FAT DIGESTIBILITY STUDIES WITH LAYING HENS

By

LEALON VERDE TONKINSON

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Thesis Approved:

Rollin H. Thayer
Thesis Adviser

John W. West
Head of the Department

Robert MacVicar
Dean of the Graduate School

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INTRODUCTION

During the past decade the use of fat in poultry rations as an energy supplement has become a common practice in many commercially prepared feeds. It becomes necessary to add fat to the diet of an animal when the energy needed to obtain nutrient balance cannot be obtained from carbohydrates. Recent research work concerning energy-protein ratio has made it possible to have the fat levels in the diets of broilers or growing turkeys as high as 30 percent when extremely high efficiency of feed conversion is desired. When the results of future experimental work are available, it is possible that the level of fat that can be utilized efficiently in diets for poultry may become even higher.

From a practical standpoint, when the fat level of a diet is greater than about 10 percent, the cost of mixing, handling and dispersing the fat in the feed becomes prohibitive. A probable solution of this problem is the development of a highly digestible dry-free-flowing fat source.

The purposes of the experiments reported in this thesis are: (1) to find basic factors which may affect the digestibility of fat in laying hens, such as age and the dietary levels of various nutrients (protein, vitamins and energy); (2) to compare the digestibility of newly developed dry fats with that of liquid or semi-solid fats of relatively high digestibility, such as corn oil or tallow; (3) to determine the effects of commercially-available lipase and lipase sources such as yeast culture upon the digestibility of fats; and (4) to relate differences in the productive performance of laying hens to differences in fat digestibility.

REVIEW OF LITERATURE

Effect of Melting Point

One of the first factors found to influence fat digestibility was the melting point of the fat. Early research workers found an inverse relationship between the melting point and digestibility of a fat (Langworthy and Holmes, 1915; and Holmes and Deuel, 1921). However, Hoagland and Snider (1943) presented data which indicated that although the melting point of fat had some effect on the digestibility of the fat, there was no consistent relationship between the melting point and digestibility. Crokett and Deuel (1947) and Chang et al. (1949) performed digestibility studies with rats in which samples of lard with varying degrees of saturation were used. The results of these trials showed very little difference in the digestibility of lard when the melting point of the samples fed ranged from 30 to 48 degrees C. When the melting point was increased above 48 degrees C., the digestibility of the fat declined rapidly. Lard samples melting from 37 to 38 degrees C. had digestibility coefficients which ranged from 94 to 96, whereas lard melting at 55 degrees C. had a digestibility coefficient of 63. When lard was hydrogenated to the extent that the melting point was 61 degrees C., the digestibility went as low as 21 percent.

The digestibility of fat in the digestive tract is dependent upon lipase coming in contact with the fat molecules. This being the case, it is necessary for the fat to be in an emulsified state in the digestive tract. If the melting point of the fat is higher than the body temperature, it emulsifies less readily in the digestive tract, and for this reason it is less digestible. It was suggested by Duckworth *et al.* (1950) that the high body temperature of the chick, as compared with other animals, might be an advantage in the digestion of higher melting point fats, but these workers found this not to be the case.

Carver *et al.* (1955) found the digestibility of tallow in chicks to be above 80 percent, but with hydrogenated tallow the digestibility was reduced to as low as 11 percent. March and Biely (1957) compared the digestibility of tallow to that of corn oil in chicks and found corn oil to be approximately 90 percent digestible and tallow to be near 73 percent digestible. When the animal fat was hydrogenated, digestibility was reduced to between 23 and 44 percent. Chicks have been shown to utilize 97 percent of the combustible energy in lard, whereas only 71 percent of the energy was utilized from tallow (Renner and Hill, 1958).

Effect of Emulsifying Agents

Augur *et al.* (1947) found lecithin to be very effective in increasing the digestibility of cottonseed oil in rats. These data showed that this effect of lecithin increased with increased hydrogenation. However, when March and Biely (1957) added lecithin to chick diets which were supplemented with fat, there was no appreciable improvement in the digestibility of either tallow or hydrogenated animal fat. These workers fed Santomerese-80 (a surface-active agent) to chicks that were fed diets containing tallow or hydrogenated animal fat, and no improvement in the digestibility was observed.

Fedde *et al.* (1960) added 0.5 percent of ox bile to a diet which contained 20 percent of tallow. When this diet was fed to two-week old chicks, it was observed that digestibility of tallow had been increased from 46 to 68 percent. In eight-week old chicks which received the same diets, 0.5 percent of ox bile increased the fat digestibility from 78 to 88 percent.

Effect of Calcium, Phosphorus and Magnesium

Bosworth (1918) found considerable quantities of fatty acids in the form of soaps in the stools of bottle-fed babies. When de-calcified milk was fed instead of normal milk, the fatty acids as soaps in the stools were greatly reduced. This points out that conditions in the intestines are very favorable for the formulation of insoluble calcium soaps with fatty acids, when excess calcium is available in the diet.

Pepper *et al.* (1955) noted that in the chick rations which contained 10 percent of animal fat, 1.0 percent of calcium did not give as good results as did 1.2 percent of calcium. However, in the same diet which contained no added fat, both levels of calcium gave equal results. The phosphorus requirements were not affected by the addition of 10 percent of animal fat. Fedde *et al.* (1960) fed graded levels of calcium to chicks which received diets that contained 20 percent of beef tallow and observed a progressive decrease in fat digestibility as the calcium content of the diet was increased.

Work by Boyd *et al.* (1932) indicated that the length of the fatty acid chain and the degree of saturation are factors affecting the solubility of the calcium soaps. Calcium stearate, calcium palmitate and calcium oleate were added singly to diets fed to rats, and the digestibility of these soaps were found to be 24 percent, 38 percent, and 90 percent, respectively. The digestibility of these soaps was improved somewhat when there was a reduction in calcium intake. Chang et al. (1949) reported that the effect of calcium and magnesium upon the digestibility of fat was a progressive one, being greater when larger proportions of these salts were present in the diet.

Effect of Dietary Level of Fat

Various workers have noted that high levels of dietary fat result in higher digestibility than do low levels of dietary fat. Walker (1959) found that when human beings are fed graded levels of fat in the same basal diet, the percentage retention of fat was increased with each increase in dietary fat. Williams et al. (1959) found the same thing to be true when graded levels of fat were fed to chicks. However, when corrections are made for the low digestibility of the fat present in the basal ration, the added fat was utilized equally at all supplemental levels.

Effect of Dietary Protein

Variations in fat retention in the normal dog which resulted from variations in protein intake were observed by Coffey and Mann (1940). Several research workers have expressed the opinion that low protein intake is associated with low fat digestibility, and high protein intake is associated with high fat digestibility. Barnes et al. (1944) found this to be true, and further found that the digestibility of hydrogenated fat was more severely affected than was the digestibility of non-hydrogenated fat when fed with low protein diet to rats. Swift *et al*. (1947) found that when casein was added to the diet of ruminants, there was an increase in the digestibility of fat. Work by Biely and March (1957) showed that the extent to which tallow was utilized by the chick depended upon the level fed and the protein content of the diet. When 10 to 12 percent of tallow was fed to chicks, it was utilized best in diets which contained protein levels above 26 percent.

Effect of Vitamins

Only very limited data were found concerning the effect of vitamins upon fat digestibility. March and Biely (1955) were able to correct a growth depressing effect caused by the addition of fat to the diet of chicks by the addition of folic acid to the diet. However, there was no evidence that the folic acid aided in fat digestion or absorption.

Effect of Age

Holt *et al*. (1919) and Gordon and McNamara (1941) presented data which suggests that infants cannot digest fat as readily as older children. Fedde *et al*. (1960) observed similar results with baby chicks. In two-week old chicks, which received diets containing 20 percent of tallow, digestibility was found to be 46 percent. When the same group of chicks was 8 weeks old, the digestibility of the fat was 78 percent.

Other evidence supports the idea that as an animal ages, it loses its ability to digest certain fatty acids. Carroll and Richards (1958) presented evidence that the digestibility of erucic acid, a fatty acid not found to any great extent in the common dietary fats, seemed to be lower in old than in young rats.

GENERAL PROCEDURE

Four trials, each 12 weeks in length, were performed to determine the effect of lecithin, yeast culture, purified lipase, various kinds of fat and various levels of dietary fat on the digestibility of fat by laying hens. One experiment, 52 weeks in length, was conducted to study the effects of graded intake levels of protein, energy and vitamin concentrate on fat digestibility. Included as part of this experiment was the effect of age on fat digestibility.

The hens in each trial were housed in individual cages in a temperature-controlled windowless house. The cages were 10 inches wide and 18 inches from front to back, and each cage had an individual feeder and waterer. All records were kept on each hen individually; thus, each hen was a complete experimental replication.

Body weight and feed consumption data were recorded periodically throughout each trial. The length of period varied from trial to trial, and will be given in the procedure for the individual trials. In all trials, egg production was recorded daily and average egg weight was determined by weighing the eggs individually for four consecutive days during each week. All data were recorded on IBM cards and summarized with the use of an IBM 650 computer to obtain the following: (1) feed consumed per hen per day, (2) energy consumed per hen per day, (3) protein consumed per hen per day, (4) body weight change per hen, (5) egg production, (6) Calories consumed per gram of egg produced, and (7) protein consumed per gram of egg produced. Statistical analyses for these data were performed by the use of the IBM 650 computer.

For the determination of fat digestibility, the fat digested was considered to be the fat consumed minus the fat excreted. A standard technique was used to determine fat digestibility in which some inert material is added to the diet as an index material. Chromic oxide was used as the index material, since it can be recovered in the feces quantitatively (Kane *et al.*, 1950; Dansky and Hill, 1952; Schurch *et al.*, 1950). The coefficient of digestibility was calculated by the following formula:

Digestibility Coefficient

$$= \left[1 - \frac{(\%\text{ Chromic oxide in feed})\ (\%\text{ fatty acids in feces})}{(\%\text{ fatty acids in feed})\ (\%\text{ chromic oxide in feces})} \right] 100$$

By using an index material such as chromic oxide, it is possible to feed hens *ad libitum*, and for this reason quantitative measurements of the feed consumption and quantitative collection of fecal excretion are unnecessary. This method not only permits a saving in time, labor and expense, but it adds to the accuracy of the data (Hill *et al.*, 1960). Feces which are contaminated with spilled feed or foreign material can be discarded.

The fecal samples were collected by hanging metal pans lined with a polyethylene sheet under each individual cage. The length of the collection period was at least 24 hours, in order to circumvent the diurnal rhythym of excretion of cecal droppings (Dansky and Hill, 1952). The fecal samples, while still in the collection pans, were placed in a forced-air drying oven and dried at a temperature of approximately

90 degrees F. The dried samples were put into polyethylene sampling bags and kept in a refrigerated room at 35 degrees F. until they could be analyzed for fatty acids and chromic oxide. Before the chemical analysis, the samples were ground in a Wiley Mill and mixed thoroughly.

Analysis for Chromic Oxide

The procedure used to determine the chromic oxide content of the feed and feces is essentially that described by Kimura and Miller (1957). A Klett-Summerson photoelectric colorimeter was used to determine the percent transmittance.

Analysis for Fatty Acids

The procedure described by Hoagland and Snider (1943) was used as a starting point in the development of a relatively accurate and rapid method for the determination of fatty acids in feed and feces. Several modifications were incorporated into the procedure of Hoagland and Snider, which resulted in the procedure used for Trial I. This procedure is as follows:

> Two grams of sample were weighed into a 250 ml. Erlenmeyer flask. After adding 25 ml. of 40 percent KOH and 50 ml. of 95 percent ethanol, a long air reflux condenser was attached to the flask and the mixture was heated on a steam plate for 2 hours. The sample was then filtered through a glass wool plug into a 500 ml. separatory funnel and diluted to 250 ml. with water. Twenty-five ml. of HCl were added and the mixture was shaken and cooled. Then 50 ml. of petroleum

ether was added and separatory funnel was placed in an automatic shaker for 3 minutes. It was then removed from the shaker and allowed to stand until the separation of the 2 phases, after which the ether phase was collected in another separatory funnel. The extraction with ether was repeated 3 times and the phases from all 4 extractions were collected in the same separatory funnel. The combined phases were washed 3 times with water to remove the HCl. Then the extract was filtered through a glass wool plug into a tared flask. The ether was evaporated and the flask was dried for 1 hour at approximately 103 degrees C., after which it was cooled and weighed.

This procedure gave relatively good results, but it was very time consuming. In order to speed up the fatty acid analysis and to improve further the results, the use of continuous liquid-liquid extraction was investigated.

Various types of commercially available liquid-liquid extractors were tried. None of these appeared adequately to disperse the extracting solvent throughout the aqueous phase for desirable extraction. Several different modifications of the inner tubes in these assemblies were tried, but none proved satisfactory. A need for a much higher degree of intimate contact between the solvent and the aqueous layer was evident, and the incorporation of vigorous stirring, such as provided by a magnetic stirrer, was contemplated.

At this time, an advertisement of the Archer-Daniels-Midland Company (1959) was noted. A description of their apparatus as well as their procedure was obtained.[1] Initially, it was planned to duplicate their assembly in all respects, but before this was accomplished a simplified modification of their apparatus was tested and appeared satisfactory. This modified liquid-liquid extraction procedure, which incorporated magnetic stirring as its major improvement, is essentially as follows:

> The extraction apparatus used is a modification of a Corning 92232 condenser and 92230 extraction tube (medium size). An inner funnel of special construction is supported by indentations in the sides of the extraction tube. This funnel delivers the extractant through a 0.5-1.0 mm. orifice to the bottom of the aqueous layer at a level approximately 0.5 cm. above a special oval-shaped magnetic stirring bar placed in the bottom of the extraction tube. The extraction tube is placed on a magnetic stirrer and a vigorous rate of stirring applied. A 3-gram sample of feed or feces is weighed into a 250 ml. Erlenmeyer flask which as a ground glass top. The addition of 50 ml. of ethanol plus 27 ml. of 40 percent KOH is made. A long air condenser is attached and the sample is placed on a steam plate for 2 hours for saponification. The saponified material is transferred to the liquid-liquid extraction tube, and 25 ml. of HCl is added. Enough petroleum ether is added to bring the ether-level to the side arm of the extraction tube. The extraction tube is attached to the condenser and placed on the magnetic stirrer. A receiving flask

[1] Archer-Daniels-Midland Company, Chemical Products Division, 739 Investors Building, Minneapolis 2, Minnesota.

which contains approximately 50 ml. of petroleum ether is attached to the side arm and is heated with a hot plate. The sample is extracted for 2 hours, after which, the material in the receiving flask is transferred to a 150 ml. beaker which is placed on a steam plate to evaporate the ether. Sixty ml. of neutralized ethanol and 10 ml. of water are added to the flask, then the material is titrated to a pH of 8.9 with 0.1 N NaOH.

The extracted fatty acids can be measured either gravimetrically or titrimetrically. It is recognized that with a continuous extraction procedure, such as adopted here, trace amounts of solids will continue to be removed as extraction time is continued. However, it is assumed that these are not fatty acids and should therefore not be included in the measurements of the extracted material. This would particularly be a source of error if the extracted material were measured gravimetrically after drying.

A comparison was made between the above two methods for measuring the extracted material and the result is plotted in Figure 1. It can be seen from this graph that the results of both methods follow almost the exact pattern until the extraction time reached one hour. As the extraction proceeded between 1 hour and 3 1/2 hours, the gravimetric procedure continued to measure extracted material, whereas, the titration method did not. This indicated that small amounts of solid material other than fatty acids were being extracted after one hour.

In preliminary analyses, the average digestibility values obtained were 82.7 percent by gravimetric measurements and 86.7 percent by titration. The difference in these values is probably due to the fact that all fatty acids require the same amount of base for titration, regardless of the length of the carbon chain, but the weight of the fatty acids depend upon the chain length. Although there is a difference in the digestibility values obtained by the two methods, the variance within each method was essentially the same. After considering the above factors, as well as the time required for each method, the titrimetric method was decided upon for Trials II, III, IV and V.

Grams of fatty acids extracted from the feed as compared to the grams of fatty acid extracted from the feces are plotted in Figure 2. It is evident from the results shown in Figure 2 that the fatty acid extraction was essentially complete at the end of 1 hour for both feed and feces. However, since a margin of safety was desired, a 2-hour extraction time was used for the analyses for Trials II, III, IV and V.

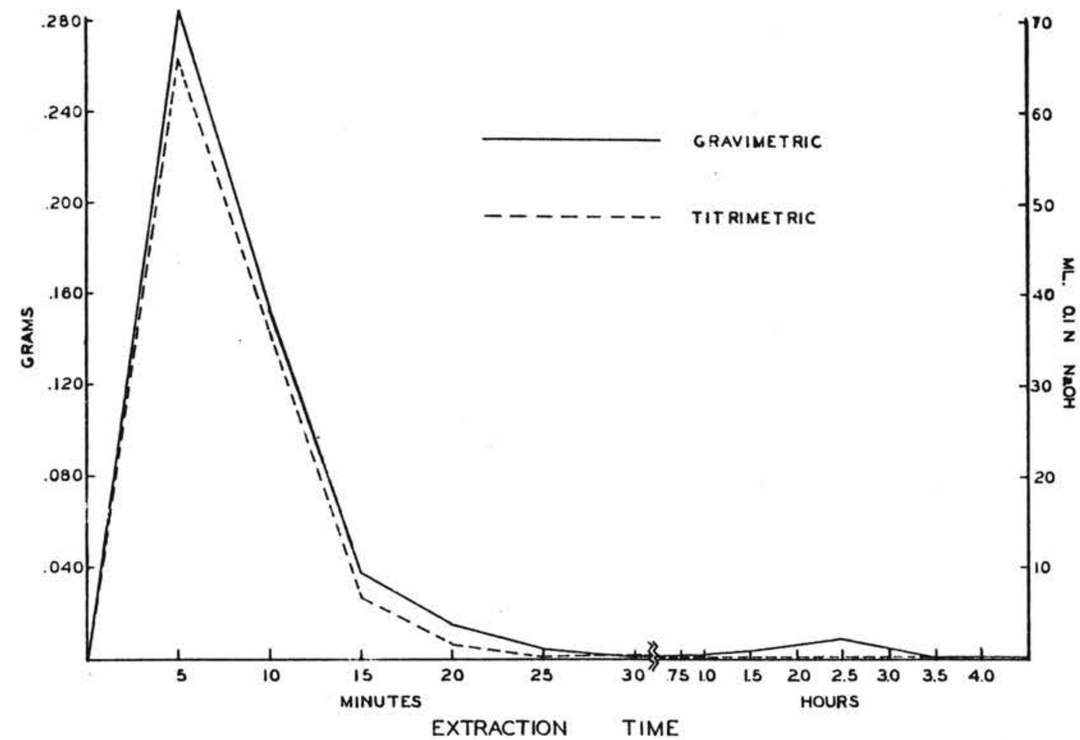

Fig. 1. **Gravimetric Versus Titrimetric Measurements of Fatty Acids Extracted from Feed** at Selected Time Intervals

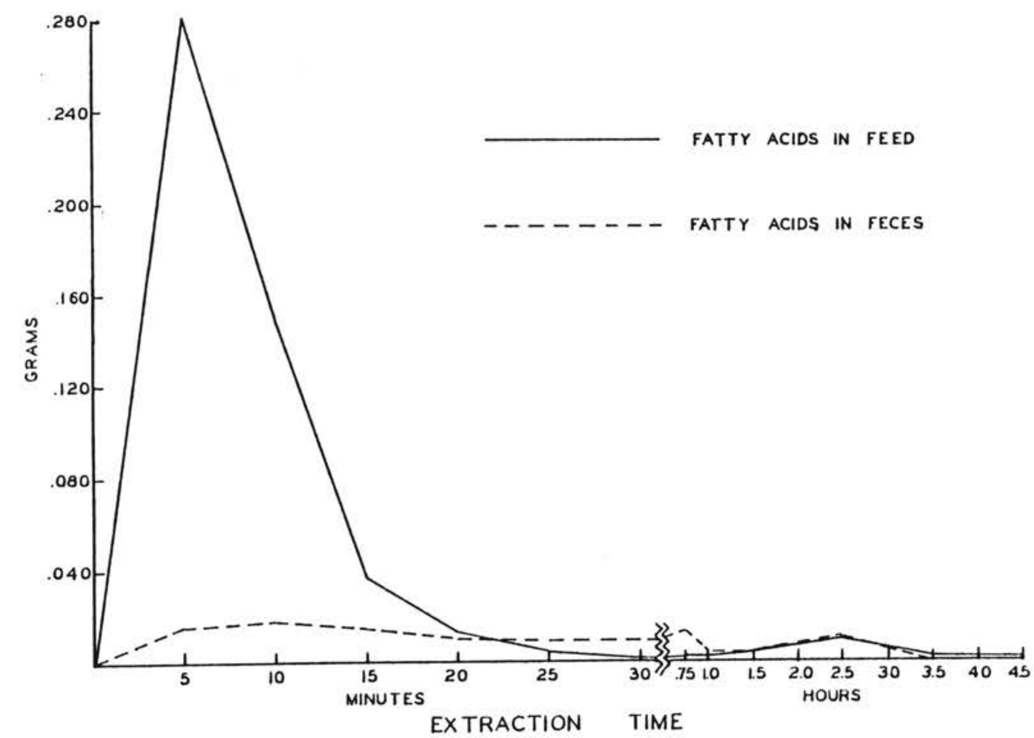

Fig. 2. **Fatty acids Extracted from Feed as compared to fatty acids Extracted from Feces** at Selected Time Intervals

TRIAL I

Purpose

The purpose of this trial was to study the effects of feeding graded levels of dietary fat to laying hens on the digestibility of the fat, and to compare the digestibility of two commercially prepared fats to that of corn oil. The two fats were Marco B-75 and Energ-E. Marco B-75 is a methyl ester of cottonseed and soybean oil processed by the Marco Chemical Company of Fort Worth, Texas. Energ-E is a patented product consisting of a combination of vegetable oil and hydrogenated animal fat in the form of small beads which have a melting point of 52 degrees C., processed by Stabilized Vitamins Division, Commercial Solvents Corporation, Garfield, New Jersey.

Procedure

Five experimental basal diets were formulated to contain graded levels of added fat (Table I). From these basals, 13 experimentsl diets, (Table II) were made. One diet contained no added fat, 4 diets contained added corn oil, 4 diets contained added Marco B-75, and 4 diets contained added Energ-E. The fat from each source was added at levels of 4, 8, 12 and 16 percent. In order to maintain nutrient balance in these diets with different levels of added fat, the 5 experimental basals contained the same Calorie-protein ratio. To do this it was necessary to assume that the metabolizable energy value of each fat was the same. The value used was 3960 Calories per pound (Titus, 1955).

TABLE I

COMPOSITION OF BASALS, TRIAL I

Basal number	1	2	3	4	5
Ingredients			Percent		
Fat	---	4.0	8.0	12.0	16.0
Ground yellow corn	10.0	12.0	14.0	15.0	15.32
Ground milo	10.0	10.0	10.0	10.0	10.0
Starch	33.12	20.32	13.42	6.92	---
Oat mill feed	4.0	10.0	10.0	10.0	10.0
Wheat shorts	3.0	3.0	3.0	3.0	3.0
Alfalfa meal (17% protein)	2.5	2.5	2.5	2.5	2.5
Fish meal (60% protein)	6.0	6.3	6.7	7.0	7.8
Soybean oil meal (44% prot.)	15.0	15.5	16.0	17.2	19.0
Dried brewers yeast	2.0	2.0	2.0	2.0	2.0
Molasses	2.0	2.0	2.0	2.0	2.0
Dried condensed fish solubles	2.0	2.0	2.0	2.0	2.0
Dried condensed fermented corn extractives[2]	2.0	2.0	2.0	2.0	2.0
Dicalcium phosphate (18% phosphorus)	4.0	4.0	4.0	4.0	4.0
Calcium carbonate	2.5	2.5	2.5	2.5	2.5
Salt (NaCl)	0.5	0.5	0.5	0.5	0.5
VC-55[3]	1.0	1.0	1.0	1.0	1.0
Trace mineral mix[4]	0.05	0.05	0.05	0.05	0.05
dl-Methionine	0.03	0.03	0.03	0.03	0.03
Chromic oxide	0.3	0.3	0.3	0.3	0.3

Calculated analyses					
Crude protein (percent)	15.5	16.5	17.1	17.9	19.2
Calories (M.E.)[5] per pound	1268	1300	1380	1460	1534
Calorie:protein ratio	82:1	79:1	82:1	82:1	81:1
Calcium (percent)	2.50	2.53	2.56	2.58	2.63
Available phosphorus (percent)	1.02	1.04	1.04	1.07	1.09
Crude fiber (percent)	3.41	5.30	5.38	5.47	5.60
Fat (percent)	1.75	5.98	10.10	14.19	18.30

Footnotes for Table I

1. Fat - The fats used in Trial I were Corn oil, Marco B-75 and Energ-E. Refer to Table II for description.
2. Dried condensed fermented corn extractives -- C.F.S. No. 3, Clinton Corn Processing Company, Clinton, Iowa.
3. VC-55 - Vitamin concentrate, adds the following per pound of finished diet: vitamin A, 8,000 I.U.; vitamin D_3, 4,000 I.C.U.; riboflavin, 6.0 milligrams; pantothenic acid, 8 milligrams; niacin, 40 milligrams; choline chloride, 600 milligrams; vitamin B_{12}, 6.0 micrograms; procaine penicillin, 4 milligrams; and menadione, 6.0 milligrams.
4. Trace Mineral Mix - adds per pound of finished diet: manganese, 55.0 milligrams; iodine, 1.76 milligrams; cobalt, 1.18 milligrams; iron, 16.6 milligrams; copper, 3.3 milligrams; and zinc, 3.04 milligrams. Calcium Carbonate Company, Carthage, Missouri.
5. (M.E.) - Metabolizable energy, Titus (1955) - The metabolizable energy value for each fat was considered to be 3960 Calories per pound.

TABLE II

EXPERIMENTAL DESIGN, TRIAL I

Treatment No.	Basal No.	Type of added fat	Percent added fat
1	1	None	None
2	2	Corn oil	4
3	3		8
4	4		12
5	5		16
6	2	Marco B-75[1]	4
7	3		8
8	4		12
9	5		16
10	2	Energ-E[2]	4
11	3		8
12	4		12
13	5		16

[1]Marco B-75 - Methyl ester of cottonseed and soybean oil processed by the Marco Chemical Company of Fort Worth, Texas.

[2]Energ-E - A patented product consisting of a combination of vegetable oil and hydrogenated animal fat in the form of small beads which have a melting point of 52 degrees C., processed by Stabilized Vitamins Division, Commercial Solvents Corporation, Garfield, New Jersey.

Each diet was replicated 5 times in a completely randomized experiment and fed to laying pullets (Dekalb 131) for 12 weeks. Body weight and feed consumption data were collected at the end of each 2-week period. Fecal samples, used for determining fat digestibility, were collected at the end of the first, second and fifth 2-week periods.

The data were summarized for each 2-week period and for the overall experiment. Average daily feed consumption, average daily protein consumption, average daily energy consumption (considering the fat in each diet to have the same metabolizable energy value), average egg production, Calories per gram of egg (considering the fat in each diet to have the same metabolizable energy value) and the grams of protein per gram of egg were obtained in each summary. Statistical analysis was performed on each of the above variables as well as on fat digestibility. Analyses of variance were obtained which gave sums of squares due to kind-of-fat and linear, quadratic and cubic effect within each fat. This was accomplished by the Doolittle technique (Goss, 1961).

Results

A summary of the coefficients of fat digestibility is presented in Table III. The analysis of variance for these data is presented in Table IV. The average digestibility coefficients were 56.4, 87.7, 83.0 and 40.0 for no added fat, corn oil, Marco B-75 and Energ-E, respectively. The differences in digestibility among these fats were significant at the 1 percent level of probability for each period tested.

TABLE III

AVERAGE COEFFICIENTS OF FAT DIGESTIBILITY, TRIAL I

Diet	Percent added fat	Period number 1	2	5
No-added-fat		56.6	60.1	52.6
Corn oil	4	82.6	86.7	78.6
	8	87.8	88.9	86.1
	12	90.0	91.2	88.8
	16	91.5	91.5	88.6
Marco B-75[1]	4	76.5	82.9	77.8
	8	81.9	84.5	80.8
	12	84.9	88.4	82.6
	16	85.9	88.1	84.1
Energ-E[2]	4	51.6	57.5	42.0
	8	23.5	23.0	42.6
	12	53.2	57.4	46.2
	16	39.3	48.3	36.2

1 Marco B-75 - refer to Table I for description.

2 Energ-E - refer to Table I for description.

TABLE IV

ANALYSIS OF VARIANCE OF COEFFICIENTS OF FAT DIGESTIBILITY, TRIAL I

Source of variation	d.f.	Period number 1	2	5
		Mean squares		
Total d.f.[1]		58	58	53
Treatment	(12)			
Kind-of-fat		9026.43**	6321.38**	7161.04**
Corn oil (C)	(3)			
C_L (Linear)	1	207.07	71.74	211.90*
C_Q (Quadratic)	1	17.11	3.96	59.29
C_C (Cubic)	1	1.51	1.46	.69
Marco B-75 (M)	(3)			
M_L	1	327.16*	79.07	86.86
M_Q	1	50.35	3.00	.34
M_C	1	.53	9.82	.67
Energ-E (E)	(3)			
E_L	1	19.42	3.23	47.69
E_Q	1	395.47*	303.46**	149.60
E_C	1	2278.25**	1861.99**	60.48
Error		76.02	35.01	42.95
Error d.f.[1]		46	46	41

1 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

**Significant at the 1 percent level.

There was a significant linear effect in the digestibility of of corn oil during the fifth period. The digestibility of corn oil ranged from 78.6 to 88.6 percent as the dietary level increased from 4 to 16 percent. This trend in digestibility of corn oil was present also in the first and second periods, although it was not significant. A similar trend can be seen in the digestibility data for Marco B-75. The linear effect on the digestibility for this fat was significant for the first period only. The digestibility of Marco B-75 for the first period ranged from 74.5 to 85.9 percent as the dietary levels increased from 4 to 16 percent. This apparent linear increase in digestibility is thought to be due in part to the low digestibility of the natural fat in the basal. An attempt was made to adjust these values so as to reflect the true digestibility of the added fat. This was accomplished through the use of the following formula:

$$\text{Digestibility of added fat} = \frac{[(\%\ \text{fat in basal})+(\%\ \text{added fat})]\ (\text{digestibility of total fat in diet})}{\%\ \text{added fat}} - \frac{(\%\ \text{fat in basal})\ (\text{digestibility of fat in basal})}{\%\ \text{added fat}}$$

With this adjustment, the linear effect was reduced to a certain extent, but the 16 percent level of dietary fat still resulted in the highest digestibility.

The digestibility of Energ-E was statistically significant for quadratic and cubic effects during the first and second periods. Since the digestibility of Energ-E was extremely low, it would be rather meaningless to attempt to interpret this significance or attach any importance to it.

The data on average daily feed consumption are presented in Table V and the analysis of variance of the data is given in Table VI. There was a great deal of fluctuation in the amount of feed consumed from period to period by the hens on any given diet. Differences in feed consumption due to kind-of-fat were not significant until the sixth period. The average feed consumed per hen per day during the sixth period was 117.3, 97.4, 98.5 and 119.6 grams for those fed diets which contained no-added-fat, corn oil, Marco B-75 and Energ-E, respectively. The overall summary indicates a trend in feed consumption similar to the sixth period, but it is not statistically significant. There were significant linear and cubic effects in feed consumption at various points throughout the trial for hens which received Marco B-75 and Energ-E, even though there was no consistent trend.

The average daily energy consumption and the statistical analysis of these data are presented in Tables VII and VIII, respectively. Since these data were calculated with the assumption that each fat furnished the same amount of metabolizable energy, most of the significance observed in the analysis of variance is not real. However, much of the significance for Energ-E can be interpreted as a reflection of the low digestibility of this fat.

The metabolizable energy values were calculated for the three fats by the method outlined by Titus (1955). The digestibility figures observed in this trial were used in these calculations, and the following values were obtained: Corn oil, 3715 Calories per pound; Marco B-75, 3516 Calories per pound; and Energ-E 1694 Calories per pound.

TABLE V

AVERAGE DAILY FEED CONSUMPTION, TRIAL I

Diet	Percent added fat	1	2	3	4	5	6	Overall[1]
		Period number						
		Grams per hen						
No-added-fat		92.4	107.0	69.7	79.3	101.4	117.3	97.0
Corn oil	4	101.8	104.4	89.5	86.2	100.5	96.9	96.6
	8	104.4	104.4	94.0	97.3	105.0	102.9	101.3
	12	96.6	96.0	80.4	90.8	97.3	99.1	93.2
	16	95.3	97.3	85.0	96.9	114.0	90.8	95.0
Marco B-75[2]	4	89.5	96.6	81.7	87.5	104.4	87.8	91.4
	8	72.9	92.5	76.5	84.3	92.8	98.4	85.9
	12	111.6	88.2	82.4	88.2	129.7	107.5	101.1
	16	101.3	110.3	98.9	87.6	102.1	100.3	100.1
Energ-E[3]	4	95.3	99.9	92.7	105.1	112.0	118.1	103.5
	8	101.8	108.9	77.2	86.9	118.7	111.3	100.5
	12	109.6	116.7	89.5	92.1	86.9	120.3	102.1
	16	97.3	123.0	79.8	94.1	123.9	128.7	107.4

1 Overall - all periods accumulated as one.

2 Marco B-75 - refer to Table I for description.

3 Energ-E - refer to Table I for description.

TABLE VI

ANALYSIS OF VARIANCE OF DAILY FEED CONSUMPTION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[1]		58	58	61	62	53	57	62
Treatment	(12)							
Kind-of-fat	3	182.66	771.82	452.73	357.90	117.00	1997.64*	294.6
Corn oil (C)	(3)							
C_L (Linear)	1	184.15	222.01	184.96	5.20	45.45	120.56	40.96
C_Q (Quadratic)	1	19.01	2.17	140.45	279.75	548.73	259.20	11.24
C_C (Cubic)	1	70.69	82.79	327.44	102.85	366.06	6.97	129.96
Marco B-75	(3)							
M_L	1	1992.72*	199.56	651.44	3.44	1021.78	568.74	397.37
M_Q	1	41.93	762.45	556.85	8.84	110.93	364.96	27.69
M_C	1	5960.47**	102.43	0.02	33.76	2388.74*	54.32	334.67
Energ-E (E)	(3)							
E_L	1	975.86	2093.93*	495.77	194.32	0.82	756.39	43.69
E_Q	1	388.67	46.92	207.21	504.00	815.56	0.43	86.11
E_C	1	75.60	5.91	13.69	176.23	3967.61**	0.05	0.18
Error		305.32	326.81	417.17	351.89	425.85	479.76	171.64
Error d.f.[1]		46	46	49	50	41	45	50

[1] Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

The energy values of the diets which contained these fats and the energy consumed per hen per day were re-calculated using the above figures.

The figures in Tables VII and VIII indicate that as dietary level of corn oil or Marco B-75 was increased, there was a linear increase in the consumption of energy. When the energy consumption was re-calculated using the above energy values, the linear increase in energy consumption of diets which contained these two fats had been reduced slightly. However, when the above energy value for Energ-E was used to recalculate the energy consumption, 276, 265, 267 and 277 Calories per day were obtained for the hens that received diets which contained 4, 8, 12 and 16 percent fat, respectively. This was in contrast to values to 310, 311, 331 and 471 Calories per hen per day which are listed in the overall summary in Table VII. It is apparent from these figures that the hens fed diets which contained Energ-E consumed essentially the same amount of energy per day regardless of the dietary fat level, whereas the linear significance in energy consumption observed for corn oil and Marco B-75 was probably valid.

The discussion in the above paragraph helps explain why the hens fed diets which contained Energ-E consumed greater quantities of feed (Table V) than did hens fed diets which contained the more highly digestible fats. The above metabolizable energy value for Energ-E is slightly less than that for corn starch. Therefore, the total energy value of the diets actually became less when Energ-E was used to replace carbohydrates. The hens fed diets which contained Energ-E became well enough adjusted to the high-fat low-energy diets by the

TABLE VII

AVERAGE DAILY ENERGY[1] CONSUMPTION, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[2]
		Calories per hen						
No-added-fat		259	301	196	273	285	329	272
Corn oil	4	305	313	268	258	301	290	289
	8	323	323	291	301	325	319	314
	12	313	311	261	294	315	321	302
	16	418	427	373	381	500	398	417
Marco B-75[3]	4	268	289	245	262	313	263	274
	8	225	286	237	261	287	304	266
	12	362	286	267	286	421	348	328
	16	444	483	434	384	448	444	439
Energ-E[4]	4	286	299	278	315	336	354	310
	8	315	337	239	269	367	344	311
	12	355	378	290	299	282	390	331
	16	427	543	350	412	453	564	471

1 The metabolizable energy value was considered to be the same for all fats. Refer to footnotes in Table II.

2 Overall - all periods accumulated as one.

3 Marco B-75 - refer to Table I for description.

4 Energ-E - refer to Table I for description.

TABLE VIII

ANALYSIS OF VARIANCE OF DAILY ENERGY[1] CONSUMPTION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[2]		58	58	61	62	53	51	62
Treatment	(12)							
Kind-of-fat	3	813	12549	13545*	4530	2730	37271**	9306*
Corn oil (C)	(3)							
C_L (Linear)	1	27159**	27224*	19909*	32797**	60665**	26634*	34151**
C_Q (Quadratic)	1	9592	13939	9901	2442	40099*	2928	10215
C_C (Cubic)	1	5125	5622	9541	5141	12781	2240	6497
Marco B-75 (M)	(3)							
M_L	1	115560**	65731**	71818**	31111**	68322**	71823**	65177**
M_Q	1	7258	41852**	35366**	11394	20199	2896	16673*
M_C	1	40055**	7091	2455	533	10116	489	103
Energ-E (E)	(3)							
E_L	1	39592**	148502**	10671	26045*	65912**	120559**	63050**
E_Q	1	1410	29386*	2123	32000**	58327**	13739	24290**
E_C	1	159	2649	2160	23	66187	0	2570
Error		3504	4717	4300	3849	5704	5141	2730
Error d.f.[2]		46	46	49	50	41	45	50

1 The metabolizable energy value was considered to be the same for all fats.

2 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

sixth period to compensate for the lack of energy by eating more feed.

The data on average daily protein consumption are presented in Table IX, with the analysis of variance of the data given in Table X. There were significant differences due to kind-of-fat during the sixth period and for the overall summary. This appears to be due to the low digestibility of Energ-E, which caused the hens to eat more feed in order to satisfy their energy hunger. Consequently, protein intake was increased.

There was a linear increase in protein intake when the dietary level of Marco B-75 was increased. This was statistically significant for Periods 1, 2, 3, 5, 6 and for the overall analysis. A similar situation is true for the diets which contained Energ-E for Periods 2, 6 and the overall. In the overall summary, hens fed diets which contained Marco B-75 increased their consumption from 14.9 to 19.1 grams of protein per day when the dietary fat level was increased from 4 to 16 percent. For the same dietary levels of Energ-E, 16.9 to 20.5 grams of protein were consumed per hen per day. Both Marco B-75 and Energ-E contained less metabolizable energy than was assumed at the start of the experiment. Therefore, energy-protein ratios were narrower in the diets which contained Marco B-75 and Energ-E than in those diets which contained corn oil. As the dietary levels of Marco B-75 or Energ-E were increased, the energy-protein ratios became progressively narrower. For this reason, when the hens which were fed the diets with the higher levels of Marco B-75 or Energ-E consumed enough feed to satisfy their energy needs, they had consumed more protein than had those hens fed diets which contained the lower

TABLE IX

AVERAGE DAILY PROTEIN CONSUMPTION, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[1]
		Grams per hen						
No-added-fat		14.3	16.6	10.8	15.1	15.7	18.2	15.0
Corn oil	4	16.6	17.0	14.5	14.1	16.3	15.8	15.7
	8	17.7	17.8	15.9	16.5	17.8	17.5	17.2
	12	17.3	17.2	14.4	16.3	17.4	17.7	16.7
	16	18.2	18.6	16.2	16.6	21.8	17.3	18.1
Marco B-75[2]	4	14.5	15.7	13.3	14.3	17.0	14.3	14.9
	8	12.4	15.7	13.0	14.3	15.8	16.7	14.6
	12	20.0	15.8	14.7	15.8	23.2	19.2	18.1
	16	19.4	21.1	18.8	16.7	19.5	19.1	19.1
Energ-E[3]	4	15.5	16.3	15.1	17.1	18.3	19.2	16.9
	8	17.3	18.5	13.1	14.8	20.2	18.9	17.1
	12	19.6	20.9	16.0	16.6	15.6	21.5	18.3
	16	18.5	23.6	15.2	18.0	23.7	24.6	20.5

[1] Overall - all periods accumulated as one.

[2] Marco B-75 - refer to Table I for description.

[3] Energ-E - refer to Table I for description.

TABLE X

ANALYSIS OF VARIANCE OF DAILY PROTEIN CONSUMPTION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[1]		58	58	61	62	53	57	62
Treatment	(12)							
Kind-of-fat	3	0.75	26.60	4.90	7.23	2.23	73.33**	15.64*
Corn oil (C)	(3)							
C_L (Linear)	1	4.82	4.23	2.74	13.44	34.71	6.00	11.12
C_Q (Quadratic)	1	0.07	0.57	0.23	5.70	23.28	5.55	0.00
C_C (Cubic)	1	2.20	2.68	10.20	2.93	12.56	0.16	4.02
Marco B-75 (M)	(3)							
M_L	1	145.00**	46.72*	70.57*	17.28	92.53*	69.80*	59.06**
M_Q	1	0.53	30.43	23.35	0.94	5.36	7.15	2.24
M_C	1	182.27**	4.02	0.03	0.92	70.97*	1.80	9.63
Energ-E (E)	(3)							
E_L	1	22.44	169.34*	0.01	4.45	27.83	80.03*	26.60*
E_Q	1	8.80	4.72	4.89	18.29	26.19	0.14	5.08
E_C	1	2.56	0.09	3.43	4.58	125.54**	0.00	0.00
Error		10.14	10.85	13.32	10.24	14.07	13.71	5.25
Error d.f.[1]		46	46	49	50	41	45	50

1 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

levels of these two fats. However, the recalculated metabolizable energy value of corn oil was near enough to the original assumed value that the linear effect was not significant for this fat.

The data on average body-weight-change are presented in Table XI and the analysis of variance of these data is given in Table XII. There was a significant linear increase in body weight of the hens fed corn oil and Marco B-75 as the dietary levels of these fats were increased. As the dietary level of corn oil was increased from 4 to 16 percent, average body weight gain in the overall summary increased from 16 grams per hen to 272 grams per hen. For the same levels of Marco B-75, body-weight-change ranged from 18 grams of gain per hen to 272 grams of gain per hen. These linear increases were significant at the 1 percent level of probability. There was no consistent or significant pattern from period to period in body-weight-change for these treatments. Increases in the level of dietary Energ-E did not result in additional increases in body weight in the overall summary. However, this was to be expected because of the low metabolizable energy content of this fat.

The differences in body-weight-change followed the same general pattern as energy intake (Table VII), with the exception of the hens fed diets which contained Energ-E. If the true energy values for each fat had been used in calculating the energy intake, it probably would have shown that body-weight-change followed the same pattern as energy consumption, regardless of the kind of fat.

The data on average egg production and the analysis of variance of the egg production data are given in Tables XIII and XIV, respectively.

TABLE XI

AVERAGE BODY WEIGHT CHANGE, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[1]
		Grams per hen						
No-added-fat		-204	+ 23	-181	+159	+ 79	+ 79	- 45
Corn oil	4	-155	0	- 92	+154	+ 73	+ 36	+ 16
	8	-181	+ 81	- 45	+117	+127	+ 18	+118
	12	- 63	+ 90	-105	+154	+145	0	+222
	16	- 82	+ 64	- 9	+117	+146	+ 36	+272
Marco B-75[2]	4	-118	- 27	- 54	+154	+ 27	+ 36	+ 18
	8	-109	+ 36	- 81	+103	+ 81	+ 54	+145
	12	-100	+ 64	- 73	+145	+100	+ 72	+208
	16	- 23	+ 45	- 34	+170	+ 45	+ 68	+272
Energ-E[3]	4	-136	+ 26	- 63	+218	+ 54	+ 9	+ 90
	8	-100	+ 18	-109	+118	+109	+ 27	+ 63
	12	-118	+ 45	-109	+163	+200	+ 9	+190
	16	-118	+ 18	-122	+126	+126	+ 36	+100

1 Overall - all periods accumulated as one.

2 Marco B-75 - refer to Table I for description.

3 Energ-E - refer to Table I for description.

TABLE XII

ANALYSIS OF VARIANCE OF BODY WEIGHT CHANGE, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[1]		58	58	61	62	53	57	62
Treatment	(12)							
Kind-of-fat	3	7503	4505	18846	3212	7459	7184	51448
Corn oil (C)	(3)							
C_L (Linear)	1	28257*	9940	9101	1317	8323	77	190183**
C_Q (Quadratic)	1	84	14742*	3026	0	1981	3698	3251
C_C (Cubic)	1	19966	320	17365	5348	997	715	745
Marco B-75 (M)	(3)							
M_L	1	26929*	10604	785	133	12409	3121	157512**
M_Q	1	346	4001	5040	278	5	584	4936
M_C	1	1982	1640	12	1209	290	116	1028
Energ-E (E)	(3)							
E_L	1	39	685	12943	3612	18654*	221	2460
E_Q	1	1758	3342	130	12551	33704**	1749	2554
E_C	1	1650	790	749	9162	1563	3	37934
Error		5546	3003	8716	9347	4546	5696	20242
Error d.f.[1]		46	46	49	50	41	45	50

1 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TABLE XIII

AVERAGE EGG PRODUCTION, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[1]
				Percent				
No-added-fat		75.0	75.0	57.1	35.7	62.5	81.3	64.0
Corn oil	4	82.9	85.7	62.9	47.1	67.1	61.7	68.0
	8	85.7	85.7	78.6	84.3	85.1	80.0	83.4
	12	85.7	75.7	81.4	78.6	81.4	83.3	81.0
	16	81.4	82.9	81.4	70.0	84.3	80.0	80.0
Marco B-75[2]	4	82.9	80.0	74.3	58.6	80.0	66.7	73.9
	8	45.3	62.9	51.4	52.9	78.6	55.0	61.2
	12	74.3	67.1	65.7	62.9	78.6	76.7	70.7
	16	85.7	82.1	64.3	51.8	7.14	64.6	70.1
Energ-E[3]	4	80.0	70.0	71.4	67.1	87.1	88.3	77.1
	8	72.9	74.3	71.3	64.3	87.1	80.0	74.9
	12	74.3	61.4	48.6	30.0	62.9	73.3	58.0
	16	62.9	57.1	31.4	27.1	55.7	58.3	48.5

[1] Overall - all periods accumulated as one.

[2] Marco B-75 - refer to Table I for description.

[3] Energ-E - refer to Table I for description.

TABLE XIV

ANALYSIS OF VARIANCE OF EGG PRODUCTION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[1]		58	58	61	62	53	57	62
	(12)							
Kind-of-fat	3	10.80	14.00	27.70**	44.16*	12.33	6.92	460.32*
Corn oil (C)	(3)							
C_L (Linear)	1	0.09	1.69	16.80	16.81	0.31	10.24	184.69
C_Q (Quadratic)	1	1.25	1.25	6.04	48.05	0.06	7.20	224.45
C_C (Cubic)	1	0.01	3.61	0.49	7.29	0.31	0.16	62.42
Marco B-75 (M)	(3)							
M_L	1	4.25	1.64	1.59	0.40	2.63	0.86	1.19
M_Q	1	25.59*	10.59	9.79	0.94	1.16	0.03	123.15
M_C	1	25.41*	5.49	11.42	5.11	1.70	13.70	173.50
Energ-E (E)	(3)							
E_L	1	16.87	12.21	94.78**	108.16**	63.15**	16.90	1764.00**
E_Q	1	0.83	1.68	7.44	0.00	0.18	9.83	44.99
E_C	1	2.13	6.60	7.29	17.63	4.44	0.00	80.99
Error		4.97	6.95	6.23	12.42	5.25	6.24	123.53
Error d.f.[1]		46	46	49	50	41	45	50

1 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

There was a general trend from period to period for egg production to be lower for the hens fed diets which contained no-added-fat and Energ-E, as compared to those which received the other diets. These differences were significant at the 5 percent level of probability. The average egg production for hens fed diets which contained no added fat, corn oil, Marco B-75 and Energ-E was 64.0, 78.1, 69.0 and 64.9 percent, respectively.

There was a general trend from period to period for a linear decline in egg production of the hens fed diets which contained Energ-E. With each increase in the level of dietary Energ-E, there was a corresponding decrease in egg production. This effect was significant at the 1 percent level of probability during the third period and remained highly significant during the remainder of the trial. In the overall summary, egg production was 77.1, 74.9, 58.0 and 48.5 percent for those hens fed diets which contained 4, 8, 12 and 16 percent of added Energ-E, respectively. These results demonstrate clearly the rapidity with which insufficient energy from a fat of low digestibility can cause a decrease in egg production.

The data on efficiency of energy utilization are presented in Table XV and the analysis of variance for these data is given in Table XVI. These efficiency data were also calculated on the assumption that each fat furnished the same amount of energy. For this reason, the statistical significance observed for kind-of-fat and for the variation within the dietary levels of Marco B-75 and Energ-E are not real, though it can be interpreted as a reflection of the low digestibility of these two fats, especially the Energ-E.

TABLE XV

EFFICIENCY OF ENERGY[1] UTILIZATION, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[2]
		Calories per gram of egg						
No-added-fat		6.49	7.37	6.34	14.58	8.12	7.09	7.78
Corn oil	4	6.92	6.63	7.91	9.95	7.66	8.01	7.65
	8	6.85	6.73	6.49	6.17	6.43	6.59	6.54
	12	7.24	7.76	5.93	6.89	6.85	6.76	6.89
	16	10.03	9.90	8.56	10.01	10.47	8.68	9.63
Marco B-75[3]	4	6.35	7.01	6.31	8.39	7.02	6.56	6.89
	8	7.61	8.24	8.65	9.35	6.22	9.13	7.79
	12	9.07	7.67	7.19	7.81	9.13	7.83	8.16
	16	9.89	11.24	12.27	13.32	11.03	11.90	11.40
Energ-E[4]	4	6.99	8.37	7.62	8.85	6.97	7.10	7.58
	8	8.06	8.44	6.03	7.61	7.44	7.40	7.49
	12	9.35	11.79	11.31	20.06	8.25	9.30	10.72
	16	12.50	16.89	19.48	27.47	16.76	15.88	17.02

1 The metabolizable energy was considered to be the same for all fats.

2 Overall - all periods accumulated as one.

3 Marco B-75 - refer to Table I for description.

4 Energ-E - refer to Table I for description.

TABLE XVI

ANALYSIS OF VARIANCE OF EFFICIENCY OF ENERGY[1] UTILIZATION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f.[2]		58	58	61	62	53	57	62
Treatment	(12)							
Kind-of-fat	3	.1780	.5751	.9534**	.9236	.2622	.3519	.2869**
Corn oil (C)	(3)							
C_L (Linear)	1	.5012	.7327	.0353	.0037	.4804	.0098	.1648*
C_Q (Quadratic)	1	.2081	.0819	.7144*	1.6762**	.2704	.7182*	.5315**
C_C (Cubic)	1	.0092	.0033	.1267	.0882	.0551	.0106	.0001
Marco B-75 (M)	(3)							
M_L	1	.9145	.1082	.7357*	.1617	.7738	.3955	.6018**
M_Q	1	.0025	.3475	.0054	.1562	.3802	.0048	.1731
M_C	1	.0695	1.5108*	.9175*	.3044	.2685	.5279	.8438**
Energ-E (E)	(3)							
E_L	1	1.0677	.7888	2.0718*	2.7126**	1.7764**	1.2960**	1.7030**
E_Q	1	.0035	.2075	.2487	.2952	.2282	.0172	.1940**
E_C	1	.0028	.1451	.2643	.9426*	.1403	.0000	.0812
Error		.2865	.2113	.1046	.2208	.1294	.1332	.0237
Error d.f.[2]		46	46	49	50	41	45	50

1 The metabolizable energy was considered to be the same for all fats.
2 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

There was a trend from period to period in which the graded levels of corn oil tended to exert a quadratic effect on the energy utilization. This effect is significant at the 1 percent level of probability in the overall summary. The numbers of Calories it took to produce a gram of egg were 7.65, 6.54, 6.78 and 9.63 for the diets which contained 4, 8, 12 and 16 percent of corn oil, respectively. The quadratic effect can be seen in these figures. The low efficiency of energy utilization in the diets with 4 percent of added corn oil apparently was due to the low egg production on this diet. The low efficiency of energy utilization in the diets which contained 16 percent of added corn oil evidently was due to the fact that the hens consumed much more digestible energy than was necessary for their rate of egg production.

Data on the efficiency of protein utilization are summarized and presented in Table XVII with the analysis of variance of the data in Table XVIII. There are significant differences in protein utilization among the treatments brought about by kind-of-fat. This appears to be due primarily to the low digestibility of Energ-E. The efficiency of protein utilization was 0.416, 0.359, 0.380 and 0.419 grams of protein per gram of egg for hens fed diets which contained 4, 8, 12 and 16 percent of added corn oil, respectively. These figures can be seen in the overall summary. Comparable figures for Marco B-75 were 0.375, 0.427, 0.450 and 0.498; and for Energ-E were 0.412, 0.422, 0.591 and 0.741.

The graded levels of Marco B-75 and Energ-E resulted in a linear effect, which was significant at the 5 percent level, for protein utilization in the overall summary. From a previous discussion, it is apparent that this linear effect was due to the fact that as the

TABLE XVII

EFFICIENCY OF PROTEIN UTILIZATION, TRIAL I

Diet	Percent added fat	Period number 1	2	3	4	5	6	Overall[1]
		Grams protein per gram of egg						
No-added-fat		.358	.407	.350	.804	.448	.391	.429
Corn oil	4	.376	.360	.430	.541	.416	.435	.416
	8	.376	.369	.356	.339	.353	.361	.359
	12	.399	.428	.327	.380	.378	.373	.380
	16	.436	.431	.373	.426	.455	.378	.419
Marco B-75[2]	4	.345	.381	.343	.546	.382	.356	.375
	8	.418	.452	.475	.513	.341	.501	.427
	12	.500	.423	.396	.431	.503	.432	.450
	16	.430	.489	.534	.575	.480	.518	.498
Energ-E[3]	4	.380	.455	.414	.481	.379	.386	.412
	8	.442	.463	.330	.417	.408	.406	.411
	12	.516	.650	.624	1.107	.454	.513	.591
	16	.544	.735	.848	1.196	.729	.691	.741

1 Overall - all periods accumulated as one.

2 Marco B-75 - refer to Table I for description.

3 Energ-E - refer to Table I for description.

TABLE XVIII

ANALYSIS OF VARIANCE OF EFFICIENCY OF PROTEIN UTILIZATION, TRIAL I

Source of variation	d.f.	Period number 1	2	3	4	5	6	Overall
		Mean squares						
Total d.f. [1]		58	58	61	62	53	57	62
Treatment	(12)							
Kind-of-fat	3	0.613	2.125*	3.328**	3.704**	1.036	0.870	1.113**
Corn oil (C)	(3)							
C_L (Linear)	1	0.390	0.769	0.194	0.634	0.460	0.981	0.001
C_Q (Quadratic)	1	0.062	0.004	0.764	3.210*	0.182	0.753	0.533
C_C (Cubic)	1	0.004	0.124	0.129	0.363	0.048	0.235	0.055
Marco B-75 (M)	(3)							
M_L	1	1.270	0.002	1.173	0.091	1.727	0.451	0.819*
M_Q	1	0.184	0.356	0.381	0.094	0.573	0.111	0.062
M_C	1	0.513	4.082*	2.384*	0.673	1.307	1.267	0.090
Energ-E (E)	(3)							
E_L	1	2.017	1.642	5.329**	7.813	4.299	2.559*	3.981**
E_Q	1	0.091	0.253	0.353	0.642	0.269	0.003	0.220
E_C	1	0.005	0.679	1.092	3.405*	0.310	0.000	0.433
Error		0.963	0.717	0.372	0.775	2.893	0.506	0.150
Error d.f. [1]		46	49	50	41	45	45	50

1 Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

dietary levels of these two fats were increased, the energy-protein ratios became smaller. This caused some protein to be used as energy, at the higher dietary levels of fat.

TRIAL II

Purpose

Trial II was conducted to study the effect of yeast culture and lecithin on the digestibility of fat when the two are added, separately and in combination, to diets of laying hens. The specific fats used in this trial were corn oil, feed-grade tallow and Sifteen. Sifteen is a powdered shortening in which soybean and cottonseed oil have been combined with liquid milk and spray dried. This product is manufactured by Kraft Foods, Division of National Dairy Products Corporation, Forest Lane, Garland, Texas.

Procedure

The basal diets for this trial are given in Table XIX, and the experimental design is presented in Table XX. Basal 1 was formulated to contain 8 percent of added corn oil or tallow. Basal 2 was formulated so that Sifteen could be added at a level which would furnish 8 percent of added fat. It was necessary to have a separate basal for Sifteen because it contained approximately 12.5 percent of protein.

This trial consisted of five experiments. A simple-reversal or cross-over design was used in each experiment. Treatments 1 and 2 consisted of diets which contained corn oil with and without the addition of yeast culture, respectively. These, as described above, were fed for six weeks, at which time, yeast culture was added to

TABLE XIX

COMPOSITION OF BASAL DIETS, TRIAL II

Basal number	1	2
Ingredients	Percent	
Fat (corn oil or tallow)	8.0	---
Sifteen[1]	---	12.4
Ground yellow corn	14.0	10.0
Ground milo	10.0	14.0
Starch	12.42	14.42
Oat mill feed	10.0	10.0
Wheat shorts	3.0	3.0
Alfalfa meal (17% protein)	2.5	2.5
Fish meal (60% protein)	6.7	5.8
Soybean oil meal (44% protein)	16.0	12.5
Yeast, dried brewers[2]	3.0	3.0
Molasses	2.0	---
Dried condensed fish solubles	2.0	2.0
Dried condensed fermented corn extractives[3]	2.0	2.0
Dicalcium phosphate (18% phosphorus)	4.0	4.0
Calcium carbonate	2.5	2.5
Salt (NaCl)	0.5	0.5
VC-55[4]	1.0	1.0
Trace mineral mix[5]	0.05	0.05
dl-Methionine	0.03	0.03
Chromic oxide	0.3	0.3

Calculated Analysis		
Crude protein (percent)	17.5	17.3
Calories (M.E.)[6] per pound	1375	1393
Calorie:protein ratio	79:1	81:1
Calcium (percent)	2.50	2.60
Available phosphorus (percent)	1.04	1.07
Crude fiber (percent)	5.38	5.05
Fat (percent)	10.10	10.04

Footnotes for Table XIX

1. Sifteen - powdered shortening in which soybean and cottonseed oil have been combined with liquid milk and spray dried. Kraft Foods, Division of National Dairy Products Corporation, Forest Lane, Garland, Texas.
2. Yeast, dried brewers - was removed when yeast culture was added.
3. Dried condensed fermented corn extractives - refer to Table II.
4. VC-55 - Vitamin concentrate. Refer to Table II for levels of supplementation.
5. Trace mineral mix - Refer to Table II for level of supplementation.
6. (M.E) - Metabolizable energy (Titus, 1955). The metabolizable energy was considered to be the same for each fat, for the purpose of comparison. The value used was 3960 Calories per pound.

TABLE XX

EXPERIMENTAL DESIGN, TRIAL II

Basal No.	Type of fat	Supplement 1-6 weeks	Supplement 7-12 weeks
1	Corn oil	None	Yeast culture
1		Yeast culture[2]	None
2	Sifteen[1]	None	Yeast culture
2		Yeast culture	None
1	Tallow	None	Lecithin
1		Lecithin[3]	None
1	Tallow	None	Yeast culture
1		Yeast culture	None
1	Tallow	None	Yeast culture + lecithin
1		Yeast culture + lecithin	

1 Sifteen - A powdered shortening. Refer to Table XIX.

2 Yeast culture was added at a level of 3 percent in place of 3 percent of dried brewers yeast.

3 Lecithin was added to the basal at a level of 0.25 percent.

Treatment 1 and removed from Treatment 2. This experiment continued for an additional 6 weeks, at which time it was terminated. This constituted one cross-over experiment. Four other experiments were conducted in the same way and were designed by combining the treatments in the following manner: 3 and 4 contained Sifteen with and without yeast culture, 5 and 6 contained tallow with and without lecithin, 6 and 7 contained tallow with and without yeast culture, and 9 and 10 contained tallow with and without the yeast culture-lecithin combination. It can be seen in Table XX that, if the first and last 6-week periods are considered independent of each other, treatments which contained the tallow basal are in a 2 x 2 factorial arrangement of yeast culture and lecithin. When the first and last 6-week periods are considered separately, all 10 treatments are in a hierarchical classification with kind-of-fat being the highest classification. The treatments were completely randomized with 5 replications each.

When yeast culture was not present in a diet, dried brewers yeast was added. This was done in order to supply the diet with factors other than lipase furnished by the yeast culture. The assumption was made that yeast culture and dried brewers yeast had similar properties, with the exception of lipase activity. However, these two sources of yeast differ greatly in their nutritional properties, therefore this was probably an invalid assumption.

Fecal samples used in the determination of fat digestibility were collected at the end of the fourth, sixth, tenth and twelfth weeks. Body weight and feed consumption data were recorded at the end of each 2-week period.

Analyses of variance were performed on the data from this trial in two ways: (1) by the method for cross-over designs, in which a comparison was made between the first 6-week period and last 6-week period; and (2) by analyzing the first and last 6-week periods independently of each other. For the fat digestibility data, comparisons were made between the fourth-week and tenth-week data and between the sixth-week and twelfth-week data. For all other data the comparisons were made between the accumulated summary of 1 through 6-week data and 7 through 12-week data. It was necessary to perform the second analysis in order to study the differences among the kinds of fat and to check for interaction of lecithin and yeast culture. This analysis was performed by the Doolittle technique (Goss, 1961). The cross-over analysis was performed by the method outlined by Lucas (unpublished notes).

Results

The summary of fat digestibility data is given in Table XXI and the analyses of variance of these data are presented in Tables XXII and XXIII. The analyses of variance by both the cross-over method and the method in which the first and last 6-week periods are considered separately, show that there are no differences in digestibility of corn oil due to yeast culture. The average digestibility of corn oil was 92.1 percent.

The cross-over analyses show that yeast culture improved the digestibility of Sifteen. This was significant at the 10 percent level of probability for the 4-week, 10-week comparison. The 12-week

TABLE XXI

COEFFICIENTS OF FAT DIGESTIBILITY, TRIAL II

Type of fat	Supplement	Weeks 4	6	Supplement	Weeks 10	12
Corn oil	None	91.8	90.9	Yeast culture	92.3	92.5
	Yeast culture	93.1	88.7	None	90.3	93.6
Sifteen	None	89.8	88.0	Yeast culture	94.1	*
	Yeast culture	92.9	91.1	None	92.0	*
Tallow	None	81.4	78.0	Lecithin	92.2	90.0
	Lecithin	82.2	83.9	None	90.0	88.8
Tallow	None	82.9	76.3	Yeast culture	91.5	94.4
	Yeast culture	82.5	78.0	None	88.6	87.1
Tallow	None	81.6	74.0	Yeast culture + lecithin	89.8	92.4
	Yeast culture + lecithin	86.3	84.9	None	90.8	90.1
Accumulation of tallow no supplement[1]		81.9	77.3		89.6	88.7

1 For the analysis of variance for interaction of yeast culture and lecithin, all the hens which received tallow diets with no supplement were considered together as one treatment. They were summarized in this way so comparisons could be made.

* Digestion coefficients were not obtained.

TABLE XXII

ANALYSES OF VARIANCE AND ADJUSTED TREATMENT MEANS FOR COEFFICIENTS OF FAT DIGESTIBILITY IN TRIAL II AS CALCULATED BY THE CROSS-OVER METHOD

Kind of fat	Source of variation	Supplement	Comparisons: Weeks 4 and 10		Comparisons: Weeks 6 and 12	
			Adjusted means			
Corn oil		Yeast culture	92.7		92.1	
		None	91.3		92.4	
			d.f.	M.S.	d.f.	M.S.
	Treatment		1	6.01	1	12.07
	Error		5	3.41	6	3.94
			Adjusted means			
Sifteen		Yeast culture	93.7		92.8[1]	
		None	90.0		89.4	
			d.f.	M.S.	d.f.	M.S.
	Treatment		1	52.5	1	40.59**
	Error		6	8.9	6	2.03
			Adjusted means			
Tallow		Lecithin	86.9		86.3	
		None	85.5		83.3	
			d.f.	M.S.	d.f.	M.S.
	Treatment		1	7.56	1	48.43[2]
	Error		6	22.27	6	11.84
			Adjusted means			
Tallow		Yeast culture	88.0		85.9	
		None	85.7		84.2	
			d.f.	M.S.	d.f.	M.S.
	Treatment		1	21.18[2]	1	17.04
	Error		6	4.97	6	8.60
			Adjusted means			
Tallow		Yeast culture + lecithin	88.9		88.8	
		None	86.2		82.6	
			d.f.	M.S.	d.f.	M.S.
	Treatment		1	21.60[2]	1	116.56*
	Error		4	3.74	4	9.93

[1] Twelve-week fat digestibility data were not obtained for Sifteens; therefore the 6-week data were compared to the 10-week data.

[2] Significant at the 10 percent level.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

TABLE XXIII

ANALYSIS OF VARIANCE FOR COEFFICIENTS OF FAT DIGESTIBILITY FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 4	6	10	12
		Mean squares			
Total d.f.[1]		42	44	41	32
Treatment	(7)				
Kind-of-fat	2	417.09**	565.67**	13.72[2]	37.05**
Corn oil Yeast culture	1	3.12	12.10	8.53	2.31
Sifteen Yeast culture	1	25.28	23.71	7.95	- - -
Tallow Lecithin (L) unadjusted	1	27.22	313.29**	14.00	9.10
Yeast culture (Y) adjusted for L	1	24.48	10.68	4.79	97.18**
LxY adjusted for L and Y	1	17.70	0.53	9.38	13.22*
Error		16.30	17.46	5.51	2.75
Error d.f.[1]		35	37	34	27

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.
2 Significant at the 10 percent level.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

digestibility data were not obtained; therefore, the comparison was made between the sixth-and tenth-week data. This did not allow for equal adjustment time for the hens on each treatment. For this reason, the highly significant results obtained may not be valid. The average adjusted mean for the digestibility of Sifteen was 93.2 percent when yeast culture was present and 89.7 percent when yeast culture was not present. When the first and last 6-week periods are considered independently, the analysis of variance does not show significant differences in the digestibility of Sifteen.

Lecithin did not cause a significant increase in the digestibility of tallow as indicated by the cross-over analysis for the 4-week, 10-week comparison, but there was significance at the 10 percent level for the 6-week, 12-week comparison. When the first and last 6-week periods were considered independently, there was significance due to lecithin at the 1 percent level of probability for the 6-week analysis, but no significance for the other weeks of the trial. The adjusted mean for the digestibility of tallow for the 4-week, 10-week comparison was 86.9 percent when lecithin was present and 85.5 percent when lecithin was not present. For the 6-week, 12-week comparison, the mean digestibility of tallow was 86.3 percent with lecithin, and 83.3 percent without lecithin.

The effect of yeast culture on the digestibility of tallow was similar to that of lecithin when such was added separately. The adjusted means for digestibility of this fat when yeast culture was present in the diets were 88.0 percent for the 4-week, 10-week comparison and 85.9 percent for the 6-week, 12-week comparison. When yeast culture was not present, the means were 85.7 and 84.2 percent for the 4-week, 10-week and 6-week, 12-week comparisons, respectively. The 6-week, 12-week comparison was significant at the 10 percent level of probability, but the 4-week, 10-week comparison was not significant. When the first and last 6-week periods were considered separately, there was significance at the 1 percent level of probability for the twelfth week, but there was no significance for the other weeks.

When yeast culture was added to the diets in combination with lecithin, the slight increase in digestibility observed when the two were added singly appears to be additive to a slight degree. In the cross-over analyses of variance there was significance at the 10 percent level for the 4-week, 10-week comparison, and the 6-week, 12-week comparison was significant at the 5 percent level of probability. In the analysis in which the first and last 6-week periods were considered independently, interaction is present at the 5 percent level for the twelfth week. The adjusted digestibility means for the 4-week, 10 week and 6-week, 12-week comparisons are 88.9 and 88.8 respectively, when yeast culture and lecithin are added together. When neither of the two additives was present in the diet the mean digestibility values were 86.2 and 82.6.

As shown in Table XXIII, the mean squares for kind-of-fat are significant for each period. This was to be expected, however, because the digestibility of tallow was from about 2 to 10 percent lower than either corn oil or Sifteen throughout the trial.

The data on average daily feed consumption are presented in Table XXIV. The analyses of variance for these data are given in Tables XXV and XXVI. When the analyses of variance were performed by the cross-over method, there were no significant differences due to

TABLE XXIV

AVERAGE DAILY FEED CONSUMPTION, TRIAL II

Type of fat	Supplement	Weeks of trial 1-2	3-4	5-6	1-6	Supplement	Weeks of trial 8	9-10	11-12	7-12
		Grams per hen					Grams per hen			
Corn oil	None	120.0	90.8	94.1	102.4	Yeast culture	88.9	105.4	98.1	96.8
	Yeast culture	106.4	115.0	105.7	108.6	None	95.3	98.6	111.1	101.0
Sifteen	None	77.8	97.9	96.0	90.6	Yeast culture	92.4	93.0	76.2	86.7
	Yeast culture	83.0	97.2	86.3	88.8	None	79.3	83.7	68.8	77.2
Tallow	None	124.9	96.4	115.1	112.2	Lecithin	104.4	87.6	80.6	89.8
	Lecithin	133.6	95.3	110.9	113.3	None	111.6	126.5	101.3	113.0
Tallow	None	113.5	83.2	81.9	93.7	Yeast culture	92.1	82.4	61.6	79.9
	Yeast culture	124.5	92.7	110.9	109.4	None	107.0	99.2	85.1	98.0
Tallow	None	112.9	89.7	96.2	102.0	Yeast culture + lecithin	90.2	77.2	87.6	85.0
	Yeast culture + lecithin	113.1	77.2	98.9	96.2	None	77.0	75.7	85.9	79.9
Accumulation of tallow no supplement[1]		118.1	90.5	97.9	103.0		100.1	102.4	90.8	97.9

[1] Tallow with no supplement considered as one. Refer to footnote of Table XXI.

TABLE XXV

ANALYSES OF VARIANCE AND ADJUSTED TREATMENT MEANS FOR DAILY FEED CONSUMPTION IN TRIAL II AS CALCULATED BY THE CROSS-OVER METHOD

Kind of fat	Source of variation	Supplement	Comparison accumulated weeks 1-6 and 7-12	
			Adjusted means	
Corn oil		Yeast culture	97.6 gm./hen/day	
		None	103.4	"
			d.f.	M.S.
	Treatment		1	6.36
	Error		8	330.08
			Adjusted means	
Sifteen		Yeast culture	86.8 gm./hen/day	
		None	84.4 gm.	"
			d.f.	M.S.
	Treatment		1	9.96
	Error		7	23.64
			Adjusted means	
Tallow		Lecithin	102.2 gm./hen/day	
		None	112.2	"
			d.f.	M.S.
	Treatment		1	483.02
	Error		7	160.60
			Adjusted means	
Tallow		Yeast culture	93.3 gm./hen/day	
		None	96.0	"
			d.f.	M.S.
	Treatment		1	31.38
	Error		7	61.79
			Adjusted means	
Tallow		Yeast culture + lecithin	93.7 gm./hen/day	
		None	91.9	"
			d.f.	M.S.
	Treatment		1	13.72
	Error		7	119.67

TABLE XXVI

ANALYSIS OF VARIANCE OF DAILY FEED CONSUMPTION FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.[1]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	5952**	659	523	899*	503	486	2299*	439
Corn oil Yeast culture	1	462	1168*	337	77	103	104	339	451
Sifteen Yeast culture	1	67	1	237	7	386	161	124	153
Tallow Lecithin (L) unadjusted	1	126	147	75	1	48	1161	5	210
Yeast culture (Y) adjusted for L	1	87	245	57	47	495	1583	991	756
LxY adjusted for L and Y	1	1179*	596	841	903*	14	95	1674	147
Error		202	275	343	169	498	572	534	459
Error d.f.[1]		40	35	37	40	39	34	34	39

[1] Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

yeast culture or lecithin. However, in the analysis for yeast culture x lecithin interaction, significance is indicated for the 1-2 week and for the 1-6 week data. The average daily feed consumption for the hens fed diets which contained yeast culture plus lecithin for the first 6-week period was 96.2 grams per hen per day, whereas the hens on the other treatments consumed from 103.0 to 113.3 grams per hen per day. This difference in feed consumption cannot be explained on the basis of fat digestibility, since the same trend was not observed during the last 6 weeks of the trial.

The analysis of variance for daily feed consumption in Table XXVI shows significance for kind-of-fat for the 1-2, 1-6 and 11-12 week periods. This appears to be due to the low feed consumption of the hens fed the diets which contained the sifteen as compared to those which received either corn oil or tallow. It seems unlikely that this can be explained on the basis of greater energy provided by the Sifteen, because the digestibility of this fat was approximately the same as that of corn oil.

The data on average daily energy consumption of the hens in Trial II are presented in Table XXVII, with the statistical analysis for these data in Table XXVIII. Since all the diets in this trial were formulated with the same number of Calories per pound, the energy consumption was a function of the feed consumption. For this reason, unless the energy furnished by the fat in one diet is greater than that of another diet, the differences in energy consumption should follow the same pattern as that of feed consumption. If each fat furnished the same energy per unit of weight, which was the assumption made when the diets were formulated, and if the energy value which

TABLE XXVII

AVERAGE DAILY ENERGY[1] CONSUMPTION, TRIAL II

Type of fat	Supplement	Weeks of trial 1-2	3-4	5-6	1-6	Supplement	Weeks of trial 7-8	9-10	11-12	7-12
		Calories per hen					Calories per hen			
Corn oil	None	371	281	291	317	Yeast culture	275	326	304	300
	Yeast culture	329	356	327	336	None	295	305	344	313
Sifteen	None	245	308	302	285	Yeast culture	291	293	240	273
	Yeast culture	262	306	272	280	None	250	264	217	243
Tallow	None	386	299	356	347	Lecithin	314	271	249	278
	Lecithin	414	295	343	351	None	345	392	314	350
Tallow	None	351	258	253	290	Yeast culture	385	255	191	247
	Yeast culture	385	287	343	339	None	331	307	263	303
Tallow	None	349	278	298	316	Yeast culture + lecithin	279	239	271	263
	Yeast culture + lecithin	350	239	306	298	None	238	234	266	247
Accumulation of tallow, no supplement[2]		366	280	303	319		310	317	281	303

[1] The metabolizable energy value was considered the same for all fats. Refer to footnotes to Table XX.

[2] Tallow with no supplement considered as one. Refer to footnotes to Table XXI.

TABLE XXVIII

ANALYSIS OF VARIANCE OF DAILY ENERGY[1] CONSUMPTION FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.[2]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	52998**	7078	3776	6907**	3637	4030	20593	3405
Corn oil Yeast culture	1	4409	11175	3204	739	1000	980	3240	4368
Sifteen Yeast culture	1	688	14	2340	72	3808	1606	1196	1537
Tallow Lecithin (L) unadjusted	1	1234	1410	720	15	469	11178	56	2685
Yeast culture adjusted for L	1	818	2333	552	464	4732	15107	9477	8150
LxY adjusted for L and Y	1	11452*	5670	8040	8574**	136	907	15894	1787
Error		1956	2642	3297	1175	4777	5474	5131	4287
Error d.f.[2]		40	35	37	40	39	34	34	39

[1] The metabolizable energy value was considered the same for all fats. Refer to Table XX.

[2] Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

was used was correct, the Calories consumed per hen per day were 316, 270, and 302 for corn oil, Sifteen and tallow, respectively. It is obvious from the digestibility data that these assumptions are not true. However, the feed consumption data do not reflect any real differences. Although tallow had a somewhat lower digestibility than corn oil and apparently had less metabolizable energy, the hens fed diets which contained tallow appeared to be satisfied with the same quantity of feed as the hens which received the corn-oil diets.

Protein consumption data for this trial are presented in Table XXIX, and the analysis of variance of the data in Table XXX. These data are in direct correlation with that of feed consumption, and the order of significance is similar to that observed for feed consumption. The average grams of protein consumed per hen per day were 17.5, 14.9, and 16.6 for corn oil, Sifteen and tallow, respectively.

Data on average body-weight-change of the hens in Trial II are summarized in Table XXXI. The analysis of variance by the cross-over method is given in Table XXXII, and the analysis in which the first and last 6-week periods of the trial are considered independently is given in Table XXXIII. The hens fed the Sifteen diets supplemented with yeast culture lost significantly less weight than did those that were fed the same diets without yeast culture. This is evident from the cross-over analysis (Table XXXII). Those which received yeast culture had a mean body-weight-change of minus 45 grams per hen, while those which did not receive yeast culture lost an average of 121 grams per hen. This could logically be attributed to the fact that the fat in Sifteen was digested to a greater extent by the hens which received yeast culture than by those which did not receive yeast culture.

TABLE XXIX

AVERAGE DAILY PROTEIN CONSUMPTION, TRIAL II

Type of fat	Supplement	1-2	3-4	5-6	1-6	Supplement	7-8	9-10	11-12	7-12
		Weeks of trial					Weeks of trial			
		Grams per hen					Grams per hen			
Corn Oil	None	20.4	15.4	16.0	17.4	Yeast culture	15.1	17.9	16.7	16.5
	Yeast culture	18.1	19.5	18.0	18.4	None	16.2	16.8	18.9	17.2
Sifteen	None	13.5	16.9	16.6	15.7	Yeast culture	16.0	16.1	13.2	15.0
	Yeast culture	14.4	16.8	14.9	15.4	None	13.7	14.5	11.9	13.4
Tallow	None	21.2	16.4	19.6	19.1	Lecithin	17.2	14.9	13.7	15.3
	Lecithin	22.7	16.2	18.9	19.3	None	19.0	21.5	17.2	19.2
Tallow	None	19.3	14.2	13.9	15.9	Yeast culture	15.7	14.0	10.5	13.6
	Yeast culture	21.2	15.7	18.8	18.6	None	18.2	16.9	14.5	16.7
Tallow	None	19.2	15.3	16.4	17.3	Yeast culture + lecithin	15.3	13.1	14.9	14.5
	Yeast culture + lecithin	19.2	13.1	16.8	16.3	None	13.1	12.9	14.6	13.6
Accumulation of tallow no supplement[1]		20.1	15.4	16.6	17.5		17.0	17.4	15.4	16.6

[1] Tallow with no supplement considered as one. Refer to footnotes to Table XXI.

TABLE XXX

ANALYSIS OF VARIANCE OF DAILY PROTEIN CONSUMPTION FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Weeks of trial — Mean squares							
Total d.f.[1]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	160.02**	21.36	11.44	20.77*	11.42	12.18	62.27*	9.68
Corn oil Yeast culture	1	13.36	33.82*	9.76	2.24	2.98	3.01	9.79	13.11
Sifteen Yeast culture	1	2.02	0.03	7.08	0.22	11.53	4.85	3.71	4.57
Tallow Lecithin (L) unadjusted	1	3.67	4.26	2.19	0.04	1.42	33.61	0.15	6.10
Yeast culture (Y) adjusted for L	1	2.52	7.09	1.67	1.37	14.37	45.74	28.70	21.82
LxY adjusted for L and Y	1	34.12*	17.21	24.30	26.21*	0.42	2.77	48.39	4.29
Error		5.88	8.00	9.97	4.91	14.43	16.57	15.49	13.29
Error d.f.[1]		40	35	37	40	39	34	34	39

[1]Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

TABLE XXXI

AVERAGE BODY WEIGHT CHANGE, TRIAL II

Type of fat	Supplement	Weeks of trial 1-2	3-4	5-6	1-6	Supplement	Weeks of trial 7-8	9-10	11-12	7-12
		Grams per hen					Grams per hen			
Corn oil	None	+109	- 91	00	+ 38	Yeast culture	-127	+237	-171	- 84
	Yeast culture	+109	-136	+ 27	+ 29	None	-125	+200	-159	- 58
Sifteen	None	-164	+ 9	-109	-263	Yeast culture	+182	-106	+ 68	+186
	Yeast culture	-118	- 54	- 82	-254	None	+182	-173	+ 27	+ 36
Tallow	None	+159	-125	+ 23	+ 57	Lecithin	- 91	+136	-125	- 80
	Lecithin	+183	-146	+ 37	+ 54	None	- 67	+238	-136	+ 21
Tallow	None	+ 68	-106	- 45	- 45	Yeast culture	- 82	+238	-193	+ 49
	Yeast culture	+ 63	- 81	+ 9	- 10	None	-145	+218	-125	- 29
	None	+ 54	- 91	00	- 00	Yeast culture + lecithin	- 36	+136	-145	- 45
	Yeast culture + lecithin	+ 18	-166	00	- 87	None	-182	+166	- 57	-120
Accumulation of tallow, no supplement[1]		+ 94	-109	- 8	- 4		-126	+212	-106	- 39

[1] Accumulated treatments considered as one. Refer to footnotes to Table XXI.

TABLE XXXII

ANALYSES OF VARIANCE AND ADJUSTED TREATMENT MEANS FOR BODY WEIGHT CHANGE IN TRIAL II AS CALCULATED BY THE CROSS-OVER METHOD

Kind of fat	Source of variation	Supplement	Comparison Accumulated weeks 1-6 and 7-12	
Corn oil			Adjusted means	
		Yeast culture	-23 gm./hen	
		None	- 9 "	
			d.f.	M.S.
	Treatment		1	925
	Error		8	8718
Sifteen			Adjusted means	
		Yeast culture	-45 gm./hen	
		None	-121 gm./hen	
			d.f.	M.S.
	Treatment		1	26129*
	Error		7	2927
Tallow			Adjusted means	
		Lecithin	-10 gm./hen	
		None	+40 gm./hen	
			d.f.	M.S.
	Treatment		1	11177
	Error		7	4251
Tallow			Adjusted means	
		Yeast culture	-47 gm./hen	
		None	-24 gm./hen	
			d.f.	M.S.
	Treatment		1	2310
	Error		7	14099
Tallow			Adjusted means	
		Yeast culture + lecithin	-42 gm./hen	
		None	-58 gm./hen	
			d.f.	M.S.
	Treatment		1	172
	Error		7	21909

* Significant at the 5 percent level.

TABLE XXXIII

ANALYSIS OF VARIANCE OF BODY WEIGHT CHANGE FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	216293**	29457*	41661**	277645**	302768**	378123**	123847**	86989*
Corn oil Yeast culture	1	0	4095	1822	202	0	3362	264	828
Sifteen Yeast culture	1	5198	10112	1849	211	0	8367	3744	40081
Tallow Lecithin (L) unadjusted	1	385	3128	3119	752	17785	26198	407	192
Yeast culture (Y) adjusted for L	1	34969**	7333	98	22902	13896	996	18005	2625
LxY adjusted for L and Y	1	20468*	468	3846	23659	132	564	5739	646
Error		3424	5915	3931	6631	8572	6710	6362	16014
Error d.f.[1]		40	35	37	40	39	34	34	39

[1] Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Since the hens fed diets with and without yeast culture consumed approximately the same quantity of feed per day, those which received the yeast culture diets consumed greater quantities of metabolizable energy per day, and thereby maintained body weight at a higher level.

There were no significant differences in body-weight-change caused by yeast culture or lecithin in the corn oil and tallow diets. There were either significant or highly significant differences for each period in body-weight-change due to kind-of-fat. This apparently was caused by the fact that hens which received Sifteen were out of phase with the hens fed the other two fats, insofar as body-weight-change by periods is concerned. For the 1-6 week summary, the average body-weight-change was +34, -259 and -7 grams per hen for corn oil, Sifteen and tallow, respectively. For the 7-12 week summary, the average body-weight-change was -71, +111 and -33 grams per hen for corn oil, Sifteen and tallow, respectively. For the entire trial the hens fed all diets lost and gained similar amounts. For this reason, it is unlikely that the apparent significant differences due to kind-of-fat are of much importance.

Egg production data of the hens in Trial II are presented in Table XXXIV, with the analyses of variance in Tables XXXV and XXXVI. There were no significant differences in egg production, as indicated by either the cross-over analyses or the analyses which considered the first and last 6-week periods independently. The average egg production was 70.1, 62.1 and 65.9 for corn oil, Sifteen and tallow, respectively.

The summary of data on efficiency of energy utilization, expressed as Calories per gram of egg, is presented in Table XXXVII and the

TABLE XXXIV

AVERAGE EGG PRODUCTION, TRIAL II

Type of fat	Supplement	Weeks 1-2	3-4	5-6	1-6	Supplement	Weeks 7-8	9-10	11-12	7-12
		Percent								
Corn oil	None	72.9	67.9	71.4	70.9	Yeast culture	68.6	69.6	69.6	69.2
	Yeast culture	61.4	80.4	72.9	70.9	None	71.4	68.6	71.4	70.4
Sifteen	None	72.9	61.4	61.4	65.2	Yeast culture	58.9	50.0	53.6	54.5
	Yeast culture	67.1	67.1	64.3	66.2	None	57.1	68.6	61.4	62.4
Tallow	None	75.0	67.8	75.0	75.6	Lecithin	75.0	57.0	73.2	74.4
	Lecithin	64.3	71.4	65.7	67.1	None	70.0	46.4	60.7	59.9
Tallow	None	76.8	73.8	64.3	71.4	Yeast culture	68.6	64.3	53.6	62.8
	Yeast culture	72.9	70.0	72.9	71.9	None	71.4	64.3	66.1	67.3
Tallow	None	67.1	66.7	61.9	64.3	Yeast culture + lecithin	61.4	58.6	68.6	62.9
	Yeast culture + lecithin	68.6	65.7	57.1	64.3	None	46.4	57.1	46.4	49.4
Accumulation of tallow, no supplement[1]		75.0	72.9	67.5	71.9		63.8	56.5	57.7	59.6

[1] Tallow with no supplement considered as one. Refer to footnotes to Table XXI.

TABLE XXXV

ANALYSES OF VARIANCE AND ADJUSTED TREATMENT MEANS FOR EGG PRODUCTION IN TRIAL II AS CALCULATED BY THE CROSS-OVER METHOD

Kind of fat	Source of variation	Supplement	Comparison Accumulated weeks 1-6 and 7-12	
			Adjusted means	
Corn oil		Yeast culture	69.7 percent	
		None	70.8 "	
			d.f.	M.S.
	Treatment		1	6.96
	Error		8	10.60
			Adjusted means	
Sifteen		Yeast culture	61.6 percent	
		None	60.8 "	
			d.f.	M.S.
	Treatment		1	2.82
	Error		7	40.47
			Adjusted means	
Tallow		Lecithin	70.2 percent	
		None	68.4 percent	
			d.f.	M.S.
	Treatment		1	13.92
	Error		7	49.94
			Adjusted means	
Tallow		Yeast culture	66.0 percent	
		None	69.4 "	
			d.f.	M.S.
	Treatment		1	50.1
	Error		7	92.2
			Adjusted means	
Tallow		Yeast culture + lecithin	65.2 percent	
		None	55.6 "	
			d.f.	M.S.
	Treatment		1	373.32
	Error		7	179.17

TABLE XXXVI

ANALYSIS OF VARIANCE OF EGG PRODUCTION FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial							
		1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.[1]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	0.78	4.58	4.32	2.96	7.01	3.75	7.04	18.39
Corn oil Yeast culture	1	6.70	6.13	0.10	0.00	0.40	0.05	0.13	14.39
Sifteen Yeast culture	1	1.60	1.60	0.40	0.40	0.14	12.67	2.68	60.08
Tallow Lecithin (L) unadjusted	1	4.83	1.30	6.00	1.40	0.70	8.70	21.93	225.89
Yeast culture (Y) adjusted for L	1	0.45	1.90	0.00	9.60	0.52	0.01	1.95	0.00
LxY adjusted for L and Y	1	0.45	0.23	5.10	76.58	9.16	12.13	0.00	82.94
Error		3.99	3.07	8.85	42.55	4.88	10.12	5.20	62.23
Error d.f.[1]		40	35	37	40	39	34	34	39

[1]Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

analyses of variance for these data are given in Table XXXVIII. There were no consistent differences in these data among the various treatments. When calculations were made to obtain these efficiency values, the diets for all treatments were considered to have the same level of energy. Since there were no differences in egg production and no significant differences in feed consumption, the differences observed in fat digestibility were not reflected in these data. The efficiency values were 7.38, 7.20 and 7.66 Calories per gram of egg for corn oil, Sifteen and tallow, respectively.

Data on the efficiency of protein utilization are summarized and presented in Table XXXIX, with the analysis of these data in Table XL. After studying the data in these two tables, it was concluded that the statistical significance found here was due to a random variation. The average efficiency of protein utilization was 4.02, 3.96 and 4.20 for corn oil, Sifteen and tallow, respectively.

TABLE XXXVII

EFFICIENCY OF ENERGY[1] UTILIZATION, TRIAL II

Type of fat	Supplement	1-2	3-4	5-6	1-6	Supplement	7-8	9-10	11-12	7-12
		Calories per gram of egg					Calories per gram of egg			
Corn oil	None	8.83	6.74	6.67	7.45	Yeast culture	6.50	7.52	6.88	6.93
	Yeast culture	8.94	7.17	7.28	7.75	None	6.83	7.42	7.54	7.24
Sifteen	None	5.75	8.58	8.54	7.53	Yeast culture	8.40	9.86	7.51	8.45
	Yeast culture	6.33	7.25	6.75	6.78	None	6.87	6.03	5.59	6.14
Tallow	None	9.22	6.83	8.32	8.11	Lecithin	7.37	6.33	5.92	6.54
	Lecithin	10.66	7.74	8.35	8.51	None	8.02	14.24	8.26	9.53
Tallow	None	8.50	6.09	6.96	7.29	Yeast culture	7.26	6.83	6.09	6.81
	Yeast culture	8.83	6.89	7.54	7.76	None	7.96	7.98	6.51	7.55
Tallow	None	9.01	8.51	8.51	8.07	Yeast culture + lecithin	7.94	7.34	6.72	7.30
	Yeast culture + lecithin	8.81	6.15	8.99	7.88	None	8.58	6.63	9.69	8.32
Accumulation of tallow, no supplement		8.72	6.70	7.90	8.11		9.32	7.96	7.83	8.43

Weeks of trial

[1] The metabolizable energy value was considered the same for all fats. Refer to footnotes to Table XX.

[2] Tallow with no supplement considered as one. Refer to footnotes to Table XXI.

TABLE XXXVIII

ANALYSIS OF VARIANCE OF EFFICIENCY OF ENERGY[1] UTILIZATION FOR TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.[2]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	1.2735**	2.5286	.1808	.1142	1.1663	.0436	.1140	.9698
Corn oil Yeast culture	1	.0384	.0018	.0706	.0084	1.7389	.0000	.0210	2.0885
Sifteen Yeast culture	1	.0672	.1277	.2371	.0547	.1986	.8602*	.4263	.4032
Tallow Lecithin (L) unadjusted	1	.0509	3.7351	.1309	.0066	.0015	.4727	.1070	.1751
Yeast culture (Y) adjusted for L	1	.0579	2.9169	.0004	.0376	.0112	.0513	.1602	.0161
LxY adjusted for L and Y	1	.0595	2.9499	.0367	.0013	.0576	.2349	.2571	.2066
Error		.1425	4.4188	.0778	.0406	.05267	.1655	.7500	.5313
Error d.f.[2]		40	35	37	40	39	34	34	39

[1] The metabolizable energy value was considered the same for all fats. Refer to footnotes to Table XX.

[2] Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TABLE XXXIX

EFFICIENCY OF PROTEIN UTILIZATION, TRIAL II

Type of fat	Supplement	1-2	3-4	5-6	1-6	Supplement	7-8	9-10	11-12	7-12
		Grams of protein per gram of egg					Grams of protein per gram of egg			
Corn oil	None	.484	.370	.366	.409	Yeast culture	.356	.413	.377	.380
	Yeast culture	.491	.393	.399	.425	None	.375	.406	.414	.397
Sifteen	None	.318	.470	.469	.413	Yeast culture	.461	.541	.412	.464
	Yeast culture	.347	.389	.370	.372	None	.377	.331	.307	.337
Tallow	None	.506	.375	.456	.445	Lecithin	.404	.347	.325	.359
	Lecithin	.585	.370	.458	.467	None	.440	.782	.453	.523
Tallow	None	.467	.334	.382	.400	Yeast culture	.390	.374	.334	.374
	Yeast culture	.484	.378	.414	.426	None	.437	.438	.357	.414
Tallow	None	.494	.392	.467	.443	Yeast culture + lecithin	.436	.403	.369	.401
	Yeast culture + lecithin	.483	.337	.493	.432	None	.471	.364	.532	.456
Accumulation of tallow, no supplement[1]		.478	.367	.433	.430		.445	.511	.437	.462

[1] Tallow with no supplement considered as one. Refer to footnotes to Table XXI.

TABLE XL

ANALYSIS OF VARIANCE OF EFFICIENCY OF PROTEIN UTILIZATION FOR THE TRIAL II WITH WEEKS 1 THROUGH 6 CONSIDERED INDEPENDENT OF WEEKS 7 THROUGH 12

Source of variation	d.f.	Weeks of trial 1-2	3-4	5-6	1-6	7-8	9-10	11-12	7-12
		Mean squares							
Total d.f.[1]		47	42	44	47	46	41	41	46
Treatment	(7)								
Kind of fat	2	4.208**	1.302	0.604	0.379	0.029	0.145	0.374	0.171
Corn oil Yeast culture	1	0.133	0.007	0.231	0.027	0.570	0.000	0.070	0.273
Sifteen Yeast culture	1	0.219	0.429	0.804	0.180	0.651	2.852*	1.403	1.327
Tallow Lecithin (L) unadjusted	1	0.162	0.058	0.436	0.022	0.004	1.558	4.345*	0.587
Yeast culture (Y) adjusted for L	1	0.193	0.129	0.001	0.128	0.036	0.165	0.124	0.058
LxY adjusted for L and Y	1	0.205	0.516	0.123	0.005	0.203	0.797	3.460*	0.683
Error		0.477	0.616	0.258	0.168	0.298	0.551	0.660	0.341
Error d.f.[1]		40	35	37	40	39	34	34	39

[1] Total d.f. and error d.f. - the degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TRIAL III

Purpose

The purpose of this trial was to test the effect of five different strains of yeast culture, and Lipase C on the digestibility of tallow in diets of laying hens. Lipase C is a product of the Rohm and Haas Company, Washington Square, Philadelphia 5, Pennsylvania.

Procedure

The experimental design for Trial III is presented in Table XLI. An experimental basal (Table XLII) was formulated on a daily intake basis. The procedure for this type of formulation is described by Gleaves (1961). In this procedure feed ingredients are put together in such a manner as to cause the hens to consume a desired intake of nutrients per day when fed *ad libitum*. Nutrient intake is regulated by the volume of feed with which the nutrients are combined. The nutrient-volume ratio is controlled by either increasing or decreasing the amounts of certain inert material in the diet. The inert material used in this basal was polyethylene fluff (See Table XLII).

The desired daily consumption of this basal, which included 10 grams of tallow, was 114 grams per hen. To the daily consumption of the basal, a desired daily consumption of yeast culture or Lipase C was added. Three grams of each of the 5 strains of yeast culture were added to 114 grams of the basal. Graded levels of Lipase C (.0284,

TABLE XLI

EXPERIMENTAL DESIGN, TRIAL III

Treatment number	Grams of basal[1]	Kind of supplement	Grams of supplement[2]
1	114	None	None
2	114	Yeast culture No. 1	3.0
3	114	Yeast culture No. 2	3.0
4	114	Yeast culture No. 3	3.0
5	114	Yeast culture No. 4	3.0
6	114	Yeast culture No. 5	3.0
7	114	Lipase C, level 1	0.0284
8	114	Lipase C, level 2	0.0568
9	114	Lipase C, level 3	0.1137

1 Grams of basal - the desired daily consumption.

2 Grams of supplement - desired daily consumption.

TABLE XLII

INGREDIENT COMPOSITION OF BASAL,[1] TRIAL III

Ingredients	Grams of ingredient[2]
Fat (tallow	10.0
Starch	13.2
Ground yellow corn	15.0
Oat mill feed[3]	30.0
Alfalfa meal (17% protein	2.0
Viobin fish meal[4]	3.0
Soybean oil meal (50% protein)	10.5
Blood meal	4.0
Gelatin	2.0
Condensed delactosed whey	2.0
Dried condensed fermented corn extractivaes[5]	2.0
Calcium carbonate	3.5
Dicalcium phosphate (18% phosphorus)	5.3
Salt (NaCl)	0.5
VMC-60[6]	0.57
VC-60A[7]	0.28
dl-Methionine	0.14
Chromic oxide	0.3
Polyethylene fluff[8]	10.00
Total weight (gm.)	114.28
Total volume (ml.)	251
Desired daily nutrient consumption	
Crude protein (gm.)	16.25
Calories (M.E.)[9]	297
Calorie:protein ratio	18.2:1
Calcium (gm.)	2.86
Available phosphorus (gm.)	1.14
Crude fiber (gm.)	19.48
Fat (gm.)	11.37

Footnotes for Table XLII

1. Ingredient composition -- the basal was calculated on a per hen per day basis and is presented on this basis.
2. Grams of ingredient -- calculated to meet the desired daily protein and energy consumption.
3. Oat mill feed -- Red-3 higrade oat mill by-product, National Oats Company, Cedar Rapids, Iowa.
4. Viobin fish meal -- Viobin Corporation, Monticello, Illinois
5. Dried condensed fermented corn extractives -- C. F. S. No. 3, Clinton Corn Processing Company, Clinton, Iowa.
6. VMC-60 -- Vitamin mineral concentrate, contain per gram; vitamin A, 3,524 U.S.P. units; vitamin D_3, 529 I.C.U.; vitamin E, 2.64 I.U.; vitamin K, 1.32 mg.; vitamin B_{12}, 3.5 mcg.; riboflavin, 1.76 mg.; niacin, 14.09 mg.; pantothenic acid, 3.52 mg.; choline chloride, 22.02 mg.; manganese, 12.20 mg.; iodine, 0.37 mg; cobalt, 0.25 mg.; iron, 9.60 mg.; copper 0.72 mg.; zinc 10.00 mg.
7. VC-60A -- vitamin concentrate, contains per gram; pyridoxine, 7.04 mg.; thiamin, 10.57 mg.; folic acid, 1.76 mg.; inositol, 44.05 mg; para amino benzoic acid, 3.52 mg.; ascorbic acid, 8.81 mg.
8. Polyethylene fluff -- "Alathon" 10, E. I. duPont deNemours and Company, Incorporated, St. Louis 1, Missouri.
9. (M.E.) -- metabolizable energy, Titus (1955).

.0568 and .1137 grams) were each added to 114 grams of the basal. The control diet consisted of 114 grams of intake per day of the unsupplemented basal. In order to reduce the fact in the basal, Viobin (defatted fish meal) was used instead of fish meal. This was done to reduce the error caused by differences in digestibility of the fat in the basal and of the added fat.

Each diet was fed ad libitum to 5-month-old Kimber-137 pullets. Each diet was fed to 5 replicates for a 12-week period in a completely randomized experiment. Fecal samples were collected at the end of each 4-week period for the determination of fat digestibility. Body weight and feed consumption data were recorded at the end of each 4-week period. The data were summarized for each 4-week period and for the 12-week overall period.

Analyses of variance were performed on the data by considering differences among the control, each of the 5 strains of yeast culture and Lipase C. Within the levels of Lipase C, linear and quadratic effects were calculated. These analyses were accomplished by the use of the Doolittle technique (Goss, 1961).

Results

The average coefficients of fat digestibility for Trial III are presented in Table XLIII, and the analysis of variance for these data is given in Table XLIV. There appears to be absolutely no difference in the digestibility of tallow due to the various treatments. According to the analysis of variance, there is a linear effect due to Lipase C for the second period. However, close examination of the digestibility values for Lipase C for the second period shows that

TABLE XLIII

AVERAGE COEFFICIENTS OF FAT DIGESTIBILITY, TRIAL III

Treatment	Period number 1	2	3
Control	70.2	71.6	75.6
Yeast culture No. 1	71.5	62.7	70.9
Yeast culture No. 2	71.3	68.9	67.7
Yeast culture No. 3	70.1	73.5	67.8
Yeast culture No. 4	72.3	73.8	73.0
Yeast culture No. 5	69.8	72.2	70.8
Lipase C			
Level 1	65.3	63.1	68.9
Level 2	72.0	71.0	74.5
Level 3	69.0	69.0	68.2

TABLE XLIV

ANALYSIS OF VARIANCE OF COEFFICIENTS OF FAT DIGESTIBILITY, TRIAL III

Source of variation	d.f.	Period number 1	2	3
		Mean squares		
Total d.f.[1]		45	45	44
Treatment	6	11.78	104.14	43.69
Lipase C				
Linear	1	36.10	449.68*	1.22
Quadratic	1	80.69	268.07	12.16
Error		27.20	98.26	35.01
Error d.f.[1]		37	34	36

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.

* Significant at the 5 percent level.

digestibility for the first level of the enzyme is extremely low. This can be accounted for by the fact that one hen on this diet had abnormally low fat digestibility for this period. The digestibility value for this hen during the second period was 23.6, while the other hens in the group were near the average of the entire trial. The average digestion coefficient of all the treatments was 70.2.

The analyses of variance for daily feed consumption, egg production and egg weight showed no differences in the performance of the hens due to treatment or level of Lipase C, and as would be expected, information calculated from these data showed no treatment differences in the analyses of variance. This information included daily energy consumption, daily protein consumption, Calories per gram of egg and grams of protein per gram of egg.

Body-weight-change is the only variable which had a statistically significant mean square due to treatment. A summary of these data and the analysis of variance of the data are given in Tables XLV and XLVI, respectively. It appears that Yeast Culture No. 1 caused a slight increase in body weight, while the hens which were given all other treatments either gained nothing or lost weight. In the overall analysis the hens which received Yeast Culture No. 1 gained an average of 36 grams per hen while the hens in the entire experiment lost an average of 51 grams.

It is almost impossible to find data in the literature concerning feed intake and nutrient intake of laying hens, as well as the types of data on nutrient utilization that are presented in this thesis. For this reason, even through there were no significant treatment differences, all of the summarized data, with the exception of egg weight, are

TABLE XLV

AVERAGE BODY WEIGHT CHANGE, TRIAL III

Treatment	Period number 1	2	3	Overall[1]
	Grams per hen			
Control	- 94	- 6	- 8	-108
Yeast culture No. 1	- 12	+42	+ 6	+ 36
Yeast culture No. 2	- 56	+16	-38	- 78
Yeast culture No. 3	-100	+18	-52	-134
Yeast culture No. 4	-110	+76	-32	- 66
Yeast culture No. 5	-102	+46	+24	- 34
Lipase C				
Level 1	- 60	+48	-18	00
Level 2	- 70	+58	- 8	- 20
Level 3	- 70	+34	-22	- 58

1 Overall - all periods accumulated as one.

TABLE XLVI

ANALYSIS OF VARIANCE OF BODY WEIGHT CHANGE, TRIAL III

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total d.f.[1]		45	42	44	45
Treatment	6	6232	4143	3559	17414*
Lipase C					
Linear	1	250	8826[2]	40	8410
Quadratic	1	83	192	481	270
Error		3114	2150	2658	5770
Error d.f.[1]		37	34	36	37

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.
2 Significant at the 10 percent level.
* Significant at the 5 percent level.

presented in this thesis.

Daily feed consumption data and the analysis of variance of these data are presented in Tables XLVII and XLVIII, respectively. The average daily feed consumption for this trial was 127.4 grams per hen. This is approximately 13 grams per day more than was desired when the diet was formulated. The average daily Calorie and protein consumption is, of course, proportionately higher than the desired amounts. The energy consumption data and the protein consumption data are presented in Tables XLIX and LI, and the corresponding analyses of variance in Tables L and LII, respectively. The values for Calories consumed per hen per day are probably higher than the actual energy consumption. This is due to the fact that the value of 3960 Calories per pound, which was used for tallow in formulating the diets, is much higher than either the value given by Hill (1960) or the value obtained when the digestibility figures of this trial were used in the formula for metabolizable energy given by Titus (1955).

Data on egg production, efficiency of energy utilization, and efficiency of protein utilization are presented in Tables LIII, LV and LVII. The corresponding analyses of variance for egg production, energy utilization and protein utilization are presented in Tables LIV, LVI and LVIII, respectively. The overall average egg production was 71.2 percent. The values on the efficiency of Calorie utilization in Table LV are probably too high, for the same reason that the average daily Calorie consumption was probably too high.

TABLE XLVII

AVERAGE DAILY FEED CONSUMPTION, TRIAL III

Treatment	Period number 1	2	3	Overall[1]
	Grams per hen			
Control	109.9	121.4	121.9	118.4
Yeast culture No. 1	130.4	142.1	136.4	136.8
Yeast culture No. 2	123.2	129.4	127.7	127.1
Yeast culture No. 3	118.8	127.5	119.2	122.1
Yeast culture No. 4	123.7	138.1	136.1	133.4
Yeast culture No. 5	102.7	125.0	119.9	116.8
Lipase C				
Level 1	129.8	139.1	133.6	134.6
Level 2	118.9	132.7	127.8	127.1
Level 3	128.7	137.3	124.2	130.2

1 Overall - all periods accumulated as one.

TABLE XLVIII

ANALYSIS OF VARIANCE OF DAILY FEED CONSUMPTION, TRIAL III

Source of variation	d.f.	Period number 1	2	3	Overall[1]
		Mean squares			
Total d.f.[1]		45	42	44	45
Treatment	6	527.07	247.99	251.98	296.12
Lipase C					
Linear	1	3.25	20.45	220.90	48.84
Quadratic	1	359.83	33.07	3.75	91.17
Error		264.25	218.49	180.14	193.15
Error d.f.[1]		37	34	36	37

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.

TABLE XLIX

AVERAGE DAILY ENERGY[1] CONSUMPTION, TRIAL III

Treatment	Period number 1	2	3	Overall[2]
		Calories per hen		
Control	279	308	310	301
Yeast culture No. 1	331	360	347	348
Yeast culture No. 2	313	329	325	323
Yeast culture No. 3	302	324	303	310
Yeast culture No. 4	314	351	346	339
Yeast culture No. 5	261	318	305	297
Lipase C				
Level 1	330	354	340	342
Level 2	302	337	325	323
Level 3	327	349	316	331

1 The metabolizable energy value of the fat was considered to be the same for each diet regardless of digestibility.
2 Overall - all periods accumulated as one.

TABLE L

ANALYSIS OF VARIANCE OF ENERGY CONSUMPTION, TRIAL III

Source of variation	d.f.	Period number 1	2	3	Overall
			Mean squares		
Total d.f.[1]		45	42	44	45
Treatment	6	3395	1606	1630	1910
Lipase C					
Linear	1	26	130	1464	302
Quadratic	1	2323	200	32	607
Error		3395	1606	1630	1911
Error d.f.[1]		37	34	36	37

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.

TABLE LI

AVERAGE DAILY PROTEIN CONSUMPTION, TRIAL III

Treatment	Period number 1	2	3	Overall[1]
	Grams per hen			
Control	15.3	16.8	16.9	16.5
Yeast culture No. 1	18.1	19.7	19.0	19.0
Yeast culture No. 2	17.1	18.0	17.8	17.7
Yeast culture No. 3	16.5	17.7	16.6	17.0
Yeast culture No. 4	17.2	19.2	18.9	18.6
Yeast culture No. 5	14.3	17.4	16.7	16.2
Lipase C				
Level 1	18.0	19.3	18.6	18.7
Level 2	16.5	18.5	17.8	17.7
Level 3	17.8	19.1	17.3	18.1

1 Overall - all periods accumulated as one.

TABLE LII

ANALYSIS OF VARIANCE OF DAILY PROTEIN CONSUMPTION, TRIAL III

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total d.f.[1]		45	42	44	45
Treatment	6	10.18	4.72	4.88	5.70
Lipase C					
Linear	1	0.06	0.38	4.26	0.94
Quadratic	1	6.95	0.64	0.07	1.78
Error		5.11	4.14	3.48	3.72
Error d.f.[1]		37	34	36	37

1 Total d.f. and error d.f. - degrees of freedom may change from period to period due to mortality or missing data.

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TABLE LVII

EFFICIENCY OF PROTEIN UTILIZATION, TRIAL III

Treatment	Period number 1	2	3	Overall[1]
	Grams of protein per gram of egg			
Control	.354	.408	.413	.394
Yeast culture No. 1	.406	.390	.412	.402
Yeast culture No. 2	.396	.401	.423	.407
Yeast culture No. 3	.382	.378	.473	.410
Yeast culture No. 4	.427	.420	.466	.438
Yeast culture No. 5	.406	.447	.443	.435
Lipase C				
Level 1	.421	.431	.443	.432
Level 2	.366	.409	.414	.399
Level 3	.384	.413	.423	.408

[1]Overall - all periods accumulated as one.

TABLE LVIII

ANALYSIS OF VARIANCE OF EFFICIENCY OF PROTEIN UTILIZATION, TRIAL III

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total d.f.[1]		45	42	44	45
Treatment	6	.1376	.0603	.1033	.0423
Lipase C					
Linear	1	.1364	.0221	.0247	.0443
Quadratic	1	.2222	.0148	.0429	.0646
Error		.0984	.0707	.1519	.0533
Error d.f.		37	34	36	37

[1]Total d.f. and error d.f. degrees of freedom may change from period to period due to mortality or missing data.

[illegible]

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TABLE LIX

INGREDIENT COMPOSITION[1] OF DIETS, TRIAL IV

Diet number	1	2	3	4	5
Ingredients	Grams of ingredient[2]				
Fat (tallow)	10.0	10.0	----	----	----
(D-1309)[3]	----	----	12.5	----	----
(D-1310)[4]	----	----	----	12.0	----
(D-1311)[5]	----	----	----	----	10.5
Starch	14.0	14.0	16.0	21.0	22.0
Ground yellow corn	15.0	15.0	15.0	15.0	15.0
Oat mill feed[6]	30.0	30.0	30.0	30.0	30.0
Alfalfa meal (17% protein)	2.0	2.0	2.0	2.0	2.0
Viobin fish meal[7]	3.0	3.0	3.0	3.0	3.0
Soybean oil meal (50% prot.)	10.5	10.5	7.0	5.4	6.0
Blood meal	4.0	4.0	4.0	4.0	4.0
Gelatin	2.0	2.0	2.0	2.0	2.0
Condensed delactosed whey	2.0	2.0	2.0	2.0	2.0
Dried condensed fermented corn extractives[8]	2.0	2.0	2.0	2.0	2.0
Calcium carbonate	3.5	3.5	3.5	3.5	3.5
Di-calcium phosphate (18% phosphorus)	5.3	5.3	5.3	5.3	5.3
Salt (NaCl)	0.5	0.5	0.5	0.5	0.5
VMC-60[9]	0.57	0.57	0.57	0.57	0.57
VC-60[10]	0.28	0.28	0.28	0.28	0.28
dl Methionine	0.14	0.14	0.14	0.14	0.14
Chromic oxide	0.5	0.5	0.5	0.5	0.5
Lipase 31-MILPA[11]	---	0.33	----	----	----
Total weight (gm.)	105.31	105.64	106.29	109.19	109.29
Total volume (ml.)	198	198	234	241	246
Desired daily nutrient consumption					
Crude protein (gms.)	16.25	16.25	16.23	16.22	16.21
Calories (M.E.)[12]	300	300	301	302	303
Calories:protein ratio	18.5:1	18.5:1	18.5:1	18.6:1	18.7:1
Calcium (gms.)	2.86	2.86	2.86	2.86	2.86
Available phosphorus (gms.)	1.14	1.14	1.14	1.14	1.14
Crude fiber (gms.)	9.48	9.48	9.47	9.47	9.47
Fat (gms.)	11.37	11.37	10.37	8.27	7.37

Footnotes for Table LIX

Ingredient composition - refer to footnote 1, Table XLII.

Grams of ingredients - refer to footnote 2, Table XLII.

Dry fat samples 1, 2, 4, and 5. D-305, 75 percent grease and 25 percent soya flour; D-310, 60 percent crude soya oil and 40 percent soya flour; D-340, 65 percent edible tallow and 35 percent soya flour. Research and Development Division, National Dairy Products Corporation, Dairy Laboratories, Oakdale, Long Island, New York.

Oat mill feed - refer to footnote 3, Table XLII.

Viobin fish meal - Viobin Corporation, Monticello, Illinois.

Dried condensed fermented extractives - refer to footnote 5, Table XLII

VMC-60 -- Vitamin-mineral concentrate - refer to footnote 6, Table XLII.

VMC-60A -- Vitamin-mineral concentrate - refer to footnote 7, Table XLII.

Lipase 3111 M -- Miles Chemical Company, Clifton, New Jersey.

(M.E.) -- Metabolizable energy (M.E.) - Titus (1955).

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same quantity of protein and quantity of the metabolizable energy. The metabolizable energy value (3960 Calories per lb.) of the fat in each diet was considered to be the same when the diets were formulated. AM in Trial III, Menhaden fish meal was substituted for fish meal to reduce the fat content in the basal ration.

Each diet was replicated 5 times in a completely randomized experiment which lasted 12 weeks. Diets were fed ad libitum to Kimber-137 hens which had been in production for 12 months. The hens were weighed and feed consumption and egg production data were recorded at the end of each 4-week period. The data were summarized at the end of each 4-week period and an overall summary was made at the end of the trial. Statistical analyses were performed on the data for each period and for the overall summary. Fecal samples were collected from each replicate at the end of each 4-week period and were used to determine fat digestibility. A single analysis of variance was performed on the data from all 3 periods combined with a hierarchical classification (Snedecor, 1956) in order to remove the period and period with treatment effect. In addition a multiple range test was performed on these data (Duncan, 1955).

Results

A summary of the egg production data is presented in Table LX. The analysis of variance of the data is presented in Table LXI, and Duncan's multiple range test of the fat digestibility data presented in Table LXII. It can be seen from the analysis of variance table that differences among treatments were significant at the 0.1 percent level of probability, with no significant

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differences due to period within treatment. The multiple range test shows that dry fat numbered D-1310 had a higher digestibility than other sources of fat tested at the five percent level of probability. The average digestibility of the test fat (crude soya oil) in sample D-1310 was 87.3 percent. The control, control + Lipase D-1309 (grease) for all periods, and D-1311 (edible tallow) for the first period were grouped together by the multiple range test at the 5 percent level of probability. The digestibility for this group ranged from 77.6 to 81.2 percent. Periods 2 and 3 for the diet which contained D-1311 were grouped together at the 5 percent level with digestibility levels of 74.4 and 75.2 percent.

The data on average daily feed consumption for this trial are presented in Table LXIII, and the analysis of variance of these data in Table LXIV. The data in this table show that the feed consumption of the diet containing fat D-1310 (crude soya oil) was significantly less than that of the diets on the other treatments. The overall feed intake of the animals fed this diet was 97 grams per day, whereas the others consumed from 112 to 120.5 grams of feed per day. Feed consumption seems to be in inverse relationship to the digestibility of the fats. It is apparent that the higher digestibility of fat D-1310 resulted in greater quantity of metabolizable energy, thus causing a reduction in feed intake.

Energy consumption data and the analysis of variance of the data are presented in Tables LXV and LXVI, respectively. The average Calorie uptake was calculated as they would be if the energy value for the fat in each diet is considered to

TABLE LXVII

AVERAGE DAILY PROTEIN CONSUMPTION, TRIAL IV

Treatment	Period number 1	2	3	Overall[1]
	Grams per hen			
Control	19.8	18.0	18.2	18.7
Control + Lipase 31	17.5	18.1	19.1	18.2
D-1309	18.5	19.5	17.1	18.3
D-1310	13.8	13.1	16.5	14.5
D-1311	17.6	18.3	17.8	17.9

[1]Overall - all periods accumulated as one.

TABLE LXVIII

ANALYSIS OF VARIANCE OF DAILY PROTEIN CONSUMPTION, TRIAL IV

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total	24				
Treatment	4	25.40*	30.31	43.02**	14.70**
Error	20	5.80	12.57	6.23	3.15

*Significant at the 5 percent level.
**Significant at the 1 percent level.

TABLE LXIX

AVERAGE BODY WEIGHT CHANGE, TRIAL IV

Treatment	Period number 1	2	3	Overall[1]
	Grams per hen			
Control	+ 72	- 2	+ 10	+ 80
Control + Lipase 31	+ 64	+ 64	+ 8	+136
D-1309	+ 14	+ 6	+ 42	+ 62
D-1310	-250	+120	+ 40	- 90
D-1311	-248	- 2	+ 22	-228

[1]Overall - all periods calculated as one.

TABLE LXX

ANALYSIS OF VARIANCE OF BODY WEIGHT CHANGE, TRIAL IV

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total	24				
Treatment	4	136574	[illegible]	[illegible]	111380[1]
Error	20	[illegible]	[illegible]	[illegible]	49364

[1]Significant at the 10 percent level.

TABLE LXXI

AVERAGE EGG PRODUCTION, TRIAL IV

Treatment	Period number 1	2	3	Overall[1]
	Percent	Percent	Percent	
Control	57.1	56.4	50.7	54.8
Control + Lipase 31	44.3	53.6	55.7	51.4
D-1309	47.1	40.7	33.6	38.1
D-1310	50.7	45.0	53.6	49.8
D-1311	62.1	55.7	50.7	56.2

[1]Overall - all periods accumulated as one.

TABLE LXXII

ANALYSIS OF VARIANCE OF EGG PRODUCTION, TRIAL IV

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares	Mean squares	Mean squares	
Total	24				
Treatment	4	19.66	[illegible]	[illegible]	180.64
Error	20	31.92	38.12	[illegible]	221.1

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[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

[illegible]
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[illegible]
[illegible]

[illegible]

TABLE LXXIII

EFFICIENCY OF ENERGY[1] UTILIZATION, TRIAL IV

Treatment	Period number 1	2	3	Overall
	Calories per gram of egg			
Control	9.68	9.05	10.33	9.66
Control + Lipase 31	11.65	10.25	10.02	10.57
D-1309	11.46	13.73	14.68	13.86
D-1310	8.05	8.76	9.12	8.65
D-1311	8.07	9.27	10.14	9.08

1 The metabolizable energy value was considered the same for the fat in each diet. Refer to footnotes to Table LIX.
2 Overall - all periods accumulated as one.

TABLE LXXIV

ANALYSIS OF VARIANCE OF EFFICIENCY OF ENERGY UTILIZATION, TRIAL IV

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total	24				
Treatment	4	.1692	.0974	.1273	.1361
Error	20	.1897	.1313	.2099	.0839

TABLE LXXV

EFFICIENCY OF PROTEIN UTILIZATION, TRIAL IV

Treatment	Period number 1	2	3	Overall[1]
	Grams protein per gram of egg			
Control	.524	.490	.560	.523
Control + Lipase 31	.631	.555	.543	.573
D-1309	.617	.739	.790	.746
D-1310	.431	.469	.488	.463
D-1311	.431	.495	.541	.485

1 Overall - all periods accumulated as one.

TABLE LXXVI

ANALYSIS OF VARIANCE OF EFFICIENCY OF PROTEIN UTILIZATION, TRIAL IV

Source of variation	d.f.	Period number 1	2	3	Overall
		Mean squares			
Total	24				
Treatment	4	0.624	0.343	0.434	0.481
Error	20	0.656	0.454	0.723	0.289

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volume of each diet of 5 animals. At the end of the first, second and third 4-week periods, adjustments were made in the volume of each diet based upon consumption during the preceding week. These adjustments were made in order to cause the consumption of energy to be such that the daily consumption of nutrients would be near to that which was desired. The adjustments are given in Table LXXIX.

The basals were combined with the vitamin concentrate listed in Table LXXX in the proportions given in Table LXXXI to form 15 experimental diets. In Study 1 the desired levels of protein intake were 13, 16 and 19 grams per day in a factorial arrangement with 250, 300 and 350 Calories of metabolizable energy. Study 2 consisted of 0.660, 0.565 and 0.490 grams of vitamin concentrate in factorial arrangement with 250, 300 and 350 Calories of energy.

Except for fat digestibility data, all data from these two studies were summarized by Chapman (1961) and Greaves (1961). For this reason, only data which showed significant effects of differences in fat digestibility are presented in this thesis.

Fecal samples were collected during the second, sixth and twelfth periods for the determination of fat digestibility. Due to equipment limitations, fat digestibility was determined only for the rats fed diets which furnished 300 Calories per day. Therefore, as far as fat digestibility is concerned, Study 1 consisted of 3 levels of protein intake with 1 level of energy intake, and was treated as such in the statistical analysis. The statistical analysis of the data in the factorial trial was performed as described by [illegible] (Goss, 1961).

[illegible]

TABLE LXXX

COMPOSITION OF VITAMIN-MINERAL CONCENTRATE, TRIAL V

Vitamins and minerals	Units	Amount supplied by one gram of concentrate
Vitamin A	U.S.P	2,349.48
Vitamin D_3	I.C.U.	352.42
Vitamin E	I.U.	1.76
Vitamin K_3	Mg.	0.88
Vitamin B_{12}	Mcg.	2.35
Riboflavin	Mg.	1.17
Niacin	Mg.	9.40
Pantothenic acid	Mg.	2.35
Pyridoxine	Mg.	2.35
d-Biotin	Mg.	0.09
Choline	Mg.	146.84
Thiamin	Mg.	3.52
Folic acid	Mg.	0.59
Ascorbic acid	Mg.	2.94
Inositol	Mg.	14.68
Para amino benzoic acid	Mg.	1.17
Manganese	Mg.	8.14
Iodine	Mg.	0.25
Cobalt	Mg.	0.17
Iron	Mg.	6.40
Copper	Mg.	0.48
Zinc	Mg.	6.67

TABLE LXXXI

COMPOSITION OF EXPERIMENTAL DIETS, TRIAL V[1]

Basal	Diet number	Grams of basal diet period 1-3	Grams of basal diet period 4-[illegible]	Grams of basal diet period [illegible]-13	Supplemental level of vitamin-mineral concentrate[2] Grams	Chromic oxide Grams
A	1	105.2	107.9	132.2	0.065	0.5
B	2	112.4	108.5	119.4	0.065	0.5
C	3	120.3	114.7	126.7	0.065	0.5
D	4	106.2	110.3	135.3	0.640	0.5
D	7	106.3	110.3	135.3	0.065	0.5
D	10	106.2	110.3	135.3	0.490	0.5
E	5	114.3	114.3	123.9	0.640	0.5
E	8	114.3	114.3	123.9	0.065	0.5
E	11	114.3	114.3	123.9	0.490	0.5
F	6	122.2	120.7	123.9	0.640	0.5
F	9	122.2	120.7	123.9	0.065	0.5
F	12	122.2	120.7	123.9	0.490	0.5
G	13	106.9	116.9	142.2	0.065	0.5
H	14	112.9	117.5	126.1	0.065	0.5
I	15	120.4	118.3	120.0	0.065	0.5

[1] Composition - The weight [illegible] the vitamin-mineral concentrate [illegible] total daily feed consumption.

[2] See Table LXXX for the composition of the concentrate.

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Results

Study 1

The coefficients of fat digestibility for Study 1 are presented in Table LXXXIII, and the corresponding analysis of variance is presented in Table LXXXII. There was an age effect on fat digestibility which was significant at the 10 percent level of probability. The protein effect was not significant. Age linear and age x protein quadratic interactions were both significant at the 10 percent level of probability. Since this significant interaction was present, the age effect is meaningful only if the level of protein intake is known.

At 13 grams of protein intake per day, fat digestibility increased with each increase in age through the last age studied. At 16 grams protein intake per day, fat digestibility increased from the second period to the fourth period and then decreased from the sixth period to the eighth period. At 19 grams of protein intake, fat digestibility was approximately the same for the second and sixth periods, but decreased for the third period. This picture can be seen in the data in Table LXXXIII. These results show the presence of an interaction between age and protein intake, since the changes in fat digestibility with age were different at one level of protein intake than at the other levels of protein intake.

Feed consumption varied with protein level due to the method of diet formulation. Therefore, it would be meaningless to try to correlate feed consumption with differences in fat digestibility.

Daily energy consumption data are presented in Table LXXXIV.

TABLE LXXXII

AVERAGE COEFFICIENTS OF FAT DIGESTIBILITY, STUDY 1, TRIAL V

Diet number	Daily protein consumption[1]	Period number 1	2	6
2	13	74.0	76.8	78.1
8	16	72.8	80.7	77.3
14	19	79.6	79.3	74.9

[1] The desired daily protein consumption.

TABLE LXXXIII

ANALYSIS OF VARIANCE OF COEFFICIENTS OF FAT DIGESTIBILITY, STUDY 1, TRIAL V

Source of variation	d.f.	Sum of squares	Mean square	F value
Total	44	891.29		
Blocks	6	119.94	20.0	
Age (A)	2	81.84	40.92	2.53[1]
Protein (P)	(2)			
(Linear) P_L	1	17.87	17.87	1.09
(Quadratic) P_Q	1	0.02	0.02	
Age x Protein interaction	(4)			
A x P_L	2	94.61	47.31	2.92[1]
A x P_Q	2	91.38	45.69	2.82[1]
Error	30	485.69	16.20	

[1] Significant at the 10 per cent level of probability.

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TABLE LXXXIV TABLE LXXXIV TABLE LXXXIV

AVERAGE DAILY CONSUMPTION OF METABOLIZABLE ENERGY
PER HEN, BY PERIODS AND OVERALL[1], STUDY 1, TRIAL V

number	Diet number 7		Diet number 12			11 3	72 14	18 3	21 9	8 15	14	15	9
red consu	Desired 250 Calories		250 Calories			250 Calories	300	350	300	350		350	
od number	Period number		Calories of metabolizable energy consumed daily										
1	296	1 318	2963 1	3131	29617	31352	31334	31354	3134	3524	314	354	
2	375	2 384	3351 2	3853	33562	38400	36363	35409	3647	4009	367	409	
3	369	3 378	3695 3	3773	36350	37338	35509	33385	3673	3885	369	385	
4	287	4 291	2833 4	2942	28333	29344	23380	34481	3350	3481	350	381	
5	295	5 303	2954 5	3035	29525	30351	28456	33873	3258	3673	368	373	
6	278	6 292	2789 6	2953	27859	29338	29851	33383	2631	3383	351	333	
8	268	8 272	2688 8	2704	26982	27047	29846	30427	2826	3327	326	327	
9	270	9 281	2789 9	2802	27891	28031	28928	30324	3022	3324	322	324	
10	276	10 283	2796 10	2806	27861	28364	29013	30653	3011	3453	311	353	
11	281	11 304	2893 11	3042	28318	30435	29328	32352	3125	3352	325	352	
12	274	12 286	2748 12	2861	27419	28331	28857	33309	3287	3309	287	309	
13	243	13 285	2437 13	2855	24384	28531	29365	33408	3365	3408	365	408	
all[1]	294	overall[1] 306	2940 overall[1]	3061	29016	30649	30262	33947	3362	3497	352	347	

[1]Overall - based upon cumulated intake data for all periods.

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TABLE LXXXV TABLE LXXXV TABLE LXXXV

EFFICIENCY OF UTILIZATION OF METABOLIZABLE ENERGY, BY PERIODS AND OVERALL[1], STUDY 1, TRIAL V

number	Diet number 2		Diet number 2 7		138	279	3813	7914	8 13	914	13	14	
od number	Period		Calories of metabolizable energy per gram of egg										
1	7.4	1 7.5	7846	1 7754	78766	77549	87664	77892	7.0	7892	7.0	8.2	
2	9.1	2 8.7	9012	2 8973	90828	89735	108889	99351	8.0	9951	8.9	9.1	
3	9.2	3 8.4	9825	3 8845	98858	88457	88381	88874	8.5	8874	8.5	8.4	
4	7.9	4 8.4	7990	4 8746	79800	87961	98006	79916	8.6	9716	13.6	7.6	
5	9.0	5 8.2	9808	5 8726	98082	87867	88827	78871	8.7	8871	13.7	8.1	
6	8.4	6 9.9	8849	6 9891	88796	98817	87867	88872	7.8	8872	8.7	8.2	
7	8.5	7 7.7	8852	7 7874	88527	78841	87273	88719	7.9	8719	11.9	7.9	
8	7.9	8 8.0	7991	8 8606	79914	86865	97846	68852	7.6	8852	10.6	8.2	1
9	8.4	9 8.1	8947	9 8715	89778	87857	97884	78872	7.4	8872	10.4	8.2	1
10	9.9	10 8.8	9996	10 8981	99767	89012	97876	90629	7.6	10629	8.6	6.9	
11	10.4	11 9.8	10949	11 9184	109892	91845	98924	119856	8.6	9856	8.6	8.6	
12	15.1	12 9.7	15017	12 9979	150870	99992	108800	99820	8.0	9820	14.0	8.0	1
13	18.7	13 11.0	18176	13 11307	181864	113871	118847	133916	8.6	13916	10.6	9.6	1
all[1]	Overall[1]	8.7	Overall[1]	8875	99830	88951	98906	89813	8.6	9813	9.6	8.3	

verall - based upon cumulated data for all periods.

TABLE LXXXVI

AVERAGE COEFFICIENTS OF DRY MATTER DIGESTIBILITY, STUDY 2, TRIAL V

Lot number	Daily energy consumption[1]	Daily vitamin consumption[2]	Period number		
	Cal./day	Gm./day	2	12	6
4	250	0.640	71.2	74.4	70.1
7	250	1.065	76.5	78.1	72.1
10	250	1.490	68.4	71.0	72.6
5	300	0.640	79.4	82.3	83.4
8	300	1.065	72.8	77.3	80.7
11	300	1.490	74.5	78.7	82.9
6	350	0.640	66.1	73.0	78.9
9	350	1.065	74.6	78.0	79.7
12	350	1.490	73.9	79.4	86.7

[1]The desired daily energy consumption.

[2]The desired daily vitamin consumption.

[illegible]

[illegible]

[illegible]

[illegible]

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TABLE LXXXVIII

AVERAGE DAILY CONSUMPTION OF METABOLIZABLE ENERGY PER HEN, BY PERIODS AND OVERALL, STUDY 2, TRIAL V

Diet number	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
Desired consumption (Calories)	250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	350	300	350	[illegible]	350
Period number	Calories of energy actually consumed											
1	312	318	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	354
2	381	384	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	409
3	356	378	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	385
4	284	291	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	381
5	296	303	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	373
6	283	292	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	333
7	282	293	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	336
8	259	272	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	327
9	264	281	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	324
10	264	283	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	353
11	287	304	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	352
12	295	286	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	309
13	290	285	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	408
Overall[1]	[illegible]	306	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	357

[1]Overall - based on cumulative total for all periods.

The average digestibility of the hydrogenated fat was only 40 percent. This is not at all surprising, [illegible] hydrogenated fat which had a melting point of 52 degrees C.

The digestibility of the fat was so low that although the metabolizable energy content was greater than that of the corn, when added to the diet it actually decreased the energy content of the diet instead of increasing it. This was reflected in decreased egg production in the hens fed the diets in which fat was added. With each decrease in dietary energy due to increasing levels of fat in the diet, there was a corresponding decrease in egg production. This situation parallels the work of Chawan (1961) which showed that egg production was affected more readily by energy consumption than by change in the composition of the protein concentrate. Due to the fact that egg production is sensitive to a change in energy consumption, the digestibility of a fat should be known before its addition to a commercial poultry diet.

There appeared to be an advantage to the diet which contained 16 percent [illegible]. This was due to the fact that the hens were consuming more metabolizable energy than was necessary for their rate of production. This points out the fact that an arbitrary addition of a fat to a poultry diet may constitute a waste of energy if the fat does not regulate

These results indicate that polyethylene fluff caused the digestibility of tallow to be reduced.

However, the results of Trial V showed no relation between the amount of polyethylene fluff in the diet and the digestibility of the dietary fat. The dietary fat in Trial V was added to 43 grams of polyethylene fluff per hen per day. One group of hens which were fed 11 grams per hen per day had a fat digestibility lower than groups which received 43 grams per hen per day. Other groups of hens which received 11 grams of polyethylene fluff per hen per day had higher fat digestibility than those which received 43 grams per hen per day. This trend in fat digestibility with amount of polyethylene fluff was not evident.

Increases in fat digestibility caused by yeast culture were reflected in body weight change of the hens fed the diet which contained fifteen. Other than fat digestibility, body weight was the only variable measured which was affected by differences in fat digestibility brought about by yeast culture. With the experimental period being only 12 weeks in length, small differences in fat digestibility would not be expected to exert a greater effect on the performance of the hens. If the trial had been of longer duration, greater differences in several variables would be expected.

Neither Lipase C nor Lipase A had any effect on the digestibility of fat. It is possible that if an emulsifier had been present in the ration, the addition of lipase might have increased the fat digestibility.

The three dry fat sources (Dry Fat 100, D-1300 and D-1311) differed somewhat in relative digestibility. However, there were essentially no differences in productive performance among the hens fed

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SUMMARY

Five trials (4 of which were 12 weeks in duration and 1 of which was for 13 four-week periods) were conducted with laying hens to study factors affecting fat digestibility. In the four 12-week trials, the factors studied were: (1) fat source, (2) graded levels of dietary fat, (3) caffeine, (4) lipase activity of yeast culture, (5) interaction between lipase and yeast culture and (6) effect of (2) commercial lipases. In the trial which was for 13 four-week periods, the factors studied were: (1) graded levels of protein intake, (2) graded levels of energy intake, (3) graded levels of protein: energy ratio intake, (4) interaction between dietary level of energy and protein concentrate, and (5) interaction between treatments and periods.

The fats studied were; the fat in the basal diet, corn oil, beef tallow, Hard D-175 (methyl ester of cottonseed and soybean oil), Energ-E (vegetable oil and partially hydrogenated animal fat), Sifteen (a mixture of cottonseed oil and soybean oil mixed with liquid milk and spray dried), D-1309 (75 percent of grease absorbed on 25 percent of soya flour), D-1310 (60 percent of soybean oil absorbed on 40 percent of soya flour), D-1311 (65 percent of edible tallow absorbed on 35 percent of soya flour). The average digestibility coefficients of these fat sources were 56.4, 89.2, 75.3, 83.9, 34.0, 70.3, 83.0, 40.0, 80.5, 89.3 and 75.7, respectively.

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