing dietary calcium and decreasing egg apparent fertility was obvious. The egg apparent fertility reported in Table 1 is not much lower than the pheasant egg fertility of 85-91 percent reported by Woodard and Snyder (1978). However, there was no indication of any calcium effect for Group 2 egg apparent fertility data ($P \geq 0.52$).

For Group 1 (Table 2) the 80-86 percent egg apparent fertility from hens fed diets with the lowest calcium:phosphorus ratios (2.5 to 4.2:1) was marginal but acceptable. According to Jordan (1977), standards for egg apparent fertility and hatchability are: 90 percent of all eggs set should be fertile and 90 percent of all fertile eggs should hatch. For Group 1 data, 47.3 percent egg apparent fertility (a 3.3% Ca treatment) was not different from 84.7 percent ($P \geq 0.20$), but was possibly different from 85.6 percent ($P \leq 0.2$) egg apparent fertility. The latter two values were from 1.5 percent Ca treatments. These data are listed in Table 2. For Group 2, there was no difference between any of the treatment combination averages of the egg apparent fertility, which ranged from 89 to 97 percent. Only some of the high or low extremes of the treatment combinations (Ca:P dietary ratios) were consistent in their relative ranking (see Table 2) between the two groups of data.

Table 1. Calcium effect on pheasant egg apparent fertility.

Percent Dietary Calcium	Mean as a percentage [*]
1.5	82.8 ^b
2.1	77.7 ^{ab}
2.7	73.1 ^{ab}
3.3	63.9 ^a

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data are from Group 1 (combined floor- plus caged-hens)
 Data are converted from the arcsin transformation which
 was used for the statistical analysis. The SEM can not
 be transformed from the arcsin.

Table 2. Effect of various dietary calcium and phosphorus combinations on the pheasant egg apparent fertility.

(A)					(B)				
trt.	mean*	P			trt.	mean*	P		
		greater than					greater than		
		.20	.10	.05			.20	.10	.05
4	85.6			n/a	15	96.9		n/a	n/a
3	84.7				4	96.8			
2	84.0				14	96.8			
7	82.7				12	96.7			
14	80.7				13	96.2			
8	80.6				9	95.8			
10	80.1				10	95.3			
1	76.1				3	94.8			
6	75.8				11	94.3			
9	74.8				8	94.0			
5	70.8				5	91.6			
15	70.0				6	89.9			
11	68.9				7	88.9			
12	68.0				2	89.4			
16	55.5				1	89.4			
13	47.3				16	88.9			

* Means within the range of a line are not significantly different for each level of significance. Treatments (trt.) are defined in Appendix B, Table 1, and Table 1 of the text.

Data are percentages as converted from the arcsin transformation. The standard error of the means could not be converted. (A) data are from Group 1, and the (B) data are from Group 2; these Groups are defined on the Abbreviations and Symbols page.

As shown in Table 2, the range of means of pheasant egg apparent fertility from Group 2 data was higher than the means from Group 1. Obviously, these differences between the egg apparent fertility means were probably primarily due to the previously discussed different mating systems. A summary of the total eggs incubated, the number of these that were apparently fertile, and the number of fertile eggs that hatched are listed in Appendix A, Table 2. These overall percentages of fertility and hatchability for each treatment (listed by experiment) are different from the data presented in the text. A reason for these differences is that the data within the text was from three selected replicates of experiment 3 but all four caged layer replicates were included in the appendix summary, for Group 2. Also, for all these data, the data within the text is from ten period observation summaries, and so reflects period variability, while the appendix summary is an overall mean.

Perhaps there was an adverse effect of temperature on the hens of experiment one (Group 1) which would partially account for the lower value in experiment one--see above and Woodard and Snyder (1978) Thomason et al. (1978) did not find such a temperature effect to 28°F (82°F) with turkeys. Also, the in-house temperature during experiment one was often greater than 80°F. Above 82°F there is embryonic development (see Winter and Funk, 1956). The storage period then could have killed or weakened the embryo, resulting in a lowered egg apparent fertility and hatchability

for the two floor experiments. The floor birds had the opportunity each day to incubate the eggs; this elevated egg temperature could have been a contributing factor in the decline in egg apparent fertility and hatchability, as has been discussed above.

There were no replicate means (zero fertility) for this Group 2 data at some time periods. Therefore, as described earlier, the same three replicates (out of four) were used for the statistical analysis of the egg apparent fertility and hatchability data. This is an explanation of the differences between Group means listed in Table 3; also, between the means of Group 2 of Table 3 and the overall mean of experiment 3 of Group 1.

Males used in the caged management system were fed a commercial pheasant layer/breeder ration with 2.6 percent dietary calcium and 0.6 percent available dietary phosphorus. One might also speculate then that the lower egg apparent fertility of the (Group 1) floor replicates could have been a dietary effect on the males, but not on their capacity to produce semen if semen production was effected by high dietary calcium, the high fertility of Group 2 could not have been attained. Additional work should be done in this area.

None of the males were rested for a week or two as suggested by Jordan (1977), and perhaps this made a difference in the overall lower apparent fertility levels of eggs of the (Group 1) floor experiments.

The period (time) effect of egg apparent fertility from

Table 3. Effect of time on percent apparent egg fertility and hatchability of pheasant eggs.

Period	Group 1		Group 2	
	Percent Fertility	Percent Hatchability	Percent Fertility	Percent Hatchability
	<u>mean*</u>	<u>mean*</u>	<u>mean*</u>	<u>mean*</u>
1	58.5 ^a	58.9 ^{ab}	89.8 ^a	68.5 ^{ab}
2	68.5 ^b	57.9 ^a	90.3 ^a	63.6 ^a
3	72.2 ^{bc}	70.2 ^{cd}	95.4 ^{ab}	69.7 ^{abc}
4	76.3 ^{bcde}	69.3 ^{cd}	96.0 ^{ab}	86.3 ^{de}
5	77.6 ^{cde}	66.6 ^{bcd}	95.4 ^{ab}	76.1 ^{bcd}
6	82.9 ^e	65.8 ^{abcd}	97.4 ^b	78.6 ^{bcde}
7	79.5 ^{cde}	61.9 ^{abc}	95.2 ^{ab}	87.0 ^e
8	77.1 ^{cde}	62.0 ^{abc}	92.3 ^{ab}	81.8 ^{de}
9	76.9 ^{cde}	72.5 ^d	92.7 ^{ab}	84.2 ^{de}
10	75.1 ^{bcd}	64.9 ^{abcd}	92.1 ^{ab}	86.7 ^e

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Standard deviations are not presented because this information could not be converted from the arcsin along with the means. All statistical analyses were done with the data as the arcsin transformation.

These period averages of all treatments are from five consecutive days egg collection during each week. Groups 1 and 2 are defined on the Abbreviations and Symbols page.

the first Group was primarily due to the differences in the first four periods (Table 3, of Figure 1). The egg apparent fertility period averages during the last seven periods ranged from 75-83 percent, which was an increase over the first periods (Figure 1, or Table 3).

Hatchability

Hatchability of pheasant eggs from both Groups 1 and 2 was not affected ($P \geq 0.05$) by dietary treatments. These data are ranked in Table 4, for both Groups. The same selection procedure as described in the section on egg apparent fertility was used here to compensate for the missing data of Group 2. The same three replicates were used for fertility and hatchability data in this second Group.

There was a significant ($P \leq 0.002$) experiment effect on the hatchability of pheasant eggs from hens in Group 1. These experiment averages for egg hatchability were: E1 = 57.5; E2 = 63.5; and E3 = 73.8 percent. The mean hatchability of eggs from the caged hens was significantly different from the means of both floor experiments ($P \leq 0.05$). There was a significant ($P \leq 0.0005$) period effect on hatchability of pheasant eggs from hens of both Groups 1 and 2 (Table 3 or Figure 1). Woodard and Snyder (1978) reported hatchability values of 69-74 percent for recycled pheasant hen's eggs, which is similar to many of the results of this study.

For both Groups 1 and 2, the period effect on hatchability was primarily due to the lower egg hatchability levels in the first three weekly periods, after which these values plateaued.

Table 4. Effect of various dietary calcium and phosphorus combinations on pheasant egg hatchability.

(A)		P			(B)		P		
trt.	mean *	greater than			trt.	mean *	greater than		
		.20	.10	.05			.20	.10	.05
14	73.5			n/a	14	91.0			
8	72.5				5	82.9			
7	68.9				9	82.8			
2	68.1				13	82.2			
12	67.8				16	82.1			
3	67.4				4	81.7			
5	67.0				3	79.7			
1	66.3				15	79.2			
11	66.0				6	77.3			
6	65.1				10	76.6			
10	64.8				7	76.4			
4	64.3				12	76.2			
15	63.6				11	74.6			
9	62.8				2	71.9			
16	58.4				1	71.5			
13	42.7				8	70.0			

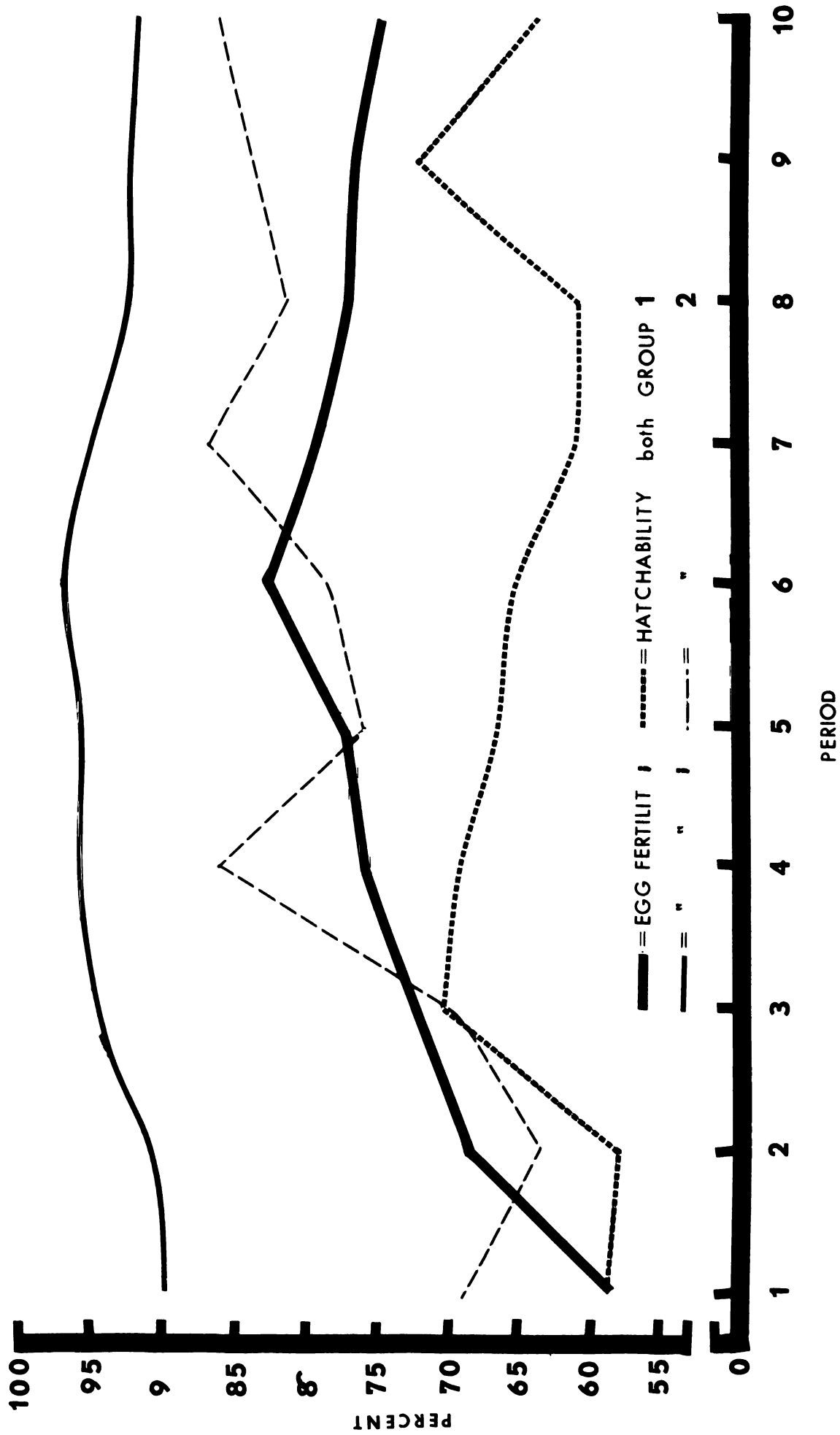
* Means within the range of a line are not significantly different for each level of significance. Treatments (trt) are defined in Appendix B, Table 1.

Data are percentages as converted from the arcsin transformation. The standard error of the means could not be converted from the arcsin.

(A) data are from Group 1, and the (B) data are from Group 2; these Groups are defined on the Abbreviations and Symbols page.

Figure 1. Effect of time on pheasant egg apparent fertility and hatchability. Each period mean represents the fertility or hatchability of all eggs from all treatments that were laid on five days per week for experiment one, but from six days for experiments two and three.

Experiments and Groups 1 and 2 are defined on the Abbreviations and Symbols page. Periods are from consecutive weeks.



The experiment effects on hatchability of eggs from hens in Group 1 can not be explained on the basis of thinner eggshells, which will be discussed later. Woodard et al. (1970) reported average hatchability of fertile Chukar Partridge eggs to be 60.3 to 72.7 percent, which is similar to the pheasant data of the present study.

Hinkson et al. (1970) studied the effect of confining pheasant breeders in cages. They stated that their results of variable fertility and hatchability confirmed work of earlier researchers.

Hen-day Percent Egg Production

The experiment effect on hen-day percent egg production of hens in Group 1 was highly significant ($P \leq 0.0005$), see Table 5, and may have been related to the fact that experiment one was conducted during the hot summer months (Woodard and Snyder, 1978). The approximate total intact eggs produced during the three experiments were: E1 = 11,506; E2 = 9,013; and E3 = 14,524 intact eggs. These data were summarized by ten-day blocks, for each treatment combination for statistical analysis.

All four replicates per treatment were summarized in the statistical analysis of the data from the caged hens in Group 2.

Unlike the data which formed part of the rationale for these experiments (Flegal et al., 1973; Flegal, 1978) the high calcium (3.3 percent) ration did not stop egg production, but may have inhibited it. Averages of the percent hen-day egg production for the non-significant calcium effect

Table 5. Percent hen-day egg production of pheasants. Data are summarized by replicates of Group 1.

Experiment	mean $\pm$ SEM [*]
One (floor)	58.3 $\pm$ 1.3 ^a
Two (floor)	68.5 1.0 ^b
Three (cage)	70.5 0.8 ^b

* Means with different superscripts are significantly different ($P \leq 0.05$).

Group 1 and experiments are defined on the Abbreviations and Symbols page.

were: 63.9; 65.5; 68.0; and 65.7 percent for Group 1, and 62.1; 70.9; 70.9; and 68.8 percent for Group 2. The dietary calcium concentrations were: 1.5; 2.1; 2.7; and 3.3 percent, respectively. Hinkson et al. (1967) reported that excessively high (3.7 percent) calcium in the ration had a depressing effect on pheasant egg production. Their 2.54 percent dietary calcium treatment resulted in the highest egg production. They used phosphorus at 0.6 percent of the diet. These data of Hinkson et al. (1967) were somewhat in agreement with the results of these experiments. King (1978) reported that Ca at 3.8 percent of the diet did not affect pheasant egg production.

The effect of the dietary phosphorus concentration on the hen-day percent egg production of hens of Group 1 was marginally significant ($P \leq 0.053$) according to the ANOVA f-statistic, see Table 6. Based on the parameter of percent hen-day egg production, determination of a minimum level of phosphorus needed by the laying hen pheasant was not possible because a deficiency state was not attained. The Group 1 results reported in Table 6 are not indicative of a linear (or dose) response of hen-day egg production to dietary phosphorus level. This response was evident in Group 2 also but means were not significantly different from each other ($P \geq 0.05$). The Group 2 means were: 68; 67; 67; and 70 percent for dietary phosphorus levels of 0.3; 0.4; 0.5; and 0.6 percent, respectively.

Vohra (1973) has suggested that the pheasant chick was able to use a number of levels of metabolizable energy and

Table 6. Effect of dietary phosphorus on percent hen-day egg production of pheasants of Group 1.

Percent Dietary Phosphorus	mean $\pm$ SEM [*]
0.3	70.2 $\pm$ 2.0 ^b
0.4	63.4 $\pm$ 2.0 ^a
0.5	62.9 $\pm$ 2.0 ^a
0.6	66.6 $\pm$ 2.0 ^{ab}

* Means with different superscripts are significantly different ($P \leq 0.05$).

Group 1 is defined on the Abbreviations and Symbols page.

protein in different combinations. As observed in these experiments, the egg producing hen pheasant was able to adapt to a wide range of calcium and phosphorus concentrations/ratios. This has also been observed by King (1978).

There was no significant difference between any of the hen-day percent production averages ($P > 0.20$) of the calcium by phosphorus interaction (these are the specific treatment combination averages). The range of these means in Group 1 was 58-74 percent and 51-76 percent hen-day egg production in Group 2; this data is listed in Appendix A, Table 3.

For both Groups 1 and 2, the appearance of the hen-day egg production graph was normal (Figure 2) but shifted downward when compared with the expected production curve for chickens (Appendix D, Figure 1; DeKalb 231 Management Guide). A possible reason for the lesser egg production, other than species differences, from the pheasants versus the chickens is that the pheasant data was summarized over all dietary treatments. All these treatments were not meant to be optimum for any production parameter, as was the case for hens generating the DeKalb data. The data from the present study are presented in Table 7 and Figure 2.

Shown in Table 7 and Figure 2 is the significant period effect on the hen-day percent egg production ($P \leq 0.0005$) for hens in both Groups 1 and 2. The data are of the natural increase and decrease of egg production with time (compare with Appendix D, Figure 1). Data from the first period for Group 1 were eliminated because hens of the experiments did not start producing at a uniform rate after administration

Figure 2. Effect of time on the hen-day percent egg production. Each period represents the egg production from all treatments for each consecutive ten-day collection period. Groups are defined on the Abbreviations and Symbols page. The first period was deleted for Group 1 because hens of all experiments did not all start production of eggs immediately after the treatments were fed.

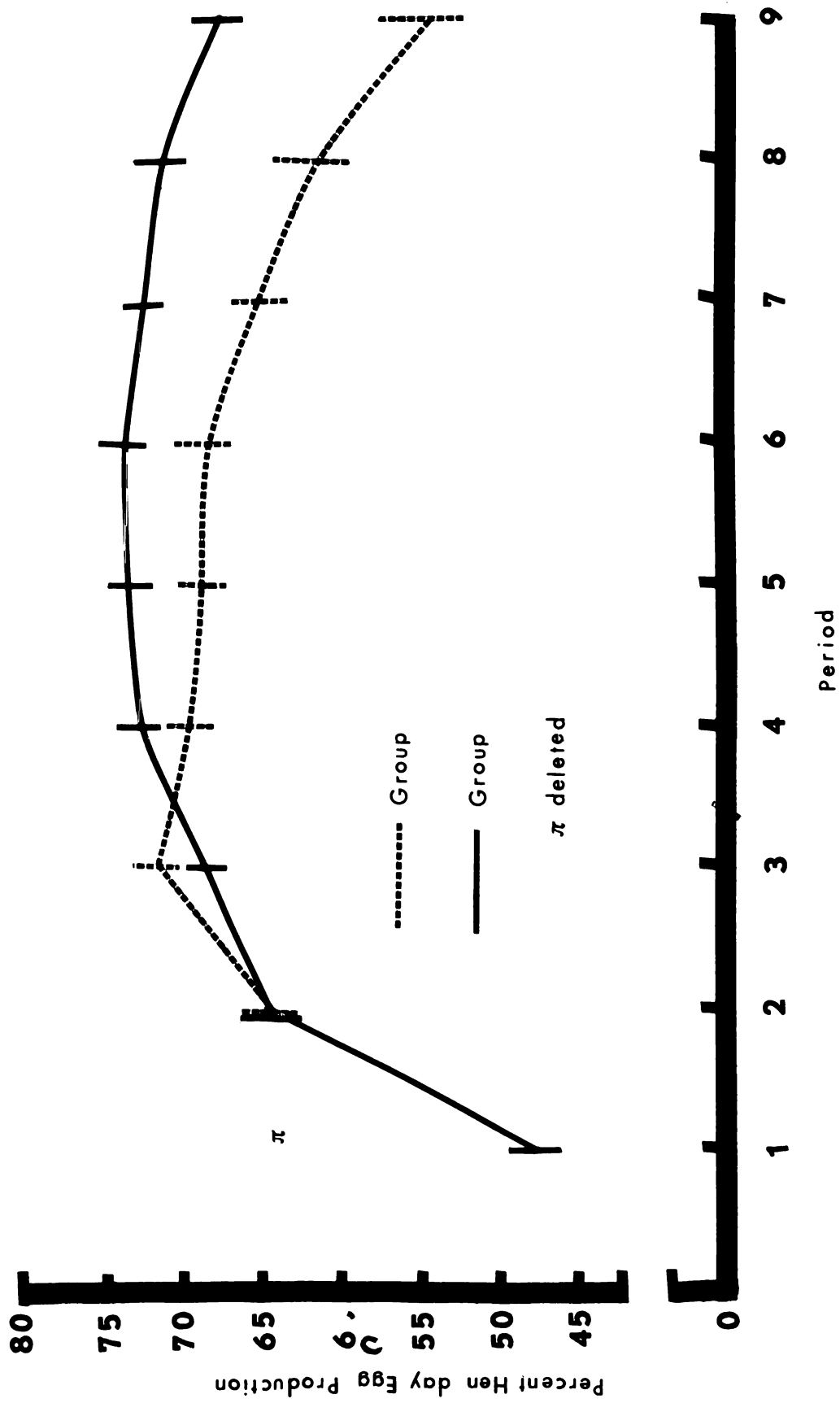


Table 7. Effect of time on pheasant hen-day percent egg production and egg weight (in grams). Part 1

Group 1	Percent Hen-day Egg Production	Egg Weight*** (in grams)
Period	mean $\pm$ SEM*	mean $\pm$ SEM*
1	---**	29.0 $\pm$ 0.2 ^a
2	64.8 $\pm$ 1.3 ^{bc}	29.6 $\pm$ 0.2 ^b
3	71.9 $\pm$ 1.2 ^d	30.3 $\pm$ 0.2 ^c
4	69.8 $\pm$ 1.2 ^{cd}	30.7 $\pm$ 0.2 ^d
5	68.9 $\pm$ 1.2 ^{bcd}	30.9 $\pm$ 0.2 ^{de}
6	69.0 $\pm$ 1.7 ^{cd}	31.1 $\pm$ 0.2 ^{ef}
7	65.1 $\pm$ 1.8 ^{bc}	31.2 $\pm$ 0.2 ^f
8	62.0 $\pm$ 2.3 ^b	31.2 $\pm$ 0.2 ^{ef}
9	54.8 $\pm$ 2.5 ^a	31.2 $\pm$ 0.2 ^f

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

** The egg production data of Group 1 are means of the last eight ten-day periods of egg production. Groups 1 and 2 are defined on the Abbreviations and Symbols page. All means are a summary of all treatments for that ten-day period.

*** Data are means of the nine ten-day periods.

Table 7. Effect of time on pheasant hen-day percent egg production and egg weight (in grams). Part 2

Group 2					
Period	Percent Hen-Day Egg Production***		Egg Weight (in grams)***		
	mean	$\pm$ SEM*	mean	$\pm$ SEM*	
1	47.8	$\pm 1.3^a$	28.3	$\pm 0.05^a$	
2	64.7	1.3^b	28.7	0.05^b	
3	68.6	1.3^{bcd}	29.1	0.05^c	
4	73.0	1.3^d	29.6	0.05^d	
5	73.5	1.3^e	29.9	0.05^e	
6	73.9	1.3^e	30.3	0.05^{fg}	
7	72.5	1.3^{de}	30.2	0.05^f	
8	71.8	1.3^{cde}	30.4	0.05^{gh}	
9	67.9	1.3^{bc}	30.5	0.05^h	

*Means within a column with different superscripts are significantly different ($P \leq 0.05$).

***Data are means of the nine ten-day periods.
For other information, see Part 1 footnotes.

of the dietary treatments.

Greeley (1962) reported that pheasant egg production reflected the level of dietary calcium. He used a range of dietary calcium of 0.37 to 2.34 percent.

Egg production figures for the treatments of the pheasant study were all higher than those for pheasants reported by Hinkson et al. (1970), who reported an 11-51 percent hen-day egg production range for all treatment averages. They stated that all their treatment egg production means were low because of the cold winter temperatures. However, the pheasants of this study were more productive during the spring versus the summer months (Table 5).

Holcombe et al. (1977) found that for chickens selected as producers of high or low specific gravity eggs, diets containing 3 or 5 percent calcium did not result in deleterious effects on egg production, egg weights, body weight, or feed consumption.

Owings et al. (1977) reported that 0.1 percent available phosphorus would substantially reduce the egg production of S.C.W.L. laying hens, but that egg production was maintained if the dietary available phosphorus was 0.19 percent and was best if the dietary available phosphorus was 0.28 percent. Anderson (1967) reported data from a second experiment which indicated that production of caged chicken layers was increased if during the pre-lay period, dietary calcium was raised to 2.6 percent. However, the first experiment results were that there was no difference in various pre-laying dietary calcium levels (0.6-2.6%).

Balloun and Miller (1964) evidently found turkey breeder hens not to be as sensitive as other previously mentioned species to calcium level in the diet. They reported levels of calcium of 1.5; 2.0; 2.5; and 3.0 percent of the ration to have no effect on egg production or egg size.

Egg Weight in Grams

For Group 1, the experiment effect on egg weight was highly significant ($P \leq 0.0005$), see Table 8. The caged layers produced lighter eggs than did hens from either of the floor experiments. Also, the floor experiment hen's egg weight means differed from each other ($P \leq 0.01$). Considering the hotter weather, the egg size of the first floor experiment would not be expected to be greater than that of eggs produced in the spring (Woodard and Snyder, 1978; Thomason, 1978).

High dietary calcium had a significant ($P \leq 0.026$) negative effect on egg weight in Group 1, and this effect was linear, see Table 9. This same effect was only a trend ($P \leq 0.12$) for the data of Group 2. In Group 1, the hens fed the 1.5 percent dietary calcium laid significantly heavier ($P \leq 0.05$) eggs than the other groups of hens. The dietary calcium effect on egg production was a trend toward decreasing production if calcium in the diet was low or high for both Groups 1 and 2.

For both Groups 1 and 2, the average of all values during period one were the lowest, the egg weight increased and gradually plateaued at around the sixth period (Table 7 or

Table 8. Pheasant egg weight averages (in grams). Data are summarized by experiments of Group 1.

Experiment	mean $\pm$ SEM [*]
One (floor)	31.4 $\pm$ 0.10 ^a
Two (floor)	30.6 $\pm$ 0.10 ^b
Three (cage)	29.7 $\pm$ 0.10 ^c

* Means with different superscripts are significantly different ($P \leq 0.05$).

Experiments and Group 1 are defined on the Abbreviations and Symbols page.

Table 9. Effect of dietary calcium on pheasant egg weight (in grams). Data is from Group 1.

Percent Dietary Calcium	mean $\pm$ SEM [*]
1.5	31.3 $\pm$ 0.13 ^a
2.1	30.5 $\pm$ 0.13 ^b
2.7	30.5 $\pm$ 0.13 ^b
3.3	30.1 $\pm$ 0.13 ^b

* Means with different superscripts are significantly different ($P \geq 0.05$).

Treatments are defined in Appendix B, Table 1. Group 1 is defined on the Abbreviations and Symbols page. Group 2 data was not significant ($P \leq 0.12$).

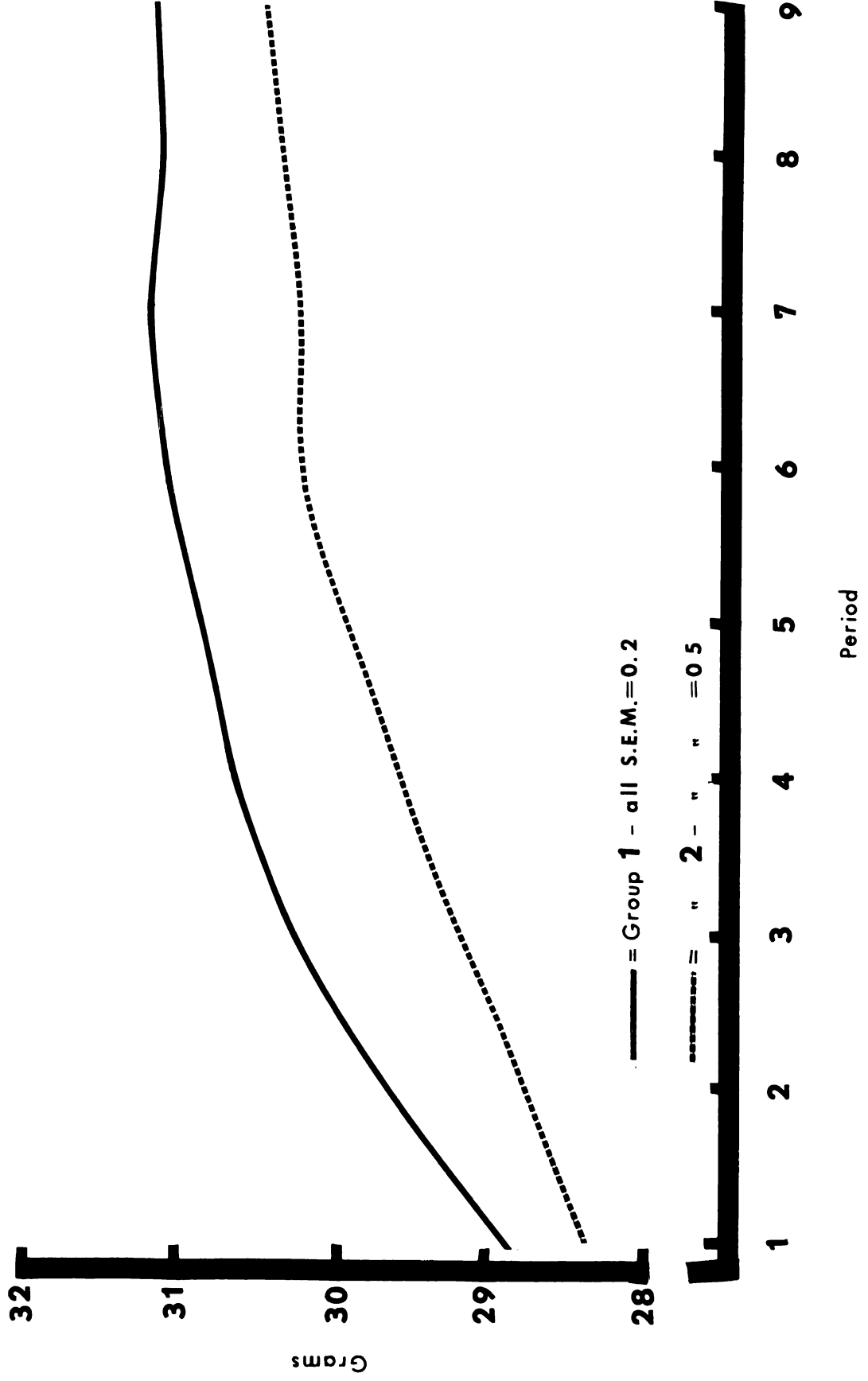
Figure 3). The orthogonal polynomials indicated a linear and quadratic shape of the response curve of this time effect.

In contrast to these data, Hinkson et al. (1967, 1970) reported the level of dietary calcium did not affect egg weight or eggshell-plus-membrane thickness of pheasant eggs. Their data on egg weight averages were very similar to the data of the present study. Hinkson et al. (1970) fed dietary calcium treatments of 0.9, 1.8, 2.5, and 3.7 percent and 0.6 percent available phosphorus. They reported average egg weights of 30, 31, 30, and 31 grams/egg, for the respective calcium level treatments. Labisky and Jackson (1969) reported the weight of eggs laid by yearling and 2-year-old pheasant hens did not decline significantly toward the end of the laying season. Average weights of eggs from one-, two-, and three-year-old pheasant hens was 28.7, 28.5, and 28.3 grams, respectively. Greeley (1962) reported pheasant egg weight averages of 31.2, 29.2, 30.4, 32.8, and 32.8 grams for hens fed dietary treatments of 0.37, 0.63, 1.09, 2.01, and 2.34 percent calcium, respectively. The dietary available phosphorus was 0.53-0.73 percent.

Atkinson et al. (1967) reported that dietary calcium did not affect turkey egg weight, among several other parameters.

Anderson (1967) suggested that chicken egg size and eggshell thickness are related to independent physiological mechanisms which apparently responded differently to calcium and/or phosphorus balances or imbalances during the growing period.

Figure 3. Effect of time on the egg weight (in grams) of pheasants over consecutive ten-day periods. Groups are defined on the Abbreviations and Symbols page.



For Group 2 there was a significant ($P \leq 0.029$) phosphorus by period interaction. For both Groups 1 and 2 the calcium by phosphorus interaction effect on the egg weight was not significant ($P > 0.05$), and the specific averages within this effect were not significant ($P > 0.20$). The approximate totals of intact eggs produced by hens of all treatments during the experiments were: E1 - 11,506; E2 = 9,013; and E3 = 14,524. All these eggs were weighed ± 0.01 gram. This information was then summarized by periods for statistical analysis.

Eggshell Weight as a Percentage of Total Egg Weight

Again, the replicate effect of Group 1 was primarily caused by the lower ($P \leq 0.01$) mean for experiment one data. The experiment averages $\pm$ SEM were: E1 = 9.06 ± 0.04 ; E2 = 9.50 ± 0.03 ; E3 = 9.58 ± 0.03 percent. These data are similar to that reported by King (1978). The cause of the lower value for replicate one is unclear, especially because the eggshell thickness average was not low for the first floor replicate.

In both Groups 1 and 2, calcium at 1.5 percent of the ration resulted in a significantly lower ($P \leq 0.01$) eggshell weight as a percentage of the total egg weight (Table 10). Thus, 1.5 percent calcium may represent a dietary calcium level which was below the practical lower limit for laying hen pheasants. Hinkson et al. (1967) reported that 1.8 percent dietary calcium may be approaching the marginal level for pheasant egg production. The relationship of eggshell percentage of total egg weight response to dietary level or

Table 10. Effect of dietary calcium on pheasant eggshell weight as a percentage of the total egg weight.

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM [*]	mean $\pm$ SEM [*]
1.5	9.07 $\pm$ 0.04 ^a	9.28 $\pm$ 0.09 ^a
2.1	9.43 $\pm$ 0.04 ^b	9.56 $\pm$ 0.09 ^b
2.7	9.49 $\pm$ 0.05 ^b	9.74 $\pm$ 0.09 ^b
3.3	9.53 $\pm$ 0.05 ^b	9.73 $\pm$ 0.09 ^b

* Means within columns with different superscripts are significantly different ($P \leq 0.05$).

calcium was linear and quadratic in Group 1, see Table 10.

In both Groups 1 and 2, time adversely affected the eggshell weight percentage values (Table 11 and Figure 4). A deficiency of calcium or an extended period of lay would be expected to bring about a gradual thinning of the eggshell, followed by a cessation of egg production (Sturkie, 1965); see Tables 7, 11, 12, 13, and Figures 2 and 4. The dietary treatments, as summarized in Groups 1 and 2 are ranked in Table 12 according to their effect on the percentage eggshell. King (1978) concluded that 2.2-2.6 percent dietary calcium to be the optimum range for proper eggshell quality of pheasant eggs.

Eggshell thickness (in mm.)

All eggshell thickness values represent the air-dried eggshell plus the shell membranes. Experiment effects on eggshell thickness were highly significant for eggs from hens in Group 1. These thickness values were significantly different but were in opposite order to that expected ($E1 = 0.302$; $E2 = 0.295$; and $E3 = 0.294$; and SEM was 0.001 for all means). When comparing these data with the eggshell percentage of the total egg weight, the first floor experiment would have been expected to have the thinnest eggshell (the eggshell percentage and thickness are obviously measures of eggshell quantity). An explanation of this anomaly would be that the eggshell thickness data was subject to rounding errors. The micrometer used for all egg measurements was only accurate to one decimal place with the second place estimated. Therefore,

Table 11. Effect of time on pheasant eggshell weight as a percentage of the total eggshell weight; and on eggshell thickness (in mm.).

Period	Group 1		Group 2	
	Shell Pct.@	Shell \$ Thickness	Shell Pct.@	Shell \$ Thickness
1	9.8 $\pm$ 0.07 ^c	0.302 ^{de}	10.0 $\pm$ 0.09 ^e	0.301 ^d
2	9.8 0.05 ^c	0.308 ^e	9.9 0.07 ^e	0.302 ^d
3	9.6 0.06 ^{bc}	0.305 ^{de}	9.6 0.12 ^{bcd}	0.293 ^{cd}
4	9.6 0.06 ^{bc}	0.304 ^{de}	9.8 0.07 ^{de}	0.299 ^d
5	9.4 0.07 ^{abc}	0.299 ^d	9.6 0.09 ^{bcd}	0.293 ^{cd}
6	9.5 0.06 ^{bc}	0.304 ^{de}	9.6 0.07 ^{cd}	0.296 ^{cd}
7	9.4 0.06 ^{abc}	0.299 ^d	9.6 0.08 ^{cd}	0.295 ^{bcd}
8	9.1 0.09 ^{ab}	0.291 ^{bc}	9.6 0.08 ^{bcd}	0.295 ^{bcd}
9	9.1 0.09 ^{ab}	0.288 ^{ab}	9.5 0.09 ^{bc}	0.291 ^{bc}
10	9.1 0.07 ^{ab}	0.291 ^{bc}	9.4 0.08 ^{abc}	0.287 ^{ab}
11	9.1 0.05 ^{ab}	0.287 ^{ab}	9.3 0.09 ^{ab}	0.282 ^a
12	8.9 0.07 ^a	0.284 ^a	9.2 0.08 ^a	0.283 ^a

* Means within a column with different superscripts are significantly different (P $\leq$ 0.05).

Groups 1 and 2 are defined on the Abbreviations and Symbols page. The 12 periods represent the average for all data from treatments on one day each week, for 12 consecutive weeks.

@ Shell Pct. represents eggshell weight as a percentage of the total egg weight mean $\pm$ SEM.

\$ Represents the eggshell thickness means (in mm.). Due to homogenous variances all SEM = 0.002.

Table 12. Effect of various dietary calcium and phosphorus combinations on the pheasant eggshell weight as a percentage of total egg weight. Part 1.

Group 1				P greater than		
Ca:P Ratio	Treat-ment	mean $\pm$ SEM*		0.20	0.10	0.05
9.0:1	9	9.64	$\pm$ 0.09			
7.0:1	5	9.59	0.09			
5.5:1	16	9.59	0.09			
6.6:1	15	9.58	0.08			
6.8:1	10	9.57	0.09			
8.3:1	14	9.52	0.08			
4.5:1	12	9.42	0.09			
5.3:1	6	9.42	0.07			
11.0:1	13	9.41	0.10			
4.2:1	7	9.41	0.06			
5.4:1	11	9.33	0.10			
3.5:1	8	9.27	0.09			
3.0:1	3	9.09	0.09			
3.8:1	2	9.07	0.08			
2.5:1	4	9.06	0.08			
5.0:1	1	9.06	0.08			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are on two pages; Groups 1 and 2 are defined on the Abbreviations and Symbols page.

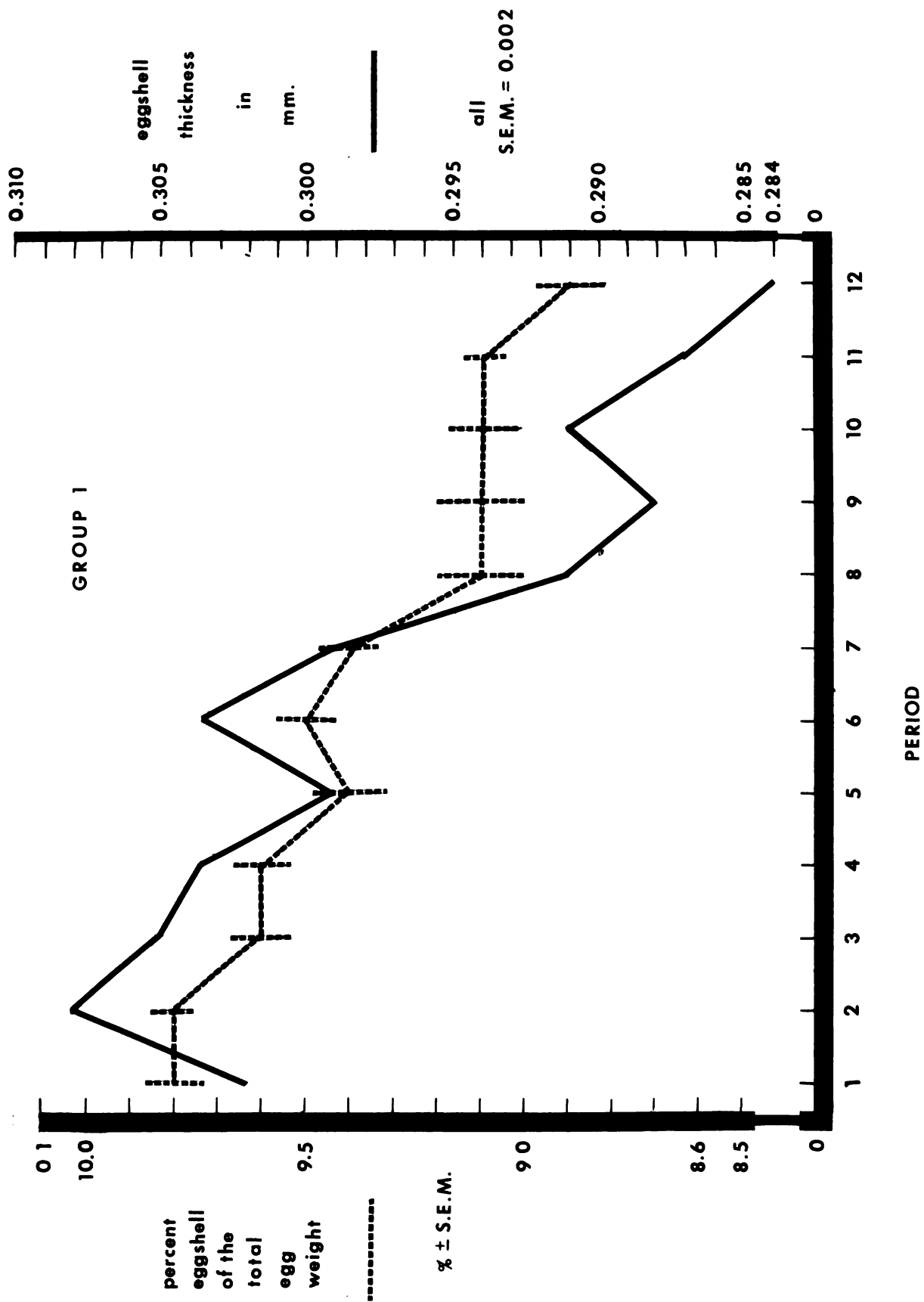
Table 12. Effect of various dietary calcium and phosphorus combinations on the pheasant eggshell weight as a percentage of total egg weight. Part 2.

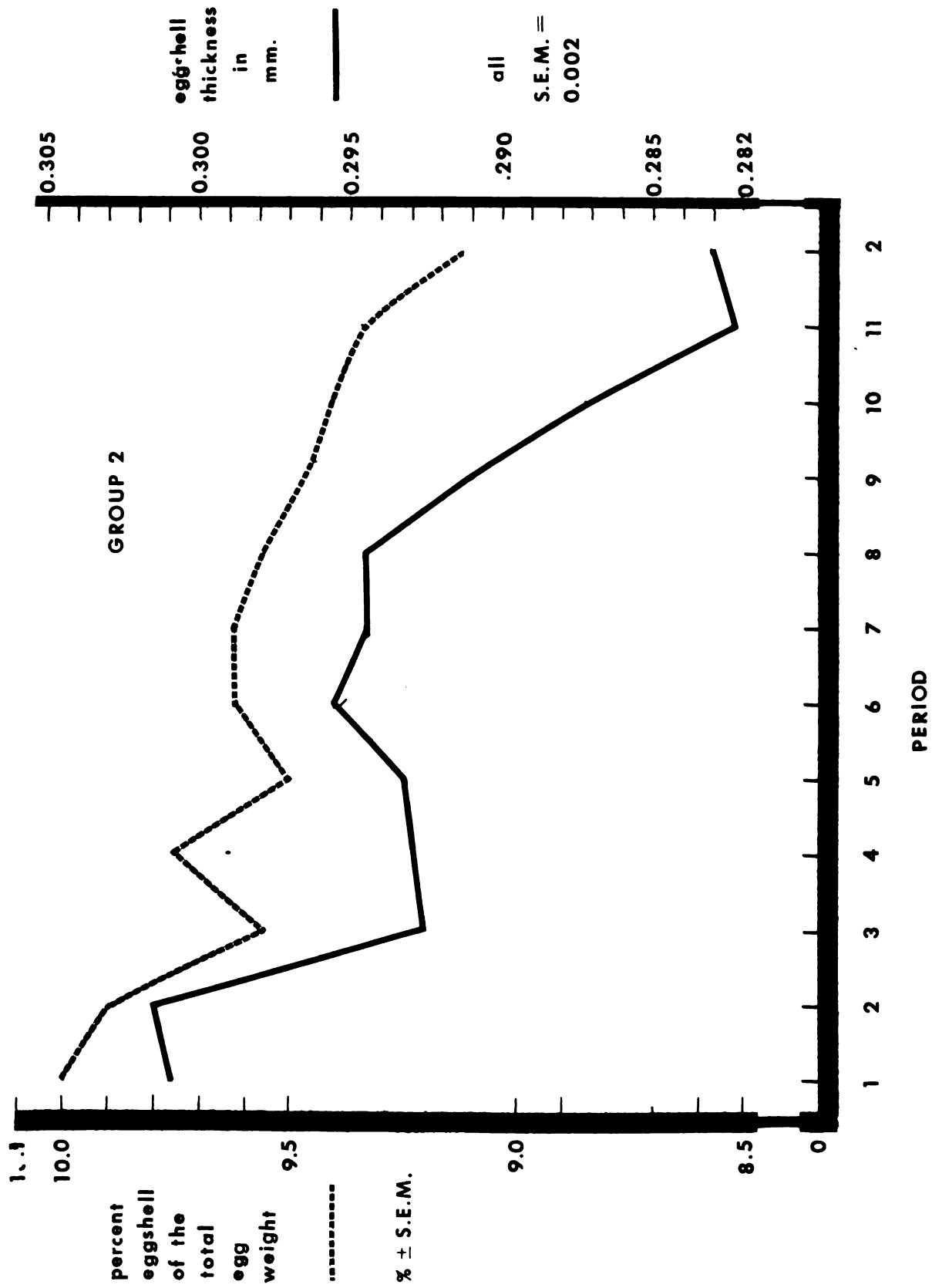
Group 2					
Ca:P Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
6.6:1	15	10.04 $\pm$ 0.10			
4.5:1	12	9.93 0.11			
9.0:1	9	9.89 0.07			
5.5:1	16	9.71 0.06			
3.5:1	8	9.67 0.10			
11.0:1	13	9.64 0.10			
4.5:1	10	9.58 0.09			
4.2:1	7	9.56 0.07			
5.4:1	11	9.56 0.12			
7.0:1	5	9.65 0.10			
8.3:1	14	9.53 0.09			
2.5:1	4	9.49 0.10			
5.3:1	6	9.45 0.09			
3.0:1	3	9.32 0.10			
3.8:1	2	9.24 0.11			
5.0:1	1	9.07 0.13			

* Means within the range of a line are not significantly different for each level of significance.

See notes in Part 1 for other information.

Figure 4. Effect of time on the eggshell as a percentage of the total egg weight; and on eggshell thickness (in mm.). Data from each period represent the total eggs collected on the same day on 12 consecutive weeks. Data are from all experiments. Data are on two pages, one for each Group. Groups 1 and 2, as well as experiments are defined on the Abbreviations and Symbols page.





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2. The second part of the document is a list of names and titles, including "The Hon. Mr. Justice" and "The Hon. Mr. Justice".

the replicate effect on eggshell thickness may be an artifact. The eggshell thickness was determined twelve times during the course of each experiment, using the total egg production for one day. The approximate number of observations recorded during each experiment was: 1,510 for all experiment one treatments; 1,277 for the experiment two treatments; and 1,991 measurements for the experiment three treatments. These figures were summarized to obtain equal replication for the statistical analysis.

For both Groups 1 and 2 there was a significant calcium effect on eggshell thickness ($P \leq 0.0005$ and ≤ 0.01 , respectively). This data is shown in Table 13. The 1.5 percent dietary calcium level was low enough to only cause a trend toward a decreased egg production, but there was a significant ($P \leq 0.01$) reduction in eggshell weight as a percentage of total egg weight (see Table 10) and a significant ($P \leq 0.05$) reduction in the thickness of the eggshells (Table 13).

Shown in Table 14 is the ranking of treatment combination means of eggshell thickness as determined for Groups 1 and 2. These calcium by phosphorus treatment combination averages are ranked according to their effectiveness in maintaining a thick eggshell.

These data indicate the pheasant eggshell is similar to, but thinner than, the chicken eggshell (about 0.325 mm.-- Owings et al., 1977) and thinner than the turkey eggshell (0.325-0.372 mm-Jensen et al., 1963; and 0.367-0.400 mm-Balloun and Miller, 1964).

Table 13. Effect of dietary calcium on pheasant eggshell thickness (in mm.).

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM [*]	mean $\pm$ SEM [*]
1.5	0.289 $\pm$ 0.003 ^a	0.286 $\pm$ 0.003 ^a
2.1	0.299 $\pm$ 0.0004 ^b	0.294 $\pm$ 0.0003 ^{ab}
2.7	0.300 $\pm$ 0.001 ^b	0.299 $\pm$ 0.003 ^b
3.3	0.300 $\pm$ 0.001 ^b	0.293 $\pm$ 0.003 ^{ab}

* Means within columns with different superscripts are significantly different ($P \leq 0.05$).

Means represent the thickness of the eggshell plus the eggshell membranes.

Table 14. Effect of various dietary calcium and phosphorus combinations on the pheasant eggshell thickness. Part 1.

Group 1			P greater than		
Ca:P Ratio	Treat- ment	mean*	0.20	0.10	0.05
9.0:1	9	0.307			
7.0:1	5	0.304			
6.8:1	10	0.303			
6.6:1	15	0.301			
4.2:1	7	0.301			
5.5:1	16	0.301			
8.3:1	14	0.300			
5.3:1	6	0.300			
4.5:1	12	0.297			
11.0:1	13	0.296			
5.4:1	11	0.295			
3.5:1	8	0.293			
3.8:1	2	0.290			
3.0:1	3	0.289			
2.5:1	4	0.288			
5.0:1	1	0.287			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are on two pages; Groups 1 and 2 are defined on the Abbreviations and Symbols page. Eggshell thickness values represent the eggshell plus eggshell membranes. The SEM of all means of Group 1 was 0.003 (homogeneous variance).

Table 14. Effect of various dietary calcium and phosphorus combinations on the pheasant eggshell thickness. Part 2.

Group 2			
Ca:P Ratio	Treat- ment	mean *	P greater than
			0.20 0.10 0.05
4.5:1	12	0.308	
6.6:1	15	0.304	
9.0:1	9	0.304	
7.0:1	5	0.297	
5.5:1	16	0.294	
3.5:1	8	0.294	
6.8:1	10	0.294	
5.3:1	6	0.293	
5.4:1	11	0.292	
4.2:1	7	0.292	
11.0:1	13	0.290	
2.5:1	4	0.290	
3,0:1	3	0.288	
3.8:1	2	0.286	
8.3:1	14	0.285	
5.0:1	1	0.279	

* Means within the range of a line are not significantly different for each level of significance.

The largest SEM was 0.0004.

See notes in Part 1 for other information.

Also, Hinkson et al. (1967) found no calcium effect on pheasant eggshell plus membrane thickness. Hinkson et al. (1970) reported that dietary calcium level did not alter the pheasant eggshell plus membrane thickness and reported values that were about 13 or 14/1000 inch (0.330-0.356 mm.).

Greeley (1962) concluded that the effect of higher dietary calcium resulting in thicker pheasant eggshells was due to variation in the shell rather than variation in the thickness of the eggshell membrane. He reported a range (in microns) for eggshell-plus-membrane thickness of 234 to 294, for dietary calcium concentration range of 0.37 to 2.34 percent. These data are similar to that presented from the present study. He also noted that the eggshell thickness of eggs from hens fed the lower calcium diets became thinner with time.

The period effect on the eggshell thickness means was linear ($P \leq 0.01$) for both Groups 1 and 2, according to the orthogonal polynomial statistics. For both Groups 1 and 2 there was a decline in the eggshell thickness over time (Table 11 and Figure 4), which was also reported by Harms and Waldroup (1971).

Eggshell Membrane Thickness

For both Groups 1 and 2, the eggshell membrane thickness values were analyzed for three periods. These data were taken from one day's egg production on three successive weeks. For Group 1, there was a trend for high calcium ($P \leq 0.096$) and low phosphorus ($P \leq 0.071$) to individually lower the eggshell

membrane thickness. The calcium by period interaction was significant ($P \leq 0.007$). The period values were: 0.031; 0.032; and 0.033, all $SEM=0.0005$ mm, for periods one through three, respectively. These values are quite similar and probably do not reflect a true difference over time because of the initial rounding error inherent in the eggshell membrane thickness measurements, as explained in the eggshell thickness discussions.

The Group 1 calcium by phosphorus interaction means were used to rank the effect of dietary treatment combinations on the eggshell membrane thickness (Table 15). The range of means for Group 2 data was 0.029-0.035 mm. Apparently, there was at least a trend for a relationship between low dietary calcium and higher eggshell membrane thickness values. Greeley (1962) reported pheasant eggshell membranes ranged in thickness from 21 to 26 microns, for dietary calcium concentrations of 0.37 to 2.34 percent, which is thinner than the data of the present study. There was no dietary effect on their eggshell membrane thickness.

Blood Calcium and Phosphorus

All these data are from the female pheasants of the three adult experiments.

1. Calcium

In Group 1 there was only a significant experiment effect ($P \leq 0.001$) on the blood plasma calcium concentration. Obviously the experiment one mean was causing the significance of this effect: $E1 = 23.7 \pm 1.5$ mg; $E2 = 29.9 \pm 0.9$

Table 15. Effect of various dietary calcium and phosphorus combinations on the pheasant eggshell membrane thickness (mm.).

Group 1					
Ca:P Ratio	Treat- ment	mean*	P greater than		
			0.20	0.10	0.05
5.3:1	6	0.036			
4.2:1	7	0.035			
3.0:1	3	0.034			
3.8:1	2	0.034			
6.6:1	15	0.032			
9.0:1	9	0.032			
2.5:1	4	0.032			
3.5:1	8	0.032			
4.5:1	12	0.032			
8.3:1	14	0.031			
5.0:1	1	0.031			
6.8:1	10	0.031			
5.4:1	11	0.031			
5.5:1	16	0.031			
7.0:1	5	0.030			
11.0:1	13	0.029			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Group 1 is defined on the Abbreviations and Symbols page.

mg; and E3 = 29.6 ± 1.0 mg Ca/100 ml plasma. The reason this entire experiment mean was so much lower than the rest is unclear as the samples were not analyzed by group. Roland et al. (1972) have shown a transient dietary restriction effect on laying hen chicken serum calcium levels. They established definite patterns of serum and feces calcium in relation to time of day and to oviposition. Serum calcium concentration was opposite to the feces and dietary intake pattern, but it coincided with time of oviposition. They listed several references to state that the literature is replete with conflicting reports of chicken blood calcium levels. They reported serum concentrations in chickens to be about 19-22 mg. percent.

As summarized for Group 1, hens fed the two lower dietary calcium levels did tend to have lower blood calcium than those fed the two higher dietary calcium treatments (Table 16). The range for Group 1 calcium by phosphorus interaction averages was 22-31 mg Ca/100 ml plasma. These treatment combination averages of blood calcium as determined in Group 2 were also not significant ($P > 0.20$). The range for Group 2 treatment combinations was 23-37 mg Ca/100 ml plasma.

Miller et al. (1977a, b) reported on the daily cyclic nature of chicken plasma calcium and phosphorus levels relative to oviposition. In the 1977a paper, they reported ranges of 33.2-34.6 mg Ca/100 ml serum and 4.55-6.71 mg phosphorus/100 ml serum for the laying hen chicken. In the 1977b paper, they reported similar values for serum phosphorus (4.88-6.08 mg. percent).

Table 16. Effect of dietary calcium on adult hen-pheasant plasma calcium concentration (mg calcium/100 ml plasma).

Percent Dietary Calcium	Group 1		Group 2	
	mean	$\pm$ SEM*	mean	$\pm$ SEM*
1.5	26.0	$\pm$ 1.3 ^a	25.5	$\pm$ 1.8 ^a
2.1	26.4	$\pm$ 1.9 ^a	28.0	$\pm$ 1.8 ^{ab}
2.7	29.8	$\pm$ 1.8 ^a	33.8	$\pm$ 1.8 ^c
3.3	28.6	$\pm$ 1.1 ^a	30.9	$\pm$ 1.8 ^{bc}

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Treatments are defined in Appendix B, Table 1.
Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Anderson and Stewart (1973) reported blood of juvenile pheasants to have a concentration of 49 ± 10 or 60 ± 5 micrograms calcium/100 grams wet weight and the blood of adults to have 110 ± 4 or 145 ± 43 micrograms calcium/100 grams wet weight. Blood phosphorus for juveniles was 546 ± 79 or 684 ± 27 micrograms, and adults 687 ± 79 or 741 ± 28 micrograms phosphorus/gram wet weight. These values appear to be different from the levels of these plasma minerals determined in the present experiments.

2. Phosphorus

The blood phosphorus concentrations as determined for Group 1 only had an experiment effect. The plasma phosphorus concentration averages for the three experiments were: E1 = 5.6 ± 0.3 ; E2 = 5.7 ± 0.2 ; and E3 = 7.1 ± 0.4 mg phosphorus/100 ml plasma $\pm$ SEM.

For Group 2 data there was a significant effect of the four replicates ($P \leq 0.012$), as well as a significant dietary calcium and dietary phosphorus concentration effect (both $P \leq 0.0005$) on the plasma phosphorus levels. This replicate effect of Group 2 was due to the chance allocation of hens to treatments, as these means represent the average over all treatments, for a particular replicate.

Shown in Table 17 are the Group 2 averages of plasma phosphorus as summarized by the dietary calcium or phosphorus treatments. The 3.3 percent dietary calcium treatment resulted in depressed plasma phosphorus levels. The lowest (0.3 percent) dietary phosphorus treatment resulted in elevated plasma phosphorus levels.

Table 17. Effect of dietary calcium or phosphorus on the adult hen-pheasant plasma phosphorus concentration (mg P/100 ml plasma).

Percent Dietary Calcium	mean $\pm$ SEM [*]	Percent Dietary phosphorus	mean $\pm$ SEM [*]
1.5	7.62 $\pm$ 0.43 ^{bc}	0.3	8.64 $\pm$ 0.70 ^b
2.1	8.27 $\pm$ 0.61 ^c	0.4	7.01 $\pm$ 0.47 ^a
2.7	7.11 $\pm$ 0.61 ^b	0.5	6.59 $\pm$ 0.30 ^a
3.3	5.39 $\pm$ 0.29 ^a	0.6	6.16 $\pm$ 0.50 ^a

* Means within a column with different superscripts are significantly different ($P \geq 0.05$).

Treatments are defined in Appendix B, Table 1.
Data are from only Group 2, which is defined on the Abbreviations and Symbols page.

There was no difference between treatment combinations of Group 1 (Ca by P interaction). However, in Group 2 there was a difference among treatments due to this effect. Shown in Table 18 is the ranking of treatment combination averages of Group 2.

Adult Feed Consumption

In Group 1 the experiment totals (E1, E2, and E3) for each treatment combination were used for statistical evaluation of the adult feed consumption as measured in grams of feed consumed/bird/day, (g/b/d). There was no difference between the treatment combination averages (Tukey test, $P \geq 0.20$). The range of means $\pm$ SEM was 69.9 to 74.5 g/b/d. In Group 1, only the experiment effect was significant ($P \leq 0.017$). These experiment averages were: E1 = 67.4; E2 = 71.0; and E3 = 69.8, all ± 0.85 g/b/d. The value of the caged hens of Group 1 was between that of the floor-housed birds so the effect of the different management systems was apparently a random one.

There was a trend for the phosphorus effect of Group 1 toward significance ($P \leq 0.085$) probably due to the greater feed consumption of hens consuming feed with 0.3 percent dietary available phosphorus. These hens also laid more eggs (Table 6). There was not a similar trend in Group 2. This may be an internal compensating mechanism for the lower dietary phosphorus or merely an increased need for nutrients due to a higher egg production of these hens (Table 6) or to a combination of these.

Table 18. Effect of various dietary calcium and phosphorus combinations on the adult pheasant's concentration of plasma phosphorus (mg P/100 ml plasma).

Group 2				P greater than		
Ca:P Ratio	Treatment	mean	$\pm$ SEM*	0.20	0.10	0.05
7.0:1	5	10.75	$\pm$ 1.34			
9.0:1	9	9.8	0.89			
5.0:1	1	8.35	1.36			
5.3:1	6	7.85	0.66			
3.5:1	8	7.80	1.15			
3.8:1	2	7.73	0.97			
3.0:1	3	7.30	0.53			
6.8:1	10	7.13	1.29			
2.5:1	4	7.13	0.68			
4.2:1	7	6.68	0.38			
5.4:1	11	6.28	0.90			
6.6:1	15	6.10	0.51			
11.0:1	13	5.65	0.60			
8.3:1	14	5.35	0.45			
4.5:1	12	5.23	0.61			
5.5:1	16	4.48	0.60			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Group 2 is defined on the Abbreviations and Symbols page.

Supplemental information obtained from the caged male breeders was that of their level of feed consumption. The averages of feed consumption of these caged males (in grams of feed consumed/male/day) are presented in Table 19.

For Group 2, the data were treated as those of Group 1 (in this case using the replicate experiment totals of each treatment combination). There were no significant ANOVA F-statistics. The range of treatment combination averages was 62.9 ± 2.7 to 75.0 ± 3.1 grams/bird/day. In addition, the data evaluated using the replicate values of each period. There was only a significant period effect for the latter statistical analysis. These means $\pm$ SEM were: 61.4 ± 0.7 ; 72.7 ± 0.9 ; 75.3 ± 0.9 ; and 69.9 ± 1.2 grams/bird/day. These data represent the three 28-day periods and the value for the last week. All were significantly different from each other ($P \leq 0.05$). These averages paralleled the egg production curve pattern (Table 7, Figure 2). Treatment combination means were not significantly different from each other (Tukey; $P > 0.20$).

Hinkson et al. (1970) reported a range of floor-reared pheasants feed consumption from 96 to 111 grams/bird/day. These values included the feed consumed by the males. Their means were about 30 grams/bird/day greater than the averages determined in these experiments. Perhaps Hinkson et al. (1970) had a feed wastage problem, which is very easy to do with pheasants.

Table 19. Average feed consumption of caged adult male Ring-necked pheasants (in grams consumed/male/day).

Period	Replicate 1	Replicate 2
1	55	57
2	70	68
3	68	69
4	59	67
weighted mean	64	65

There were three (periods 1-3) 28-day periods with the fourth period lasting for seven days. There were 24 males per replicate. The feed for both replicates 1 and 2 was a commercial pheasant layer-breeder ration.

Hurwitz et al. (1969) reported that high (4.5 percent) dietary calcium suppressed feed intake of chicken laying hens but improved the feed conversion, and lowered the body weight of the hens. This effect tended to be greater in the presence of dietary fat. Gleaves et al. (1977) indicated that feed intake of adult chicken laying hens was not influenced by dietary calcium. They used dietary calcium levels of 1.8; 3.6; and 5.4 percent. Gleaves et al. (1977) reported these chicken laying hens which consumed the low-calcium rations laid eight percent fewer eggs and consumed as much feed as their better producing counterparts. This would indicate that in the experiments by Gleaves et al. (1977), that there was possibly a dietary calcium effect on feed consumption in that the hens may have attempted to compensate for the low dietary calcium by consuming more feed.

Adult Bone (Tibia)

1. Percent dry fat-free bone (dfffb); in mg dfffb/100 mg tibia.

In Group 1 the caged layers, on the average, had a greater percentage of dfffb than did hens of the second floor experiment ($E3 = 71.2 \pm 1.36$ and $E2 = 66.4 \pm 0.76$) ($P \leq 0.01$). No samples were taken from hens of experiment one.

There was a significant linear response of tibia dfffb to dietary calcium concentration ($P \leq 0.05$) in both Groups 1 and 2--see Table 20.

In both Groups 1 and 2 the 1.5 percent dietary calcium treatments resulted in lower tibia dfffb means than the other

Table 20. Calcium effect on adult pheasant tibia percentage dry fat-free bone (dffb), in mg dffb/100 mg tibia.

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM*	mean $\pm$ SEM*
1.5	63.7 $\pm$ 2.8 ^a	63.8 $\pm$ 1.3 ^a
2.1	70.0 $\pm$ 1.2 ^b	73.2 $\pm$ 1.3 ^{bc}
2.7	69.5 $\pm$ 1.4 ^b	71.4 $\pm$ 1.3 ^b
3.3	72.1 $\pm$ 1.8 ^b	76.5 $\pm$ 1.3 ^c

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Treatments are defined in Appendix B, Table 1.
Groups 1 and 2 are defined on the Abbreviations and Symbols page.

dietary concentrations of calcium. The dffb means from birds receiving the other levels of higher dietary calcium were similar to each other in Group 1 but not Group 2 (Table 20). Using either grouping of the data would indicate the 1.5 percent dietary calcium was not adequate, but that 2.1 percent and greater dietary calcium was adequate, as measured by the plateau of tibia dffb (Table 20). Dietary phosphorus was not low enough to affect a change in dffb using either grouping of the data (Groups 1 or 2).

Shown in Table 21 are the significant treatment combination averages as determined for Groups 1 and 2.

2. Percent ash in mg ash/100 mg dffb

There was a significant experiment effect in Group 1 on the dffb percentage ash ($P \leq 0.031$). These means were: $E2 = 66.0 \pm 0.4$; and $E3 = 65.1 \pm 0.6$ percent. These significant effects of experiments on tibia dffb and the dffb percentage ash were probably due to chance because they are opposite each other.

Hinkson et al. (1970) found no differences between means of dffb percentage ash due to dietary calcium treatments of 0.9; 1.8; 2.5; and 3.7 percent. Their means for the pheasant hen femur dffb percentage ash ranged from 62.99 through 65.17 percent, which is similar to the values for ash determined in the present study. King (1978) also found no difference in the bone ash of the femur and tibia of adult female pheasants fed rations with calcium at 1.4-3.8 percent.

Table 21. Effect of various dietary calcium and phosphorus treatment combinations on the adult pheasant tibia percentage dry fat-free bone (dffb). Part 1.

Group 1						
Ca:P Ratio	Treat- ment	mean $\pm$ SEM*		P greater than		
				0.20	0.10	0.05
6.6:1	15	73.9	$\pm$ 3.8			
5.5:1	16	73.4	3.6			
4.5:1	12	71.5	3.1			
6.8:1	10	71.5	1.0			
11.0:1	13	71.3	4.5			
4.2:1	7	70.8	2.4			
5.3:1	6	70.7	3.2			
8.3:1	14	70.1	5.7			
7.0:1	5	69.5	4.3			
3.5:1	8	69.1	2.6			
5.4:1	11	68.6	5.2			
9.0:1	9	66.4	1.4			
5.0:1	1	65.2	1.5			
2.5:1	4	64.9	1.9			
3.0:1	3	64.5	3.8			
3.8:1	2	60.3	0.1			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are on two pages; Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Table 21. Effect of various dietary calcium and phosphorus treatment combinations on the adult pheasant tibia percentage dry fat-free bone (dffb). Part 2.

Group 2				P greater than		
Ca:P Ratio	Treat-ment	mean	$\pm$ SEM*	0.20	0.10	0.05
6.6:1	15	77.7	$\pm$ 3.3			
5.5:1	16	76.9	1.7			
11.0:1	13	75.8	3.6			
8.3:1	14	75.7	2.4			
4.5:1	12	74.5	1.9			
5.3:1	6	74.0	2.0			
5.4:1	11	73.7	3.3			
7.0:1	5	73.7	5.3			
4.2:1	7	73.2	0.9			
6.8:1	10	72.5	2.5			
3.5:1	8	71.7	3.4			
3.0:1	3	68.2	3.2			
9.0:1	9	65.0	4.0			
5.0:1	1	63.7	3.5			
2.5:1	4	63.0	1.3			
3.8:1	2	60.4	3.1			

* Means within the range of a line are not significantly different for each level of significance.

See notes in Part 1 for other information.

In both Groups 1 and 2, calcium at 1.5 percent of the ration resulted in a lower amount of bone ash than the other calcium treatments ($P \leq 0.01$), see Table 22.

The calcium by phosphorus interaction (treatment combination) averages of dffb percentage ash are ranked in Table 23. For both Groups 1 and 2 the lower (1.5 percent) dietary calcium treatments resulted in the least dffb percentage ash.

Chambers et al. (1966) reported femur percentage ash levels of 62.73-71.57 percent, with no difference between the sexes, which is similar to the data from this study. Greeley (1962) reported ash percentages of pheasant femurs and tibias. The femur data was three to four percentage points greater than that of the tibia (pre-laying hen's femur was 66.77, and the tibia was 63.54 percent). Final means of the tibia percentage ash were about 60.5; 60.4; 61.3; 62.4; and 64.2 percent for dietary calcium levels of 0.37; 0.63; 1.09; 2.01; and 2.34 percent, respectively. These data are similar, as is the response to dietary calcium, to the tibia data reported in the present study.

Greeley (1962) stated there was a direct relationship of ash content in the bone to the amount of calcium in the diet, and this difference was more evident after 51-53 days than after 10 days being fed the experimental diets. However, Chambers et al. (1966) reported no such relationship. Anderson and Stewart (1973) reported the adult pheasant femur to have 78.7 ± 1.61 to 79.6 ± 1.16 grams ash/100 grams dry fat-free bone, which is somewhat greater than the data reported in the present study in which the tibia was evaluated.

Table 22. Calcium effect on adult pheasant tibia dry fat-free bone (dffb) percentage ash (mg ash/100 mg dffb).

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM*	mean $\pm$ SEM*
1.5	63.2 $\pm$ 0.6 ^a	61.8 $\pm$ 0.7 ^a
2.1	66.3 $\pm$ 0.3 ^b	66.0 $\pm$ 0.7 ^b
2.7	66.0 $\pm$ 0.5 ^b	65.6 $\pm$ 0.7 ^b
3.3	66.7 $\pm$ 0.4 ^b	66.8 $\pm$ 0.7 ^b

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Treatments are defined in Appendix B, Table 1.
Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Table 23. Effect of various dietary calcium and phosphorus combinations on the adult pheasant tibia dry fat-free bone (dffb) percentage ash. Part 1.

Group 1				P greater than		
Ca:P Ratio	Treat-ment	mean $\pm$ SEM*		0.20	0.10	0.05
5.5:1	16	67.3 $\pm$ 0.9				
4.5:1	12	67.2 0.9				
6.6:1	15	67.2 ---				
7.0:1	5	67.0 0.2				
6.8:1	10	66.9 0.1				
11.0:1	13	66.8 0.9				
5.3:1	6	66.3 0.3				
4.2:1	7	66.2 1.1				
3.5:1	8	65.9 0.2				
8.3:1	14	65.7 0.6				
5.4:1	11	65.5 0.2				
9.0:1	9	64.4 0.8				
2.5:1	4	64.3 2.2				
5.0:1	1	63.1 1.9				
3.0:1	3	62.9 0.6				
3.8:1	3	62.5 0.9				

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are on two pages; Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Table 23. Effect of various dietary calcium and phosphorus combinations on the adult pheasant tibia dry fat-free bone (dffb) percentage ash. Part 2.

Group 2				P greater than		
Ca:P Ratio	Treat-ment	mean	$\pm$ SEM*	0.20	0.10	0.05
11.0:1	13	67.3	$\pm$ 1.8			
6.6:1	15	67.2	1.1			
7.0:1	5	67.1	2.3			
6.8:1	10	67.0	1.3			
5.5:1	16	66.4	1.2			
8.3:1	14	66.2	1.5			
4.5:1	12	66.3	1.7			
5.3:1	6	66.0	1.0			
3.5:1	8	65.7	1.5			
5.4:1	11	65.6	1.7			
4.2:1	7	65.1	0.9			
9.0:1	9	63.5	0.4			
3.0:1	3	62.3	2.0			
2.5:1	4	62.1	1.0			
3.8:1	2	61.6	1.3			
5.0:1	1	61.2	2.3			

* Means within the range of a line are not significantly different for each level of significance.

See notes in Part 1 for other information.

Branion (1938) (see O'Rourke et al., 1955) stated the absolute amounts of calcium and phosphorus were important for optimal growth (of chickens) and for their bone ash; but the Ca:P ratio could vary from 1:1 to 3:1 with an optimum of 2:1 if the Vitamin D was present at an optimum level. O'Rourke et al. (1955) could not determine the requirement of dietary phosphorus for the laying pullet as the practical rations employed were not sufficiently low in phosphorus to demonstrate a deficiency. Apparently, that was the case with the adult pheasants of the present study.

Waibel et al. (1961) reported that 8 through 24-week-old turkeys averaged 64.8 mg ash/100 mg dffb, which was similar to the data reported in this trial. They reported a decreased requirement for calcium and phosphorus with increased age.

3. Ash percent calcium; in mg Ca/100 mg ash

The ash percentage calcium response to dietary calcium levels was only cubic ($P \leq 0.001$) in both Groups 1 and 2. Basically, this means there was no consistent dose response of the ash calcium content to levels of dietary calcium (Table 24). In both Groups 1 and 2 the hens fed the 2.1 percent dietary calcium treatments had the lowest concentrations of calcium in the tibia ash. Even though statistically significant, in no case were the means different by more than 1.4 percent. The averages of tibia percent calcium for the treatment combinations are ranked in Table 25. The ranking of specific treatments were similar for both Groups 1 and 2.

For aired-dried femurs (Chambers et al., 1966) reported calcium

Table 24. Calcium effect on the adult pheasant tibia ash percentage calcium (mg calcium/100 mg ash).

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM*	mean $\pm$ SEM*
1.5	37.7 $\pm$ 0.3 ^b	36.8 $\pm$ 0.2 ^b
2.1	36.8 $\pm$ 0.4 ^a	35.9 $\pm$ 0.3 ^a
2.7	38.2 $\pm$ 0.6 ^b	36.6 $\pm$ 0.2 ^b
3.3	37.9 $\pm$ 0.5 ^b	36.7 $\pm$ 0.2 ^b

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Treatments are defined in Appendix B, Table 1.
Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Table 25. Effect of various dietary calcium and phosphorus combinations on the adult pheasant tibia ash percentage calcium. Part 1.

Group 1				P greater than		
Ca:P Ratio	Treatment	mean $\pm$ SEM*		0.20	0.10	0.05
5.4:1	11	38.5	$\pm$ 1.40			
6.8:1	10	38.5	1.30			
4.5:1	12	38.3	1.35			
5.5:1	16	38.1	1.35			
5.0:1	1	38.1	0.95			
8.3:1	14	37.9	0.95			
6.6:1	15	37.9	0.75			
11.0:1	13	37.7	1.50			
3.0:1	3	37.7	0.80			
2.5:1	4	37.6	0.65			
9.0:1	9	37.5	2.15			
3.8:1	2	37.3	1.00			
3.5:1	8	37.1	1.20			
4.2:1	7	37.1	0.75			
7.0:1	5	36.9	1.20			
5.3:1	6	36.3	0.50			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are on two pages; Groups 1 and 2 are defined on the Abbreviations and Symbols page.

Table 25. Effect of various dietary calcium and phosphorus combinations on the adult pheasant tibia ash percentage calcium. Part 2.

Group 2					
Ca:P Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
6.8:1	10	37.2 $\pm$ 0.3			n/a
5.0:1	1	37.1 0.2			
5.4:1	11	37.1 0.1			
6.6:1	15	37.1 0.1			
2.5:1	4	36.9 0.6			
8.3:1	14	36.9 0.4			
3.0:1	3	36.9 0.4			
4.5:1	12	36.9 0.3			
5.5:1	16	36.7 0.2			
3.8:1	2	36.3 0.1			
4.2:1	7	36.3 0.3			
11.0:1	13	36.2 0.4			
3.5:1	8	35.9 0.9			
5.3:1	6	35.8 0.6			
7.0:1	5	35.7 0.6			
9.0:1	9	35.3 0.2			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

See notes in Part 1 for other information.

levels of 23.77 to 27.31 percent, with no difference between the sexes. If the estimates of Chambers are converted to the dffb ash percentage calcium of the present study, the data are comparable. Anderson and Stewart (1973) reported that adult pheasant femurs have about $282,400 \pm 8,200$ to $289,100 \pm 8,000$ micrograms Ca/gram of dry fat-free femur bone, which is slightly higher than the results of this study. This difference between the femur data of Anderson and Stewart (1973) and the tibia data of the present study might be expected (Greeley, 1962).

4. Ash percent phosphorus; in mg P/100 mg ash

The calcium treatments as determined for Group 1 were not statistically effective in altering the bone phosphorus levels (ANOVA, $P > 0.164$). This trend in Group 1 of the lowest (1.5 percent) dietary calcium treatment resulting in the highest adult hen pheasant tibia ash percentage phosphorus was significant (ANOVA, $P \leq 0.005$) in Group 2, see Table 26. The specific calcium treatment effects were significant, according to the Bonferroni test of means (Table 26), but these effects were not consistent between Groups 1 and 2. The treatment combination averages of tibia ash percentage phosphorus were not significantly different in Group 1 ($P > 0.20$), but were in Group 2 (Table 27). The range of means of Group 1 was: 18.0 ± 1.0 to 19.2 ± 0.2 SEM. The relative treatment rankings of this data were not consistent between the two Groups.

For air-dried femurs, Chambers et al. (1966) reported the

Table 26. Calcium effect on adult pheasant tibia ash percentage phosphorus (mg P/100 mg ash).

Percent Dietary Calcium	Group 1	Group 2
	mean $\pm$ SEM [*]	mean $\pm$ SEM [*]
1.5	19.2 $\pm$ 0.05 ^b	19.1 $\pm$ 0.12 ^b
2.1	18.6 $\pm$ 0.24 ^a	18.8 $\pm$ 0.12 ^b
2.7	18.9 $\pm$ 0.09 ^a	18.9 $\pm$ 0.12 ^b
3.3	18.7 $\pm$ 0.15 ^a	18.3 $\pm$ 0.12 ^a

* Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Groups 1 and 2 are defined on the Abbreviations and Symbols page. Treatments are defined in Appendix B, Table 1.

Table 27. Effect of various dietary calcium and phosphorus combinations on the adult hen-pheasant tibia ash percentage phosphorus (mg P/100 mg ash).

Group 2					
Ca:P Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
5.0:1	1	19.28 $\pm$ 0.14			
9.0:1	9	19.18 0.24			
5.4:1	11	19.13 0.24			
3.0:1	3	19.10 0.29			
2.5:1	4	19.05 0.48			
5.3:1	6	18.98 0.08			
7.0:1	5	18.95 0.13			
3.8:1	2	18.95 0.05			
4.2:1	7	18.90 0.15			
4.5:1	12	18.75 0.12			
6.8:1	10	18.70 0.25			
11.0:1	13	18.55 0.17			
3.5:1	8	18.50 0.35			
6.6:1	15	18.40 0.22			
8.3:1	14	18.25 0.13			
5.5:1	16	17.98 0.26			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Group 2 is defined on the Appendix and Symbols page.

phosphorus was 10.84-12.28 percent, with no difference between the sexes. If this data were converted to the dffb ash percentage phosphorus, the two sets of data are similar. Anderson and Stewart (1973) reported adult pheasant femurs to contain $84,800 \pm 3,700$ to $85,900 \pm 5,100$ micrograms phosphorus/gram dffb. These data are slightly lower than the results of the present study.

Salem and Reda (1955) showed, with balance studies, that body retention of phosphorus was depressed by high calcium levels in the diet. The data from this experiment apparently support the findings of Salem and Reda (1955). In these adults the bone was already formed at the beginning of the experiment so the final value of bone ash and mineral contents would be an indicator of the degree of depletion/repletion of the bones due to egg production. Pheasant hens have the ability to lay eggs at least sporadically when fed diets with 0.9 percent of the ration as calcium (Hinkson et al., 1970), but not when the dietary calcium is 0.63 or 0.37 percent (Greeley, 1962).

Adult Body Weight (as the percentage change)

Body weight change was measured as a percentage of the initial body weight. Only data combined as Group 1 were used for the statistical analysis.

Only an experiment effect existed for the adult body weight percent change ($P \leq 0.001$). Only hens of experiment two showed an overall gain in body weight (change = $+ 2.4 \pm 0.11$ SEM percent). The overall change of all experiments was negative 0.4 ± 0.4 SEM percent of the initial body weight (Table 28).

Table 28. Adult hen-pheasant body weight percentage change over the 90-day experiment. Data are summarized by experiment.

Experiment	change $\pm$ SEM [*]
One (floor)	-1.18 $\pm$ 0.91
Two (floor)	+2.35 0.11
Three (caged-layer)	-1.46 0.56
Total	-0.40 0.44

* Data are means $\pm$ SEM over all the treatments of that replicate.

The hens in experiments two and three were from the same parent stock and were kept in the same growing pens. The statistics only tested the percentage change in body weight and not actual body weight. No treatment affected a greater than four percentage point change in body weight (Table 29).

Owings et al. (1977) reported similar negative changes in chicken S.C.W.L. laying hen's body weight over the experimental laying period.

Likewise, Hinkson et al. (1967) found no effect of calcium level on overall change in pheasant breeder hen's body weight at the end of 18 weeks egg production.

In 1970, Hinkson et al. reported all female pheasants gained weight over the reproductive period during which they were fed rations with different calcium levels.

Woodard et al. (1977) reported weekly body weights, through 20-weeks of age, for Chinese and Mongolian Ring-necked male and female pheasants. The values presented are similar to the data collected in this study for growing and adult pheasants.

Table 29. Adult hen-pheasant body weight percentage change over the 90-day experiment. Data are summarized by treatments over all experiments.

Trt. * Comb. *	Pct. D. Ca *	Pct. D. P *	Change mean $\pm$ SEM		No. * hens
1	1.5	0.3	+4.12	$\pm$ 2.32	38
2	1.5	0.4	-2.58	$\pm$ 2.14	35
3	1.5	0.5	-3.44	1.38	39
4	1.5	0.6	+0.15	1.85	35
mean of the 1.5 percent dietary calcium effect			-0.43	0.99	147
5	2.1	0.3	-1.08	2.63	39
6	2.1	0.4	-0.96	1.32	40
7	2.1	0.5	+0.71	1.82	40
8	2.1	0.6	+0.99	2.69	38
mean of the 2.1 percent dietary calcium effect			-0.09	0.95	157
9	2.7	0.3	-0.26	1.31	38
10	2.7	0.4	+0.78	1.93	38
11	2.7	0.5	+1.58	1.72	38
12	2.7	0.6	-2.12	1.89	40
mean of the 2.7 percent dietary calcium effect			-0.03	0.87	154
13	3.3	0.3	+0.86	1.46	38
14	3.3	0.4	-3.12	1.54	39
15	3.3	0.5	-1.88	1.36	40
16	3.3	0.6	+0.03	1.34	40
mean of the 3.3 percent dietary calcium effect			-1.04	0.72	157

Treatment combinations are also defined in Appendix B, Table 1.

* Trt. Comb. represents treatment combination; Pct. D. Ca represents the percent dietary calcium; Pct. D. P represents the percent dietary phosphorus; the no. hens represents the total of the hens left at the end of the 90 days, from all experiments of the adults experiments (E1, E2, E3).

F1 Mortality

The F1 mortality is the percentage mortality of chicks hatched from eggs laid by hens which were fed the different dietary treatments. The eggs and chicks were pedigreed by dam and wing banded at the time of hatching. The chicks were raised through three weeks of age and the number of deaths were recorded for this time period. Only Group 1 data were used for this statistical analysis.

One of the more interesting pieces of data from this research was the significant ($P \leq 0.016$) effect of the hen's dietary calcium concentration on the livability of these chicks through three weeks of age (Table 30). Chicks from the hens fed diets with the highest levels of calcium (2.7 and 3.3 percent) had higher mortality than the chicks from the lower calcium content treatments. Only the mortality of chicks from hens fed the 3.3 percent dietary calcium treatments was different from chicks whose parents were fed rations with the two lower calcium concentrations. The chick mortality from hens fed the 2.7 percent calcium diets was not different from the mortality of groups of chicks from hens fed any of the other levels of dietary calcium, (Table 30). No explanation will be proposed at this time for these results as more work should be done to determine if this is a true effect.

Table 30. Effect of dietary calcium on percentage mortality of offspring of pheasant hens fed rations with various calcium and phosphorus concentrations.

Percent Dietary Calcium ^{**}	mean $\pm$ SEM [*]
1.5	13.3 $\pm$ 0.9 ^a
2.1	13.0 $\pm$ 1.3 ^a
2.7	15.1 $\pm$ 0.6 ^{ab}
3.3	16.9 $\pm$ 0.9 ^b

* Means with different superscripts are significantly different ($P \leq 0.05$).

** This is the dietary calcium concentration in the diet of the dam.

Data is the mortality through three weeks of age.

STARTER/GROWER DATA

Feed Consumption of Battery-reared Chicks (SC Ic and SG IIc)

The replicate effect on the feed consumption of battery-reared chicks was significant ($P \leq 0.012$). The four-week average of feed consumption for the SG Ic replicate was 14.9 and for the SG IIc replicate it was 13.0, both $SEM=0.35$ grams/chick/day.

There was a trend for higher dietary calcium to inhibit feed consumption ($P \leq 0.27$) as well as a trend for low dietary phosphorus to inhibit feed consumption ($P \leq 0.07$) of these battery-reared chicks. These averages $\pm SEM$ of feed consumption as summarized by the level of dietary calcium were: 0.6 percent = 14.4 ± 0.8 ; 1.2 percent = 14.0 ± 0.9 ; and 1.8 percent = 13.3 ± 1.2 grams/chick/day. Averages $\pm SEM$ for the dietary phosphorus effect were: 0.4 percent = 13.3 ± 0.82 ; and 0.6 percent = 14.5 ± 0.61 percent. Table 31 shows this data as evaluated by the Bonferroni t-test of means.

As shown in Table 31, at the 0.4 percent level of dietary phosphorus, the two higher levels of calcium inhibited feed intake. This inhibition was not evident with 0.6 percent dietary phosphorus. From this data (Tables 31 and 32) there was obviously a relationship between a wider Ca:P ratio, the level of available phosphorus in the ration and the resulting levels of feed intake. These relationships were exhibited in the significant interaction ($P \leq 0.02$) effect of calcium and phosphorus on feed consumption of these battery-reared chicks (Tables 31 and 32). The specific ratio of Ca:P may have had a more pronounced effect on consump-

Table 31. Dietary calcium by phosphorus interaction effect on the feed consumption of battery-reared pheasants and chicks through four-weeks of age. Data are in grams/bird/day.

Pct. D. Ca ^{**}	Percent Dietary Phosphorus			
	0.2	0.4	0.6	mean [*]
0.6	6.6 ^{***}	15.4 ± 0.7	13.5 ± 0.5	14.4 ^b
1.2	5.3 ^{***}	12.6 ± 0.1	15.5 ± 0.3	14.0 ^b
1.8	5.8 ^{***}	12.1 ± 1.2	14.6 ± 1.2	13.3 ^a
mean [*]	5.9 ^{***}	13.3 ^a	14.5 ^b	

* Means within a column or row with different superscripts are significantly different ($P \leq 0.05$).

** Pct. D. Ca represents percent dietary calcium.

*** Not used in the statistical analysis.

Data are means ± SEM, of replicates SG Ic and SG IIc. These replicates are defined on the Abbreviations and Symbols page.

Table 32. Effect of various dietary calcium and phosphorus combinations on the feed consumption of battery-reared pheasant chicks through four-weeks of age. Data are in grams/bird/day.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM [*]	P greater than		
			0.20	0.10	0.05
2.0:1	6	15.5 $\pm$ 0.32			
1.5:1	2	15.4 0.74			
3.0:1	9	14.6 1.17			
1.0:1	3	13.5 0.53			
3.0:1	5	12.6 0.14			
4.5:1	8	12.1 1.17			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

The statistical analysis did not include treatments 1, 4, or 7.

tion than the absolute levels of dietary calcium or phosphorus.

Treatment one (0.6 Ca:0.2 P) of the second floor replicate had three birds left for ashing at the twelfth week, but all other starter-grower replicates of this treatment only lived until about the fourth week of age. Therefore, not all the 0.2 percent dietary phosphorus treatments were as anorectic (all were rachitic) as they appeared.

Comparisons of Starter-, Grower-, and Flight-Aged Bird's Feed Consumption (SG IF, and SG IIF replicates, only)

Totals of starter (day old-6 week), grower (7 wk-12 wk), and flight (13 wk-16 wk) feed consumed included neither treatments one, four, or seven, nor data from the caged chicks.

For the replicate effect on feed consumption through 16-weeks of age, the means found to be statistically different from each other ($P \leq 0.038$). These means were: SG IF = 38 grams/chick/day; and SG IIF = 42 grams/chick/day.

Over the course of the 16 weeks of the experiments, many factors could be responsible for this difference. Possible the colder weather the chicks of the second floor replicate were reared in played a role in this overall difference in feed consumption means. Also, the chicks of SG IF were from a different source than the chicks of SG IIF. There was a trend toward high dietary calcium and low dietary phosphorus inhibition of feed consumption of battery-reared chicks according to the ANOVA F-statistic. In contrast to the battery-reared chick data, high dietary calcium (Table 33) levels resulted in a significant decline ($P \leq 0.045$) in feed consumption over 16-weeks. The dietary available phosphorus effect again approached

Table 33. Effect of dietary calcium on feed consumption of growing pheasants. Data are in grams consumed/bird/day.

Percent Dietary Calcium	mean $\pm$ SEM [*]
0.6	42.5 $\pm$ 3.8 ^a
1.2	41.6 $\pm$ 4.0 ^a
1.8	36.4 $\pm$ 3.4 ^b

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data from treatments 1, 4, and 7 were not included in the statistical analysis due to the nearly total mortality of chicks fed these rations. Treatments are defined in Appendix B, Table 1.

Data are means of feed consumption over the sixteen weeks of the experiment. Data are from only the floor-reared replicates (SG IF, SG IIF).

significance for this floor-reared chick data ($P \leq 0.08$). The Dunnett t-test was used to evaluate these specific feed consumption means because there were not enough degrees of freedom to use the Bonferroni t-test. Overall means $\pm$ SEM for the dietary phosphorus treatments were: 38.4 ± 3.0 and 41.9 ± 3.0 grams consumed/chick/day, for phosphorus levels of 0.4 and 0.6 percent of the diet, respectively.

High calcium and low phosphorus rations (wide Ca:P ratios), as defined in the textbook by Scott et al. (1978), possibly resulted in a depressing effect on the feed intake (Table 34) of these floor-reared pheasant chicks.

The averages in Table 35 represented the significant ($P \leq 0.0005$) period effect on feed consumption through sixteen weeks of age. Total feed consumed by period is also listed in this table. Appendix D, Table 2 is a summary, by treatment, of the average feed consumption by chicks of these floor replicates for the three periods. This summary includes treatments one, four, and seven; but these treatments were not included in any statistical analysis of feed consumption.

Hinkson et al. (1971), reported that for pheasant chicks three to five weeks of age, the feed consumption increased with increasing levels of calcium to 0.9 percent. But there was no difference between the 0.9 percent treatment and those through 1.62 percent dietary calcium. Their information differs somewhat from the data presented in this report.

The pheasant chicks of the present experiments appeared to be more sensitive to dietary calcium and phosphorus ratios and levels than the pheasants of Hinkson et al. (1971) or the

Table 34. Effect of various dietary calcium and phosphorus combinations on the average feed consumption of growing pheasants during the starter, grower, and flight age periods (day-old through 16-weeks of age). Data are in grams feed consumed/bird/day.

Treatment	mean $\pm$ SEM*	P greater than		
		0.20	0.10	0.05
6	44.2 $\pm$ 1.9			
3	42.8 1.9			
2	42.3 1.9			
5	39.1 1.9			
9	38.6 1.9			
8	34.1 1.9			
1	----			
4	----			
7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

The SEM are the same due to homogenous variance (f-max test).

Data are in grams consumed/bird/day.

The statistical analysis did not include treatments 1, 4, or 7.

Table 35. Feed consumption by growing pheasants (in grams), according to the growth period. Data are in grams consumed/bird/day.

Period	Week	Feed* Consumed mean $\pm$ SEM	No. of days	total gm. feed consumed	total feed pounds/ bird/period
Starter	1-6	19.6 $\pm$ 0.6 ^a	42	814.8	1.80
Grower	7-12	45.9 $\pm$ 1.7 ^b	42	1927.8	4.25
Flight	13-16	55.2 $\pm$ 1.3 ^c	28	<u>1545.6</u>	<u>3.41</u>
Total				4288.2	9.46

* Means with different superscripts are significantly different ($P \leq 0.05$).

Starter data are from day-old through six weeks of age;
 Grower data are from weeks seven through twelve;
 Flight data are from weeks 13 through 16.

chickens of Nelson et al. (1965) (see Tables 31, 32, 33, 36, and 37).

Waldroup et al. (1963) indicated that broiler chicks are more sensitive to the dietary calcium:phosphorus ratio if the levels of these minerals is low, which in general is what the results of the present study indicated.

Nelson et al. (1965) found a 4:1 (vs. 2:1 Ca:P ratio) caused a significant decline in body weight and decreased feed consumption of chicks. Biely and March (1967) indicated that up to 1.3 percent dietary calcium was well tolerated by broilers with no indication of any growth inhibition or decrease in feed efficiency.

Scott et al. (1976) listed broiler feed consumption at 11.8 grams/bird/day at one week of age to 135 grams/male/day, or 110 grams/female/day at eight-weeks of age. The combined sexes averaged about 90 grams/bird/day at six-weeks of age, which is about double that of pheasants (Table 35).

Body Weight (in grams)

1. Day-old through four-weeks of age

Statistical comparisons were made only on data from replicates SG IF, SG IIF, SG Ic, and SG IIc. Chicks from treatments one, four, and seven also were not evaluated because there was excess mortality within these treatments, with few survivors.

The numbers reported for the significant replicate, dietary calcium and phosphorus averages were of negligible quantitative value because they represented the average between day-old average weight and the weight of the chick at four weeks of age. However, a comparison of means within the calcium effect (Table 36) may be of value. The significant calcium effect ($P \leq 0.035$) on body weight averages of day-old and four-week old pheasant chicks is presented in Table 36.

In Table 37 the initial group average weight at day-old was 20-22 grams/chick; this weight was with the wing band included in the total weight of each chick. The four-week old chick body weights reported in Table 37 are similar to those reported by Fuentes (1978).

As summarized in this analysis, the replicate effect on body weight means was significant ($P \leq 0.035$). The major function of this part of the ANOVA was to evaluate the effect of cage versus floor-rearing of pheasant chicks. The range extremes of this body weight data are of averages of the floor-reared chicks. Therefore, this replicate effect was probably due to chance. The body weight averages for these replicates were: SG IF = 102.8; SG IIF = 116.8; SG Ic = 115.1; and SG IIc = 112.6 grams.

Table 36. Effect of dietary calcium on pheasant chick's body weight averages (in grams). Data are the average between day-old and four-week-old chick body weights

Percent Dietary Calcium	mean $\pm$ SEM [*]
0.6	115.4 $\pm$ 1.60 ^a
1.2	110.9 $\pm$ 1.60 ^{ab}
1.8	109.1 $\pm$ 1.60 ^b

* Means with different superscripts are significantly different ($P \leq 0.05$).

Due to homogenous variances (f-max test) all SEM = 1.60.
Data are from all starter/grower replicates except SG IIIc.

Replicates are defined on the Abbreviations and Symbols page, and the calcium levels are defined by treatment in Appendix B, Table 1.

Data from treatments 1, 4, and 7 were not included in the statistical analysis due to the nearly total mortality of chicks fed these rations.

Table 37. The dietary calcium by dietary phosphorus by period effect on growing pheasant chick's body weight (in grams).

Percent Dietary Phosphorus	Period	
	Day-old*	Four-weeks old*
Percentage Dietary Phosphorus by 0.6 Percent Dietary Calcium		
0.4	21.0 $\pm$ 0.48	211.0 $\pm$ 7.7 ^b
0.6	21.8 0.50	208.0 2.6 ^b
Percentage Dietary Phosphorus by 1.2 Percent Dietary Calcium		
0.4	21.3 0.3	185.5 5.9 ^a
0.6	21.3 0.5	215.8 7.0 ^b
Percentage Dietary Phosphorus by 1.8 Percent Dietary Calcium		
0.4	21.5 0.3	179.8 9.1 ^a
0.6	21.5 0.3	213.5 9.9 ^b

* Means within a column with different superscripts are significantly different ($P \leq 0.01$).

Data are a summary of body weights from day-old and four-weeks of age. The body weights of the day-old chicks included the weight of the wing band.

The phosphorus effect on body weight average was highly significant ($P \leq 0.0005$). The average body weight of chicks at day-old and four-weeks of age was lower for the 0.4 percent (106.7 ± 1.3 grams) vs. the 0.6 percent (117.0 ± 1.3 grams) dietary phosphorus treated chicks.

The period effect is a summary of the average body weight for all chicks at day-old (21.4 ± 0.15 grams) and at four-weeks of age (202.3 ± 4.0 grams). Also the phosphorus by period effect for body weight was significant ($P \leq 0.004$) but with the ten-fold difference in body weights from day-old through four-weeks of age, these should be significant.

The calcium by phosphorus by period effect was significant for body weight averages-see Table 37- ($P \leq 0.039$) but more importantly, it re-emphasized the high dietary calcium:low dietary phosphorus (wide ratio) effect of lowering feed consumption and therefore body weight of these pheasant chicks. At the 0.6 percent dietary calcium level, the effect of the level of phosphorus (0.4 or 0.6 percent) on the average chick body weight was insignificant. With the treatment combinations using calcium at 1.2 percent of the ration, the high dietary calcium:low dietary phosphorus interaction effect on feed intake was supported by its significant effect ($P \leq 0.002$)-see Table 38-on these body weight means (Tables 31, 33, 36, 37, and 38).

Hinkson et al. (1971) reported the dietary calcium requirement of pheasant chicks for optimum body weight and bone mineralization at four and five weeks of age to be between

Table 38. Effect of various dietary calcium and phosphorus combinations on the growing pheasant body weight in grams.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM [*]	P greater than		
			0.20	0.10	0.05
2.0:1	6	118.5 $\pm$ 2.3			
3.0:1	9	117.5 2.3			
1.5:1	2	116.0 2.3			
1.0:1	3	114.9 2.3			
3.0:1	5	103.4 2.3			
4.5:1	8	100.6 2.3			
3.0:1	1	-----			
6.0:1	4	-----			
9.0:1	7	-----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

SEM are the same due to homogenous variance (f-max test). Data are averages of day-old and four-week old growing pheasant's body weight in grams.

The statistical analysis did not include treatments 1, 4, or 7. Data are from all starter/grower replicates except SG 111c.

0.90 and 1.06 percent. Dietary phosphorus was about 0.79 percent in their three studies.

Body Weight through Sixteen-weeks of Age

The replicate averages of pheasant chicks are for body weights from day-old through 16-weeks of age for starter/grower floor replicates one and two. Chicks in floor replicate one gained less body weight as an average, over the course of the experiments, than did chicks of replicate two. This difference may have been due to the variation of the chick sources or to other factors, such as weather, which were discussed under feed consumption.

Period effects on body weight are summarized in Table 39. A significant response for the period effect should be expected because this data is of the rapid growth phase of a biological system. The larger variation after four-weeks of age was probably due to the males and females not being separated for the statistical analysis of body weight.

Woodard et al. (1977) reported the body weights of pheasants from one-through 20-weeks of age. His data on weight gain were similar to those reported in this study. However, the birds used by Woodard et al. (1977) were fed adequate diets. Woodard et al. (1977) also reported data for less than optimum dietary protein concentrations and stated that there was a subsequent decline in body weight.

Table 39. Body weight averages (in grams) for pheasants at day-old through sixteen-weeks of age.

Time Period	mean $\pm$ SEM [*]
Day-old	21.7 $\pm$ 0.2
4-weeks of age	197.9 5.8
8-weeks of age	528.6 15.8
12-weeks of age	908.3 17.5
16-weeks of age	1062.3 13.2

* Means at all ages include the weight of the wing band.

Data are from floor-reared replicates (SG IF, SG IIF) and do not include data from treatments 1, 4, or 7 due to the nearly total mortality of chicks fed these rations.

In the present study, when using rations with similar levels of calcium and phosphorus (low Ca:P ratios) there was essentially no difference between the effect of the two higher dietary levels of phosphorus on body weights (Table 38). As the Ca:P ratio widened, the chick apparently required a higher dietary level of phosphorus to maintain a higher (optimum) body weight. Waldroup et al. (1963) reported similar results for broiler chicks. They found that the calcium:phosphorus ratio significantly affected the body weight gains and feed utilization of those chicks.

Starter/Grower Tibia Measurements

1. Two-week-old Pheasant Chicks

These data are from tibiae taken from two-weeks-old pheasant chicks. Data are from all replicates and all treatments.

Tibia dry fat-free bone (dffb)

The dietary calcium treatments had no effect on the amount of tibia dffb, but the low dietary phosphorus treated chicks consistently had a much lower concentration of dffb when compared relative to all calcium levels. The ranking of individual treatment combination means are shown in Table 40 and help to illustrate this point. The phosphorus effect was linear ($P \leq 0.01$) for the range of dietary phosphorus studied (see Table 41). The same relationship between dietary calcium and phosphorus combinations existed for this dffb as it had for all other parameters (see Tables 31, 32, 34, 38, 42, and 43). The treatment combination rankings exhibited in Table 40 of the effectiveness of the various treatment combinations was rather constant over all parameters studied. Treatment 6 was usually the most effective, followed by treatments 9 and 2, and then always 5 and 8, for most parameters.

Table 40. Effect of various dietary calcium and phosphorus combinations on the two-week-old pheasant chick tibia percentage dry fat-free bone (dffb).

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
2.0:1	6	51.6 $\pm$ 3.2			
1.5:1	2	50.4 3.6			
3.0:1	9	50.2 2.6			
1.0:1	3	47.5 2.9			
4.5:1	8	42.9 2.7			
3.0:1	5	42.6 1.2			
3.0:1	1	36.8 2.3			
9.0:1	7	36.4 2.4			
6.0:1	4	36.0 2.2			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all replicates (floor and battery-reared) and from all treatments.

Table 41. Effect of dietary phosphorus on the two-week old pheasant chick's tibia percentage of dry fat-free bone (dfffb). Data are in mg dfffb/100 mg tibia.

Percent Dietary Phosphorus	mean $\pm$ SEM [*]
0.2	36.4 $\pm$ 1.30 ^a
0.4	45.3 $\pm$ 1.30 ^b
0.6	49.8 $\pm$ 1.30 ^c

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data include all starter/grower replicates and treatments. Because of homogenous variance (f-max test) all SEM=1.30.

Treatment combination calcium and phosphorus ratios and levels are defined in Appendix B, Table 1.

Dry fat-free bone percentage ash

As measured by the ANOVA F-statistic, a higher calcium concentration of the ration tended to have a negative effect on the dry fat-free bone percentage ash ($P \leq 0.064$). As can be seen in Table 42, of the calcium effect (Bonferroni test was sig. $P \leq 0.05$) was probably due to the very low value for treatments seven and eight (1.8 Ca:0.2 P, and 1.8 Ca:0.4 P, respectively). Therefore, this tendency for a calcium effect on dffb percentage ash was possibly more a result of the wider Ca:P ratio than a specific calcium effect on the bone ash. The phosphorus effect was highly significant due to the very low values for the 0.2 percent dietary phosphorus treatments (Tables 42 and 43). The specific rankings of the treatment combinations of Table 42 are in Table 43. All remaining birds in these 0.2 percent phosphorus treatments (except a few in treatment one of the second floor replicate) were dead within two-weeks post-treatment. All chicks that were fed diets with 0.2 percent dietary phosphorus were anorectic and rachitic. The reason data from the second week were collected was because so many chicks fed these 0.2 percent dietary phosphorus treatment combinations had died prior to that time. The calcium by phosphorus interaction was also significant ($P \leq 0.002$) due to these same low values (Table 42). The phosphorus effect on dffb percentage ash was more pronounced as the Ca:P ratio

Table 42. Dietary calcium by phosphorus interaction effect on the two-week old pheasant chick's tibia dry fat-free bone (dffb) percentage ash (mg ash/100 mg dffb).

Pct. D. Ca ^{**}	Percent Dietary Phosphorus			
	0.2	0.4	0.6	mean [*]
0.6	38.9 ± 0.6	54.9 ± 0.9	52.1 ± 1.7	48.6 ^b
1.2	37.9 1.4	50.5 1.6	58.4 0.5	48.9 ^b
1.8	35.7 1.2	47.4 2.1	56.1 1.1	46.4 ^a
mean [*]	37.5 ^a	50.9 ^b	55.5 ^c	

* Means within a column or row with different superscripts are significantly different ($P \leq 0.05$).

** Pct. D. Ca represents percent dietary calcium
Data are mean ± SEM. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates, as defined on the Abbreviations and Symbols page.

Table 43. Effect of various dietary calcium and phosphorus combinations on the two-week old pheasant chick's tibia dry-fat-free bone percentage ash.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM [*]		P greater than		
				0.20	0.10	0.05
2.0:1	6	58.4	$\pm$ 0.53			
3.0:1	9	56.1	1.10			
1.5:1	2	54.9	0.86			
1.0:1	3	52.1	1.67			
3.0:1	5	50.5	1.56			
4.5:1	8	47.4	2.12			
3.0:1	1	38.9	0.55			
6.0:1	4	37.9	1.44			
9.0:1	7	35.7	1.16			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates (floor- and battery-reared) and from all treatments.

widened; also see Waldroup et al. (1963).

For three-week old cockerels, Christmas and Harms (1978) found tibia ash values of about 39-41 percent, depending on the dietary treatment. Branion (1938) (see O'Rourke et al., 1955) concluded that the ratio of dietary calcium to phosphorus was not of prime importance to the growing chicken when vitamin D₃ and reasonable levels of calcium and phosphorus were in the ration. With adequate vitamin D₃ the Ca:P ratio could vary from 1:1 to 3:1 with an optimum of 2:1. However, the absolute amounts of calcium and phosphorus were important for optimal growth and bone ash. The results of this study agree with these other reports.

Nelson et al. (1965) also found a Ca:P ratio effect on the percentage of chick bone ash. They reported ash means of about 33-41 percent for the 2:1 ratios and 20-43 percent for the 4:1 Ca:P ratios for various phosphorus supplements which is similar to but lower than the results of the present study.

Wilcox et al. (1955) reported that four-week old poult had tibia bone ash values of 43.41 and 43.37 percent for practical type rations with 0.8 or 1.0 percent total phosphorus and 2.0 percent dietary calcium. The ash values that resulted from feeding the purified rations ranged from 24.95 to 47.99 percent. The data of Wilcox et al. (1955) were from different experiments and are comparable to the data of the present study.

Ash percentage calcium

Only the replicate means of the ash calcium content of these two-week-old chicks were significantly different ($P \leq 0.024$) from each other (Table 44). Only the range extremes of these replicate means were significantly different from each other. The floor-reared chicks average ash percentage calcium was lower than that of their caged counterparts (35.18 ± 0.08 and 36.2 ± 0.34 SEM percent, respectively).

The treatment combination averages, as summarized by the calcium by phosphorus interaction, were not significantly different from each other ($P \leq 0.05$); all these values were between 35-36 mg Ca/100 mg dffb (Table 45).

Ash percentage phosphorus

For the significant replicate effect ($P \leq 0.005$) on pheasant chick tibia ash percentage phosphorus, the SG Ic chicks had the greatest amount of phosphorus (20.6 mg P/100 mg ash). All other replicate effect means were 19.8 or 19.9 mg P/100 mg ash.

The significant calcium ($P \leq 0.001$) and phosphorus ($P \leq 0.001$) effects may be better visualized by looking at Tables 46 and 47. Shown on these tables are the treatment combination means of the calcium and phosphorus interaction, either summarized by dietary mineral level or ranked according to their effect on the ash percentage phosphorus. The low (0.6 percent) dietary calcium treatments all had the higher ash percentage phosphorus in their respective dietary phosphorus categories.

Table 44. Growing pheasant's tibia ash percentage calcium (mg calcium/100 mg ash). Data are summarized by replicate.

Starter/Grower Replicates	mean $\pm$ SEM [*]
First floor	35.2 $\pm$ 0.3 ^a
Second floor	35.0 0.4 ^a
First battery	36.9 0.4 ^b
Second battery	35.8 0.5 ^{ab}
Third battery	35.9 0.2 ^{ab}

* Means with different superscripts are significantly different ($P \leq 0.05$).

Replicates are defined on the Abbreviations and Symbols page. Data are from all replicates and all treatments at two-weeks of age.

Table 45. Effect of various dietary calcium and phosphorus combinations on the two-week old pheasant chick's tibia ash calcium concentration (mg calcium/100 mg ash).

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
9.0:1	7	36.1 $\pm$ 1.20		n/a	n/a
1.5:1	2	36.1 0.32			
3.0:1	9	35.9 0.40			
4.5:1	8	35.9 0.40			
3.0:1	5	35.8 0.41			
3.0:1	1	35.6 0.37			
6.0:1	4	35.5 0.64			
1.0:1	3	35.4 0.83			
2.0:1	6	35.4 0.50			

* Means within the range of a line are significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates (floor- and battery-reared) and from all treatments.

Table 46. Dietary calcium by phosphorus interaction effect on the two-week old pheasant chick's tibia ash percentage phosphorus (mg P/100 mg ash).

Pct. D. Ca**	Percent Dietary Phosphorus			mean*
	0.2	0.4	0.6	
0.6	20.0 $\pm$ 0.2	20.7 $\pm$ 0.2	20.6 $\pm$ 0.3	20.4 ^a
1.2	19.3 0.5	20.1 0.1	20.3 0.2	19.9 ^b
1.8	19.4 0.2	19.9 0.1	19.9 0.2	19.7 ^b
mean*	19.6 ^a	20.2 ^b	20.3 ^b	

* Means within a column or row with different superscripts are significantly different ($P \leq 0.05$).

Treatments are defined in Appendix B, Table 1.
Data are from all starter/grower replicates.

** Pct. D. Ca represents percent dietary calcium.
Data are means + SEM.
Replicates are defined on the Abbreviations and Symbols page.

Table 47. Effect of various dietary calcium and phosphorus combinations on the two-week old pheasant chick's tibia ash phosphorus concentration (mg phosphorus/100 mg ash).

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
1.5:1	2	20.7 $\pm$ 0.16			
1.0:1	3	20.6 0.29			
2.0:1	6	20.3 0.19			
3.0:1	5	20.1 0.09			
3.0:1	1	20.0 0.17			
4.5:1	8	19.9 0.10			
3.0:1	9	19.9 0.14			
9.0:1	7	19.4 0.22			
6.0:1	4	19.3 0.51			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B. Table 1.

Data are from all starter/grower replicates (floor- and battery-reared) and from all treatments.

As the level of dietary calcium was increased to 1.2 percent and 1.8 percent within each level of dietary phosphorus, the bone phosphorus declined. The effect of dietary calcium on the ash percentage phosphorus was linear ($P \leq 0.05$). This phenomenon was also consistent for the two-week old chick's data, not 2-12 wk data.

2. Two- and four-week old chick bone values for replicates SG IF; SG IIF; SG Ic; and SG IIIc.

Tibia percentage dry fat-free bone (dffb)

The 0.2 percent dietary phosphorus treatments (1, 4, 7) were not included in the statistical analysis for any of the data in this section because of missing data from these groups.

Chicks fed the 0.4 percent phosphorus rations had less dffb ($P \leq 0.027$) than did the chicks fed the 0.6 percent phosphorus rations (47.9 ± 1.3 and 51.2 ± 1.5 percent, respectively). This indicated that 0.4 percent dietary phosphorus was not adequate over all levels of calcium fed, for optimum dffb.

The tibia percentage of dffb at two weeks of age (48.2 ± 1.5 SEM) was similar to that at four weeks of age (50.9 ± 1.0 SEM) ($P \leq 0.05$), but less when compared to the eight-week old floor-reared chicks tibia percentage dffb (Table 52).

The calcium by phosphorus interaction was significant ($P \leq 0.015$). These treatment combinations are ranked in Table 48. The chicks tended to deposit minerals in the skeleton in adequate quantity only if the Ca:P ratio was low and if a

Table 48. Effect of various dietary calcium and phosphorus combinations on the two- and four-week old pheasant chick's tibia percentage dry fat-free bone (mg dry fat-free bone/100 mg tibia).

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
3.0:1	9	53.3 $\pm$ 2.3			
1.5:1	2	51.8 2.4			
2.0:1	6	51.5 1.9			
1.0:1	3	48.8 2.0			
3.0:1	5	46.0 1.9			
4.5:1	8	45.8 1.9			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates except SG IIc. Data from treatments 1, 4, or 7 were not used for the statistical analysis.

certain minimum amount of phosphorus was available in the diet. The Ca:P ratio apparently plays a role in determining that minimum level.

As can be seen in Table 48, treatments two and six resulted in very similar tibia dffb. Specific treatment combination calcium and phosphorus levels and ratios are defined in Appendix B, Table 1.

Treatment three was less effective in the deposition of bone minerals than treatments two, six, or nine; but was more effective than treatments five and eight. These differences were not statistically significant, see Table 48, but were consistent for these measurements (Tables 40, 48, and 53). Evidently a Ca:P ratio of greater than 1:1 was needed by pheasant chicks for maximum bone development. The response of the two- and four-week-old chicks to wide Ca:P ratio treatments, as measured by the chick dffb and ash, are generally as reported in this study for the two-week through 12-week-old chicks (Tables 40, 43, 48, 49, 53, and 54).

Dry fat-free bone percentage ash (from two- and four-week of age chicks).

Chicks fed the rations with the 0.4 percent level of phosphorus had less bone ash than those fed rations with the 0.6 percent phosphorus level ($P \leq 0.002$). These means were 54.2 ± 1.5 percent and 58.7 ± 0.9 percent, respectively. Similarly, chicks at two weeks of age had less bone ash than those at four weeks of age ($P \leq 0.005$); these means were: 52.2 ± 1.3 and 60.0 ± 0.6 percent, respectively. By two-weeks of age, the bone was not completely calcified but by four to

eight weeks of age the adult levels of the percentage dffb and ash had been reached (see Table 52 for the floor-reared chick data); which indicated that full mineralization had occurred. In each set of tibia data, the values from the younger chicks were more variable and more responsive to dietary mineral levels than when the chicks were eight to twelve weeks of age. The phosphorus by period interaction showed a strong trend toward significance ($P \leq 0.054$). The averages of treatment combinations are shown in Table 49. This calcium by phosphorus interaction was not significant ($P \leq 0.12$).

Sunde and Bird (1956) have reported similar bone ash values for four-week old pheasant chicks. For total dietary phosphorus levels of 0.66, 0.76, 0.86, 0.96, 1.06, 1.16, and 1.46 percent, they reported percent bone ash averages of 37.92, 45.71, 49.20, 52.93, 51.74, 51.76, and 51.94 percent, respectively. The dietary calcium level was 1.51 percent.

Biely and March (1967) reported tibia dffb percentage ash values for six or seven-week old broilers that were slightly less (about 45-48 percent) than the data from the pheasants of the present study. Anderson and Stewart (1973) reported juvenile pheasant's femurs to have 64.9 ± 8.57 to 81.6 ± 1.29 grams ash/100 grams dry fat-free bone, which is somewhat greater than the data reported from this study.

Ash percentage calcium (from two- and four-week of age chicks)

Only the replicate effect was significant ($P \leq 0.0005$). The first battery replicate averaged 36.96 ± 0.18 percent; while the second battery replicate averaged 35.08 ± 0.19 per-

Table 49. Effect of various dietary calcium and phosphorus combinations on the two- and four-week old pheasant chick's tibia dry fat-free bone (dffb) percentage ash (mg ash/100 mg dffb).

Ca:p Ratio	Treat- ment	means $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
2.0:1	6	60.9 $\pm$ 1.04			
3.0:1	9	59.0 1.35			
1.0:1	3	56.2 1.88			
3.0:1	5	55.2 2.26			
1.5:1	2	55.1 2.94			
4.5:1	8	52.4 2.72			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates except SG IIc. Data from treatments 1, 4, or 7 were not used for the statistical analysis.

cent which was about the midway point between the averages of the two floor replicates ($SG\ IF = 34.74 \pm 0.18$; $SG\ IIF = 35.62 \pm 0.21$). The 35 percent value was constant for all averages of the growing pheasant ash percentage calcium (Table 44); and similar to the adult levels (Table 24). The Ca:P interaction was not significant ($P \times 0.05$).

Ash percentage phosphorus (from two- and four-week old chicks)

The percentages of calcium and phosphorus in the ash did not show a period effect. The best ratio of the calcium by phosphorus interaction effect on percentages of ash phosphorus (Table 50) was approximately 2:1.

The lowest dietary calcium level (0.6 percent) resulted in the highest ($P \leq 0.01$) chick tibia ash percentage phosphorus (Table 51). The calcium concentration had a linear ($P \leq 0.05$) effect on the ash percentage phosphorus (Table 51). These data agree with previously discussed two-week old pheasant chick data of this study (Table 46) and the results of balance studies of Salem and Reda (1955). Salem and Reda (1955) showed that body retention of phosphorus was depressed by high dietary calcium. The adult bone of this study showed the same relationship between dietary calcium concentration and bone minerals.

3. Two-, Four-, Eight-, and Twelve-week old Pheasant Chick Tibiae Values for Replicates SG IF, and SG IIF

There was not sufficient data for the 0.2 percent dietary phosphorus treatments (1, 4, 7) to be included in the statistical analysis.

Table 50. Effect of various dietary calcium and phosphorus combinations on the two- and four-week old pheasant chick's tibia ash percentage phosphorus (mg P/100 mg ash).

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
1.5:1	2	20.5 $\pm$ 0.18			
1.0:1	3	20.5 0.24			
2.0:1	6	20.3 0.15			
3.0:1	9	19.9 0.11			
4.5:1	8	19.9 0.11			
3.0:1	5	19.8 0.08			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates except SG IIc. Data from treatments 1, 4, or 7 were not used for the statistical analysis.

Table 51. Effect of dietary calcium on pheasant chick tibia ash percentage phosphorus.

Percent Dietary Calcium	mean $\pm$ SEM [*]
0.6	20.5 $\pm$ 0.14 ^a
1.2	20.1 $\pm$ 0.10 ^b
1.8	19.8 $\pm$ 0.07 ^c

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data are from two- and four-week old pheasant chicks. The means represent mg phosphorus/100 mg ash.

Tibia percentage dry fat-free bone (dffb) (Two-through Twelve-week Data).

The ANOVA F-statistic indicated that floor replicate one had a lower ($P \leq 0.025$) dffb percentage of total bone than floor replicate two (56.0 ± 1.9 SEM vs. 60.0 ± 2.2 SEM percent, respectively).

The phosphorus effect on tibia percentage dffb approached significance ($P \leq 0.056$). The trend was for the chicks fed the 0.4 percent dietary phosphorus treatment to have less dffb as a percentage of the total bone than those fed the diets with 0.6 percent phosphorus (56.2 ± 2.1 and 59.6 ± 2.1 SEM percent, respectively).

The significant ($P \leq 0.0005$) period effect was because the first readings were from two-weeks of age, then at four-, eight-, and twelve weeks of age (Table 52).

Feeding treatment six (1.2 percent Ca:0.6 percent P) resulted in the highest tibia percentage dffb. Treatments nine (1.8 Ca:0.6 P), two (0.6 Ca:0.4 P), and three (0.6 Ca:0.6 P) chicks had a lesser amount of, although not significantly different, tibia percentage dffb (Table 53) than treatment six chicks.

Dry fat-free bone percentage ash (Two-through Twelve-week data).

There was a significant phosphorus effect ($P \leq 0.001$) on the dffb percentage ash. Bones from the 0.4 percent phosphorus treatments had less ash than the bones from the 0.6 percent dietary phosphorus treatments (58.6 ± 1.2 SEM and

Table 52. Effect of time on growing pheasant's tibia percentage dry fat-free bone (dffb), and the dffb percentage ash.

Time Period	mg dffb [*]		mg ash [*]	
	100 mg tibia		100 mg dffb	
2-weeks of age	47.8	$\pm 2.3^a$	53.5	$\pm 1.5^a$
4-weeks of age	53.3	1.5^a	60.4	0.9^b
8-weeks of age	68.6	2.4^b	63.0	0.4^b
12-weeks of age	62.4	0.5^b	62.2	0.4^b

* Means within columns with different superscripts are significantly different ($P \leq 0.05$).

Data are from floor-reared pheasant chicks at two, four eight, and twelve weeks of age. These replicates are defined on the Abbreviations and Symbols page.

Table 53. Effect of various dietary calcium and phosphorus combinations on the grower pheasant's tibia percentage dry fat-free bone (dfffb). Data are mg dfffb/100 mg tibia.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
2.0:1	6	61.8 $\pm$ 4.1			
3.0:1	9	59.5 3.4			
1.5:1	2	58.0 3.2			
1.0:1	3	57.6 3.1			
4.5:1	8	55.9 4.4			
3.0:1	5	55.5 3.9			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from two-, four-, eight-, and twelve-week old pheasant chicks.

Data from treatments 1, 4, or 7 were not used for the statistical analysis.

61.0 $\pm$ 0.7 SEM percent, respectively).

There was an interaction of the calcium and phosphorus levels ($P \leq 0.005$) on the dffb percentage ash (Tables 54 and 55). The reason why treatment two (0.6 Ca:0.4 P) averages were consistently different (Dunnet t-test = $P \leq 0.05$) from the other averages at this phosphorus level is not known, see Tables 42, 49, and 55. However, this could be related to an altered intestinal absorption due to the imbalanced Ca:P ratios as described by Scott *et al.*, 1978, who suggested that the 0.4 percent dietary phosphorus was adequate only at a low Ca:P ratio (i.e. 1.5 or 2:1).

The highly significant ($P \leq 0.005$) period effect (Table 52) can also be explained by the lower ash values for chicks that are maturing; and subsequently increasing the percentage of mineralized cartilage as measured by the percentage dffb and ash of the tibia. The tibia ash concentration had plateaued by four-weeks of age.

Ash percentage calcium

Chicks of replicate one had a lower percentage of tibia ash calcium ($P \leq 0.003$) (35.7 ± 0.27) than those of the second replicate (36.7 ± 0.27 percent). Calcium in the bone ash increased over the four periods (Table 56). After reviewing the previously discussed data, one would also expect these values to plateau with maturity, which they did, between four- and eight-weeks of age.

Anderson and Stewart (1973) reported juvenile pheasant

Table 54. Effect of various dietary calcium and phosphorus combinations on the grower pheasant's tibia dry fat-free bone (dffb) percentage ash. Data are in mg ash/100 mg dffb.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
2.0:1	6	62.3 $\pm$ 1.0			
3.0:1	9	61.2 1.2			
1.5:1	2	60.1 1.2			
1.0:1	3	59.4 1.5			
4.5:1	8	57.9 2.4			
3.0:1	5	57.9 2.4			
3.0:1	1	----			
6.0:1	4	----			
9.0:1	7	----			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from two-, four-, eight-, and twelve-week old pheasant chicks.

Data from treatments 1, 4, or 7 were not used for the statistical analysis.

Table 55. Dietary calcium by phosphorus interaction effect on grower pheasant chick's tibia dry fat-free bone (dffb) percentage ash. Data are in mg ash/100 mg dffb.

Percent Dietary Calcium	Percent Dietary Phosphorus		
	0.4	0.6	mean*
0.6	60.1 $\pm$ 1.2	59.4 $\pm$ 1.5	59.7 ^a
1.2	57.9 2.4	62.2 1.0	60.0 ^a
1.8	57.9 2.4	61.3 1.2	59.6 ^a
mean*	58.6 ^a	61.0 ^b	

* Means within a column or row with different superscripts are significantly different ($P \leq 0.05$).

Treatments 0.2 percent dietary phosphorus (1, 4, and 7) were not included in the statistical analysis due to the nearly total mortality of chicks fed these rations.

Data are from chicks from the two floor-reared replicates (SG IF, SG IIF) at two-, four-, eight-, and twelve-weeks of age. Treatments are defined in Appendix B, Table 1.

Table 56. Effect of time on growing pheasant chick's tibia ash percentages of calcium and phosphorus. Part 1.

Period	mg calcium/100 mg ash
2 weeks of age	35.16 $\pm$ 0.18
4 weeks of age	35.20 0.28
8 weeks of age	37.11 0.18
12 weeks of age	37.37 0.39

Table 56. Effect of time on growing pheasant chick's tibia ash percentages of calcium and phosphorus. Part 2.

Period	mg phosphorus/100 mg ash	
2 weeks of age	20.16	± 0.14
4 weeks of age	20.07	0.15
8 weeks of age	19.44	0.25
12 weeks of age	19.40	0.18

femurs to have 243,600 to 277,000 micrograms calcium/gram dry fat-free bone and 76,900 to 122,900 micrograms phosphorus/gram dry fat-free bone. These data are similar to the data from the present study.

Ash percentage phosphorus

According to the ANOVA table, the only significant part of the analysis was the period effect. The phosphorus of the bone declined in a linear fashion ($P \leq 0.01$) over the 16 week experimental period (Table 56). However, the range of means was not different ($P > 0.05$).

STARTER/GROWER MORTALITY

Day-old through Four-weeks of Age

Data are from all replicates and treatments.

Although not significant, the two floor replicates had less mortality than did battery-reared chicks (Table 57). Raising pheasant chicks in battery-brooders, even with conventional starter diets, is difficult because they are still a wild species. Their instinctive reaction when frightened is to try to fly. When in battery-brooders, if they are frightened, they frequently beat themselves to death trying to fly out of the six-inch-tall sections. During this four-week growing period, the chicks would also naturally start trying their wings and often damage themselves during this process. Flegal (1978) stated that in a conventional battery-brooding situation, up to 40 percent of the chicks killed themselves in this way.

Table 57. Percentage mortality of starter/grower chicks through four-weeks of age. Data are summarized by replicate.

Starter/grower replicate	Percent mortality	Number/ treatment	Total chicks
First floor	36.6	52	468
Second floor	36.6	45	405
First battery	38.9	22	198
Second battery	43.3	26	234
Third battery	45.1	25	225

Data are means, using all treatment. Treatments are defined in Appendix B, Table 1. Replicates are defined on the Abbreviations and Symbols page.

For these experiments, the batteries were in rooms which were partially secluded from the main activity areas. Excreta was not removed until necessary and all unnecessary work around the birds was avoided, especially as the chicks grew older. A very minimal number of deaths were due to this panic-stricken attempt to escape. Some chicks did develop abscesses on their heads where they were hit on the section ceiling.

The chicks fed the rachitic rations did not live long enough to die from head/neck injuries. They died from starvation, primarily. They refused to eat the highly imbalanced calcium/phosphorus diets (see Appendix D, Table 1, or Table 31 of the text). The MSU diagnostic laboratory determined the cause of death of these chicks. Hinkson et al. (1971) reported high (42-48%) mortality due to rickets with lower (0.22-0.58 percent) dietary calcium levels, and dietary phosphorus at about 0.79 percent. They reported no treatment to have less than 10% mortality, but their data was confounded with deaths in all treatments due to mechanical hock damage.

Apparently, the use of higher levels of calcium in the ration (wider Ca:P ratios) significantly increased the chick mortality through four-weeks of age. Shown in Table 58 is the mortality as summarized by the dietary calcium level. The effects of dietary phosphorus (Table 59) were opposite to and more severe than dietary calcium at the levels used in these experiments. The response to both calcium and phosphorus dietary levels was linear ($P \leq 0.05$).

Table 58. Effect of dietary calcium on the percentage mortality of pheasant chicks from all replicates through four-weeks of age.

Percent Dietary Calcium	mean $\pm$ SEM [*]
0.6	34.1 $\pm$ 10.8 ^a
1.2	42.0 11.2 ^{ab}
1.8	44.2 10.9 ^b

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data include the 0.2 percent dietary phosphorus treatments (1, 4, 7) which resulted in nearly total mortality of chicks fed these ration.

Table 59. Effect of dietary phosphorus on the percentage mortality of pheasant chicks from all replicates through four-weeks of age.

Percent Dietary Phosphorus	mean $\pm$ SEM [*]
0.2	96.2 $\pm$ 3.2 ^a
0.4	14.9 $\pm$ 3.1 ^b
0.6	9.2 $\pm$ 2.3 ^c

* Means with different superscripts are significantly different ($P \leq 0.05$).

Data include the 0.2 percent dietary phosphorus treatments (1, 4, 7) which resulted in nearly total mortality of chicks fed these rations.

Phosphorus at 0.4 percent of the ration was adequate if dietary calcium was also low (0.6 percent), but rapidly became a marginal phosphorus level if the dietary calcium level increased. Phosphorus at 0.2 percent of the ration was severely anorectic, rachitic and lethal over all calcium levels used. The effectiveness of the 0.4 and 0.6 percent phosphorus rations was similar if the Ca:P ratio was kept low for the lower phosphorus rations. The response to phosphorus levels was linear and quadratic ($P \leq 0.01$). Shown in Table 60 is the ranking of the treatment combinations according to their effect on the chick mortality through four-weeks of age.

Table 60. Effect of various dietary calcium and phosphorus combinations on the percentage mortality of pheasant chicks through four-weeks of age.

Ca:p Ratio	Treat- ment	mean $\pm$ SEM*	P greater than		
			0.20	0.10	0.05
1.5:1	2	6.4 $\pm$ 2.0			
1.0:1	3	7.2 3.6			
3.0:1	9	9.2 3.6			
2.0:1	6	11.2 5.4			
3.0:1	5	14.8 4.9			
4.5:1	8	23.4 5.9			
3.0:1	1	88.6 9.2			
6.0:1	4	100			
9.0:1	7	100			

* Means within the range of a line are not significantly different for each level of significance. Treatments are defined in Appendix B, Table 1.

Data are from all starter/grower replicates (floor- and battery-reared) and from all treatments.

SUMMARY

Adult Pheasants

1. For both Groups 1 and 2, calcium at 1.5 percent of the diet of laying pheasants was not as effective as the three higher levels of dietary calcium as compared using eggshell thickness, tibia percentage dry fat-free bone, dry fat-free bone percentage ash, plasma calcium and phosphorus.

2. Phosphorus minimum or maximum values for adult hen pheasants were not determined, as measured by egg production.

3. Laying hen pheasants are very adaptable to wide ranges of dietary calcium and phosphorus levels and ratios, as judged by egg production.

4. In Group 1, increased dietary calcium concentration caused a linear decline in egg apparent fertility.

5. High (3.3 percent) or low (1.5 percent) dietary calcium showed only a tendency to cause an inhibition of egg production by the pheasant hens.

6. There was a possible relationship between the higher dietary calcium concentrations and lowered shell membrane thickness (Group 1).

7. Pheasant hens kept in cages laid a smaller egg than hens kept in floor pens.

8. As indicated by blood plasma calcium levels, 1.5 or 2.1 percent of the diet as calcium may not be adequate levels.

9. Mortality of chicks from eggs laid by hens fed the

various treatment combinations was measured. The group of chicks from the dams that received the 3.3 percent dietary calcium treatment combinations experienced more mortality than the groups of chicks whose dams received the 1.5 or 2.1 percent dietary calcium treatment combinations.

Growing Pheasants

1. Available phosphorus at 0.2 percent of the diet, fed at all dietary calcium levels, was rachitic, anorectic, and lethal.
2. Phosphorus in the diet at 0.4 percent, and at a Ca:P ratio or 3:1 or 4.5:1, caused a slight depression in feed intake and body weight at all ages.
3. Pheasant chick body weight averages fluctuated in a manner parallel to the chicks average feed intake response to the various treatment combinations.
4. The same groups of chicks that showed the most positive response to treatments as measured by feed intake and body weight were also highest in dry fat-free bone (dffb) and dffb percentage ash.
5. The maximum response to starter/grower treatment combinations, as measured by the chick tibia mineralization, was when there was a small excess of dietary calcium (1.5 to 3:1 vs. a 1:1 ratio of dietary calcium: phosphorus).
6. The highest pheasant chick tibia percentages of dry fat-free bone (dffb) and dffb percentage ash content resulted from their eating feed with 2:1, 3:1, or 1.5:1 dietary Ca:P

ratios, respectively.

7. Mineralization of pheasant chick's tibiae reached adult levels of mineralization, as measured by the percentage of dffb, or dffb percentage ash, between four and eight-weeks of age.

8. Pheasant chick tibia percents calcium and phosphorus were not readily changed by treatment combinations.

9. Mortality at four weeks of age was least for chicks fed rations with calcium and phosphorus at 0.6 and 0.4 percent of the diet, respectively. However, 0.6 percent dietary phosphorus resulted in the lowest overall mortality (as summarized over all levels of dietary calcium).

CONCLUSIONS

Adult Pheasants

In this study, adult laying hen pheasants were shown to require at least 2.1 percent dietary calcium for optimum egg production.

There was no beneficial influence on these pheasant hen's egg production from increasing the dietary level of calcium about 2.7 percent. In addition, 3.3 percent of the diet as calcium was detrimental to egg apparent fertility as measured in Group 1.

Based on the criteria studied, a phosphorus deficiency was not demonstrated in these pheasant laying hens, but 0.4 percent available dietary phosphorus would provide a margin of safety.

Starter/Grower Pheasants

Available phosphorus at 0.4 percent of the diet was adequate only with a low Ca:P ratio; in this case, if the dietary calcium was 0.6 percent. The optimum response by chicks to dietary treatments, as indicated by the values for all parameters, was to the treatment combination of 1.2 percent Ca:0.6 percent available phosphorus (treatment 6). Treatment combinations of 1.8 Ca:0.6 P (treatment 9) and 0.6 Ca:0.4 P (treatment 2) also produced favorable results.

APPENDIX A

Table A1. National Research Council Calcium and Phosphorus Requirement Recommendations

<u>CHICKEN</u>				
	Starter	Grower	Laying Hen	
Ca	0.9	0.6	3.25	
P	0.7	0.4	0.51	
<u>TURKEY</u>				
	Starter 0-8 week	Grower 8 week	Layer Breeders	Breeder
Ca	1.2	0.8	2.25	2.75
P	0.8	0.7	0.70	0.50
<u>PHEASANT</u>				
	Starter 0-6 weeks	Grower 6-20 week	Laying Hen	
Ca	estab. 1.0	estimate 0.7	X	
P	estab. 0.8	estimate 0.6	X	

Appendix A, Table 2. Summary of total pheasant eggs used for determination of egg apparent fertility and hatchability. Data are reported by experiment.

EXPERIMENT 1		PERIOD															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
# set		529	515	434	502	567	440	572	482	597	444	465	578	598	530	536	547
# fertile		392	417	369	360	365	202	413	303	470	321	206	258	93	359	161	165
% fertile		74	81	85	72	64	46	72	63	79	72	44	45	16	68	30	30
# hatch		219	303	278	227	218	94	260	230	306	207	132	138	58	247	89	82
% hatch		56	73	75	63	60	47	63	76	65	64	64	53	62	69	55	50
EXPERIMENT 2																	
# set		382	286	375	231	370	351	295	313	359	355	308	435	380	311	294	361
# fertile		236	232	255	206	229	291	251	234	169	265	220	272	246	241	225	176
% fertile		62	81	68	89	62	83	85	75	47	75	71	63	65	77	77	49
# hatch		190	87	156	113	165	215	172	162	127	189	129	191	147	167	114	104
% hatch		81	38	61	55	72	74	69	69	75	71	59	70	60	69	51	59
EXPERIMENT 3																	
# set		428	346	528	469	523	525	553	489	551	571	439	552	390	538	526	559
# fertile		353	267	448	407	434	434	449	428	492	476	350	489	308	464	443	459
% fertile		82	77	85	87	83	83	81	88	89	83	81	89	79	86	84	82
# hatch		221	188	335	308	327	312	321	305	352	338	262	357	210	369	326	340
% hatch		63	70	75	76	75	72	71	71	72	71	75	73	68	80	74	74

Appendix A, Table 3. Percent hen-day egg production of Ring-necked pheasants. Data are $\pm$ SEM.

Ca:P Ratio	Treatment	Group 1		Group 2	
		mean	$\pm$ SEM	mean	$\pm$ SEM
5.0:1	1	67.5	$\pm$ 2.3	62.8	$\pm$ 3.1
3.8:1	2	59.2	$\pm$ 1.7	51.4	$\pm$ 4.0
3.0:1	3	65.8	$\pm$ 3.4	68.4	$\pm$ 2.4
2.5:1	4	63.0	$\pm$ 2.4	66.0	$\pm$ 2.3
7.0:1	5	68.9	$\pm$ 2.5	70.1	$\pm$ 2.3
5.3:1	6	64.5	$\pm$ 2.9	68.9	$\pm$ 3.5
4.2:1	7	65.5	$\pm$ 2.9	75.1	$\pm$ 1.8
3.5:1	8	63.1	$\pm$ 3.0	69.6	$\pm$ 2.8
9.0:1	9	72.6	$\pm$ 2.3	76.5	$\pm$ 2.7
6.8:1	10	67.0	$\pm$ 3.0	75.3	$\pm$ 2.4
5.4:1	11	58.4	$\pm$ 2.1	59.5	$\pm$ 4.3
4.5:1	12	74.1	$\pm$ 1.9	72.2	$\pm$ 2.3
1.1:1	13	71.8	$\pm$ 1.8	63.8	$\pm$ 2.5
8.3:1	14	63.0	$\pm$ 2.7	72.9	$\pm$ 3.1
6.6:1	15	61.8	$\pm$ 2.1	65.6	$\pm$ 2.5
5.5:1	16	66.3	$\pm$ 2.5	72.9	$\pm$ 2.4

Groups 1 and 2 are defined on the Abbreviations and Symbols page. Means were not significantly different from each other ($P > 0.20$).

Data are from the last 80 days egg production as summarized by Group 1. Data are from the nine ten-day periods of egg production as summarized by Group 2.

APPENDIX B

Table B1. Ca:P Ratios of Treatment Combinations for Adults.

Percent Dietary Calcium	Percent Dietary Available Phosphorus			
	0.3	0.4	0.5	0.6
1.5	5:1 (1)	3.8:1 (2)	3:1 (3)	2.5:1 (4)
2.1	7:1 (5)	5.3:1 (6)	4.2:1 (7)	3.5:1 (8)
2.7	9:1 (9)	6.8:1 (10)	5.4:1 (11)	4.5:1 (12)
3.3	11:1 (13)	8.3:1 (14)	6.6:1 (15)	5.5:1 (16)

The treatment numerical designation is in parenthesis.

Ca:P Ratios of Treatment Combinations for Growing Pheasants.

Percent Dietary Calcium	Percent Dietary Available Phosphorus		
	0.2	0.4	0.6
0.6	3:1 (1)	1.5:1 (2)	1:1 (3)
1.2	6:1 (4)	3:1 (5)	2:1 (6)
1.8	9:1 (7)	4.5:1 (8)	3:1 (9)

The treatment numerical designation is in parenthesis.

Table B2. Feed Ingredient Analysis and Restrictions on Amounts that can Appear in Poultry and Game Bird Rations.

Feed Nutrient	ME (Kcal/ lb.)	CP (%)	Meth. (%)	Metn. + Cys. (%)	Tryp. (%)	Ca. (%)	Avail. Phos. (%)	Na. (%)	Fat (%)	CF (%)
Alfalfa, 17%	516	17.0	.25	.50	.40	1.30	.23	.09	2.5	24.3
Corn, normal	1560	8.8	.18	.34	.09	.02	.09	.02	3.8	2.7
Fat, hydrolyzed animal & vegetable	3700	---	---	---	---	---	---	---	97.0	---
Limestone	---	---	---	---	---	38.00	---	---	---	---
Meat & bone meal	1010	50.0	.53	1.10	.30	10.00	5.00	.73	10.0	2.5
Methionine, DL	---	98.0	98.00	98.00	---	---	---	---	---	---
Phosphorus, dicalcium	---	---	---	---	---	21.00	18.50	.10	---	---
Salt	---	---	---	---	---	---	---	38.00	---	---
Soybean meal, 44%	1020	44.0	.65	1.32	.66	.25	.28	.04	.5	6.6
Soybean meal, 49%	1100	49.0	.70	1.46	.74	.20	.24	.05	.5	3.0
Wheat, hard	1400	13.0	.20	.53	.16	.05	.10	.06	1.5	2.4
Wheat bran	510	15.0	.11	.41	.30	.14	.12	.20	4.0	10.5
Wheat standard middlings	890	17.0	.16	.36	.21	.14	.12	.20	4.5	7.0

Table B3. Vitamin-Trace Mineral Premixes for Pheasants

Ingredient	Per 10 lbs. Premix	
	Starter-Grower Maintenance	Breeder
Vitamin A, I.U.	6,000,000	8,000,000
Vitamin D ₃ , I.C.U.	1,500,000*	2,000,000**
Riboflavin, mg.	4,000	7,000
Pantothenic acid, mg.	8,000	12,000
Niacin, mg.	20,000	24,000
Choline chloride, mg.	400,000	400,000
Vitamin B ₁₂ , mg.	10	12
Vitamin E, I.U.	3,000	5,000
Menadione sodium bisulfite, mg.	1,500	1,500
Manganese, gm.	54	54
Iodine, gm.	1	1
Cooper, gm.	2	2
Cobalt, gm.	.20	.20
Zinc, gm.	25	25
Iron, gm.	18	18

* There were 750 I.C.U./lb. starter-grower ration.

** There were 800 I.C.U./lb. breeder ration.

Table B4. Pheasant Rations Used at M.S.U.

Calculated Analysis	PS-75 Starter 0-6 wks.	PG-75 Grower 6-12 wks.	PF-75 Flight 12 wks-Flight	PB-75 Breeder (Pelleted)
Crude protein, %	28.00	22.00	14.00	17.50
Fat, %	2.29	2.80	3.70	3.36
Fiber, %	3.34	4.82	5.33	5.10
Calcium, %	1.46	1.32	1.30	2.34
Phosphorus, avail, %	.66	.56	.54	.63
ME, Cal/lb.	1236	1220	1282	1210
ME, Cal/kg.	2725	2690	2826	2668

Table B5. Starter Ration Composition

Feed Description	Treatment								
	1	2	3	4	5	6	7	8	9
Corn	430	424	433	433	427	428	436	430	431
Limestone	11	0.85	--	27	17	10	42	32	26
Dicalcium	--	--	22.0	--	--	10	--	--	10
Meat & bone meal	2.05	42	--	4.61	45	50	7	47	50
Methionine, DL	1.59	1.61	1.58	1.58	1.60	1.60	1.58	1.60	1.60
Salt	4.35	3.68	4.31	4.28	3.56	3.43	4.20	3.48	3.40
Soybean meal, 49%	100	1.06	222	278	179	216	452	345	400
Soybean meal, 44%	448	524	314	249	324	280	53	129	76
Vit./Min.	6	6	6	6	6	6	6	6	6
Sum	1002.99	1003.20	1002.89	1003.47	1003.16	1005.03	1001.78	1003.08	1004.00
Item	Nutrient Composition								
Metabolizable energy in:									
Kcal/lb.	1236	1236	1236	1236	1236	1234	1238	1236	1235
Kcal/kg.	2725	2725	2725	2725	2725	2720	2729	2725	2723
Crude protein *	28.56/2.31	29.02/2.35	28.60/2.31	28.66/2.32	29.12/2.36	29.14/2.36	28.80/2.32	29.23/2.36	29.25/2.37
Calcium *	0.60/0.048	0.60/0.048	0.60/0.049	1.20/0.097	1.20/0.097	1.19/0.096	1.80/0.145	1.80/0.145	1.80/0.145
Phosphorus *	0.20/0.016	0.40/0.32	0.60/0.048	0.20/0.016	0.40/0.032	0.60/0.048	0.20/0.016	0.40/0.032	0.60/0.048

* As pct of ration/pct of ME

Table B6. Grower Ration Composition

Feed Description	Treatment								
	1**	2	3	4	5	6	7	8	9
Corn	501	496	516	Dead	513	518	Dead	530	535
Limestone	10	--	--		16	9		32	26
Meat & bone meal	14	48	--		50	50		50	50
Methionine, DL	1.00	1.09	0.93		1.04	1.03		0.99	0.98
Dicalcium	--	2.11	25		1.05	12.15		1.05	12
Salt	3.78	3.06	4.16		3.23	3.27		3.45	3.49
Fat, hydrolyzed animal & vegetable	--	--	8.67		6.0	8.4		12.35	14.79
soybean meal, 49%	275	234	302		244	248		258	262
Hard wheat	193	214	150		170	155		123	108
Vit./Min.	6	6	6		6	6		6	6
Sum	1003.78	1004.26	1012.76		1010.32	1010.85		1016.84	1018.26
Item	Nutrient Composition								
Metabolizable energy in:									
Kcal/lb.	1363	1373	1330		1343	1365		1356	1354
Kcal/kg.	3005	3027	2932		2961	3009		2989	2985
Crude protein *	21.1/1.55	21.0/1.53	21.1/1.59		21.1/1.57	21.1/1.55		21.1/1.56	21.2/1.56
Calcium	0.60/0.044	0.59/0.043	0.60/0.045		1.21/0.090	1.19/0.087		1.78/0.131	1.78/0.131
Phosphorus, avail.	0.20/0.015	0.40/0.029	0.59/0.045		0.39/0.029	0.62/0.046		0.38/0.028	0.58/0.043

* Pct of ration/pct of ME

** only for SG IIF

Table B7. Flight Ration Composition

Feed Description	Treatment								
	1	2	3	4	5	6	7	8	9
Corn	Dead	756	750	Dead	738	732	Dead	719	713
Alfalfa, 17%		14	15		16	16		17	17
Limestone		5	--		21	15		37	31
Methionine, DL		0.45	0.46		0.47	0.48		0.50	0.50
Dicalcium		15	26		15	26		15	26
Salt		4.95	4.93		4.96	4.93		4.96	4.94
Soybean meal, 44%		201	202		203	203		204	205
Vit./Min.		6	6		6	6		6	6
Sum		1002.4	1004.39		1002.43	1003.41		1003.46	1003.44
Item	Nutrient Composition								
Metabolizable energy in:									
Kcal/lb.		1389	1377		1363	1353		1334	1326
Kcal/kg.		3062	3036		3005	2983		2941	2923
Crude protein [*]		15.76/1.13	15.71/1.14		15.69/1.15	15.65/1.16		15.60/1.17	15.58/1.17
Calcium [*]		0.60/0.043	0.63/0.045		1.20/0.088	1.20/0.088		1.79/0.134	1.79/0.135
Phosphorus [*]		0.40/0.029	0.60/0.044		0.40/0.030	0.60/0.044		0.40/0.030	0.60/0.045

* As pct of ration/pct of ME

Table B8. Breeder Ration Composition - Part 1.

Feed Description	Treatment							
	1	2	3	4	5	6	7	8
Corn	578	589	591	593	599	601	602	604
Alfalfa, 17%	21	21	21	21	21	21	21	21
Limestone	32	29	26	23	47	44	41	39
Methionine, DL	1.02	1.01	1.00	1.00	0.98	0.97	0.96	0.96
Dicalcium	10	15	20	26	10	15	20	26
Salt	4.89	4.9	4.92	4.93	5	5	5	5
Soybean meal, 49%	209	211	213	214	220	222	223	225
Wheat bran	68	66	64	63	57	55	53	51
Wheat middlings	65	61	57	53	38	34	30	26
Vit./Min.	6	6	6	6	6	6	6	6
Sum	1003.91	1003.91	1003.92	1004.93	1003.98	1003.97	1001.96	1003.96
Item	Nutrient Composition							
Metabolizable energy in:								
Kcal/lb.	1245	1245	1245	1244	1245	1245	1248	1245
Kcal/kg.	2745	2745	2745	2743	2745	2745	2751	2745
Crude protein*	17.9/1.44	17.0/1.44	17.9/1.44	17.9/1.44	17.9/1.44	17.9/1.44	18.0/1.44	17.9/1.44
Calcium*	1.49/0.12	1.49/0.12	1.49/0.12	1.49/0.12	2.09/0.17	2/09/0.17	2.10/0.17	2.09/0.17
Phosphorus*	0.30/0.024	0.40/0.032	0.50/0.040	0.60/0.048	0.30/0.024	0.40/0.032	0.50/0.040	0.60/0.048

* As pct of ration/pct of ME.

(cont'd.)

Table B8. Breeder Ration Composition - Part 2.

Feed Description	Treatment									
	9	10	11	12	13	14	15	16		
Corn	610	612	614	615	616	616	616	617		
Alfalfa, 17%	21	21	21	21	22	22	22	22		
Limestone	63	60	57	54	79	76	73	70		
Methionine, DL	0.93	0.93	0.92	0.91	0.89	0.88	0.87	0.86		
Dicalcium	10	15	20	26	10	15	20	26		
Salt	5	5	5	5	5	5	5	5		
Soybean meal, 49%	231	233	234	236	242	244	245	247		
Wheat bran	45	43	42	39	23	18	14	9		
Wheat middlings	11	7	3.09	--	--	--	--	--		
Vit./Min.	6	6	6	6	6	6	6	6		
Sum	1002.93	1002.93	1003.01	1002.91	1003.89	1002.88	1001.87	1002.86		
Item	Nutrient Composition									
Metabolizable energy in:										
Kcal/lb.	1246	1246	1246	1246	1245	1246	1248	1246		
Kcal/kg.	2747	2746	2746	2746	2745	2746	2751	2746		
Crude Protein*	17.9/1.44	17.9/1.44	17.9/1.44	17.9/1.44	18.0/1.45	18.0/1.45	18.1/1.45	18.1/1.45		
Calcium*	2.70/0.22	2.70/0.22	2.7/0.22	2.7/0.22	3.29/0.27	3.29/0.26	3.29/0.26	3.29/0.26		
Phosphorus*	0.30/0.024	0.40/0.032	0.50/0.040	0.60/0.048	0.30/0.024	0.40/0.032	0.50/0.040	0.60/0.048		

* As pct of ration/pct of ME.

APPENDIX C. Analysis of Variance Tables. Groups
are defined on the Abbreviations and
Symbols page.

Table C1. Egg Fertility - Group 1

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	23916.36	2	11958.18	11.846287	<0.0005
Ca	9888.4148	3	3296.1383	3.265297	.035
P	4530.7624	3	1510.2541	1.496123	.236
Ca*P	6272.5230	9	696.9470	.69042578	.712
Error 1	30283.36	30	1009.4452		
Period	8191.4869	9	910.1652	9.570222	<0.0005
Ca*Period	1531.5512	27	56.724119	.59644383	.946
P*Period	2916.7192	27	108.0266	1.135880	.297
Ca*P*Period	6925.3195	81	85.497772	.89899356	.712
Residual error	27389.92	288	95.103875		
TOTAL	121846.40	479			

Table C2. Egg Fertility - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	78.9393	2	39.4697	.04972434	0.952
Ca	1830.4335	3	610.1445	.76866738	0.521
P	168.2898	3	56.096604	.07067118	0.975
Ca*P	3874.8211	9	430.5357	.54239401	0.832
Error 1	23813.08	30	793.7682		
Period	4023.8562	9	447.0951	2.056778	0.033
Ca*Period	6356.8743	27	235.4398	1.983097	0.359
P*Period	4118.5191	27	152.5377	.70172163	0.865
Ca*P*Period	16204.39	81	200.0542	.92031236	0.666
Residual error	62604.41	288	217.3764		
TOTAL	123073.61	479			

Table C3. Hatchability - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	8031.5679	2	4015.7840	7.561997	.002
Ca	1775.3121	3	591.7707	1.114345	.359
P	1635.4410	3	545.1470	1.026549	.395
Ca P	4150.1498	9	461.1278	.86833529	.563
Error 1	15931.44	30	531.0480		
Period	3690.8407	9	410.0934	4.180700	<0.0005
Ca*Period	3236.7465	27	119.8795	1.222112	.212
P*Period	2066.6458	27	76.542438	.78031246	.777
Ca P*Period	7380.3350	81	91.115247	.92887506	.647
Residual Error	28250.51	288	98.092036		
TOTAL	76148.99	479			

Table C4. Hatchability - Group 2

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	137.1624	2	68.581221	.19992222	0.820
Ca	2365.0240	3	788.3413	2.298106	0.098
P	332.4362	3	110.8121	.32303008	0.809
Ca*P	4184.2470	9	464.9163	1.355285	0.252
Error 1	10291.19	30	343.0395		
Period	14780.84	9	1642.3151	7.929325	0.0005
Ca*Period	4551.8460	27	168.5869	.81396083	0.773
P*Period	5633.1357	27	208.6347	1.007317	0.458
Ca*P*Period	19786.51	81	244.2779	1.179408	0.165
Residual Error	59650.32	288	207.1192		
TOTAL	121712.70	479			

Table C5. Percent Hen-Day Egg Production - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	11012.57	2	5506.2839	14.338535	<0.0005
Ca	840.8438	3	280.2813	.72986114	.542
P	3295.2188	3	1098.4063	2.860284	.053
Ca*P	3151.2604	9	350.1400	.91177563	.528
Error I	11520.60	30	384.0200		
Period	10019.07	7	1431.2961	16.687301	<0.0005
Ca*Period	489.4895	21	23.309028	.27175701	1.000
P*Period	506.1146	21	24.100694	.28098696	.999
Ca*P*Period	2326.7396	63	36.932374	.43058989	1.000
Residual error	19212.83	224	85.771577		
TOTAL	62374.74	383			

Table C6. Percent Hen-Day Egg Production - Group 2.

Source of Variance	Sum of Squares	Degr. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	949.0206	3	316.3403	0.19403960	0.900
Ca	7435.8958	3	2478.6319	1.520365	0.222
P	893.1181	3	297.7060	0.18260955	0.908
Ca*P	15179.96	9	1686.6644	1.034581	0.428
Error I	73362.92	45	1630.2872		
Period	34772.27	8	4346.5343	39.184115	0.0005
Ca*Period	2465.4479	24	102.7270	0.92608645	0.566
P*Period	2094.7257	24	87.280237	0.78683352	0.651
Residual Error	42595.56	384	110.9259		
TOTAL	187128.49	575			

Table C7. Egg Weight - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	209.4403	2	104.7202	22.280586	<0.0005
Ca	50.182292	3	16.727431	3.558980	.026
P	.51451430	3	.17150477	.03648988	.990
*Ca P	27.648727	9	3.072081	.65362540	.743
Error I	141.0010	30	4.700063		
Period	243.6069	8	30.450857	98.912694	<0.0005
*Ca P	4.818333	24	.20076387	.65213586	.894
*P Period	7.199444	24	.29997684	.97440664	.501
*Ca P Period	22.859815	72	.31749743	1.031318	.421
Residual error	78.811111	256	.30785590		
TOTAL	786.0833	431			

Table C8. Egg Weight - Group 2.

Source of Variation	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	60.454319	2	30.227159	2.424927	0.106
Ca	78.440209	3	26.146736	2.097599	0.121
P	9.252344	3	3.084115	0.24742035	0.863
Ca P [*]	110.9224	9	12.324716	0.98873933	0.469
Error I	373.9524	30	12.465081		
Period	242.9276	8	30.365946	51.569796	0.0005
Ca [*] Period	9.450750	24	0.39378124	0.66874972	0.880
P [*] Period	23.579065	24	0.98246102	1.668491	0.029
Ca [*] P [*] Period	38.073869	72	0.52880373	0.89805535	0.701
Residual error	150.7410	256	0.58883200		
TOTAL	1097.7940	431			

Table C9. Shell Percent of Total Egg Weight - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	30.288854	2	15.144427	42.436636	<0.0005
Ca	18.909722	3	6.303241	17.662493	<0.0005
P	.75097229	3	.25032410	.70144037	.559
Ca*P	3.980139	9	.44223765	1.239207	.309
Error I	10.706148	30	.35687153		
Period	46.936250	11	4.266932	39.813386	<0.0005
Ca*Period	4.429861	33	.13423821	1.252534	.166
P*Period	2.711944	33	.08218013	.76679673	.821
Ca*P*Period	9.078611	99	.09170314	.85565292	.822
Residual error	37.725000	352	.10717330		
TOTAL	165.5175	575			

Table C10. Shell Percent of Total Egg Weight - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	3.869201	2	1.934601	1.586836	0.221
Ca	19.625052	3	6.541684	5.365747	0.004
P	4.945747	3	1.648582	1.352232	0.276
Ca*P	8.608628	9	0.95651427	0.78457070	0.632
Error I	36.574687	30	1.219156		
Period	28.666441	11	2.606040	10.784107	0.0005
Ca*Period	8.618490	33	0.26116635	1.080738	0.354
P*Period	6.176128	33	0.18715541	0.77447157	0.812
Ca*P*Period	23.076997	99	0.23310098	0.96459986	0.576
Residual error	85.062778	352	0.24165562		
TOTAL	225.2241	575			

Table C11. Eggshell Thickness - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	.00787522	2	.00393761	10.559159	<0.0005
Ca	.01379855	3	.00459952	12.334138	<0.0005
P	.00138219	3	.00046073	1.235498	.314
Ca P [*]	.00529650	9	.00058850	1.578132	.167
Error I	.01118728	30	.00037291		
Period	.03384109	11	.00307646	26.555373	<0.0005
Ca [*] Period	.00432627	33	.00013110	1.131618	.288
P [*] Period	.00216663	33	.00006566	.56672310	.975
Ca [*] P [*] Period	.00710777	99	.00007180	.61972481	.997
Residual error	.04077950	352	.00011585		
TOTAL	.12776098	575			

Table C12. Eggshell Thickness - Group 2

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Apprx. Sig. of F Statistic
Replicate	0.00038271	2	0.00019135	0.19108692	0.827
Ca	0.01352581	3	0.00450860	4.502266	0.010
P	0.00365905	3	0.00121968	1.217968	0.320
Ca P	0.01269999	9	0.00141111	1.409126	0.228
Error I	0.03004223	30	0.00100141		
Period	0.02077714	11	0.00188883	9.198295	0.0005
Ca Period	0.00972500	33	0.00029470	1.435126	0.061
P Period	0.00656660	33	0.00019899	0.96903781	0.521
Ca P Period	0.2048245	99	0.00020689	1.007537	0.469
Residual error	0.07228172	352	0.00020535		
TOTAL	0.19014271	575			

Table C13. Eggshell Membrane Thickness - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	.00000001	1	.00000001	.00085465	.977
Ca	.00009286	3	.00003095	2.539741	.096
P	.00010511	3	.00003504	2.874765	.071
Ca P*	.00010726	9	.00001192	.97781703	.495
Error I	.00018282	15	.00001219		
Period	.00004540	2	.00002270	5.873315	.007
Ca*Period	.00006160	6	.00001027	2.656783	.033
P*Period	.00001285	6	.00000214	.55435759	.763
Ca P*Period	.00002115	18	.00000117	.30398323	.995
Residual error	.00012367	32	.00000386		
TOTAL	.00075274	95			

Table C14. Eggshell Membrane Thickness - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	0.00002639	2	0.00001319	0.65819862	0.525
Ca	0.00001708	3	0.00000569	0.28394919	0.837
P	0.00005641	3	0.00001880	0.93799076	0.435
Ca P [*]	0.00028940	9	0.00003216	1.604042	0.159
Error I	0.00060139	30	0.00002005		
Period	0.00010239	2	0.00005119	5.666410	0.005
Ca [*] Period	0.00002578	6	0.00000430	0.47553164	0.824
P [*] Period	0.00001344	6	0.00000224	0.24801435	0.958
Ca P [*] Period	0.00006083	18	0.00000338	0.37407123	0.989
Residual error	0.00057822	64	0.00000903		
TOTAL	0.00177133	143			

Table C15. Blood Plasma Calcium--Adult Females - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	392.8004	2	196.4002	8.562308	.001
Ca	118.9540	3	39.651319	1.728648	.182
P	3.765625	3	1.255208	.05472235	.983
Ca*P	159.6619	9	17.740208	.77340618	.642
Error I	688.1329	30	22.937764		
TOTAL	1363.3148	47			

Table C16. Blood Plasma Calcium---Adult Females - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	351.1186	3	117.0396	2.299441	0.090
Ca	615.4613	3	205.1538	4.030594	0.013
P	44.876250	3	14.958750	0.29389004	0.830
Ca*P	361.2200	9	40.135556	0.76853113	0.628
Error I	2290.4612	45	50.899139		
TOTAL	3663.1275	63			

Table C17. Blood Plasma Phosphorus--Adult Female - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	23.291667	2	11.645833	5.751818	.008
Ca	6.251667	3	2.083889	1.029222	.394
P	2.225000	3	.74166667	.36630539	.778
Ca*P	5.616667	9	.62407407	.30822701	.966
Error I	60.741667	30	2.024722		
TOTAL	98.126667	47			

Table C18. Blood Plasma Phosphorus--Adult Female - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	30.601719	3	10.200573	4.080926	0.012
Ca	72.846719	3	24.282240	9.714555	0.0005
P	56.397969	3	18.799323	7.521024	0.0005
Ca P [*]	35.122656	9	3.902517	1.561274	0.156
Error I	112.4808	45	2.499573		
TOTAL	307.4498	63			

Table C19. Adult Feed Consumption--Experiment Average - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	106.9067	2	53.453333	4.671677	.017
Ca	26.928333	3	8.976111	.78448795	.512
P	83.355000	3	27.785000	2.428334	.085
Ca*P	73.366667	9	3.151852	.71244991	.693
Error I	343.2600	30	11.442000		
TOTAL	633.8167	47			

Table C20. Adult Feed Consumption--using the replicate values at each period - Group 2.

Source of Variation	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	217.3484	3	72.449427	0.50480464	0.681
Ca	486.0755	3	162.0252	1.128940	0.347
P	343.2208	3	114.4069	0.79715120	0.502
Ca*P	1881.3323	9	209.0369	1.456503	0.194
Error I	6458.3880	45	143.5197		
Period	6993.0942	3	2331.0314	101.7373	0.0005
Ca*Period	254.6414	9	28.293490	1.234863	0.278
P*Period	64.871093	9	7.207899	0.31468717	0.969
Ca*P*Period	729.1845	27	27.006835	1.178707	0.264
Residual error	3299.3637	144	22.912248		
TOTAL	20727.52	255			

Table C21. Adult Female Tibia Dry Fat-Free Bone (dffb) - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	184.3200	1	184.3200	15.914350	.001
Ca	312.3125	3	104.1042	8.988445	.001
P	17.730000	3	5.910000	.51027456	.681
Ca*P	74.367500	9	8.263056	.71343944	.690
Error I	173.7300	15	11.582000		
TOTAL	762.4600	31			

Table C22. Adult Female Tibia Dry Fat-Free Bone (dffb) - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	511.5963	3	170.5321	6.114337	0.001
Ca	1381.9650	3	460.6550	16.6550	0.0005
P	113.0813	3	37.693750	1.351489	0.270
Ca*P	262.4412	9	29.160139	1.045521	0.420
Error I	1255.0737	45	27.890528		
TOTAL	3524.1575	63			

Table 23. Adult Bone, Dry Fat-Free Bone Percent Ash--Females - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	7.702813	1	7.702813	5.643861	.031
Ca	61.173438	3	20.391146	14.940621	<0.0005
P	3.865938	3	1.288646	.94419258	.444
Ca*P	14.565312	9	1.618368	1.185781	.370
Error I	20.472187	15	1.364812		
TOTAL	107.7797	31			

Table 24. Adult Bone, Dry Fat-Free Bone Percentage Ash--Females - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Replicate	119.4156	3	39.805208	5.520929	0.003
Ca	240.9231	3	80.307708	11.138572	0.0005
P	1.103125	3	0.36770834	0.05100065	0.985
Ca*P	42.428125	9	4.714236	0.65385823	0.745
Error I	324.4444	45	7.209875		
TOTAL	728.3144	63			

Table C25. Adult Bone Dry Fat-Free Bone Ash Percent Calcium--Females - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	39.605000	1	39.605000	119.4121	0.0005
Ca	7.836250	3	2.612083	7.875628	.002
P	.51125000	3	.17041667	.51381910	.679
Ca*P	2.501250	9	.27791667	.83793970	.594
Error I	4.975000	15	.33166667		
TOTAL	55.428750	31			

Table C26. Adult Bone Dry Fat-Free Bone Ash Percent Calcium--Females - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Rep	2.555625	3	0.85187500	1.257509	0.300
Ca	7.673125	3	2.557708	3.775602	0.017
P	4.885625	3	1.628542	2.403998	0.080
Ca*P	8.580625	9	0.95340278	1.407381	0.214
Error I	30.484375	45	0.67743056		
TOTAL	54.179375	63			

Table C27. Adult Bone, Ash Percent Phosphorus--Female - Group 1.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	.01531250	1	.01531250	.05920258	.811
Ca	1.518438	3	.50614583	1.956907	.164
P	.46593750	3	.15631250	.60048329	.625
Ca*P	.81281250	9	.09031250	.34917439	.942
Error I	3.879687	15	.25864583		
TOTAL	6.692188	31			

Table C28. Adult Bone, Dry Fat-Free Bone Ash Percent Phosphorus--Female - Group 2.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. of F Statistic
Rep.	0.14546875	3	0.04848958	0.21881513	0.883
Ca	5.791719	3	1.930573	8.711944	0.0005
P	1.621719	3	0.54057292	2.439401	0.077
Ca*P	0.65140625	9	0.07237847	0.32661663	0.962
Error I	9.972031	45			
TOTAL	18.182344	63			

Table C29. Adult Body Weight

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	1585.00937	2	792.50469	6.769	0.00124
Ca	97.96437	3	32.65479	0.279	0.84063
P	441.66446	3	147.22149	1.25750	0.28818
Ca*P	1672.89576	9	185.87731	1.58870	0.11497
Error I	66381.54943	567	117.07504		
Error 2: within + residual	69848.95472	597	116.99992		

Table C30. F1 Mortality.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Experiment	12.625313	1	12.625313	2.231943	.156
Ca	80.150938	3	26.716979	4.723113	.016
P	14.515938	3	4.838646	.85539134	.485
Ca*P	70.815312	9	7.868368	1.390995	.275
Error I	84.849687	15	5.656646		
TOTAL	262.9572	31			

Table C31. Feed Consumption of Battery-Reared Chicks (through four-weeks of age).

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	11.020833	1	11.020833	14.957023	.012
Ca	2.501667	2	1.250883	1.697580	.274
P	3.967500	1	3.967500	5.384528	.068
Ca*P	14.015000	2	7.007500	9.510292	.020
Error I	3.684167	5	.73683333		
TOTAL	35.189167	11			

Table C32. Feed Consumption for Starter, Grower and Flight Periods.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep.	170.3025	1	170.3025	7.901263	.038
Ca	265.8317	2	132.9158	6.166691	.045
P	103.7003	1	103.7003	4.811222	.080
* Ca P	36.890556	2	18.445278	.85577714	.479
Error I	107.7692	5	21.553833		
Period	8292.1267	2	4146.0633	229.3247	<0.0005
* Ca Period	140.2467	4	35.061667	1.939311	.168
* P Period	.29555555	3	.14777778	.00817380	.992
* * Ca P Period	37.831111	4	9.457778	.52312325	.721
Residual error	216.9533	12	18.079444		
TOTAL	9371.9475	35			

Table C33. Chick Body Weight from Day-Old through Four Weeks-of-Age---All Treatments.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	1395.5625	3	465.1875	11.409811	<0.0005
Ca	343.5000	2	171.7500	4.212570	.035
P	1271.0208	1	1271.0208	31.174757	<0.0005
Ca P *	788.1667	2	394.0833	9.665815	.002
Error I	611.5625	15	40.770833		
Period	392589.19	1	392589.19	3567.8664	<0.0005
Ca Period *	351.5000	2	175.7500	1.597223	.230
P Period *	1210.0208	1	1210.0208	10.996718	.004
Ca P Period *	858.1667	2	429.0833	3.899527	.039
Residual error	1980.6250	18	110.0347		
TOTAL	401399.31	47			

Table C34. Body Weight through Sixteen Weeks.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	40716.15	1	40716.15	23.310728	.005
Ca	2265.7000	2	1132.8500	.64857701	.562
P	6100.4167	1	6100.4167	3.492598	.121
* Ca P	5936.0333	2	2968.0167	1.699243	.273
Error I	8733.3500	5	1746.6700		
Period	9529980.	4	2382495.	2499.6981	<0.0005
* Ca Period	3131.9667	8	391.4958	.41075486	.905
* * Ca P Period	7332.6333	8	918.5792	.95166884	.485
Residual error	26687.17	28	953.1131		
TOTAL	9630883.	59			

Table C35. Percent DFFB from Two Week Data; All Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	445.1608	4	111.2902	4.358857	.006
Ca	26.777333	2	13.388667	.52438827	.597
P	1387.9693	2	693.9847	27.181005	<0.0005
Ca P [*]	216.1013	4	54.025333	2.115987	.102
Error I	817.0231	32	25.531972		
TOTAL	2893.0320	44			

Table C36. Percent Ash from Two Week Data; All Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	6.414222	4	1.603556	.16803377	.953
Ca	57.221778	2	28.610889	2.998085	.064
P	2640.9658	2	1320.4829	138.3711	<0.0005
Ca P [*]	208.2369	4	52.059222	5.455194	.002
Error I	305.3778	32	9.543056		
TOTAL	3218.2164	44			

Table C37. Ash Percent Calcium from Two Week Data; All Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	20.143111	4	5.035778	3.245951	.024
Ca	1.348000	2	.67400000	.43444553	.651
P	.97200001	2	.48600000	.31326488	.733
* Ca P	.82400000	4	.20600000	.13278305	.969
Error I	49.644889	32	1.551403		
TOTAL	72.932000	44			

Table C38. Ash Percent Phosphorus from Two Week Data; All Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	3.807556	4	.95188889	4.546033	.005
Ca	3.953778	2	1.976889	9.441231	.001
P	4.320444	2	2.160222	10.316795	<0.0005
Ca P [*]	.55422222	4	.13855556	.66171398	.623
Error I	6.700444	32	.20938889		
TOTAL	19.336444	44			

Table C39. DFFB from Two and Four Week Values for Floor and Caged Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	127.0723	3	42.357431	1.885575	.175
Ca	19.082917	2	9.541458	.42474572	.662
P	134.3352	1	134.3352	5.980040	.027
Ca P *	254.4004	2	127.2002	5.662420	.015
Error I	336.9591	15	22.463931		
Period	89.926875	1	89.926875	2.304992	.146
Ca Period *	40.976250	2	20.488125	.52514858	.600
P Period *	20.150208	1	20.150208	.51648715	.482
Ca P Period *	108.8504	2	54.425208	1.395019	.273
Residual error	702.2512	18	39.013958		
TOTAL	1834.0048	47			

Table C40. Percent Ash from Two and Four Week Values for Floor and Caged Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	40.630000	3	13.610000	.77032649	.528
Ca	61.165417	2	30.682708	1.730982	.211
P	234.9675	1	234.9675	13.299169	.002
Ca P *	69.326250	2	34.663125	1.961934	.175
Error I	265.0175	15	17.667833		
Period	851.7675	1	851.7675	51.700171	<0.0005
Ca Period *	8.416250	2	4.208125	.25542273	.777
P Period *	70.083333	1	70.083333	4.253884	.054
Ca P Period *	11.230417	2	5.615208	.34082920	.716
Residual error	296.5525	18	16.475139		
TOTAL	1909.3567	47			

Table C41. Ash Percent Calcium; Two and Four Week Values for Floor and Caged Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	34.292292	3	11.430764	27.048838	<0.0005
Ca	.9516687	2	.47583334	1.125974	.350
P	.58520834	1	.58520834	1.384790	.258
Ca P *	.1888668	2	.05333333	.12620370	.882
Error I	6.338958	15	.42259722		
Period	.25520838	1	.25520834	.48196722	.496
Ca Period *	.98686668	2	.49333333	.93167213	.412
P Period *	.06020833	1	.06020833	.11370491	.740
Ca P Period *	.60166667	2	.30083333	.56813115	.576
Residual error	9.531250	18	.52951389		
TOTAL	53.709792	47			

Table C42. Ash Percent Phosphorus; Two and Four Week Values for Floor and Caged Replicates.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	1.620000	3	.54000000	3.223881	.053
Ca	3.738750	2	1.869375	11.160448	.001
P	.30083333	1	.30083333	1.796020	.200
Ca P *	.26791667	2	.13395833	.79975124	.468
Error I	2.512500	15	.16750000		
Period	.48000000	1	.48000000	3.197040	.091
Ca Period *	.27375000	2	.13687500	.91165587	.420
P Period *	.24083333	1	.24083333	1.604070	.221
Ca P Period *	.10291667	2	.05145833	.38273821	.714
Residual error	2.702500	18	.15013889		
TOTAL	12.240000	47			

Table C43. Percent DFFB from Two through Twelve Week Data, Replicates If, IIf.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	193.2019	1	193.2019	9.939966	.025
Ca	8.790417	2	4.395208	.22612731	.805
P	118.7552	1	118.7552	6.109789	.056
* Ca P	91.230417	2	45.615208	2.346839	.191
Error I	97.184375	5	19.436875		
Period	3093.1956	3	1031.0652	23.257438	<0.0005
* Ca Period	181.9112	6	30.318542	.68388652	.665
* P Period	47.027292	3	15.675764	.35359364	.787
* * Ca P Period	187.0646	6	31.177431	.70326023	.651
Residual error	797.9887	18	44.332708		
TOTAL	4816.3498	47			

Table C44. Percent Ash from Two through Twelve Week Data; Replicate If, IIf.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	.44083335	1	.44083335	.28036889	.619
Ca	1.882917	2	.94145834	.59876511	.585
P	67.213333	1	67.213333	42.747509	.001
* Ca P	57.005417	2	28.502708	18.127650	.005
Error I	7.861667	5	1.572333		
Period	678.7825	3	226.2608	28.558771	<0.0005
* Ca Period	25.363750	6	4.227292	.53357117	.776
* P Period	62.246667	3	20.748889	2.618937	.082
* * Ca P Period	58.274583	6	9.712431	1.225909	.339
Residual error	142.6075	18	7.922639		
TOTAL	1101.6792	47			

Table C45. Ash Percent Calcium from Two through Twelve Week Data; Replicates If, IIf.

Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	11.603333	1	11.603333	28.004827	.003
Ca	2.526667	2	1.263333	3.049075	.136
P	.01333334	1	.01333334	.03218022	.865
Ca P	.72166666	2	.36083333	.87087691	.474
Error I	2.071667	5	.41433333		
Period	51.251667	3	17.083889	20.000650	<0.0005
Ca Period	4.693333	6	.78222222	.91577236	.506
P Period	1.271667	3	.42388889	.49626016	.689
Ca P Period	.94833333	8	.15805556	.18504065	.977
Residual error	15.375000	18	.85416667		
TOTAL	90.476667	47			

Table C46. Ash Percent Phosphorus from Two through Twelve Week Data; Replicates If, IIf.

Source of Variance	Sum of Squares	Sum of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	.403333333	1	.403333333	.92015209	.381
Ca	3.115417	2	1.557708	3.553707	.110
P	.213333333	1	.213333333	.48669202	.517
Ca P	.14291667	2	.07145833	.16302281	.854
Error I	2.191667	5	.43833333		
Period	5.801667	3	1.933889	3.944476	.025
Ca Period	2.134583	6	.35576389	.72563739	.635
P Period	.59166667	3	.19722222	.40226629	.753
Ca P Period	.72708333	6	.12118056	.24716714	.954
Residual error	8.825000	18	.49027778		
TOTAL	24.146667	47			

Table C47. Starter Chick Mortality through Four Weeks-of-Age.

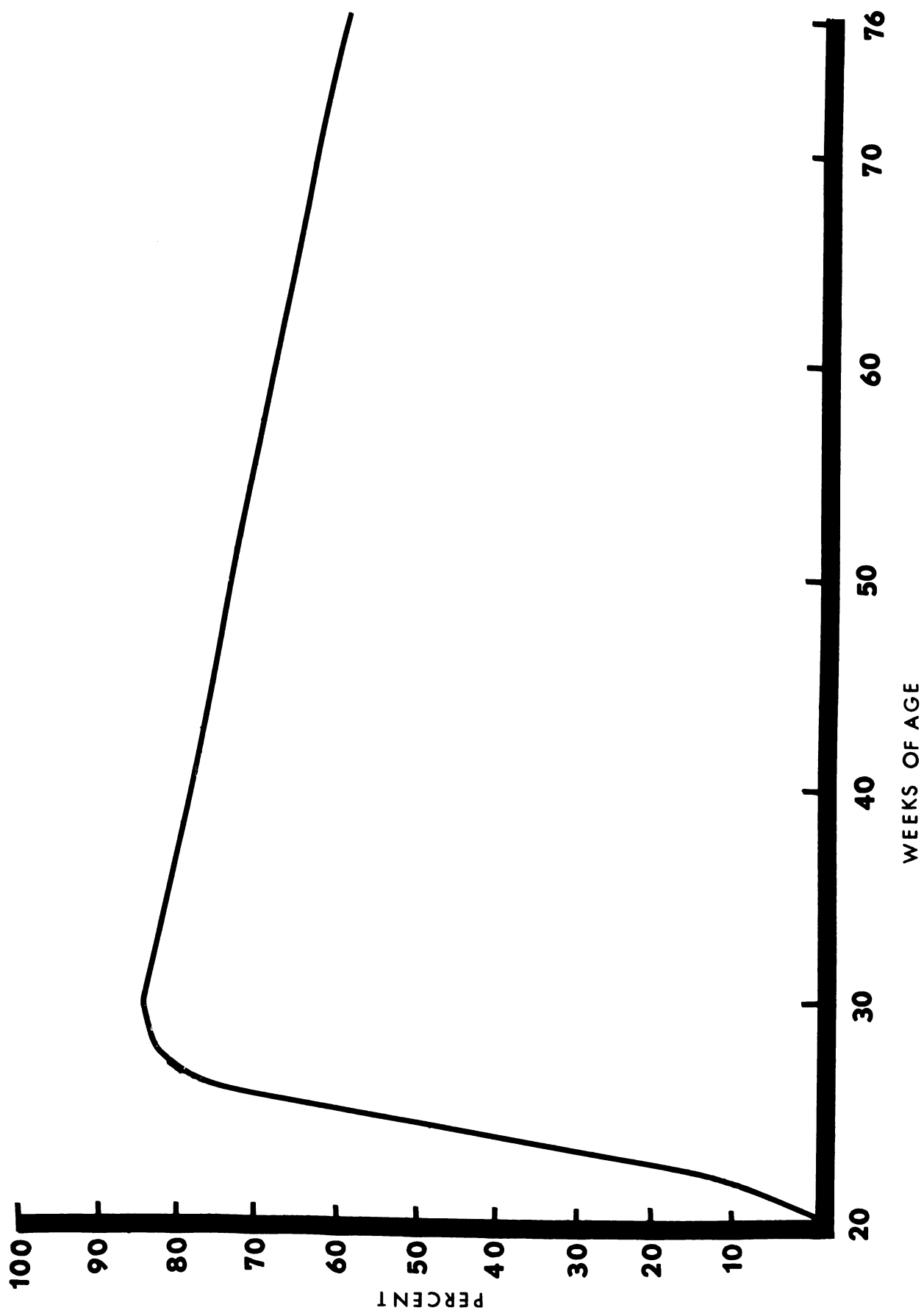
Source of Variance	Sum of Squares	Degs. of Freedom	Mean Square	F Statistic	Approx. Sig. Prob. of F Statistic
Rep	559.4222	4	139.8556	1.286258	.296
Ca	852.3111	2	426.1556	3.919373	.030
P	71081.11	2	35540.56	326.8682	<0.0005
Ca P [*]	343.4222	4	85.855556	.78961756	.541
Error I	3479.3778	32	108.7306		
TOTAL	76315.64	44			

APPENDIX D.

STARTER/GROWER: Period Averages of Feed Consumption for Starter (Weeks 1-6),
 Grower (Weeks 7-12), and Flight-Aged (Weeks 13-16), Pheasants
 from Floor Replicates, in Grams/Bird/Day.

Treatment	Replicate	WEEKS		
		1-6	7-12	13-16
1	SG If	9.3	--	--
	SG IIf	11.7	36.7	--
2	SG If	20.9	46.4	52.8
	SG IIf	20.1	54.0	59.3
3	SG If	23.6	47.8	49.4
	SG IIf	18.1	56.3	61.6
4	SG If	6.1	--	--
	SG IIf	6.3	--	--
5	SG If	19.2	40.0	47.2
	SG IIf	17.7	51.8	58.6
6	SG If	19.8	42.5	56.2
	SG IIf	21.3	58.1	67.2
7	SG If	5.5	--	--
	SG IIf	5.9	--	--
8	SG If	14.5	36.3	51.5
	SG IIf	21.7	60.7	72.2
9	SG If	21.5	40.8	53.6
	SG IIf	19.4	55.8	62.6

Appendix D, Figure 1.
Expected hen-day egg production for
S.C.W.L. laying hens. Reproduced
from the DeKalb Management Guide.



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VITA

Richard Douglas Reynnells was born on May 19, 1947 in Paw Paw, Michigan. With his younger brothers (Russ, Bob, and Tom), he grew up working on the family farm in nearby Lawrence. The farm had grown from about 80 to 160 acres and had changed from dairy to chickens, corn, and tart cherries by the time he graduated from Lawrence High School in 1965.

After one year at Lake Michigan College, Rich joined the Air Force as an aircraft mechanic. While in Hawaii, Okinawa, and the Philippines he worked on C-124 aircraft. While in the Philippines in 1969 Rich married Estela Chavez. They now have three children: Kathy, Mike, and Steve.

After transfer to Grand Forks AFB, ND, an early-out allowed Rich to attend Southwestern Michigan College in 1970. When the Applied Science degree requirements were completed in 1972, they moved to married housing at Michigan State University. By winter term of 1974, the Poultry Science Bachelor degree requirements were completed. Rich then worked as a technician on the Poultry Department anaphage experiments and then received a Training Fellowship from the National Institute of Health while he worked on the Master and Ph.D. degrees. The M.S. degree was completed in June of 1976. Rich then started on the Ph.D. program with Cal Flegal as the major professor. The subject of the Ph.D. dissertation was the determination of the calcium and available phosphorus requirements of growing and adult Ring-necked Pheasants. This was completed in June of 1979.

