EFFECT OF ENERGY, SUPPLEMENTAL PELLETS AND STRESS ADDITIVES UPON THE REPRODUCTIVE PERFORMANCE OF LAYING HENS

By

WILLIAM LESLEY McCASLAN

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Oklahoma State University

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Thesis Approved:

Rollin H. Thayer
Thesis Adviser

John W. West
Head of the Department

[illegible]
Dean of the Graduate School

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INTRODUCTION

The Oklahoma Egg Laying Test was started at the Oklahoma Agricultural Experiment Station in 1923 and was discontinued in 1957. During the years between 1945 and 1957, nutritional observations made in the Oklahoma Egg Laying Test led to the development of three layer rations. Data on these rations were collected during the years in which they were fed. These data are summarized in the Oklahoma Agricultural Experiment Bulletin T-66.

The experiment described in this thesis was designed to permit an evaluation of these three rations (BMC 501, BMC 551, BMC 560) under the same enviromental conditions. In addition, antibiotic and pellet studies were included in this feeding trial. The factors which were used to evaluate the various rations were: egg production, body weight gain, hatchability, egg size, efficiency of feed utilization, mortality and production costs.

REVIEW OF LITERATURE

ENERGY

Efficiency of Feed Conversion

It has been known for many years that the crude fiber content of poultry diets is correlated inversely with feed efficiency. Heuser _et al_. (1945) found rations which were fiberous in nature to be less efficient than rations with a lower fiber content. Bird and Whitson (1946) reported that a fiber level of 5.89 percent is sufficient to exert a detrimental effect on efficiency of feed conversion.

Peterson _et al_. (1957) reported that a low energy ration (660 Calories per pound) required ten percent more total feed than did a ration which contained 910 Calories per pound. Anderson _et al_. (1957) noted that a ration which contained 723 Calories per pound required four-tenths of a pound more feed, as measured by pounds of feed per dozen eggs, than did a ration which contained 884 Calories per pound.

MacIntrye and Aitken (1957) reported that each one hundred Calorie decrease in the energy content of the diet increased by eleven percent the pounds of feed required per dozen eggs. In a recent study McDaniel _et al_. (1957) increased the energy content of a low energy diet by 88 Calories per pound. This was done by adding 10.5 percent of poultry oil at the expense of corn and milo. The result was a 12.2 percent increase in efficiency as measured in pounds of feed required per dozen eggs produced.

Hill (1956) fed rations which contained 930, 840, and 740 Calories of productive energy per pound. This series of energy levels was produced by replacing corn with wheat by-products, oats, and alfalfa meal. Relative efficiency indices, as calculated by the Byerly (1941) partition equation were 101, 90.5, and 82.7 for the high, medium, and low energy diets, respectively.

An extensive analysis of the productive performance of hens fed low and high energy rations in the Oklahoma Egg Laying Test was made by Thayer *et al.* (1956). They stated that 5.41 pounds of feed were required per dozen eggs produced during the three best years when low energy rations were fed. An average of 4.79 pounds was required during the three years when high energy rations were fed. These data support previous work conducted by Skinner *et al.* (1951); Singsen *et al.* (1952); Gerry *et al.* (1952); and Lillie *et al.* (1952). These researchers concluded that rations which contained a high calorie content were more efficient, as measured by pounds of feed per dozen eggs produced, than rations which were low in energy.

Hatchability

It is thought that the first attempt to evaluate the effect of fat in poultry rations on hatchability was made by Heywang (1942). Rations which contained 0.80, 2.80, 4.80, and 8.80 percent fat were fed to Single Comb White Leghorn pullets.

Eggs from these pullets were set during two trials through the winter and spring months. No significant differences in hatchability could be attributed to the fat content of the diets. Berg and Bearse (1956) found that hatchability remained approximately the same regardless of the diet fed. Skinner et al. (1951) were of the opinion that high efficiency rations were equal or better than low efficiency ration with regard to hatchability.

Egg Size

Little work has been reported on the correlation of dietary energy to egg size, although this is of great importance to the producer. MacIntrye and Aitken (1957) and Berg and Bearse (1956) found that egg size for heavy and light breeds was not affected by the energy content of the diet. During a four year period Gerry et al. (1952) studied several lots of pullets which were raised and maintained on both high efficiency and conventional rations. Egg size was found to be similar on either ration. On the other hand, Hochreich et al. (1957) noted an increase in egg size with the addition of 6.6 percent of animal fat to the conventional ration.

Body Weight

Heywang (1943) demonstrated that a linear relationship exists between body gains and the energy content of the diet. Rations which contained 0.80, 2.80, 4.80, and 8.80 percent of fat were fed to laying hens over a twenty six-week period. Changes in body weight averaged -67, +17, +66, and +86 grams per bird, respectively. Hill et al. (1956) obtained similar results. Body weight gains of 516, 458, and 398 grams per bird, over a thirty six-week period, resulted when rations were fed which contained 930, 840, and 740 Calories per pound, respectively. Dietary energy in relationship to body weight was studied by Heuser et al. (1945); Skinner et al. (1951); Lillie et al. (1952); Berg and Bearse (1956); Anderson et al. (1957); and MacIntrye and Aitken (1957). These researchers concluded that the calorie content of the diet is an important factor in maintaining and increasing the body weight of laying birds. On the other hand, some researchers failed to verify the above data. Miller et al. (1956) and McDaniel et al. (1957) reported no differences in body weight regardless of the calorie content of the diet.

Production

The literature contains conflicting data on the role of high calorie diets on egg production. Russell et al. (1941) concluded that rations which contained between 4 and 5 percent of fat were inadequate for high producing hens. In the case of some hens, the fat in the egg and fecal material surpassed the fat content of the diet when 66 percent production was reached. Therefore, it was evident that some of the fat of the egg was synthesized from other constituents in the ration or drawn from the bird's body. It has been known for many years that egg production is the first to be affected when birds fail to obtain an adequate diet for maintenance, growth, and egg production.

Hill *et al.* (1956) found that rate of lay during the winter months was increased when rations were fed which varied in energy content from 740 to 1025 Calories per pound. This was not the case at other times of the year. Singsen *et al.* (1952) and Skinner *et al.* (1951) reported higher production on high energy diets than on the simplified rations which had been used in previous years. This was also shown to be the case by Thayer *et al.* (1956). In the analysis of productive performance at the Oklahoma Egg Laying Test it was found that average egg production was 196 eggs per hen (1948-1951) when low energy rations were used as compared to 225.5 eggs per hen (1952-1954) on the high energy ration.

On the other hand, many research workers have failed to verify the above data. Berg and Bearse (1956) worked with energy levels of 1148 and 1331 Calories of metabolizable energy per pound. It was concluded that energy, at these levels, had no effect on the rate of lay with birds which were below 60 percent in production. In recent studies Hochreich *et al.* (1957) found no significant difference in the production of Single Comb White Leghorn pullets with the addition of 6.6 percent of animal fat to the conventional ration. It has been observed by Bird and Whitson (1946) that fiber, which was contributed largely from wheat mill feeds, oats, and alfalfa meal, had no effect on the production of eggs.

In a study by Miller *et al.* (1956) no increase in egg production could be attributed to energy when the rations contained 930, 745, and 640 Calories per pound and protein levels ranging from 12 to 21 percent at each energy level.

This work was confirmed in a recent calorie-protein study by MacIntrye and Aitken (1957).

ANTIBIOTICS

Production

Several reports have appeared in the literature which pertain to the effect of antibiotics upon egg production. Elam et al. (1953) used groups of 10 New Hampshire pullets which were fed an all-vegetable ration. They noted an increase in egg production with the administration of the following antibiotic preparations: (1) penicillin (1.2 mg per bird every other day): (2) inactivated penicillin injection (1.2 mg per bird per week): (3) penicillin injection in oil (15,000 units every other day) and (4) orally administered penicillin or bacitracin (33 mg/kg). However, the injection of bacitracin (1.2 mg per bird per week) and of the orally administered inactivated penicillin (33 mg/kg) did not increase egg production. When birds were injected with 1 ug of vitamin B-12 per week, an increase in egg production was observed in all treatments. Lillie and Bird (1952) observed an increase in egg production when birds were fed an aureomycin-vitamin B-12 supplement over that obtained when a diet was fed which contained only vitamin B-12. Elam et al. (1951) concluded that 33 PPM of penicillin had no effect on egg production. However, when penicillin was administered in combination with vitamin B-12, production was substantially higher than with either penicillin or the vitamin B-12. These data would indicate a definite stimilus by antibiotics in the presence of vitamin B-12.

Peterson and Lampman (1952) reported that 9 grams of procaine penicillin or streptomycin per ton when added to a high quality ration failed to increase egg production. However, Carlson et al. (1953) reported that 24 grams of penicillin per ton increased egg production in three out of four cases and 60 grams of streptomycin per ton resulted in an increase in egg production in all cases.

Peterson and Lampman (1952) observed no increase in egg production when a high quality ration was supplemented with terramycin at a level of 9 grams per ton. Carver et al. (1951) fed Single Comb White Leghorn pullets a basal soybean oil meal diet which included 3 percent of fish meal. When this diet was supplemented with 2, 4, 8, or 12 PPM of terramycin, there was no effect on the production of eggs. Berg et al. (1952) confirmed these data with a series of rations and levels of terramycin or aureomycin which ranged from 4 to 15 PPM. Sherwood and Milby (1954) top dressed a standard ration with a pellet which contained terramycin or aureomycin at approximately 100 mg per pound of total ration. Neither egg production nor efficiency of feed conversion was affected by this treatment. Boone and Morgan (1955) found that birds which were raised and maintained on low levels of terramycin, bacitracin, penicillin, or aureomycin had a slightly higher rate of egg production than birds which failed to receive the antibiotics.

Carver et al. (1951) reported that 10 PPM of aureomycin or terramycin when added to a basal soybean oil meal diet, both with and without 3 percent of fish meal, had no effect on the production of eggs. Bearse and Berg (1955) reported a slight increase in egg production, with 10 and 100 PPM of aureomycin. This increase was not statistically significant. However, Branion _et al_. (1956) found that although 10 PPM of aureomycin resulted in only a slight increase in egg production, 100 PPM significantly increased the rate of lay.

Heywang (1954) noted an increase in the egg production of Single Comb White Leghorn pullets when their diet was supplemented with aureomycin at levels of 50 or 100 grams per ton. However, 180 grams of aureomycin per ton failed to increase the rate of lay of birds which had completed their first year of production, Sherwood and Milby, (1954).

Balloun (1954) concluded that, under unfavorable conditions for high egg production, the addition of high levels of antibiotics may improve egg production. Production began to increase within two weeks after 50 mg of aureomycin per pound was administered to the diet of birds which were observed to be decreasing in egg production. Price _et al_. (1956) supplemented the diet of Single Comb White Leghorn pullets which had stopped laying with 0, 5, 25, and 50 mg of aureomycin per pound. After 3 months of such treatment the egg production was 15, 16, 25, and 45 percent, respectively.

Atkinson and Couch (1951) reported that turkeys which had been maintained on an all vegetable diet increased in egg production with the addition of 25 mg aureomycin per kilogram of ration.

Hatchability

Brown *et al*. (1953), Halbrook and Beeckler (1951), and Sunde *et al*. (1952) reported that the addition of an antibiotic supplement resulted in no increase in hatchability. Waibel *et al*. (1952) supplemented a practical breeder diet with 5 and 200 mg of penicillin per kilogram. They observed no increase in hatchability on either level of the antibiotic. Jacobs *et al*. (1955) reported that hatchability of eggs set from Single Comb White Leghorn pullets was unaffected when 25 to 50 mg of penicillin or streptomycin per pound was administered to a diet which contained some sources of fish and whey factors. However, Carlson *et al*. (1953) reported an increase in hatchability in three out of four cases when 24 grams of penicillin or 60 grams of streptomycin per ton were added to a high quality diet.

Sizemore *et al*. (1953) reported that aureomycin, at the levels of 5, 10, 20, and 40 mg per kilogram of ration, increased the hatchability of fertile eggs when the breeder diet was deficient in vitamin B-12. Bentley and Hershburger (1954) found that 10 grams of penicillin, terramycin, bacitracin, or aureomycin HCL per ton administered to a vitamin B-12 deficient diet did not improve hatchability. However, 20 grams of aureomycin or bacitracin per ton increased the hatchability 8 to 9 percent. On the other hand when the diet was adequate, neither 10 nor 100 grams per ton of aureomycin increased hatchability, Bearse and Berg, (1955).

Lillie and Bird (1952) concluded that an aureomycin-supplemented diet was less efficient, with regard to hatchability, than either the basal or the basal supplemented with vitamin B-12. These data support the work of Carlson _et al_. (1953), who found that eggs set from turkey breeder hens hatched very poorly when the diet contained an aureomycin-vitamin B-12 supplement. However, the hatchability was substantially higher when the diet contained only the vitamin B-12 supplement.

PELLETS

Production

In recent years there has been a gradual increase in the use of pelleted feeds for laying hens. Lunn _et al_. (1932), as reported by Morris, (1947), conducted a feeding trial using four feeding methods and concluded that the pelleted all-mash ration produced fewer eggs than did the other feeding methods. Morris (1947) observed no difference in egg production between hens which received a pelleted all mash ration and hens which received an all-mash ration. However, when pellets were fed only as a noon lunch, production was greater than on any of the other feeding methods which were tested. Robertson _et al_. (1939) reported an increase in the egg production of birds when pellets were top dressed, as a noon lunch, on an all-mash ration. Morgan and Heywang (1941) conducted two feeding trials, each of which covered a complete laying year. It was reported that the birds which were fed a pelleted all-mash ration had a higher rate of lay than birds fed an unpelleted all-mash ration.

Body Weight

Lunn (1932), as reported by Morris (1947), stated that a pelleted all-mash ration, when compared to other feeding methods, did not increase the body weight of the birds. On the other hand, Morris (1947); Morgan and Heywang (1941); and Robertson *et al.* (1939) reported that body weight gains were greater on pelleted rations than on all-mash rations.

PROCEDURE

Experimental Design

The experiment was set up on a completely randomized design which consisted of eight treatments (Table I) with three replications per treatment. Data were summarized by pens and no individual records were kept on hens.

Analysis of variance (Snedecor, 1946) was computed for each treatment by four-week periods. At the completion of the experiment an analysis of variance and the multiple range test (Duncan, 1955) were computed for the complete trial.

Management

Six hundred Single Comb White Leghorn pullets and seventy-seven Single Comb White Leghorn cockerels were hatched on June 3, 1957. These birds were reared in confinement and fed the Oklahoma State starter mast SMC 550 during the first eight weeks of life. The birds were fed the Oklahoma State grower mash GMC 550 (without grain) from eight weeks until housing time, except during stress periods. Stress periods included dubbing at eight weeks; vaccinating for fowl pox at 11 weeks; vaccinating for bronchitis at 16 weeks; and moving the pullets to the laying house at 20 weeks. Five days prior to and five days after these times of stress, the standard grower ration was supplemented with 50 grams of bacitracin and 50 grams of terramycin per ton.

Four hundred and eighty pullets were selected at random and were housed on October 22, 1957. Pullets with obvious defects which would alter the true results of the experiment were rejected at this time. Thereafter, no pullets were replaced or culled from the trial.

The laying house was 20 feet by 162 feet in dimensions, with a four-foot walkway which ran the length of the building. The house contained 27 pens with dimensions of 6 feet by 16 feet each. The pens were separated by partitions, the lower five feet of which were boards and the remainder poultry netting. Each pen had a concrete floor which was covered with three inches of new litter. Twenty pullets were placed in each of the pens with the exception of the pen on each end and the center pen. One male was placed in each of the twenty-four pens on January 5, 1958 and the males were rotated each month thereafter.

The feeding schedule consisted of providing water, oyster shell, grit, and the experimental mash to the pullets *ad libitum*. In addition to the experimental mash, the pullets which were fed rations BMC 560-A and BMC 560-B received pellets as a noon lunch at the rate of 2 pounds per 100 birds per day. The BMC 560-A pellets contained 80 grams of bacitracin per ton. The pullets fed Ration BMC 560-B received BMC 560 in the pelleted form, unless the conditions were such that it was thought the pullets were under a stress condition. If this were found to be the case, BMC 560-A pellets were administered in place of the non-antibiotic pellets.

Evaluating Production

Egg production records were kept by four-week periods from November 26, 1957 through September 2, 1958. At the end of each period egg production was calculated on a hen-day basis. Eggs which were soft shelled or broken were recorded the same as other eggs. It was felt that this would be a more valid measure of the treatment upon the pullets than would be the case if such eggs were not recorded.

Determining Body Weight

The pullets were individually weighed at the end of each four-week period from November 26, 1957 through September 2, 1958, with the exception of the fourth period (March 18, 1958 to April 15, 1958).

Dairy scales which were calibrated to tenths of a pound were used to weigh the birds. Periodically, during each weighing the scales were checked with a two-pound test weight to minimize weighing error.

Determining Egg Size

Egg size was determined for each four-week period from November 26, 1957 through August 5, 1958. At the mid-point of each four-week period, eggs were pen marked, cased, and put into the Oklahoma State University egg cooler each day for four consecutive days. At the completion of each collection period the eggs were sorted by pens. A maximum of fifty eggs was selected at random from each pen and group weighed with gram scales to establish the average egg size for each pen. If the production of any pen failed to yield fifty eggs, the total number of eggs for the pen was weighed. The smallest number of eggs ever group weighed at any period to measure the average egg size for any pen was forty-one eggs. The purpose of weighing a maximum of only fifty eggs per pen was to eliminate a large variation in the total number of eggs used to obtain the average egg size.

Determining Hatchability

Six trials were run to determine the effects of these treatments upon hatchability. Five trials were run in the normal hatching months of January, February, March, April, and May. A sixth trial was run in late July during hot weather.

Eggs were collected four days prior to each setting date and placed in the egg cooler. The total number of eggs collected, with a maximum of 50 eggs per pen, were set during the six hatchability trials. Eggs which were under 22 or over 28 ounces per dozen or were dirty, cracked or malformed were not used in the hatchability studies. Infertile eggs were candled out on the eighteenth day of incubation, and hatchability data were collected only on fertile eggs.

TABLE I

COMPOSITION OF RATIONS

Ration	BMC 501	BMC 551	BMC 560	BMC 560-A	BMC 560-B	BMC 561	BMC 562	BMC 563
Ingredients				percent of diet				
Ground yellow corn	36	41.4	32.2	32.2	32.2	32.2	32.2	32.2
Ground milo	16	16	16	16	16	16	16	16
Pulverized oats	14	8	11	11	11	11	11	11
Wheat shorts	6	6	3	3	3	3	3	3
Wheat bran	6	-	-	-	-	-	-	-
Alfalfa meal (17%)	3	3	3	3	3	3	3	3
Fish meal (70%)	3	6	6	6	6	6	6	6
Soybean meal (44%)	9	6	12	12	12	12	12	12
Meat & bone scraps	3	-	-	-	-	-	-	-
Live yeast culture	-	1	1	1	1	1	1	1
Dried whey	-	2	2	2	2	2	2	2
Dried fish solubles	-	2	2	2	2	2	2	2
Distillers dried grain	-	2	2	2	2	2	2	2
Dicalcium phosphate	2	3	3	3	3	3	3	3

Calcium carbonate	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Salt	.5	.5	.5	.5	.5	.5	.5	.5
Trace mineral mix	.05	.05	.05	.05	.05	.05	.05	.05
Vitamin supplement VC-55*1	.025	.05	1	1	1	1	1	1
Fluid pex	-	-	2	2	2	2	2	2
Fat (Marco B-75)*2	-	3	5	5	5	5	5	5
Coliver	-	-	2	2	2	2	2	2
Methionine	.02	.02	.02	.02	.02	.02	.02	.02
Parvo	-	3 gms	3 gms	3 gms	3 gms	3 gms	3 gms	3 gms
Vitamin E concentrate	-	3 gms	3 gms	3 gms	3 gms	3 gms	3 gms	3 gms
Baciferm	-	-	-	.04	-	-	-	.02
TM-10	-	-	-	-	-	-	.05	-
NF-180	-	-	-	-	-	.01	-	-
Calories of metabolizable energy per pound	1255.9	1357.6	1366.9	1366.9	1366.9	1366.9	1366.9	1366.9
Percent protein	16.66	16.23	16.94	16.94	16.94	16.94	16.94	16.94

FOOTNOTES

1. Vitamin supplement VC-55 provided the following quantities per pound: riboflavin, 600 mgs., calcium pantothenate dextrorotatory, 800 mgs., niacin, 4,000 mgs., choline chloride, 60,000 mgs., vitamin B-12 activity, 0.6 mgs., penicillin, 0.4 grams procaine penicillin, vitamin A, 800,000 USP, vitamin D-3, 400,000 ICU, menadione, 600 mgs.

2. Fat, Marco B-75, a feed grade fat prepared from cottonseed and soybean oils.

RESULTS AND DISCUSSION

Statistical Analysis

The F values which were computed for the factors of egg production, egg size, body weight and efficiency of feed utilization by four-week periods are given in graphs 1 through 13. It was not feasible to list each of the 117 values which were computed in the statistical analysis of these data. However, when the trial was completed an anlysis of variance and Duncan's multiple range test were computed for these factors over the entire 280-day trial period. Since all the assumptions that are required to compute an analysis of variance and a Duncan's multiple range test could not be met in this experiment, it is not desirable to attach a great deal of importance to the F values in the complete trial. This does not mean that these particular analyses are not valid. We simply do not have a statistical method which will give us a better estimate of the differences among the factors studied.

Egg Production

Effect of supplemental fat and energy

A comparison of rations BMC 501, BMC 551, and BMC 560 during the first six periods showed there were no significant differences in egg production among the three treatments (Graph 1).

During the seventh period there was a significant difference in egg production of approximately 7.5 percent between rations BMC 501 and BMC 560 as compared to ration BMC 551. It would appear from these data that ration BMC 551 had become less efficient with regard to egg production by the seventh four-week period. However, rations BMC 561, BMC 562, and BMC 563 also showed a decline in egg production at this time. The fact that ration BMC 560 maintained egg production during this period led to a significant difference among the treatments over the complete trial. The statistical analysis made by Duncan's multiple range test is listed in Table II.

TABLE II

COMPARISON OF EGG PRODUCTION AMONG RATIONS BMC 501, BMC 551, AND BMC 560 BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 551	BMC 501	BMC 560
P:	2	3	4
RP:	1.98	2.09	2.14
Ranked means*	75.04	76.08	77.54

*Any two means underscored by the same line were not statistically different.

The egg production in this trial was higher than was the egg production in the Oklahoma Egg Laying test during those years in which these rations were fed. There are two reasons for this increase in egg production: (1) the strain of White

Leghorn pullets used in this trial was probably more efficient, with regard to egg production, than were many strains of birds used in the Laying Test in the previous years; and (2) the weather conditions under which this test was run were very favorable to high egg production. There were only four days during the trial in which the temperature reached 100 degrees F. July had only two days in which the temperature was above 95 degrees F. and ten days in August during which the temperature failed to exceed 90 degrees F.

One of the primary factors which promoted the development of the high-efficiency ration was that in the presence of stress conditions it was superior to low-efficiency rations. One of the greatest stress problems in this area is the high temperature in the summer. Due to the abnormally cool summer in which this test was run the BMC 501 performed satisfactorily. This was contradictory to results obtained in the Oklahoma Egg Laying Test when the weather conditions were such that a stress condition existed.

Effect of supplemental pellets

When ration BMC 560 was pelleted and fed as a supplement with (BMC 560-A) and without (BMC 560-B) antibiotics, the supplemental pellets did not affect egg production during any of the four-week periods (Graph 2). Ration BMC 560 resulted in a slightly higher rate of egg production over the entire period, but the difference was not significant according to Duncan's multiple range test (Table III).

TABLE III

COMPARISON OF EGG PRODUCTION AMONG RATIONS BMC 560, BMC 560-A AND BMC 560-B BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 560-B	BMC 560-A	BMC 560
P:	2	3	4
RP:	2.99	3.14	3.23
Ranked means*	75.36	76.99	77.54

*Any two means underscored by the same line were not significantly different.

The theory which promoted the use of pellets was that it could give producers a method of increasing the feed consumption of laying hens. In this way the pullets would receive adequate nutrients both for body maintenance and for maximum egg production. Robertson et al. (1939) and Morgan and Heywang (1941) found this to be the case. However, it must be noted that during the years in which these experiments were conducted, rations were of such high fiber and low vitamin fortification that the birds were not getting the required nutrients in sufficient amounts for high egg production. When a ration like BMC 560 was fed, which contained a high level of protein, fat and vitamins, intake was not a problem. Therefore, results similar to those reported in this thesis would be expected.

Effect of bacitracin, terramycin and furazolidone

Ration BMC 561 performed significantly better during the first four-week period than did rations BMC 560, BMC 562, or BMC 563 (Graph 3). Such a relationship did not hold for the entire trial period of 40 weeks. This would indicate that furazolidone at high levels promoted higher egg production than did either bacitracin or terramycin during the first few week of egg production. Duncan's multiple range test was run on the complete trial (Table IV).

TABLE IV

COMPARISON OF EGG PRODUCTION AMONG RATIONS BMC 560, BMC 561, BMC 562, AND BMC 563 BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 563	BMC 562	BMC 560	BMC 561
P:	2	3	4	5
RP:	2.81	2.95	3.03	3.11
Ranked means*	73.88	76.23	77.54	78.36

*Any two means underscored by the same line were not significantly different.

The majority of research workers who have conducted experiments involving the effect of antibiotics upon the reproductive performance of laying hens have concluded that antibiotics do not improve egg production unless the birds are under stress conditions. However, very few of these workers have used levels that are equivalent to the levels used in this trial. In the analysis of this experiment it was found that egg production for rations BMC 562 and BMC 563, which contained 100 grams of terramycin per ton and 40 grams of bacitracin per ton, respectively, was below the egg production for BMC 560. It could be concluded that either the birds fed BMC 560 performed abnormally well or that high levels of antibiotics had a detrimental effect upon egg production.

Body Weight

Effect of supplemental fat and energy

Statistical analysis of the data, computed by four-week periods, indicated that there were no significant differences in body weights of birds fed rations BMC 501, BMC 551, or BMC 560 through the first nine four-week periods (Graph 4). An analysis of the data for the tenth period showed a high level of significance, with a direct relationship to the energy content of the diet. An analysis of variance and Duncan's multiple range test were computed on the entire trial. There were significant differences between ration BMC 501 and rations BMC 551 and BMC 560 (Tables V and VI).

TABLE V

COMPARISON OF BODY WEIGHTS AMONG BIRDS FED RATIONS BMC 501, BMC 551, AND BMC 560 BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 501	BMC 551	BMC 560
P:	2	3	4
RP:	.083	.087	.089
Ranked means*	4.16	4.38	4.43

*Any two means underscored by the same line were not significantly different.

TABLE VI

COMPARISON OF BODY WEIGHTS AMONG BIRDS FED RATIONS BMC 501, BMC 551, AND BMC 560 AS MEASURED BY THE ANALYSIS OF VARIANCE

Source of variation	df	ss	ms	f
Total	80	3.6034		
Treatment	2	1.1778	.5885	26.63**
Month	8	.9025	.1128	5.10
Month X treatment	16	.3315	.2072	9.38
Error	54	1.924	.0221	

**Significant at .01 confidence level

The most efficient ration, with regard to body weight, would be one that developed the birds to an optimum weight and maintained this weight for the duration of the laying year even through stress conditions. However, recent trends in poultry nutrition lead research workers to believe that birds can be and should be held over for the second year of production. If this be the case, a ration must be fed which will let a bird complete the first year's production at a satisfactory weight at which to start the second year. Graph 4 shows that neither rations BMC 501 nor BMC 551 met these requirements, even under favorable conditions. Recent research work at Oklahoma State University indicates that amino acid-calorie ratios and vitamin-calorie ratios must be considered in developing such a ration.

Effect of supplemental pellets

The results of the individual four-week periods indicated that there are significant differences in body weight among birds fed rations BMC 560, BMC 560-A and BMC 560-B in the first and fourth periods. This difference approached significance in the seventh period (Graph 5). Duncan's multiple range test and the analysis of variance which were computed over the entire trial indicated significant differences among treatments (Tables VII and VIII).

TABLE VII

COMPARISON OF BODY WEIGHTS AMONG BIRDS FED RATIONS BMC 560, BMC 560-A AND BMC 560-B BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 560-B	BMC 560	BMC 560-A
P:	2	3	4
RP:	.136	.143	.146
Ranked means*	4.33	4.43	4.55

*Any two means underscored by the same line were not significantly different.

TABLE VIII

COMPARISON OF BODY WEIGHTS OF BIRDS FED RATIONS BMC 560, BMC 560-A AND BMC 560-B AS MEASURED BY THE ANALYSIS OF VARIANCE.

Source of variation	df	ss	ms	f
Total	80	1.957		
Treatment	2	.624	.312	5.29*
Month	8	.901	.113	1.91
Month X treatment	16	.114	.071	1.21
Error	54	.318	.059	

*Significant at the .05 confidence level.

It would be expected that pullets which were fed ration BMC 560-A would be heavier in body weight than pullets which received ration BMC 560 (Graph 5). On the other hand there is no explanation as to why the pullets which were fed ration BMC 560-B weighed less than those fed ration BMC 560.

Effect of bacitracin, terramycin and furazolidone

The statistical analysis of the ten four-week periods, indicated that there were no differences in body weight among birds fed rations BMC 560, BMC 561, BMC 562, or BMC 563 during any of the four-week periods (Graph 6). The Duncan's multiple range test which was computed over the entire trial indicated that the addition of bacitracin or terramycin at high levels did significantly increase body weight (Table IX).

TABLE IX

COMPARISON OF BODY WEIGHT AMONG BIRDS FED RATIONS BMC 560, BMC 561, BMC 562 AND BMC 563 BY DUNCAN'S MULTIPLE RANGE TEST AT .05 CONFIDENCE LEVEL.

Rations	BMC 561	BMC 560	BMC 563	BMC 562
P:	2	3	4	5
RP:	.055	.057	.059	.060
Ranked means*	4.42	4.43	4.57	4.59

*Any two means underscored by the same line were not significantly different.

It was found that pullets which were fed terramycin at high levels or bacitracin at high and low levels increased their body weight. Pullets on these treatments tended to lay fewer eggs than did pullets which did not receive the antibiotics. This would indicate that antibiotics when fed at high levels should only be fed under stress conditions. Furazolidone, when fed at high levels, did not cause an increase in body weight of the pullets. However, it appeared to be less effective in maintaining a constant body weight over an extended period of time than did ration BMC 560.

Pounds of Feed Required to Produce One Dozen Eggs

Effect of supplemental fat and energy

The data for the fourth and ninth four-week periods indicated a significant difference in pounds of feed required to produce one dozen eggs when rations BMC 501, BMC 551 and

BMC 560 were compared in this feeding trial (Graph 7). There were no significant differences in pounds of feed required to produce one dozen eggs among the treatments over the entire trial. However, there was a direct relationship between the pounds of feed required to produce one dozen eggs and the quality of ration which was fed. Rations BMC 560, BMC 551 and BMC 501 required 4.155, 4.24 and 4.34 pounds of feed to produce one dozen eggs, respectively. There were two reasons for this report to be contradictory to the majority of research work: (1) the production obtained with these rations was similar, since there were no stress factors to cause the lower quality rations to be less efficient; and (2) the body weights of the birds increased directly as the calorie content of the ration increased, which resulted in an increase in the amount of feed required for maintenance.

Effect of supplemental pellets

It was found that the pounds of feed required to produce one dozen eggs was not affected by supplementation with pellets during any four-week period or over the complete trial (Graph 8). Ration BMC 560-A was slightly more efficient in this regard than either rations BMC 560 or BMC 560-B.

Effect of bacitracin, terramycin and furazolidone

The data of the last three four-week periods indicated a significant difference among rations BMC 560, BMC 561, BMC 562, and BMC 563 (Graph 9). Significantly fewer pounds of feed were required to produce one dozen eggs with ration

BMC 561 than with rations BMC 560, BMC 562, or BMC 563, as measured by Duncan's multiple range test (Table X).

TABLE X

COMPARISON OF THE POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS AMONG RATIONS BMC 560, BMC 561, BMC 562, AND BMC 563 AS MEASURED BY DUNCAN'S MULTIPLE RANGE TEST AT THE .05 CONFIDENCE LEVEL.

Ration	BMC 561	BMC 560	BMC 562	BMC 563
P:	2	3	4	5
RP:	.156	.164	.168	.173
Ranked means*	3.97	4.16	4.23	4.27

*Any two means underscored by the same line were not significantly different.

This superior efficiency rating of ration BMC 561 was due to the fact that the pullets fed this ration gained less weight over the year than did the pullets fed the rations which contained antibiotics. These pullets also laid slightly more eggs than did any of the pullets fed the other rations this series.

The fallacy of using pounds of feed required to produce one dozen eggs as a measure of the performance of a feed is that it is virtually 100 percent dependent upon egg production, while it has been shown that from 60 to 75 percent of the feed consumed by laying hens is used for maintenance. From a research standpoint, this is a less efficient measure of the performance of a feed than is the Byerly's partition equation.

However, pounds of feed required to produce one dozen eggs is an excellent method for commercial people, because it is simple to calculate and it is relatively accurate in measuring what these people want from a feed.

Egg Size

Effect of supplemental fat and energy

The energy and fat content of the diet failed to have a significant effect upon egg size among rations BMC 501, BMC 551 and BMC 560 until late in the trial (Graph 10). There was a significant difference during the last two four-week periods, with a direct relationship to the energy level of the ration. Statistical analysis by the Duncan's multiple range test illustrated the effect of the treatments over the ten four-week periods (Table XI).

TABLE XI

COMPARISON OF EGG SIZE AMONG RATIONS BMC 501, BMC 551, AND BMC 560 AS MEASURED BY THE DUNCAN'S MULTIPLE RANGE TEST AT THE .05 CONFIDENCE LEVEL.

Rations	BMC 501	BMC 551	BMC 560
P:	2	3	4
RP:	.64	.67	.69
Ranked means*	53.26	53.66	54.64

*Any two means underscored by the same line were not significantly different.

It can be concluded that the energy content of the diet had little effect on egg size, because rations BMC 551 and BMC 560 were similar in energy content. The increase in egg size with ration BMC 560 could have been the result of supplemental fat as suggested by Hochreich (1957). It could also have been attributed to the vitamin fortification in the rations. Ration BMC 560 contained 20 pounds of vitamin concentrate per ton in comparison to 10 pounds of vitamin concentrate per ton in ration BMC 551. Ration 501 contained, by present day standards, very little fortification (0.52 pound of vitamin concentrate per ton).

Effect of bacitracin, terramycin and furazolidone

The effect of bacitracin, terramycin and furazolidone upon egg size was one of the more significant findings in this experiment. There were significant differences among rations BMC 560, BMC 561, BMC 562, and BMC 563 in all but the second four-week period (Graph 11). The analysis of variance and Duncan's multiple range test indicated that large differences existed among these treatments over the entire trial (Tables XII and XIII).

TABLE XII

COMPARISON OF EGG SIZE AMONG RATIONS BMC 560, BMC 561, BMC 562, AND BMC 563 AS MEASURED BY THE DUNCAN'S MULTIPLE RANGE TEST AT THE .05 CONFIDENCE LEVEL.

Rations	BMC 561	BMC 562	BMC 563	BMC 560
P:	2	3	4	5
RP:	.513	.54	.554	.566
Ranked means*	52.17	53.87	54.10	54.64

*Any two means underscored by the same line were not significantly different.

TABLE XIII

COMPARISON OF EGG SIZE AMONG RATIONS BMC 560, BMC 561, BMC 562, AND BMC 563 AS MEASURED BY THE ANALYSIS OF VARIANCE

Source of variation	df	ss	ms	f
Total	107	1193.59		
Treatment	3	91.71	30.57	36.13**
Month	8	1026.01	128.25	151.60
Treatment X month	24	14.96	.623	.736
Error	72	60.92	.846	

**Significant at the .01 confidence level.

It was found that all pens which received bacitracin, terramycin or furazolidone were below the control pen in egg size. Ration BMC 561 which contained furazolidone produced eggs which were consistently smaller than eggs produced by any of the other three rations in this experiment. This appears to be a weakness of ration BMC 561. However, other factors should be considered in making a critical evaluation of ration BMC 561: (1) this ration had the highest egg production of any ration in the experiment; (2) this ration had the best feed:egg ratio of any ration in the experiment; (3) it was next to the best ration in the test with regard to relative efficiency; and (4) it was equal to the best ration in the test in maintaining a satisfactory body weight throughout the experiment. It should also be recalled that furazolidone was fed at a high level and perhaps if fed at a lower level this drug could be beneficial during the times of the year when egg size is larger than necessary from an economic standpoint.

Hatchability of Fertile Eggs Set

Effect of supplemental fat and energy

It was found that the birds fed ration BMC 501 had a slightly higher percentage of hatchability of fertile eggs than did either rations BMC 551 or BMC 560 during the first of the six hatchability trials (Graph 12). There were no differences among treatments over the entire trial. However, ration BMC 501 had a slightly higher percentage of hatchability over the entire trial than did either ration BMC 551 or BMC 560. The hatchability percentages were 91.39, 90.26, and 87.09, respectively. These results are contradictory to the majority of results which have been reported in the past. It is thought that these results were due to the fact that the number of eggs set for the treatments were not adequate. The variation among replications within treatments was in many instances larger than the variation among treatments.

Effect of bacitracin, terramycin and furazolidone

There were no differences between rations BMC 560, BMC 561, BMC 562, and BMC 563 (Graph 13). When the analysis was computed over the complete trial there were also no differences among treatments. It was observed that all rations which received additives were slightly above the control ration in hatchability of fertile eggs. The average hatchability of eggs set over the complete trial for rations BMC 560, BMC 561, BMC 562, and BMC 563 was 90.26, 91.06, 91.31 and 92.97 percent, respectively.

Mortality

Effect of supplemental fat and energy

Graph 14 shows the variation in percentage mortality by four-week periods among rations BMC 501, BMC 551 and BMC 560. Cumulative mortality for rations BMC 551, BMC 501 and BMC 560 was 10.3, 13.6, and 15.5 percent, respectively, over the entire trial. It is thought that since the mortality percentages are so similar, and the number of birds on each treatment was small, that no conclusion should be drawn from these data.

Effect of supplemental pellets

Graph 15 shows that supplemental feeding of pellets in rations BMC 560-A and BMC 560-B did lower mortality by approximately eight percent, as compared to ration BMC 560. Because of the small numbers of birds on each treatment, it is not possible to draw definite conclusions. However, pellets may be beneficial in reducing mortality in laying hens.

Effect of bacitracin, terramycin and furazolidone

It was observed that birds which were fed ration BMC 562 had seven percent higher mortality than did the birds which were fed the control ration (Graph 16). However, this was due to the fact that one of the replications on this ration had an abnormally high mortality during the early periods of the trial. Since this high mortality was not evident in the other replications during these periods, it was thought that other factors were more responsible for the mortality level than was the treatment. Birds fed rations BMC 561 and BMC 563 had a mortality which was similar to the control ration.

Byerly Equation

This equation was devised in 1941 by T. C. Byerly. This formula takes into consideration body weight, body weight gains or losses, and egg production when evaluating a ration for laying hens. The end product of this formula is a relative efficiency index which is determined by dividing the actual feed consumption in grams per day into the predicted feed consumption in grams per day. The formula for determining the predicted feed consumption is as follows:

$$F = 0.523W^{0.653} \pm 1.126 \Delta W + 1.135E$$

F = Predicted feed consumption in grams per hen per day

W = Average weight in grams

ΔW = Average daily weight change in grams

E = Grams of egg produced per hen per day

$$\text{Relative efficiency} = \frac{100 \text{ X Predicted feed consumption}}{\text{Observed feed consumption}}$$

At the present time this is the most accurate method of evaluating a feed for efficiency of utilization. However, it is thought that the formula gives too much emphasis to body weight and too little emphasis to egg production.

Effect of supplemental fat and energy

Graph 17 shows the effect of supplemental fat and energy upon the relative efficiency indices of rations BMC 501, BMC 551, and BMC 560. Although ration BMC 501 was the least efficient throughout all of the trial, there appeared to be a greater difference among the relative efficiency indices during the early periods. This was due to the fact that the low energy ration failed to increase body weight, as was found to be the case with the high energy rations. The relative efficiency indices, when calculated on the cumulative data, increased as the energy content of the rations was increased (Graph 18).

Effect of supplemental pellets

With regard to the effect of pellets upon the relative efficiency indices of rations BMC 560, BMC 560-A and BMC 560-B, there were small differences among four-week periods (Graph 19). The relative efficiency index for ration BMC 560-B fluctuated over a wide range from period to period. However, there was close agreement among the replicates for each of the periods. No logical explanation can be offered by the author for the wide fluctuation of the relative efficiency indices for this ration.

The cumulative efficiency index for ration BMC 560-A was higher than with the control ration (Graph 20). Although bacitracin did not increase the rate of lay, it significantly increased body weight. This is one of the fallacies of the Byerly equation, as was indicated on page 37.

Effect of bacitracin, terramycin and furazolidone

Graph 21 shows that through the first eight four-week periods there were no great differences in the relative efficiency indices among rations BMC 560, BMC 561, BMC 562, and BMC 563. In the ninth period, ration BMC 562 dropped to 95.15 in relative efficiency. Birds which were fed this ration lost body weight during this period.

The relative efficiency indices calculated from cumulative data over the ten four-week periods are shown in Graph 22. All rations which received additives were equal or better than the control ration. Birds which were fed rations BMC 562 and

BMC 563 showed a high relative efficiency index rating. This index rating was primarily due to the significant increase in body weight of the birds on these rations during the trial. The birds fed rations BMC 560 and BMC 561 maintained a somewhat lower body weight than did the birds on rations BMC 562 and BMC 563. Therefore, it could be concluded that lower feed intake and high egg production are primarily responsible for the relatively high index rating of rations BMC 560 and BMC 561.

CONCLUSIONS

1. The energy content of the diet had little effect upon egg production when laying hens were not under stress conditions.
2. Supplemental feeding of a pelleted high quality diet at the rate of 2 pounds per 100 hens per day, either with or without antibiotics, had no effect upon egg production.
3. Supplementing a high quality ration with bacitracin or terramycin at high levels over an extended period of time seemed to have a detrimental effect upon egg production.
4. There was a direct correlation between the body weight of laying hens and the calorie content of the diet.
5. High levels of bacitracin and terramycin when fed over an extended period of time significantly increased the body weight of laying hens.
6. Dietary energy levels between 1250 and 1375 calories of metabolizable energy per pound had little effect upon the pounds of feed required to produce one dozen eggs when laying hens were not under stress conditions.
7. Furazolidone appeared to be beneficial in reducing the pounds of feed required to produce one dozen eggs.
8. Furazolidone significantly decreased egg size. In order for this drug to be beneficial for commercial use, it must be fed at low levels if it is to be used over an extended period of time.

9. Supplementing a ration with pellets at the rate of 2 pounds per 100 birds per day appeared to be beneficial in reducing mortality.

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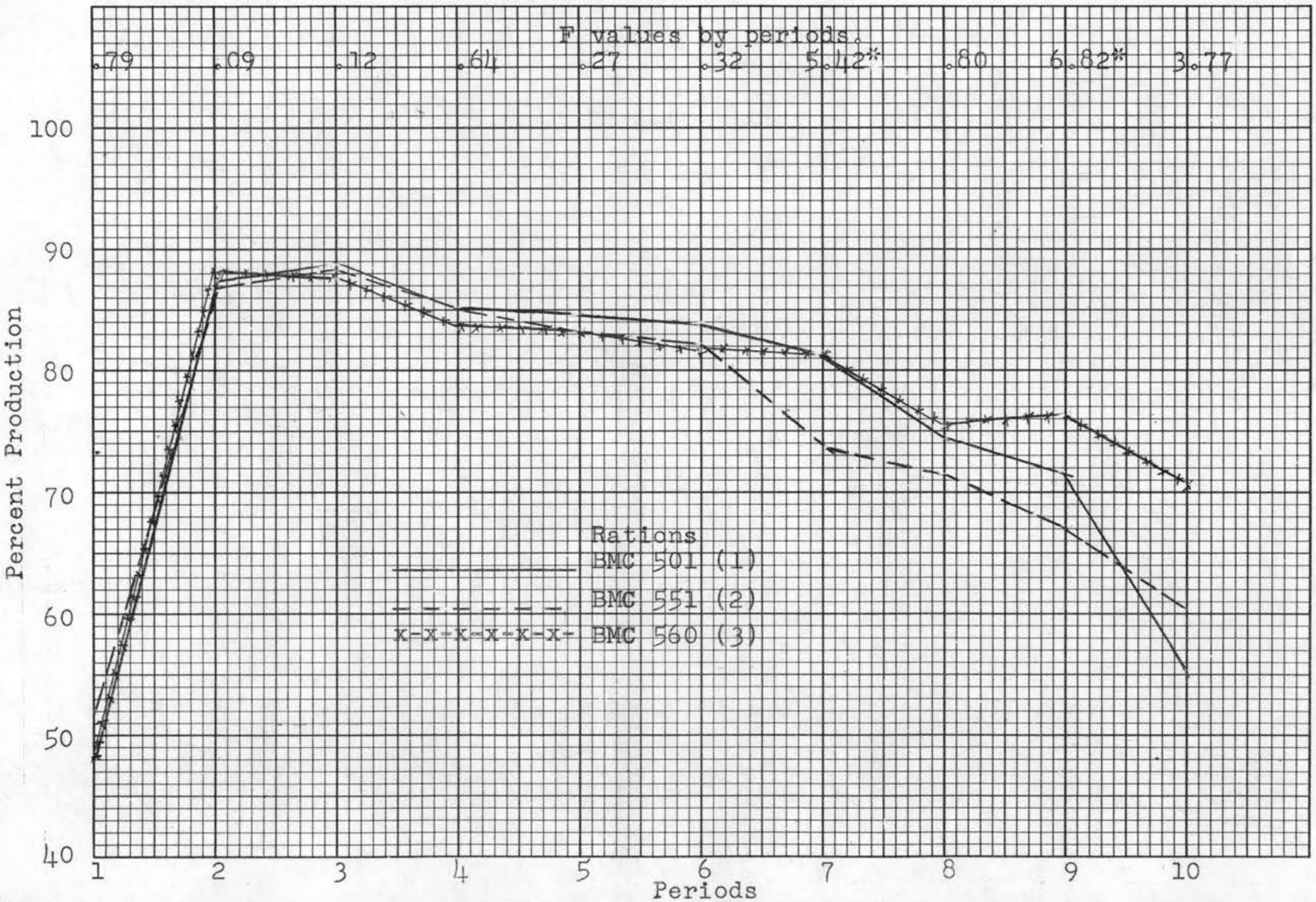
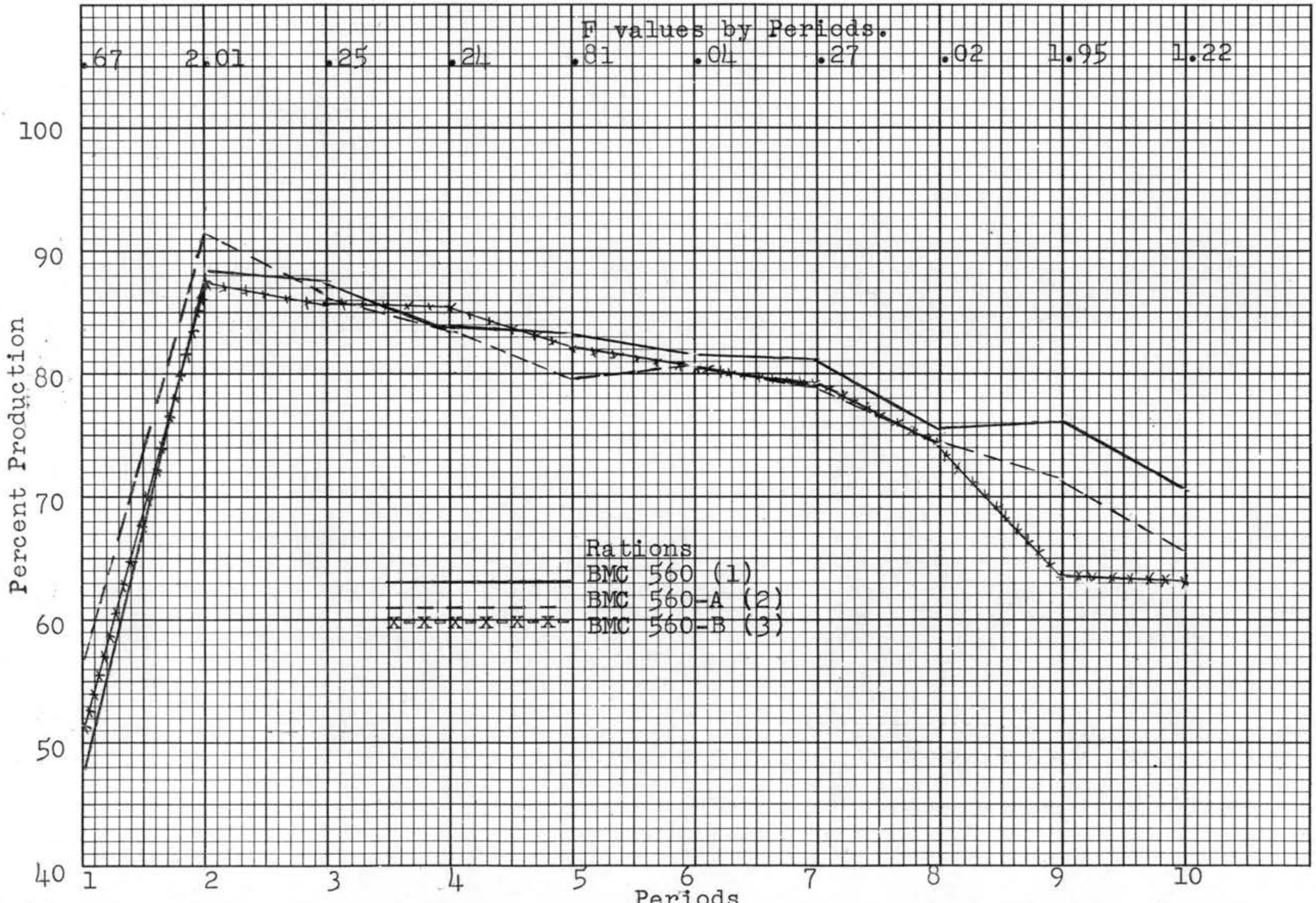
Graph 1. Egg production by four week periods as affected by the energy and the fat content of the diet.



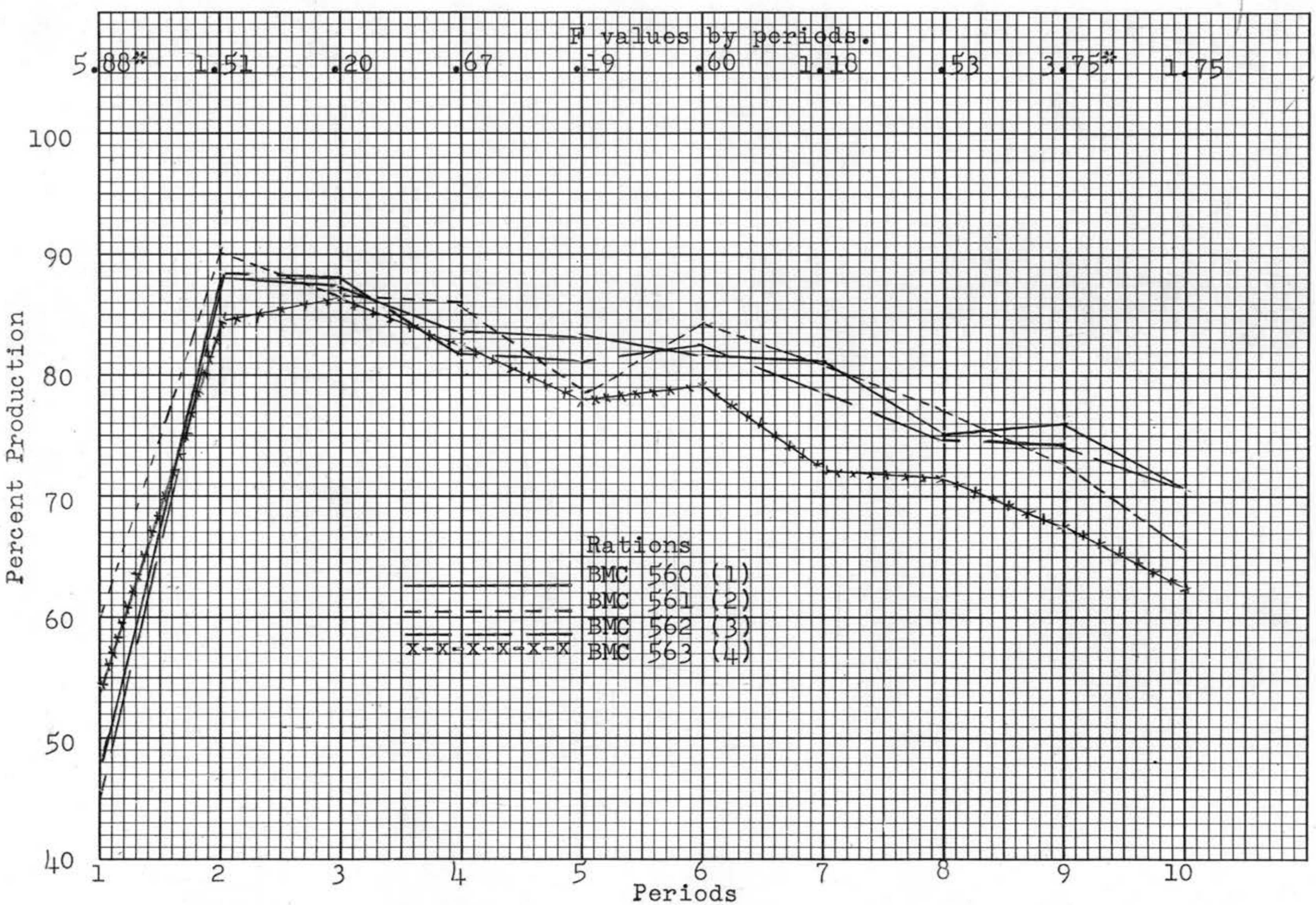
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.
* Significant difference at the 5% level.

Graph 2. Egg production by four week periods as affected by supplementing ration BMC 560 with pellets.



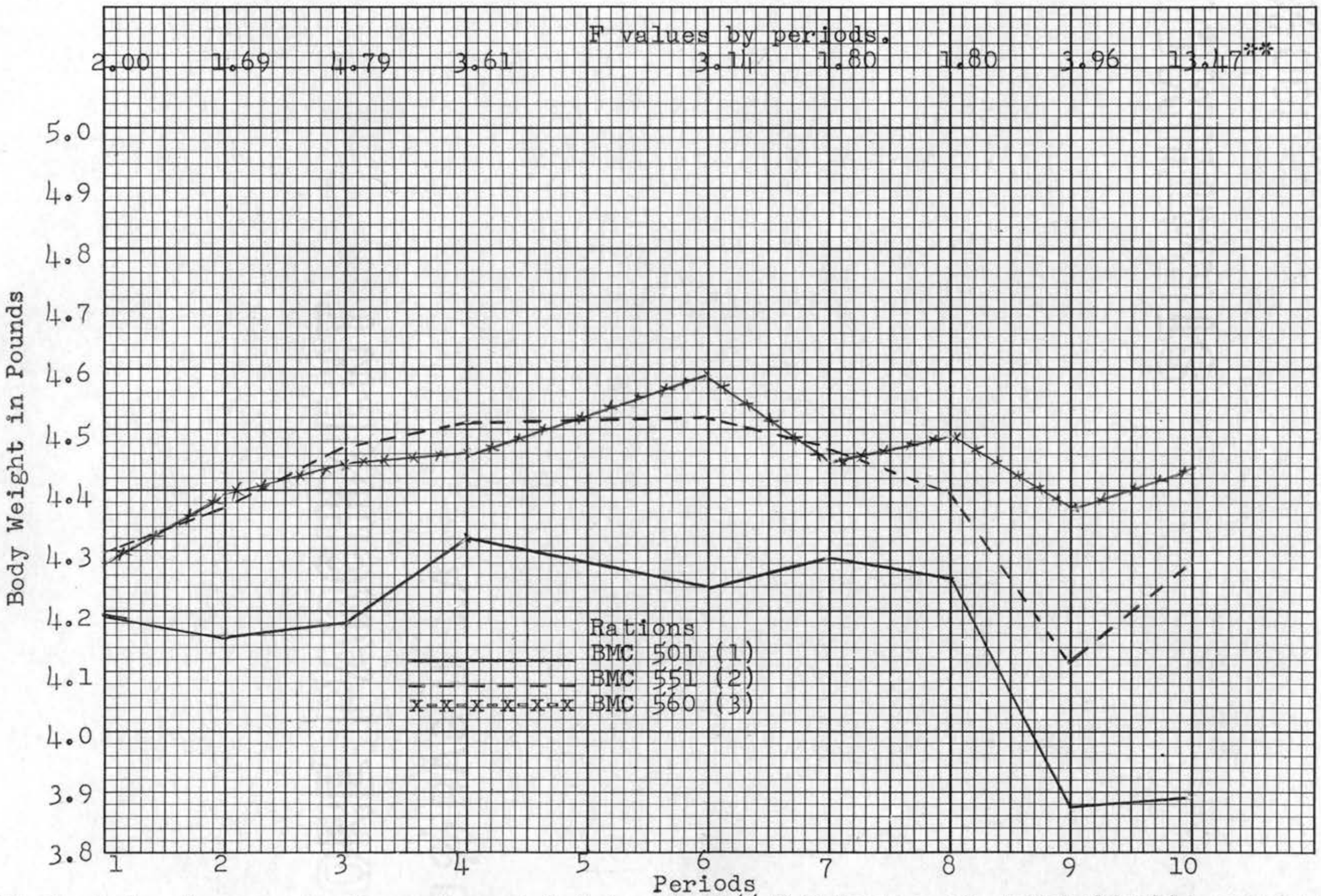
(1) BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per 100 birds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

Graph 3. Egg production by four week periods as affected by antibiotics and furazolidone.



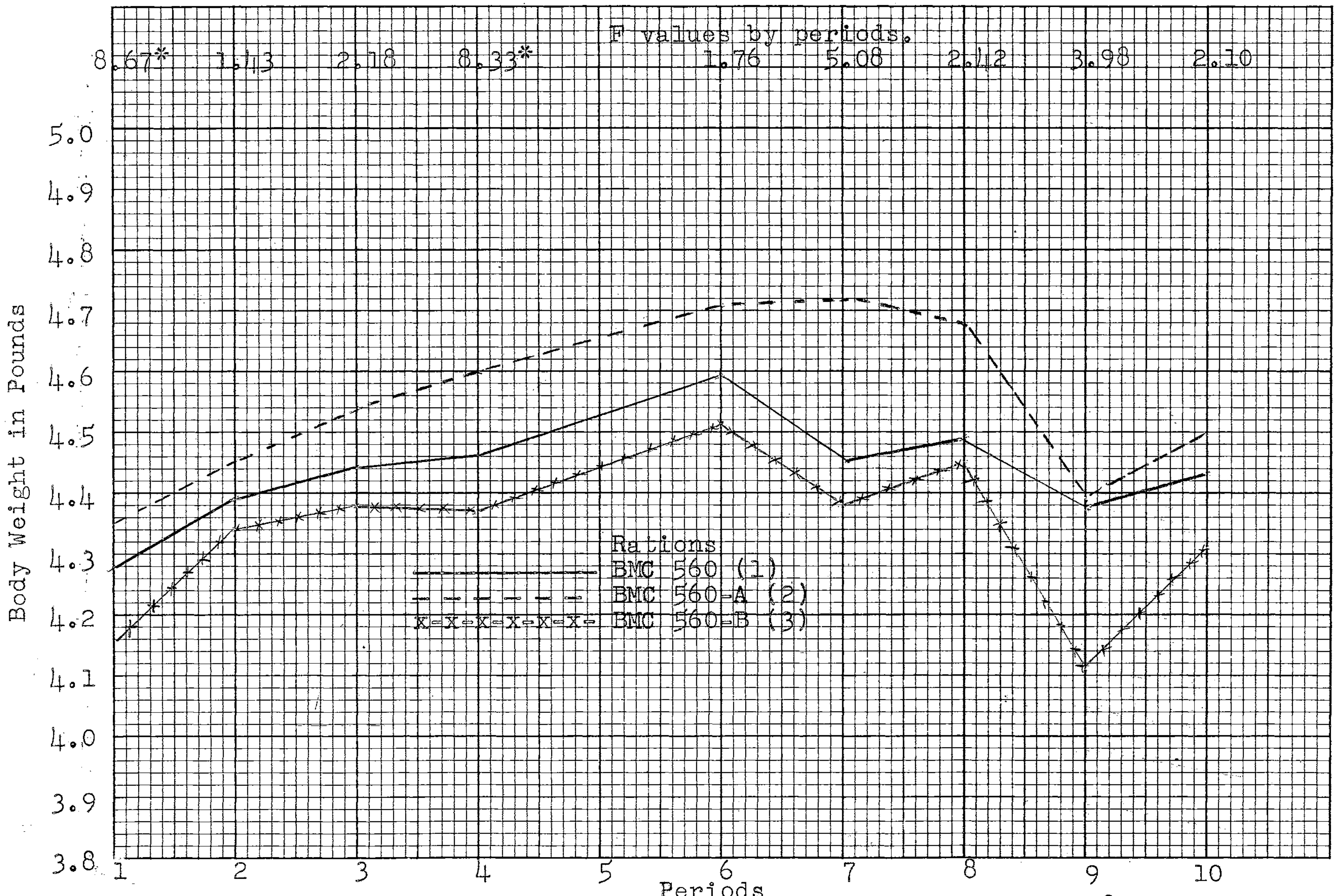
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.
* Significant difference at the 5% level.

Graph 4. Body weight by four week periods as affected by the energy and the fat content of the diet.



(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.
** Significant difference at the 1% level.

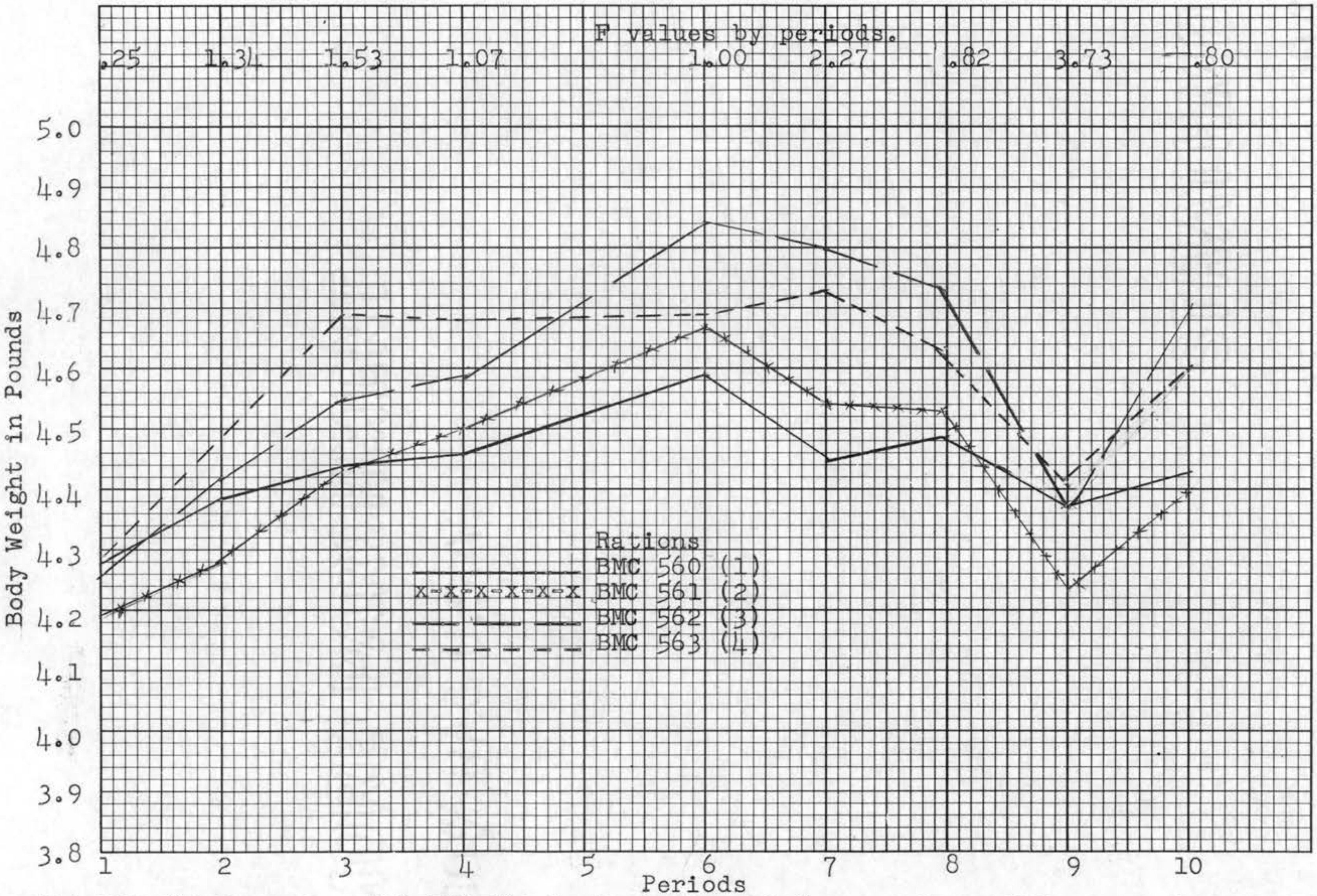
Graph 5. Body weight by four week periods as affected by supplementing ration BMC 560 with pellets.



(1)BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per 100 birds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

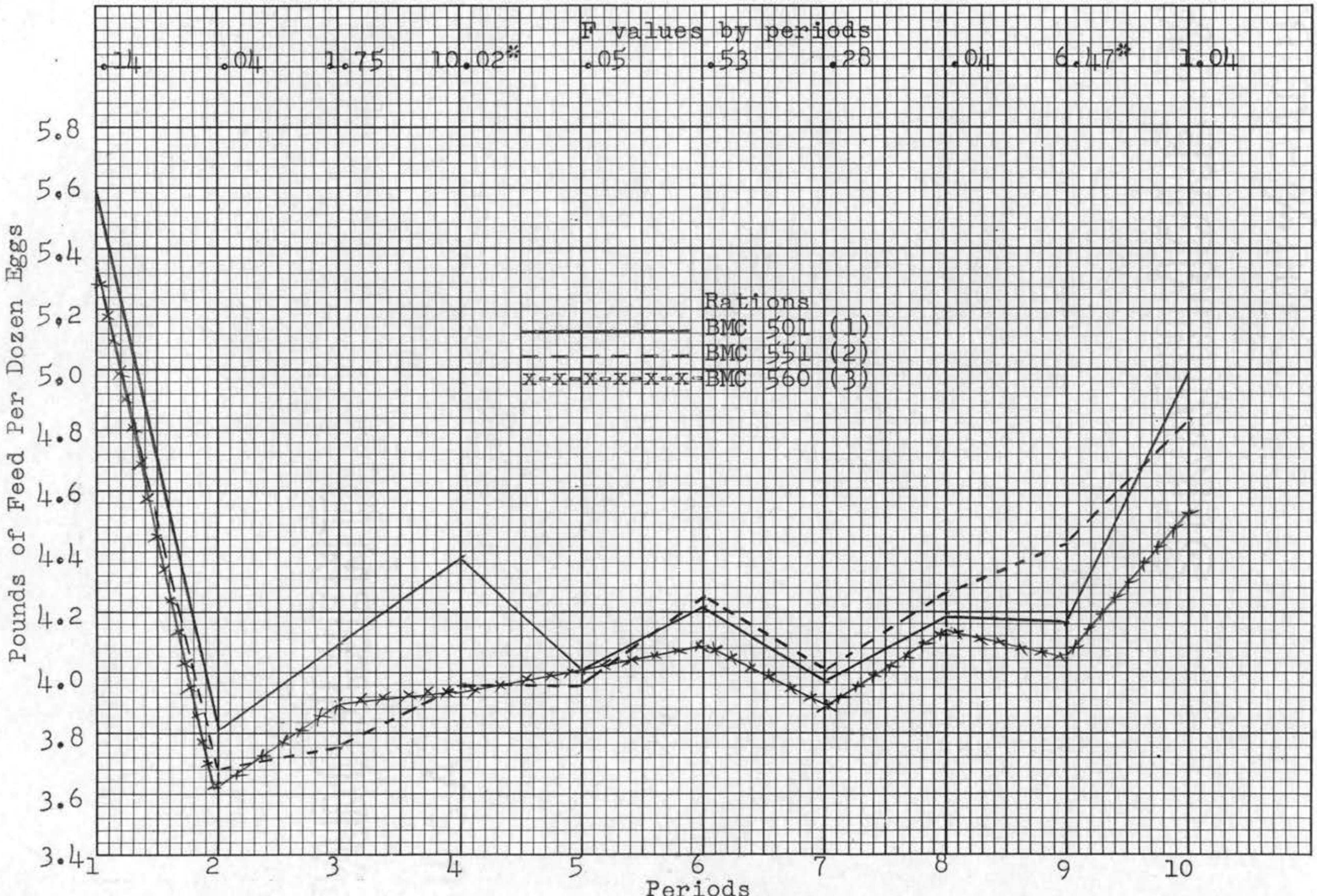
* Significant difference at the 5% level.

Graph 6. Body weight by four week periods as affected by antibiotics and furazolidone.



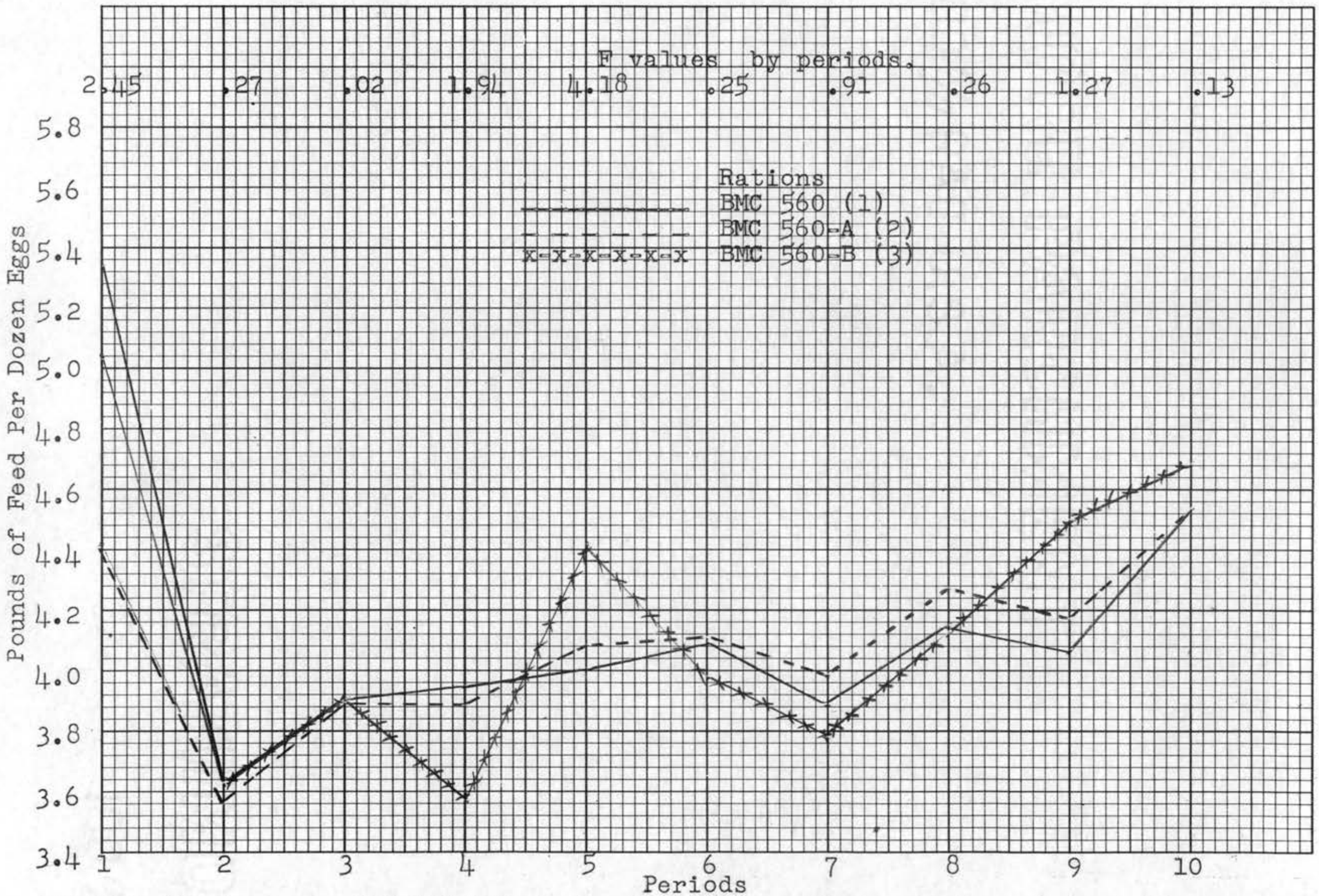
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.

Graph 7. Pounds of feed required to produce one dozen eggs by four week periods as affected by the energy and fat content of the diet.



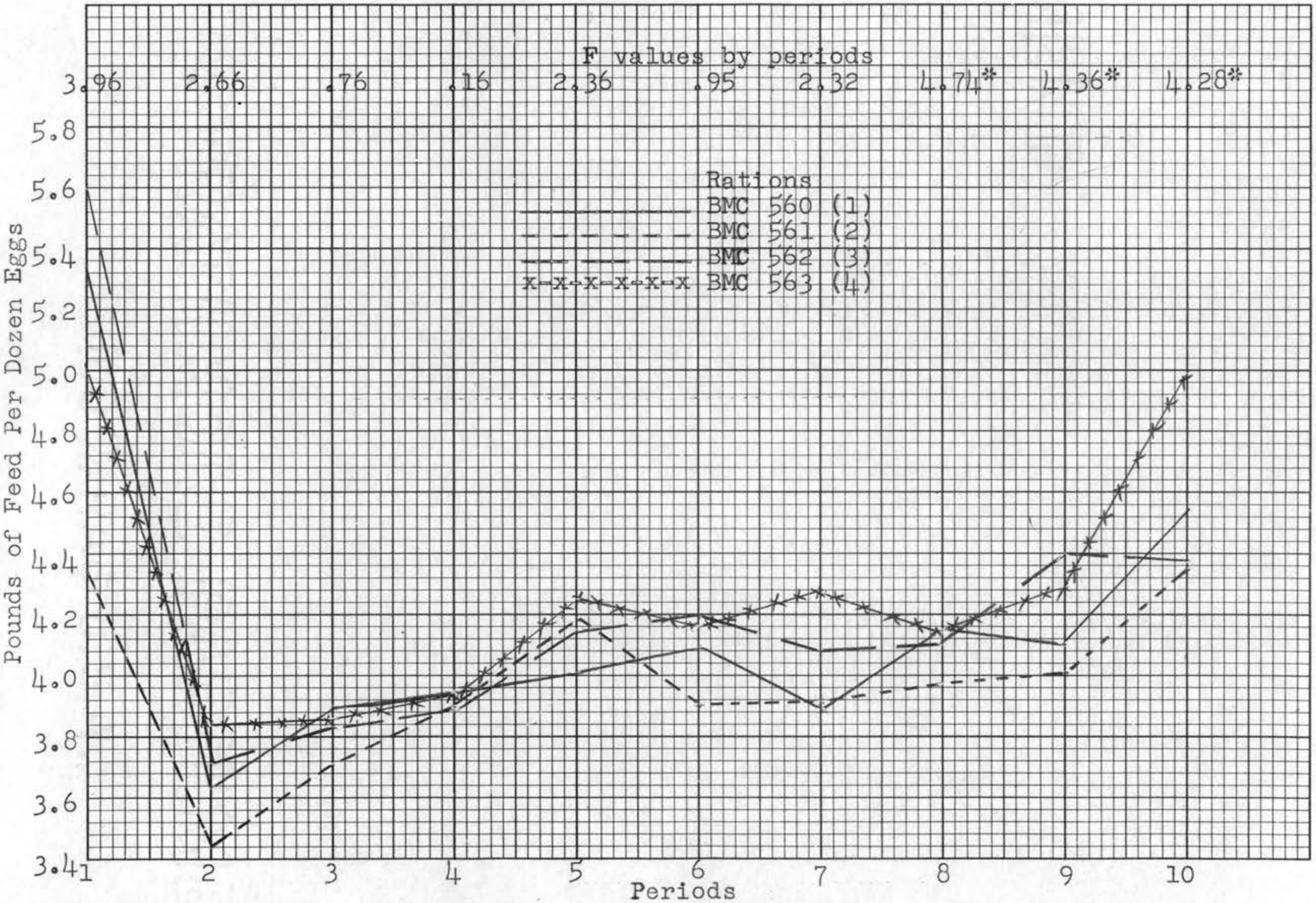
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.
* Significant difference at the 5% level.

Graph 8. Pounds of feed required to produce one dozen eggs by four week periods as affected by supplementing ration BMC 560 with pellets.



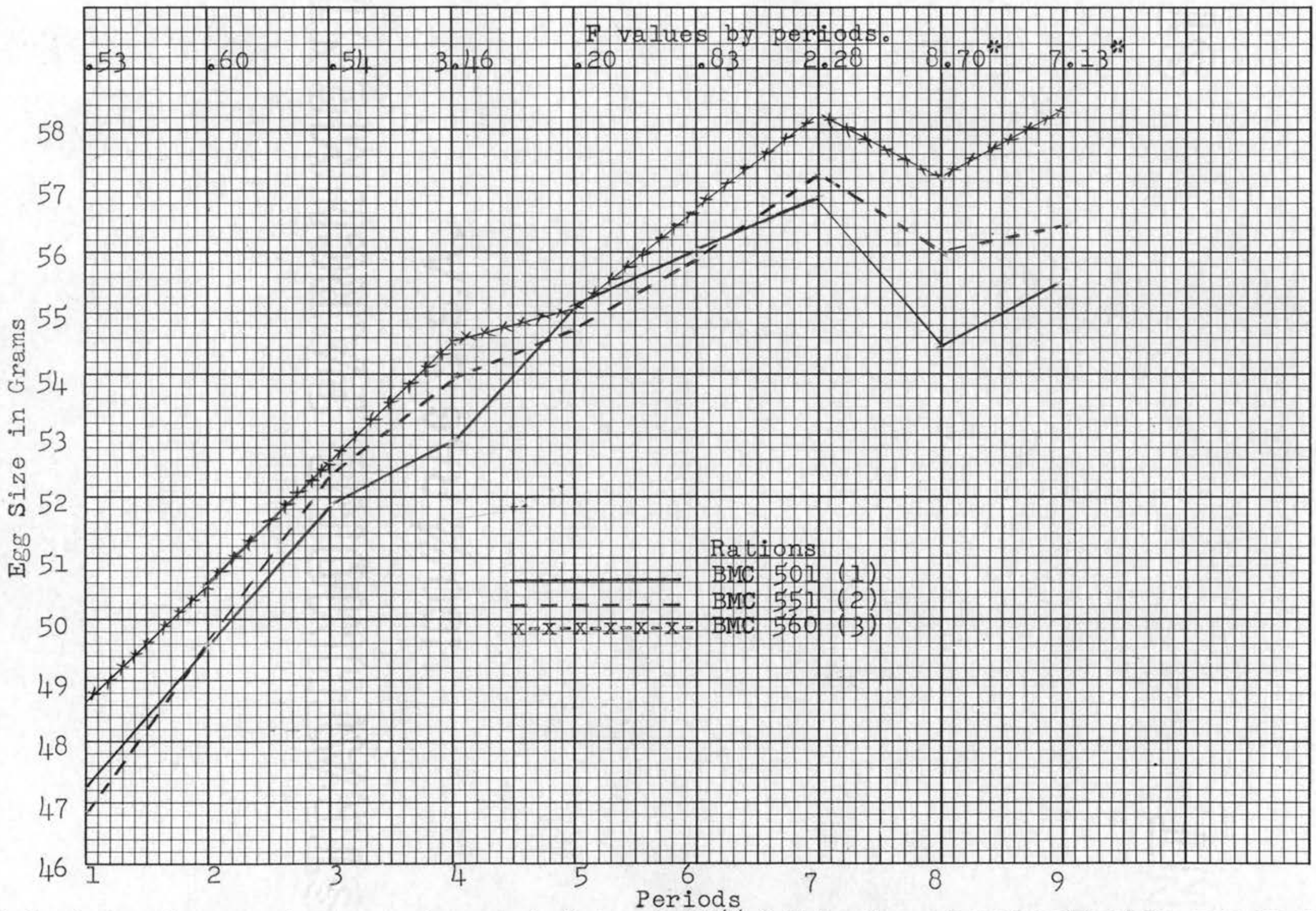
(1) BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per 100 birds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

Graph 9. Pounds of feed required to produce one dozen eggs by four week periods as affected by antibiotics and furazolidone.



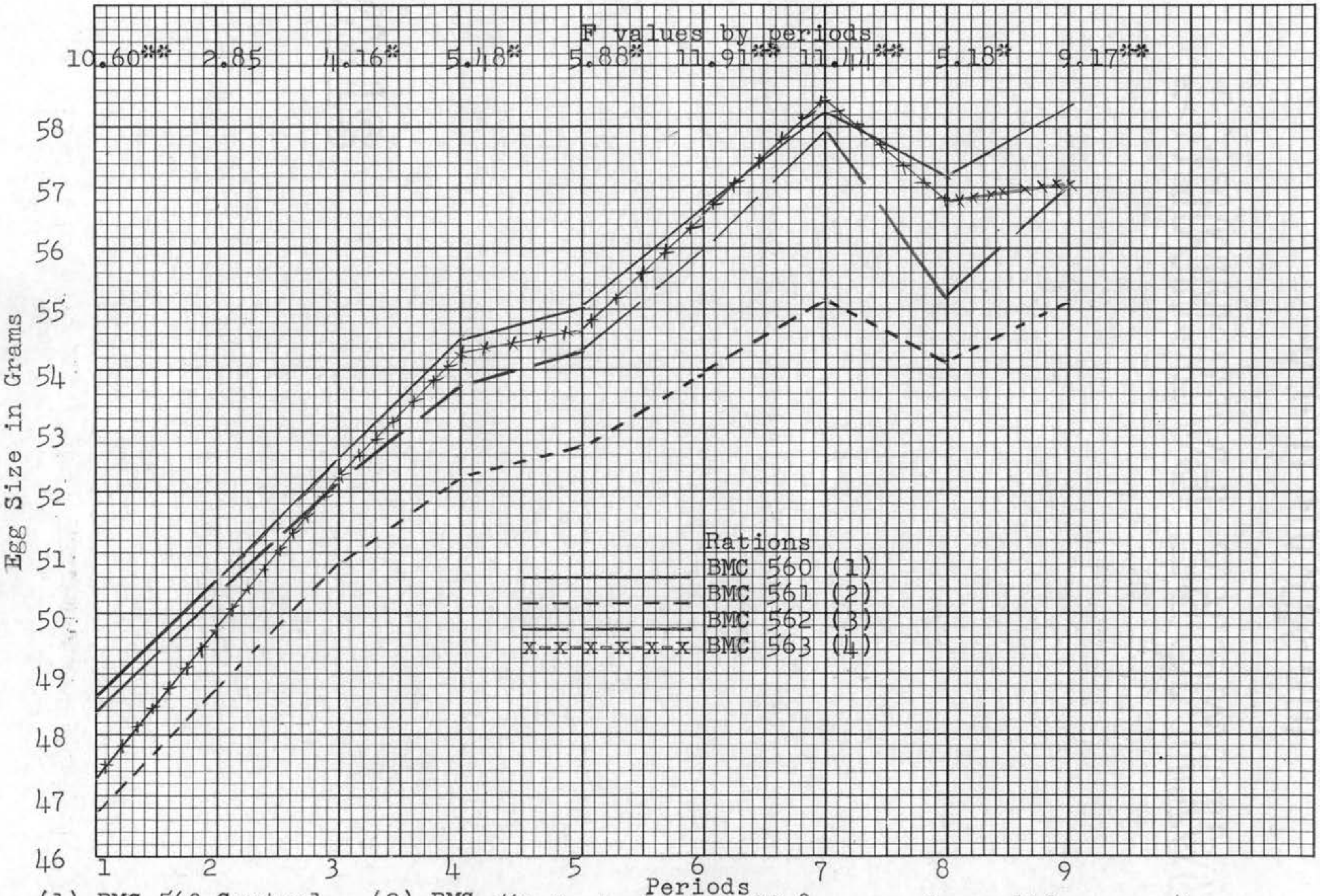
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.
* Significant difference at the 5% level.

Graph 10. Egg size by four week periods as affected by the energy and fat content of the diet.



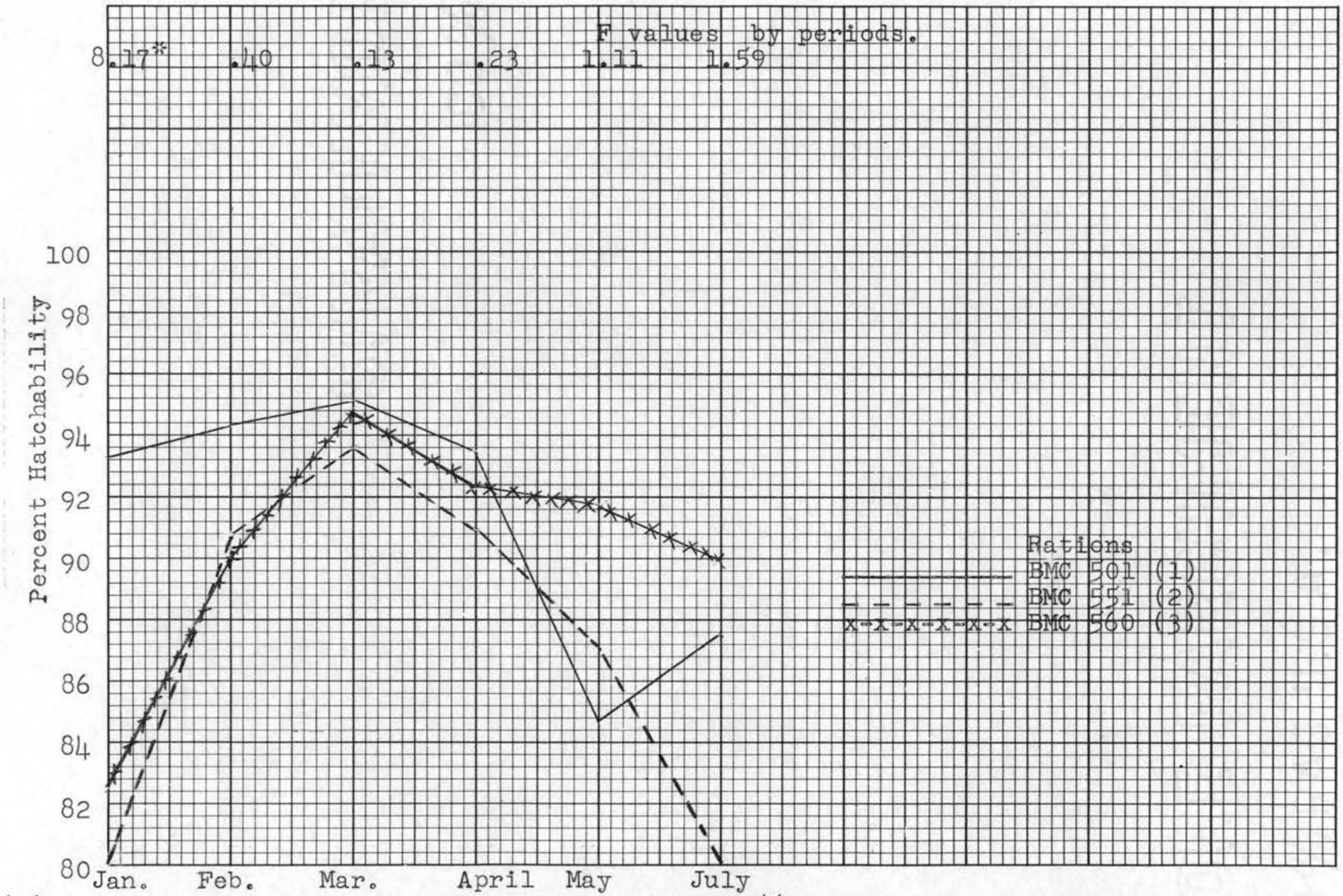
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.
* Significant difference at the 5% level.

Graph 11. Egg size by four week periods as affected by antibiotics and furazolidone.



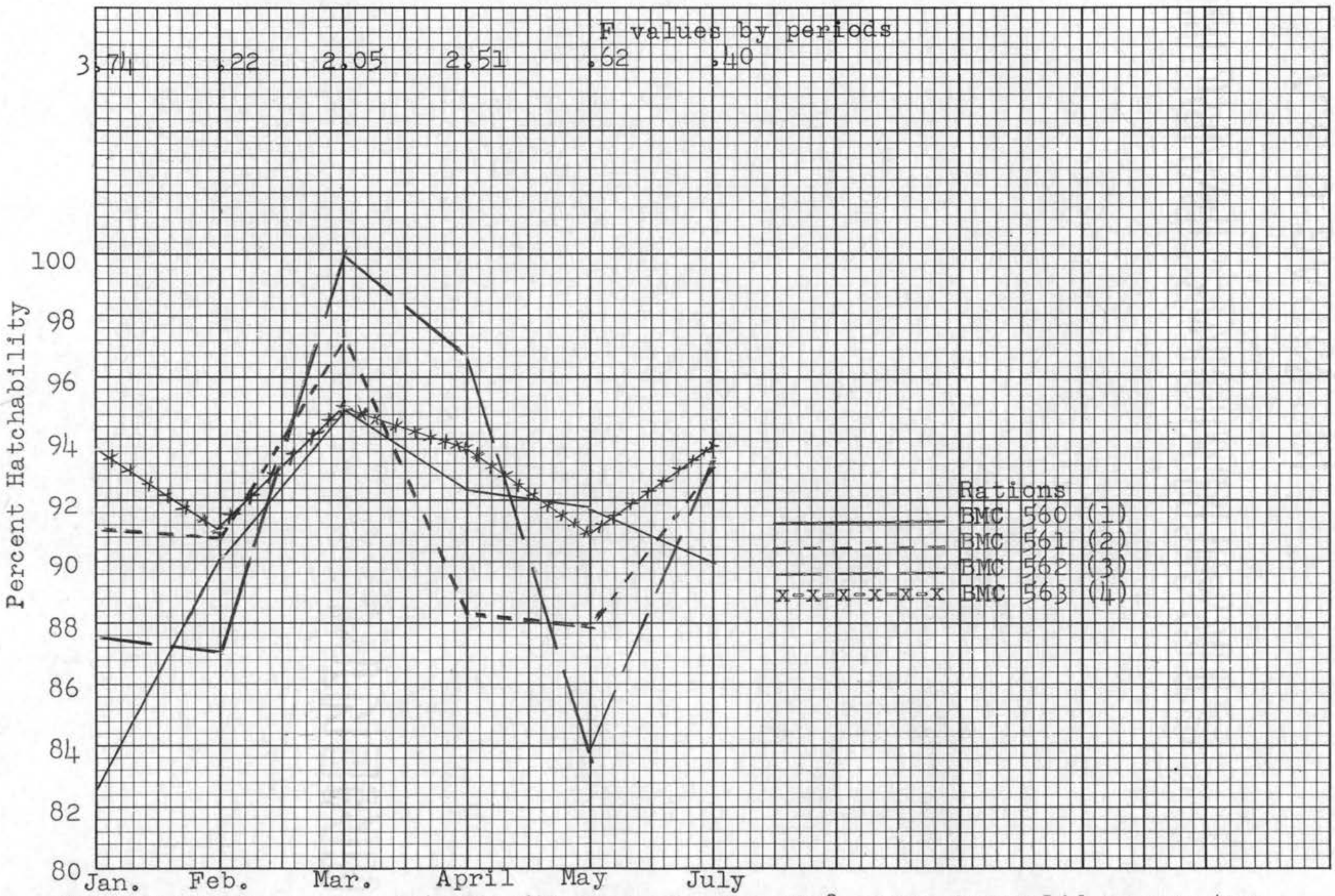
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.
* Significant difference at the 5% level.
** Significant difference at the 1% level.

Graph 12. Hatchability of fertile eggs by months as affected by the energy and fat content of the diet.



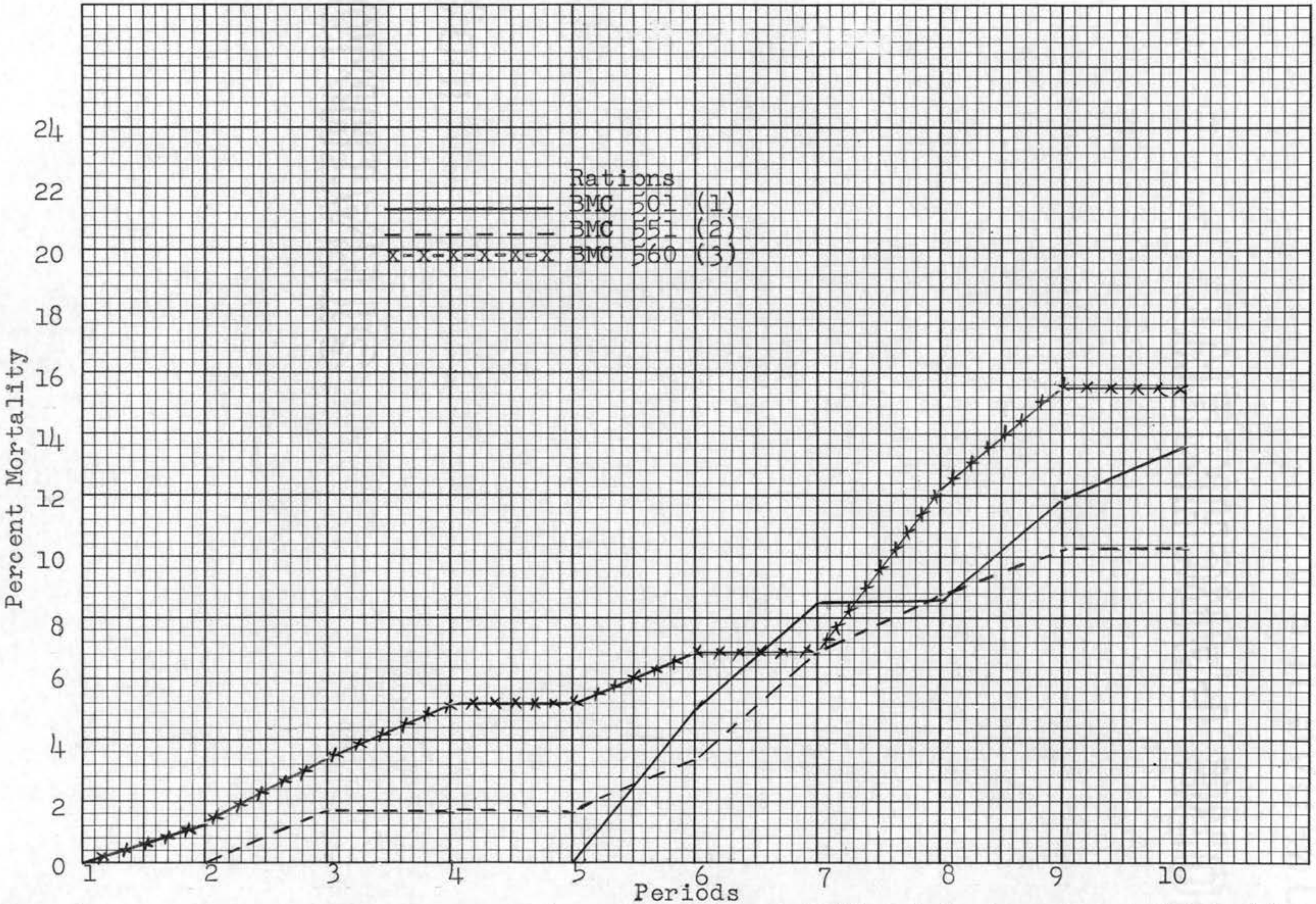
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.
* Significant difference at the 5% level.

Graph 13. Hatchability of fertile eggs by months as affected by antibiotics and furazolidone.



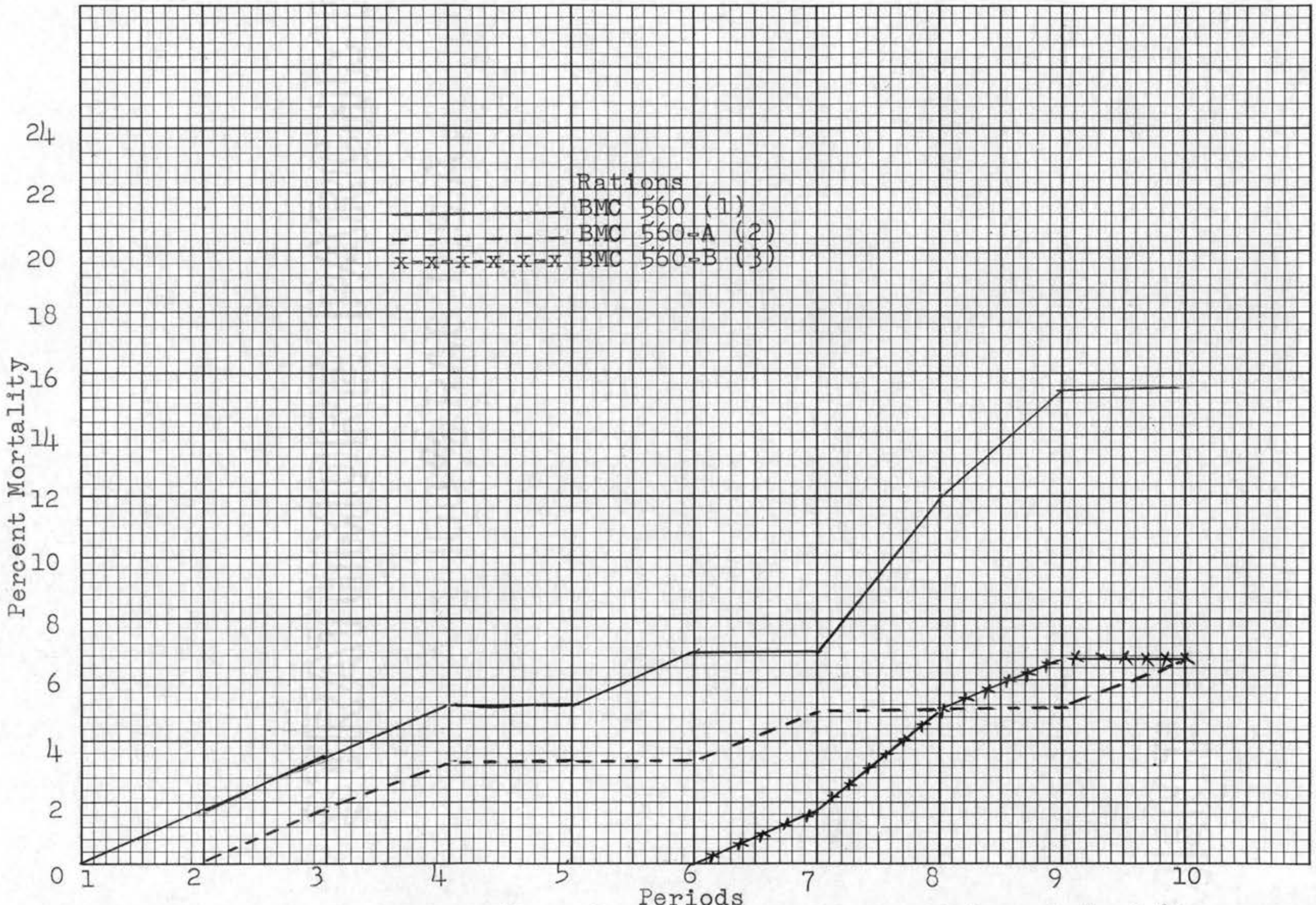
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.

Graph 14. Mortality cumulated by four week periods as affected by the energy and fat content of the diet.



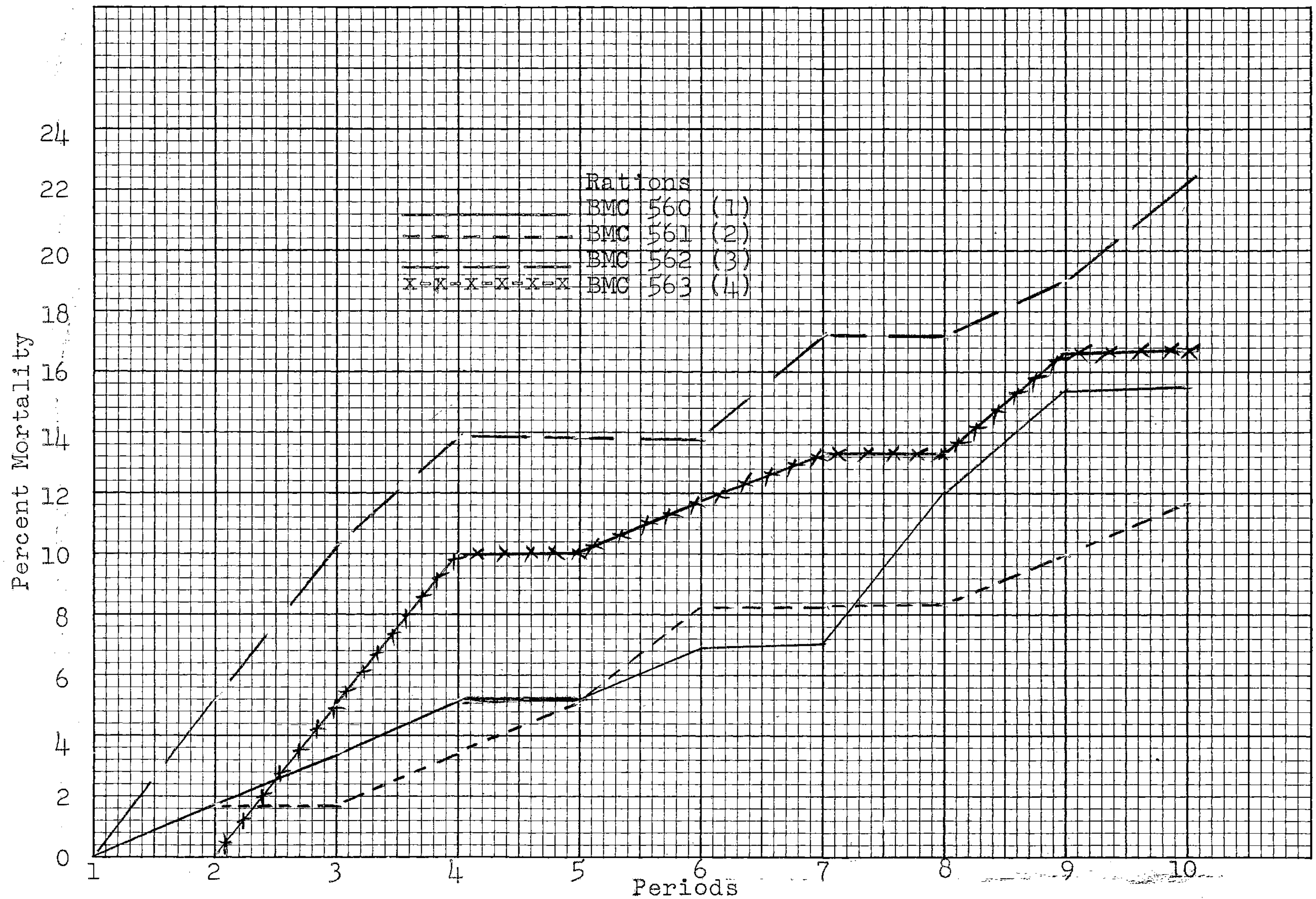
(1) BMC 501 Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound. (2) BMC 551 Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound. (3) BMC 560 Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.

Graph 15. Mortality cumulated by four week periods as affected by supplementing ration BMC 560 with pellets.



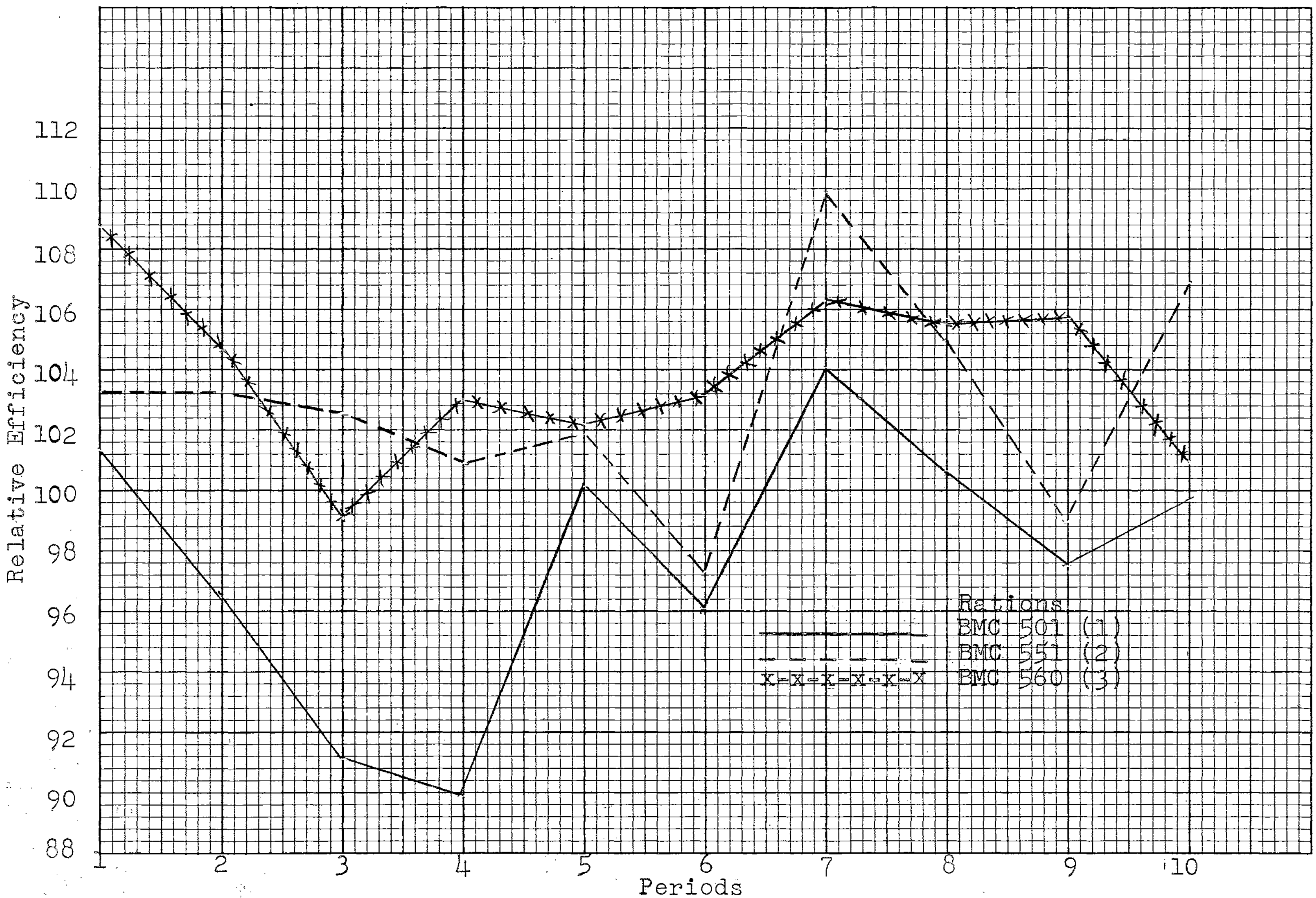
(1) BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per 100 birds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

Graph 16. Mortality cumulated by four week periods as affected by antibiotics and furazolidone.



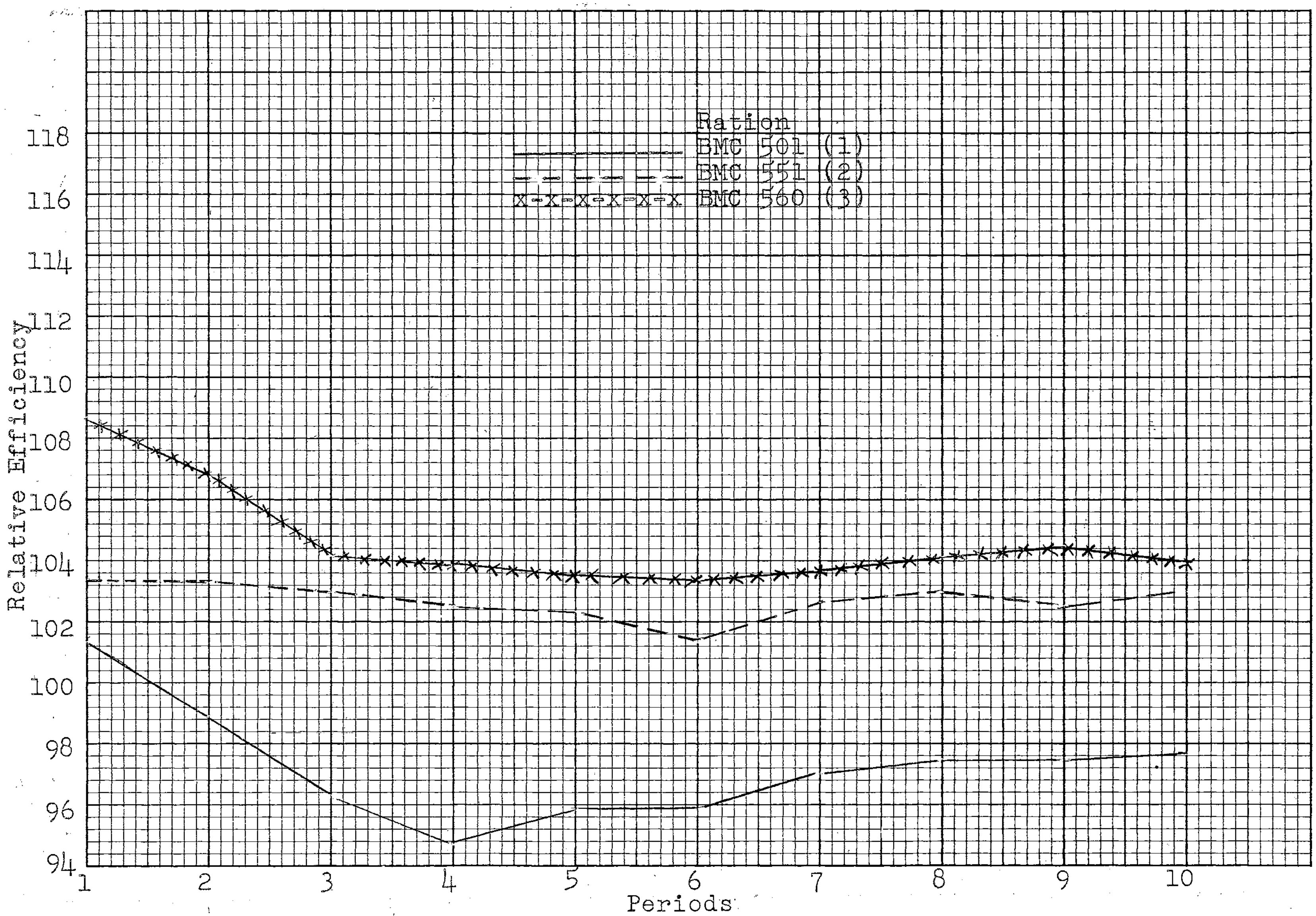
(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.

Graph 17. Relative efficiency indices by four week periods as affected by the energy and fat content of the diet.



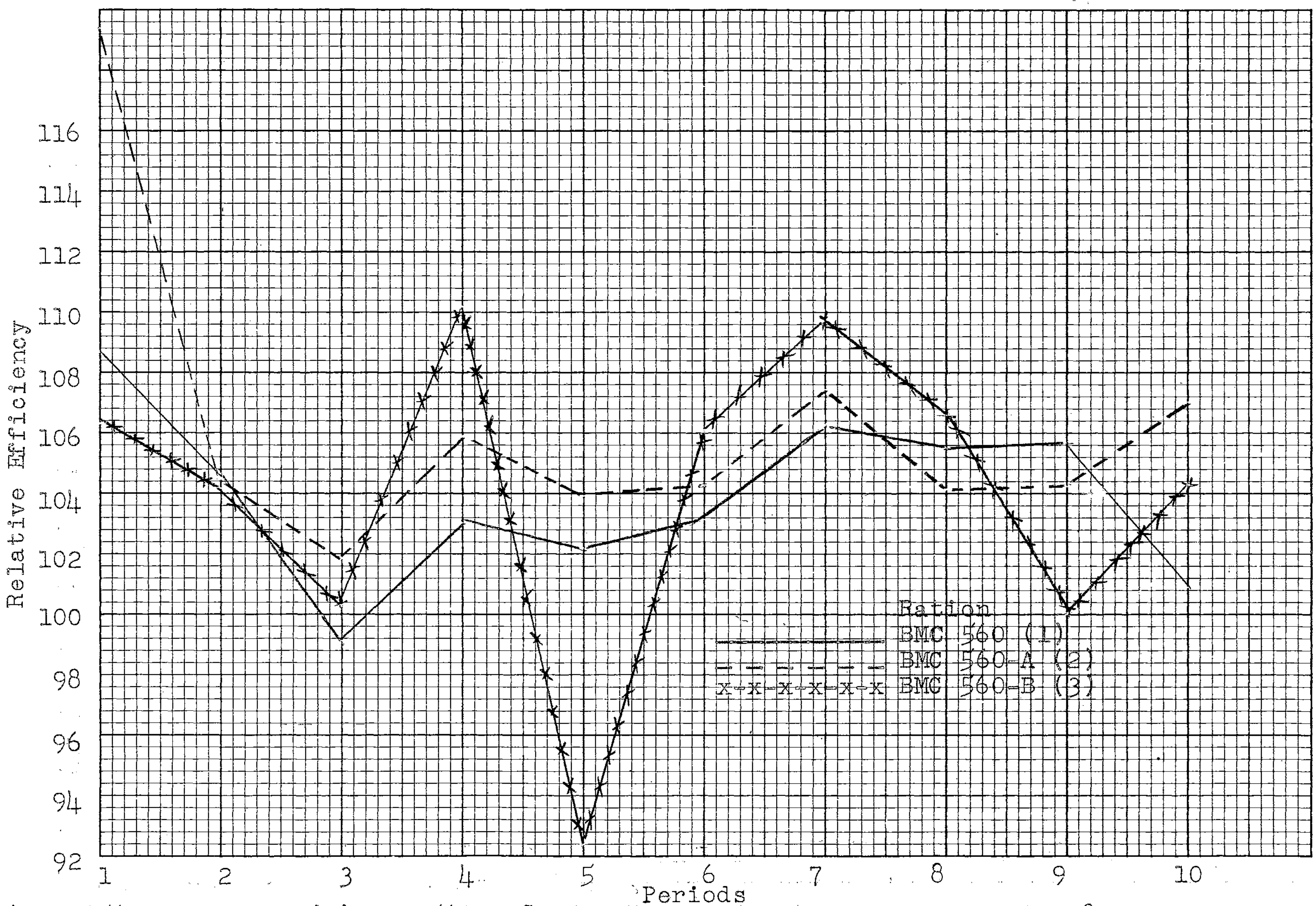
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.

Graph 18. Relative efficiency indices cumulated by four week periods as affected by the energy and fat content of the diet.



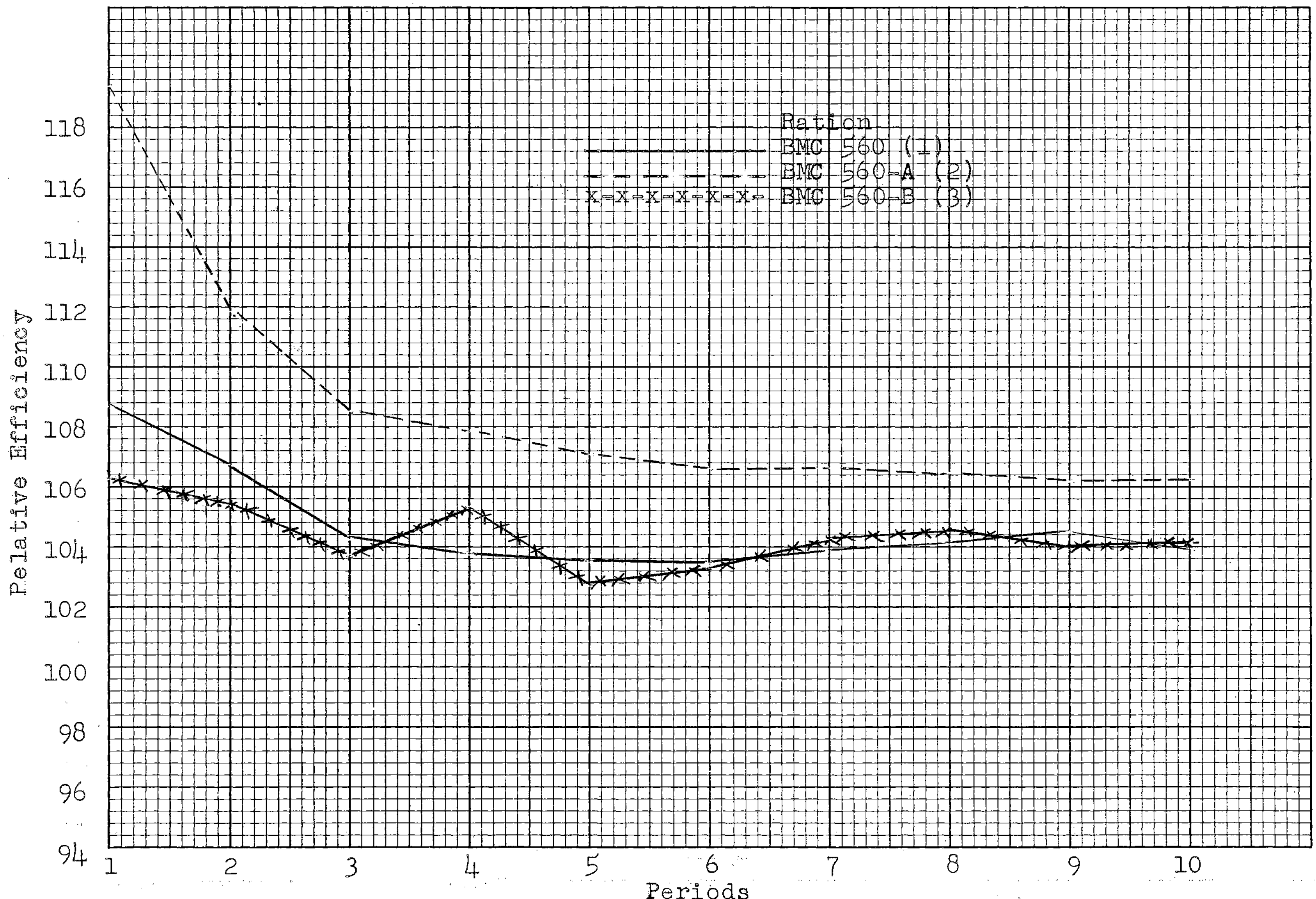
(1) Contains 0 percent of supplemental fat and 1255.9 Calories of metabolizable energy per pound.
(2) Contains 3 percent of supplemental fat and 1357.6 Calories of metabolizable energy per pound.
(3) Contains 5 percent of supplemental fat and 1366.9 Calories of metabolizable energy per pound.

Graph 19. Relative efficiency indices by four week periods as affected by supplementing ration BMC 560 with pellets.



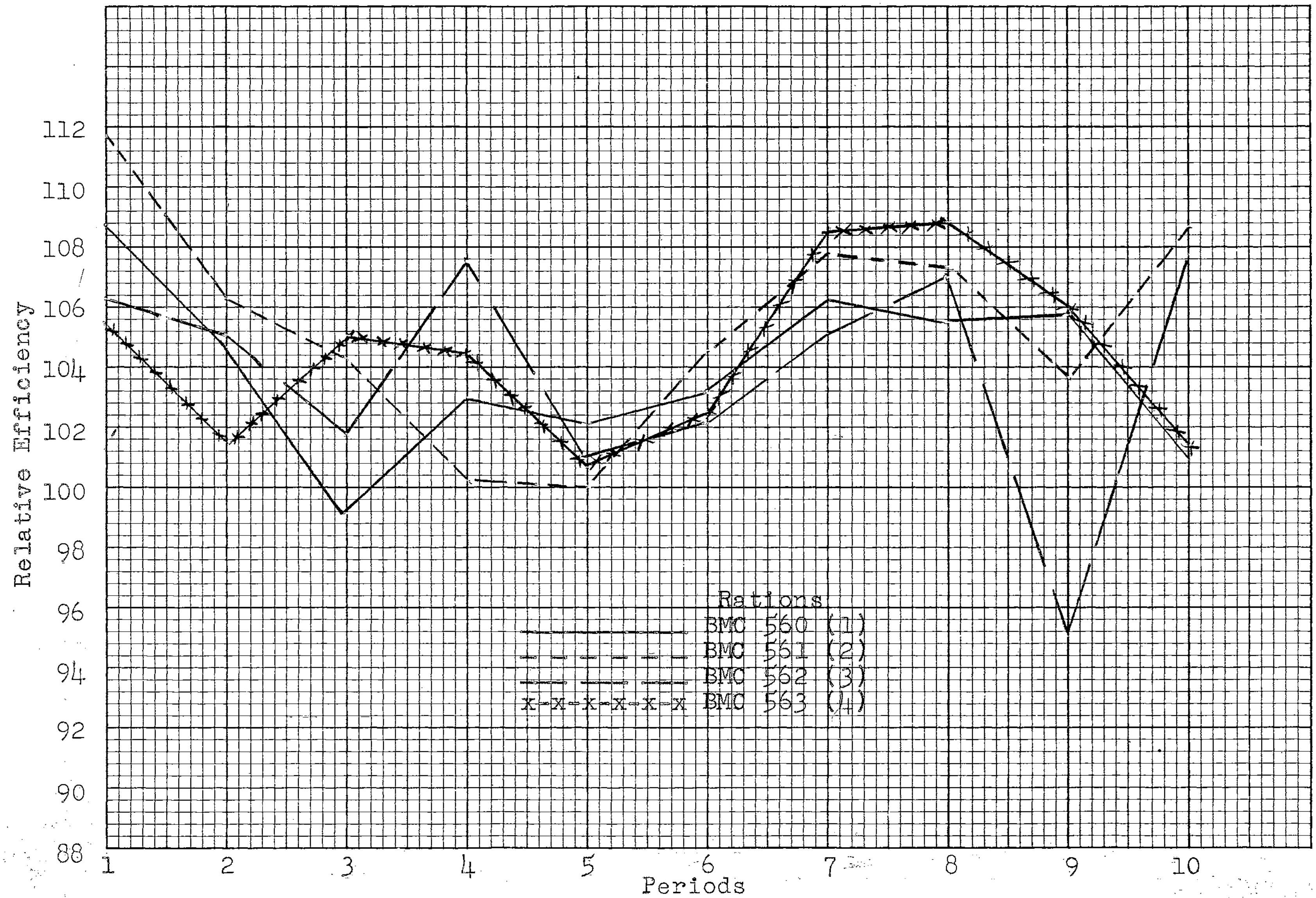
(1) BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

Graph 20. Relative efficiency indices cumulated by four week periods as affected by supplementing ration BMC 560 with pellets.



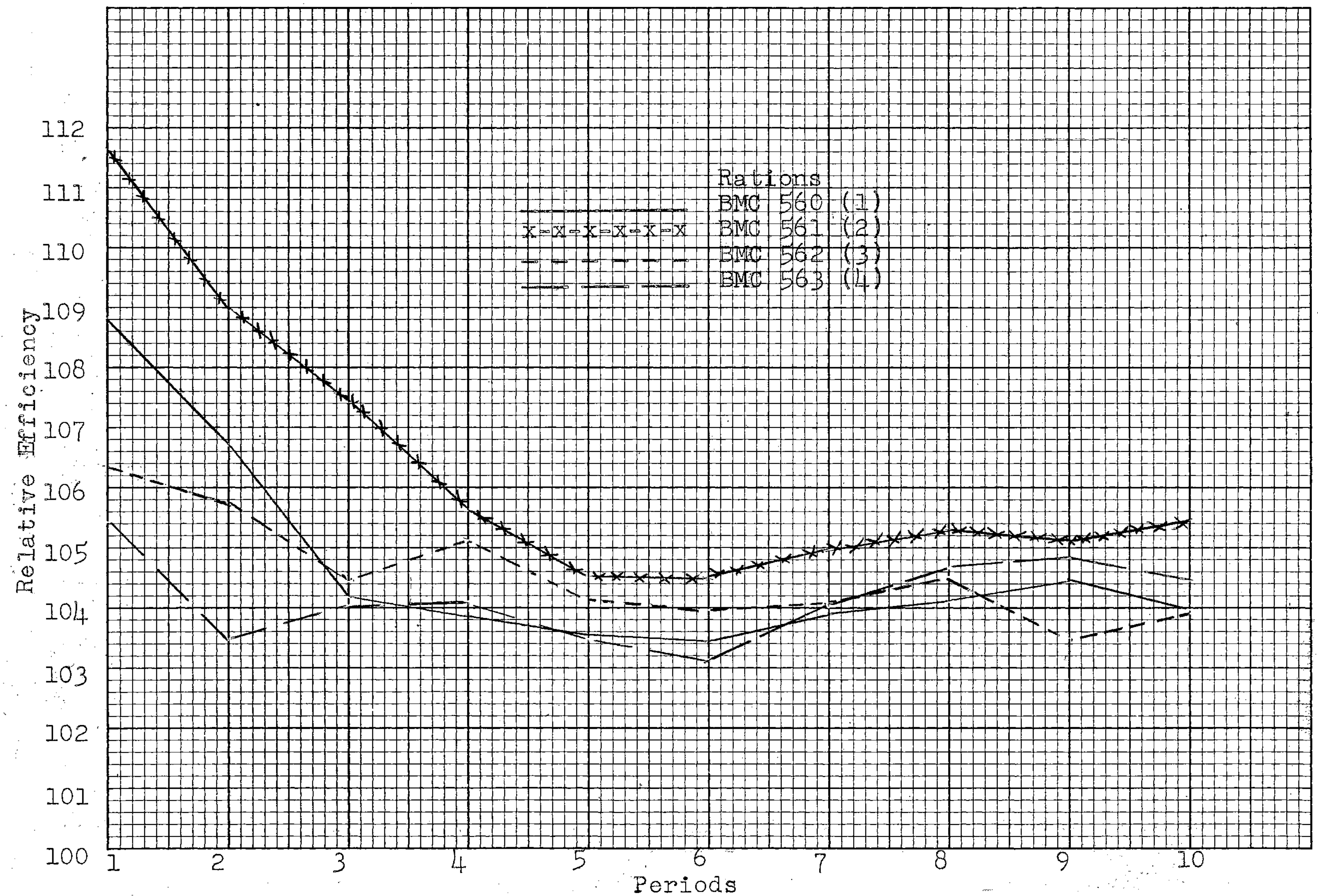
(1) BMC 560 Control. (2) BMC 560-A Control plus pellets which contained 80 grams of bacitracin per ton. The pellets were fed as a noon lunch at the rate of 2 pounds per 100 birds per day. (3) BMC 560-B Control plus pelleted control fed as a noon lunch at the rate of 2 pounds per 100 birds per day. Ration BMC 560-A was administered when it was thought birds were under stress conditions.

Graph 21. Relative efficiency indices by four week periods as affected by antibiotics and furazolidone.



(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.

Graph 22. Relative efficiency indices cumulated by four week periods as affected by antibiotics and furazolidone.



(1) BMC 560 Control. (2) BMC 561 Control plus 99.8 grams furazolidone per ton.
(3) BMC 562 Control plus 100 grams terramycin per ton.
(4) BMC 563 Control plus 40 grams bacitracin per ton.

VITA

William Lesley McCaslan

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF ENERGY, SUPPLEMENTAL PELLETS, AND STRESS ADDITIVES UPON THE REPRODUCTIVE PERFORMANCE OF LAYING HENS

Major Field: Poultry Management

Biographical:

Personal data: Born: Blair, Oklahoma, July 14, 1930.

Education: Undergraduate study: Altus Junior College, Altus, Oklahoma; Southwestern State College, Weatherford, Oklahoma; Bachelor of Science degree in Poultry Science from Oklahoma State University, May 1956.

Experiences: Active duty in United States Air Force, December, 1948--September, 1952; Sales and Service with Chickasha Cotton and Oil, February, 1956--December, 1956; Teaching and Research Assistant, Poultry Science Department, Oklahoma State University, February, 1957--May, 1959.

Organizations: Poultry Science Association.