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LIPID SUPPLEMENTATION OF LAYING HEN DIETS DEFICIENT IN PROTEIN AND SULPHUR AMINO ACIDS[1]

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ABSTRACT

Two experiments were conducted to study the response of brown egg layers to supplemental lipids in feeds deficient in protein and total sulphur amino acids (TSAA). The deficient feeds were prepared by diluting a protein-free isoenergetic diet. Supplemental lipids consisting of coconut oil, palm oil, stearin and olein, added either singly or as mixtures, were included at concentrations ranging up to 62 g kg^{-1}. The TSAA content of the feeds ranged from 410 to 590 mg kg^{-1}. In experiment 1, five hundred and sixty birds at 26 weeks of age were fed 10 experimental diets (56 birds per diet) for 8 weeks and the collected data for the last four weeks were analyzed. The daily TSAA intake varied from 360 to 620 mg per hen. Egg mass output per bird during the last four weeks varied from 40.4 to 52.5 g day^{-1}. In experiment 2, each diet was fed to 48 birds randomly selected from the original flock. At the start of this experiment the birds were 43 weeks old and the diets were fed for eight weeks. The daily TSAA intake varied from 435 to 705 mg hen^{-1}. The egg mass output for the last four weeks was 38.7 to 53.0 g hen^{-1} day^{-1}. In this experiment the efficiency of protein and TSAA utilization was improved by the addition of lipids to the diets especially those adequate in protein and TSAA. The results indicate that a role of lipids is to improve the utilization of proteins and limiting amino acids.

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افزودن چربی به‌جیره‌های مرغهای تخمگذا ردرشرا یط کمبودپروتئین و اسیدهای آمینه گوگرددار

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خلاصه

جهت تحقیق درواکنش مرغهای تخمگذا رنسبت به‌افزودن چربیها به‌غذاهایی که‌از نظر پروتئین و اسیدهای آمینه‌گوگردا رکمبوددا رند ، دوآزمایش انجام‌شد .جیره‌های فقیر با افزودن یک جیره‌بدون پروتئین هم‌انرژی به‌جیره‌پایه‌تهیه‌گردیدند .چربیهای مکمل شامل روغن نارگیل ، روغن نخل ، استئارین واولئین بودندکه‌بصورت تکی یا مخلوط تا حداکثر ۶۲ گرم درکیلوگرم درجیره‌بکا ررفتند .اسیدهای آمینه‌گوگردا رجیره‌ها بین ۴۱۰ تا ۵۹۰ میلی گرم‌درکیلوگرم‌درنوسان بود .درآزمایش اول ۵۶۰ مرغ با سن ۲۶ هفته‌با ده‌جیره غذایی (هرجیره ۵۶ مرغ) برای مدت ۸ هفته‌تغذیه‌شدندوداده‌های حاصل برای چهار هفته‌آخرآزمایش تجزیه‌آماری گردید .مصرف روزانه‌امینواسیدهای گوگرددار بین ۳۶۰ تا ۶۲۰ میلی گرم بازای هرمرغ وتولیدروزانه‌تخم‌مرغ بین ۴۰/۴ تا ۵۲/۵ گرم‌درنوسان بود .درآزمایش دوم هرجیره‌به ۴۸ مرغ که‌بطورتصادفی ازگله‌ما درانتخاب شده‌بودند تغذیه‌شد .درابتدای این آزمایش مرغها ۴۳ هفته‌داشتندوجیره‌ها برای ۸ هفته‌تغذیه گردید .مصرف روزانه‌آمینواسیدهای گوگردا ربین ۴۳۵ تا ۷۰۵ میلی گرم برای هرمرغ درنوسان بود .دراین آزمایش با اضافه‌کردن چربی به‌جیره‌راندمان مصرف پروتئین وامینواسیدهای گوگرددار ، بخصوص درموردجیره‌هایی که‌پروتئین واین امینواسیدها درآنها کافی نبود ، بهترشد . نتیجه‌های این آزمایشها نشان می دهدکه‌یکی ازتاثیرات چربی بهترکردن راندمان مصرف پروتئین ها وامینواسیدهای محدودکننده‌است .

INTRODUCTION

Dietary supplementation with vegetable oils and animal fats exerts beneficial effects on the performance of broilers and laying hens. These beneficial effects have normally been assumed to be due to the linoleic acid content of the diet and the improvement in efficiency of metabolizable energy of the fats and other dietary nutrients due to the synergistic effect between fats and non-lipid nutrients of the diet.

Improvements in egg production and egg weight due to supplemental fats and linoleic acid have been reported (14, 15, 20, 27, 28). Edwards and Morris (10) and Balnave (3) found egg weight to increase after additions of maize oil were made to the diets of laying hens. Whitehead (32) supplemented the diet of laying hens with maize oil and olive oil and showed increases in egg weight, which he concluded were due to the greater amounts of readily absorbable dietary fatty acids.

In contrast many reports have indicated a lack of effect of supplemental oils and fats on increasing egg weight and egg production (2, 6, 26).

Better nutrient utilization due to supplemental fats has been reported. Carew and Hill (8, 9) demonstrated that the efficiency of energy utilization increased when the diet of chicks was supplemented with corn oil. The synergistic interaction between fats and other dietary nutrients has been investigated. Sue (31) reported that the metabolizable energy of tallow was increased with the level of protein and decreased with the level of calcium in the diet. Enhanced energy utilization from non-lipid dietary constituents of the diet has been reported by Mateos and Sell (16, 17, 18). Better dietary nutrient utilization due to supplemental fats is attributed to the effect of fat on slowing the transport of food through the gastrointestinal tract (16, 17, 19).

The following experiments were carried out to investigate the effects of supplemental saturated and unsaturated fats on the performance of laying hens and their effects on improving the efficiency of dietary protein and sulphur amino acid utilization.

MATERIALS AND METHODS

Housing and Management

The experiments were carried out in a windowless house, equipped with Thornber cages. Four birds were housed in each cage. Two adjacent cages were used as an experimental replicate. The birds were fed *ad libitum* and the feed intake per replicate was measured by weighing back any remaining feed at appropriate intervals.

The house temperature control system was set to maintain a daily minimum of 21°C at the middle tier by controlling the ventilation rate.

Day-length was increased by 20 minutes per week from eight hours at 20 weeks of age to 17 hours, and then was held constant. At the beginning of the experiment I, the photoperiod was 10 hours and 20 minutes. When experiment II commenced the day-length was 15 hours and 20 minutes.

Daily records of mortality and egg production were kept. Egg weight, from accumulation of three consecutive days, was determined in bulk every two weeks. The initial body weight was recorded and body weight was then determined at the end of weeks 30 and 34 in experiment I, and the end of weeks 46 and 50 in experiment II, by weighing all the birds from one cage per replicate per tier.

Samples of feed received from the feed mill were taken for chemical analysis. Dietary protein was determined by the method described by Spillane (29) and calcium and phosphorus were determined spectrophotometrically.

In order to keep the same amino acid balance in all diets, the dilution technique described by Fisher and Morris (12) was used. Methionine was the first limiting amino acid in experimental diets.

The analyses of variance were performed using a computerized program (24).

In both experiments egg mass output during the last four weeks of the experiment was taken as the measure of response to the treatments.

Experiment I

Five hundred and sixty Ross Brown layers at 26 weeks of age were used in this experiment. The birds were randomly divided into 70 plots of two cages, 35 plots per block, eight birds per plot. The 10 experimental diets were fed to seven replicates of birds from 27 until 35 weeks of age.

To obtain the experimental rations, one basal and one dilution diets were formulated. The 10 experimental diets were obtained by mixing appropriate portions of basal and dilution diets and by adding coconut oil, palm oil and stearin. The deficient protein and TSAA diet (diet 1) contained 116 g kg^{-1} protein and 4.1 g kg^{-1} TSAA which were 72% and 87% of requirements respectively. The sufficient diet (diet 6) contained 161 g kg^{-1} protein and 5.7 g kg^{-1} TSAA which were 100% and 120% of requirements. The composition of the basal, dilution and experimental diets is shown in Tables 1 and 2.

The nutrient composition of the dilution diet was similar to the basal diet except that it contained little or no digestible protein. Cellulose was used as an inert compound in the diets to keep diets equi-energetic and fat was substituted in lieu of maize starch.

Coconut oil as a source of short and medium chain fatty acids, stearin as a source of stearic acid and palm oil as a source of palmitic and oleic acids each at a level of 13 g kg^{-1} and as a mixture at a level of 39 g kg^{-1} (13 g kg^{-1} each) were added to diets 1 and 6. The fatty acid composition of the lipids used is shown in Table 3. All fatty acid composition of the lipids used is shown in Table 3. All diets were isoenergetic and contained 11.6 MJ kg^{-1} of metabolizable energy (ME).

Experiment II

Seven hundred and twenty birds at 43-51 weeks of age were taken from the same flock used in experiment I. These had been fed a conventional layer diet for four weeks before commencement of the experiment, and their daily egg production was recorded during this period. At the beginning of the experiment the average egg production and egg weight were 87.7% and 62.7 g, respectively.

The experimental birds were randomly divided into 90 plots of two cages, 45 plots per block, eight birds per plot and each of the 15 experimental rations were fed to six plots, three plots per block, one plot per tier for a

Table 1. Composition of basal and dilution diets (g kg^{-1}).

Ingredients	Experiment I		Experiment II	
	Basal	Dilution	Basal	Dilution
Maize	55	--	100.0	--
Wheat	480	--	488.0	--
Barley	113	--	--	--
Full fat soya	47	--	48.0	--
Soya bean meal (44% CP[†])	165	--	198.0	--
Fish meal (63% CP)	33	--	36.0	--
Oat hulls	--	104.9	--	166.0
Maize starch	--	540.0	--	490.0
Glucose	--	220.0	--	193.0
Maize oil	--	17.0	4.4	26.0
Ground limestone	84.5	79.6	103.0	103.0
Dicalcium phosphate	13.0	28.4	13.4	13.4
Salt	3.0	3.5	3.0	3.0
Vitamins+minerals[‡]	5.5	5.0	5.0	5.0
Yolk color[§]	0.5	0.37	0.6	0.6
Methionine supplement	0.5	--	0.6	--
Choline chloride 70%	--	1.23	--	--
Total	1000.0	1000.0	1000.0	1000.0

[†] CP = crude protein.

[‡] Provides the following vitamins and minerals per kilogram of diet: Vit. A, 16000 IU; Vit. D3, 3000 IU; Vit. E, 16 IU; Vit. K, 4 mg; Riboflavin, 6 mg; Pantothenic acid, 9 mg; Choline, 200 mg; Nicotinic acid, 20 mg; B12, 8 ug; Mn, 120 mg; Zn, 120 mg; Fe, 80 mg; Cu, 9 mg; Co, 0.4 mg; I, 1.0 mg; Se, 0.2 mg; Antioxidant, 145 mg.

[§] Used as yolk coloring.

Table 2. Composition of diets used in experiment I.

Constituents (%)	Diets†									
	1	2	3	4	5	6	7	8	9	10
Basal diet‡	65	65	65	65	65	90	90	90	90	90
Dilution diet‡	25	25	25	25	25	-	-	-	-	-
Maize starch	10	0.43	6.8	6.8	6.8	10	0.43	6.8	6.8	6.8
Cellulose	-	5.67	1.9	1.9	1.9	-	5.67	1.9	1.9	1.9
Coconut oil	-	1.3	1.3	-	-	-	1.3	1.3	-	-
Palm oil	-	1.3	-	1.3	-	-	1.3	-	1.3	-
Stearin	-	1.3	-	-	1.3	-	1.3	-	-	1.3

†All diets contained 36 g kg^{-1} Ca and 5.2 g kg^{-1} P. Diets 1 to 5 contained 116 g kg^{-1} protein and 4.1 g kg^{-1} TSAA. Diets 6 to 10 contained 161 g kg^{-1} protein and 5.7 g kg^{-1} TSAA. Diets 1 and 6 contained 18 g kg^{-1} total fat and 10 g kg^{-1} linoleic acid. Diets 2 and 7 contained 57 g kg^{-1} total fat and 11.2 g kg^{-1} linoleic acid. Diets 3, 4, 5, 8, 9 and 10 contained 31 g kg^{-1} total fat and 10.7 g kg^{-1} linoleic acid.

‡For composition see Table 1.

Table 3. Fatty acid composition of lipids used in layer diets†.

Lipid	Fatty acids (%)					
	C12	C14	C16	C18	C18:1	C18:2
Coconut oil	50	21	11	4	10	1
Palm oil	--	2	41	5	43	9
Stearin	2	2	28	65	2	--
Olein	3	3	4	1	71	10

†Lipids were supplied by Unichema International Ltd. United Kingdom, Bebington, Wirral, Merseyside L62 4UF.

period of eight weeks.

The 15 experimental diets were obtained by mixing appropriate portions of the basal and dilution diets and by adding coconut oil, palm oil, stearin and olein. Fats were substituted in lieu of glucose, and cellulose was used as an inert compound to keep diets equi-energetic. The basal diet contained wheat and maize as cereal sources. The dilution portion contained starch, glucose and maize oil as energy sources. The nutrient composition of the dilution portion was similar to the basal diet, except it contained little or no digestible protein and amino acids. The deficient protein and TSAA diet (diet 1) contained 123 g kg^{-1} protein and 4.1 g kg^{-1} TSAA which were 76% and 87% of requirements, respectively. The moderately deficient diet (diet 8) contained 142 g kg^{-1} protein and 4.7 g kg^{-1} TSAA which were 88% and 100% of requirements, respectively. The sufficient diet (diet 15) was supplemented with 0.47 g kg^{-1} methionine and contained 160 g kg^{-1} protein and 5.9 g kg^{-1} TSAA which were 100% and 125% of requirements respectively. The composition of the basal, dilution and experimental diets is shown in Tables 1 and 4.

Coconut oil, stearin, and palm oil each at the level of 40 g kg^{-1}, were used as sources of saturated and unsaturated fatty acids. In order to increase the oleic acid and unsaturated fatty acid content of the diets, olein at a level of 22 g kg^{-1} was added to diets which contained coconut oil, palm oil and stearin. The low and medium TSAA diets (diets 1 and 8) were supplemented with different types of fats. The fatty acid composition of the fats used is shown in Table 3. All diets were isoenergetic and contained 11.7 MJ kg^{-1} of ME.

RESULTS

The results obtained from the first experiment for egg weight, egg output, feed intake, body weight change and feed

Table 4. Composition of diets used in experiment II.

Diet No.†	Constituents (%)							
	Basal	Dilution	Glucose	Cellulose	Coconut oil	Palm oil	Stearin	Olein
1	65	20	15.0	--	--	--	--	--
2	65	20	5.3	5.7	4.0	--	--	--
3	65	20	5.3	5.7	--	4.0	--	--
4	65	20	5.3	5.7	--	--	4.0	--
5	65	20	--	8.8	4.0	--	--	2.2
6	65	20	--	8.8	--	4.0	--	2.2
7	65	20	--	8.8	--	--	4.0	2.2
8	75	10	15.0	--	--	--	--	--
9	75	10	5.3	5.7	4.0	--	--	--
10	75	10	5.3	5.7	--	4.0	--	--
11	75	10	5.3	5.7	--	--	4.0	--
12	75	10	--	8.8	4.0	--	--	2.2
13	75	10	--	8.8	--	4.0	--	2.2
14	75	10	--	8.8	--	--	4.0	2.2
15	85	--	15.0	--	--	--	--	--

† Diets 1-7 contained 123 g kg^{-1} protein, 6.50 g kg^{-1} lysine, 2.25 g kg^{-1} methionine and 4.10 g kg^{-1} TSAA. Diets 8-14 contained 142 g kg^{-1} protein, 7.50 g kg^{-1} lysine, 2.60 g kg^{-1} methionine and 4.70 g kg^{-1} TSAA. Diet 15 contained 160 g kg^{-1} protein, 8.50 g kg^{-1} lysine, 3.5 g kg^{-1} methionine and 5.90 g kg^{-1}TSAA. Diets 1, 8 and 15 contained 23.0 g kg^{-1}, diets 2, 3, 4, 9, 10, 11, contained 63.0 g kg^{-1} and diets 5, 6, 7, 12, 13, 14, contained 85.0 g kg^{-1} total fat, respectively.

conversion are presented in Table 5. Figure 1 shows the response of egg output to TSAA and supplemental lipids. When diet was deficient in protein and TSAA (116 g kg^{-1} protein and 4.1 g kg^{-1} TSAA) egg weight and egg output were increased significantly by the addition of 39 g kg^{-1} of a mixture of coconut oil, palm oil and stearin. The addition of 13 g kg^{-1} of each fat to a low protein and TSAA diet (diet 1) slightly

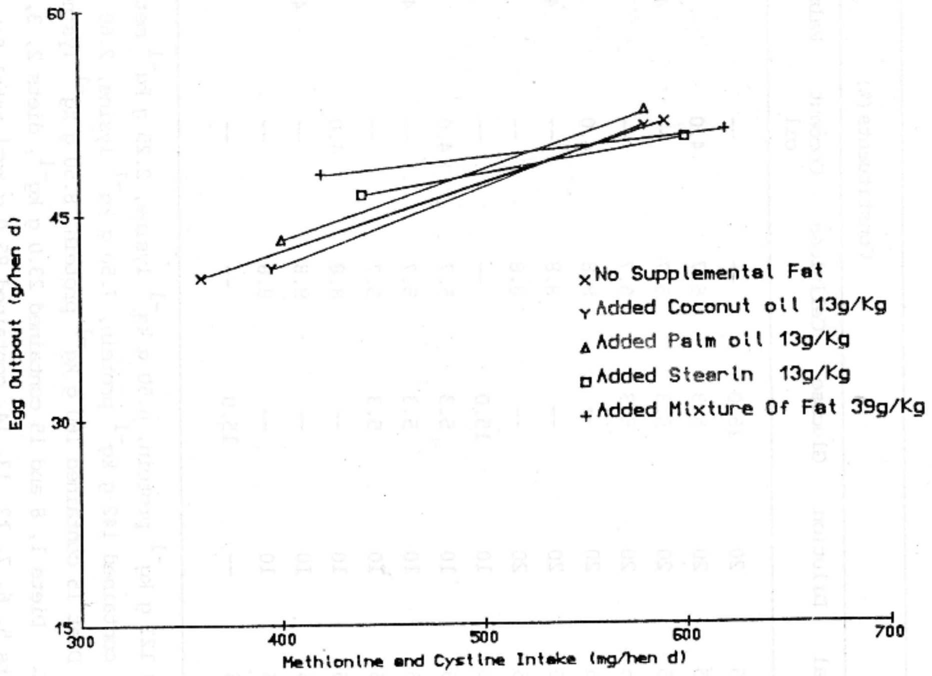

Fig. 1. Response of egg output to TSAA with and without supplemental fat in experiment I

Table 5. The effect of fat on egg weight egg output, feed intake and feed conversion of laying hens fed diets with different levels of sulphur amino acids in experiment I.

Diet No.	Added fat g kg^{-1}	TSAA intake mg hen^{-1} d^{-1}	Egg weight† g	Egg output† g hen^{-1} d^{-1}	Body weight change g hen^{-1} d^{-1}	Feed intake† g hen^{-1} d^{-1}	Feed conversion† kg feed kg^{-1} egg
1	None	360	54.4a	40.4a	-5.4	88.1a	2.18a
2	39 C+P+S‡	430	58.2b	47.9b	-3.1	105.5bc	2.21a
3	13 C	395	56.1ab	41.1a	-4.2	96.2ab	2.34ab
4	13 P	400	55.5ab	42.0ab	-4.3	97.7bc	2.33ab
5	13 S	440	56.0ab	44.7ab	-4.8	106.8c	2.39b
6	None	590	58.6b	51.0b	-2.1	103.6bc	2.04a
7	39 C+P+S	620	58.8b	51.0b	-1.5	109.1c	2.14a
8	13 C	580	58.7b	51.3b	-2.7	101.5bc	1.98a
9	13 P	580	58.8b	52.5b	-2.1	102.3bc	1.95a
10	13 S	600	58.3b	50.5b	-2.4	105.6bc	2.10a
Standard error			±0.22	±0.38	±0.65	±0.84	±0.04

†Values followed by the same letters in each column are not significantly different ($P > 0.05$).

‡C = Coconut oil, P = Palm oil, S = Stearin.

improved egg weight and egg output. When the protein and TSAA content of the low protein diet was increased, egg weight and egg output were increased significantly (diet 1 vs. diet 6). Supplementation of diets with one fat or a mixture of three types of fat at the levels used did not increase performance, when dietary protein and TSAA (161 g kg^{-1} protein and 5.7 g kg^{-1} TSAA) were adequate.

Feed intake and loss in body weight gain were improved significantly by the addition of 39 g kg^{-1} of fat to the diet inadequate in protein and TSAA (diet 1). Hens fed on diet adequate in protein and TSAA lost less weight and had significantly higher feed intake (diet 1 vs. diet 6) than those fed on deficient diet. In general, supplemental fats improved feed intake with diets inadequate in protein and TSAA, but did not improve feed intake with diets containing adequate protein and TSAA. Added coconut or palm oil caused numerical but nonsignificant improvement in feed efficiency with diets containing adequate protein and TSAA diet. No improvement in feed efficiency observed as a result of the addition of 13 g kg^{-1} of each type of fat to the low protein and TSAA diet. When a mixture of unsaturated and saturated fats were used with the diet inadequate in protein and TSAA performance was significantly better than with the addition of each single fat.

The results of the second experiment are shown in Table 6. The egg output response curve to the TSAA and supplemental lipids is shown in Fig. 2. Egg Output was increased significantly due to supplemental stearin at the level of 40 g kg^{-1} to a low protein and TSAA diet (123 g kg^{-1} protein and 4.1 g kg^{-1} TSAA). Only palm oil increased egg weight significantly. Increasing the oleic acid content of the low protein and TSAA diets (diets 3 and 4 vs. diets 6 and 7) which were supplemented with palm oil or stearin increased egg weight significantly.

When protein and TSAA contents of the deficient diet were

Table 6. The effect of fat on egg weight, egg output, feed intake and feed conversion of laying hens fed diets with different levels of sulphur amino acids in experiment II.

Diet No.	Added fat g kg^{-1}	TSAA intake mg hen^{-1} d^{-1}	Egg weight† g	Egg output† g hen^{-1} d^{-1}	Body weight change g hen^{-1} d^{-1}	Feed intake† g hen^{-1} d^{-1}	Feed conversion† kg feed kg^{-1} egg
1	None	460	60.2a	38.7a	-0.6	112.0ab	2.90d
2	40 C‡	466	62.0abc	44.2ab	1.0	113.7ab	2.57abcd
3	40 P	440	62.6bcd	42.9ab	0.6	107.5a	2.52abc
4	40 S	506	61.0ab	46.8bc	1.2	123.4bcd	2.64bcd
5	62 C+O	435	62.4bcd	46.1b	0.0	106.0a	2.30a
6	62 P+O	450	64.4ef	44.1ab	-1.6	109.4ab	2.54abc
7	62 S+O	535	64.3ef	44.6ab	0.0	130.1d	2.82d
8	None	535	61.6ab	46.3b	0.8	114.1ab	2.50ab
9	40 C	545	64.4ef	50.8bc	-0.8	115.5abc	2.30a
10	40 P	575	64.7ef	49.0bc	0.5	122.0abcd	2.52abc
11	40 S	610	64.5ef	51.6bc	0.6	129.7cd	2.53abc
12	62 C+O	550	64.4ef	50.0bc	1.0	116.4abcd	2.34ab
13	62 P+O	560	64.7ef	49.2bc	1.4	119.5abcd	2.47ab
14	62 S+O	605	65.1f	52.8c	-1.6	128.5cd	2.43ab
15	None	705	64.3ef	53.0c	-1.0	119.2abcd	2.32ab
Standard error			±0.75	±1.05	±0.6	±3.18	±0.07

†Values followed by the same letters in each column are not significantly different ($P > 0.05$).

‡C = Coconut oil, P = Palm oil, S = Stearin, O = Olein.

increased respectively from 123 to 142 g kg^{-1} and 4.1 to 4.7 g kg^{-1}, egg output increased significantly (diet 1 vs. diet 8). Further increases in protein and TSAA contents of the inadequate diet to meet requirements increased egg output significantly (diet 1 vs. diet 15). In contrast with the moderately inadequate protein and TSAA diet (diet 8 vs. diet 15) the increases in both egg weight and egg output

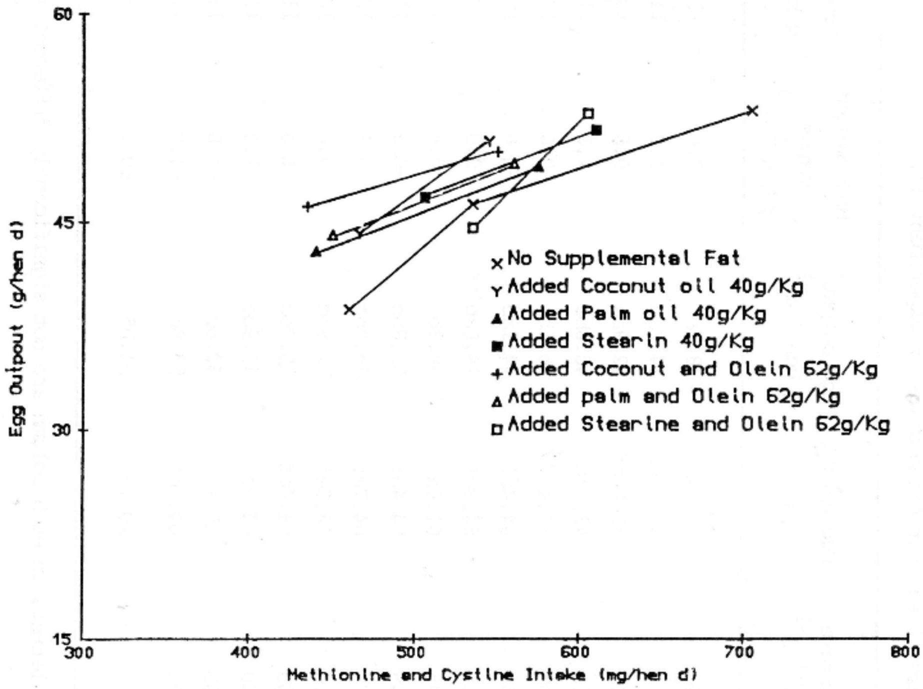

Fig. 2. Response of egg output to TSAA with and without supplemental fat in experiment II.

were significant.

Addition of 40 g kg^{-1} of coconut oil, palm oil or stearin to the moderately insufficient diet (diet 8) significantly increased egg weight (diet 8 vs diets 9, 10 and 11). Increasing the oleic acid content of the moderate protein and TSAA diets which were supplemented with different types of fats did not increase egg weight and egg output (diets 9, 10, 11 vs. diets 12, 23 and 14).

There was no significant difference in body weight between treatments. There were no significant differences in daily feed intake between treatments, except that those hens fed on diets which contained stearin had a significantly higher feed intakes. Supplemental palm oil and a mixture of coconut oil-olein and palm oil-olein significantly improved feed efficiency with inadequate diet (diet 1 vs. diets 3, 5 and 6).

As indicated in Table 7, supplemental lipids improved the efficiency of protein and TSAA utilization. This improvement ranged between about 3% to 8% for protein and about 5% to 13% for TSAA with diets inadequate in protein and TSAA. The improvement in protein and TSAA utilization was low with adequate protein and TSAA diets and ranged between 0.5% to 2.6% for protein and about 0.5% to 4% for TSAA. The improvement varied with the lipid source. Coconut oil and palm oil gave the best response with the inadequate protein and TSAA diet, especially when the unsaturated fatty acid content of the diets was increased by adding olein to the diets (diet 1 vs. diets 2, 3 and 5). Supplementation of moderately inadequate diet with DL-methionine (diet 15) in order to increase daily TSAA intake depressed the efficiency of TSAA utilization by about 6.7% (diet 8 vs. diet 15).

DISCUSSION

The results obtained indicate an increase in egg output and egg weight due to fat supplementation of diets which were

Table 7. Utilization efficiency of protein and sulphur amino acid as % of daily intake (47-50 weeks).

Diet No.	Added fat g kg^{-1}	Efficiency[†] (%)	
		Protein	TSAA
1	None	30.3	49.7
2	40 C[‡]	33.6(3.3)	56.0(6.3)
3	40 P	35.0(4.7)	57.6(7.9)
4	40 S	33.2(3.0)	54.6(4.9)
5	62 C&O	38.3(8.0)	62.6(12.9)
6	62 P&O	35.5(5.2)	57.9(8.2)
7	62 S&O	30.1(---)	49.2(-0.5)
8	None	30.8	51.1
9	40 C	33.4(2.6)	55.1(4.0)
10	40 P	30.6(---)	50.4(-0.7)
11	40 S	30.3(---)	50.0(-1.1)
12	62 C&O	32.8(2.0)	53.7(2.6)
13	62 P&O	31.4(0.6)	51.9(---)
14	62 S&O	31.3(0.5)	51.6(0.5)
15	None	31.4(0.6)	44.4(-6.7)

[†]Calculated on the basis of 5.91 mg and 0.108 g TSAA and protein per gram of shell egg respectively. Stadelman and Cotterill (30) Figures in parentheses represent percent changes in the protein and TSAA efficiency corresponded diets without added lipids.

[‡]See Table 6.

inadequate in protein and TSAA. The response varied with lipid sources and levels. Sources of short chain and unsaturated fatty acids were most effective. These results agree with the findings indicating higher utilization for shorter chain and unsaturated fatty acids (23, 33).

The egg output response to fat diminished at higher TSAA intakes which shows response to supplemental fat was greater with the diets deficient in protein and TSAA. At lower levels of dietary TSAA, increasing the unsaturated fatty acid content of the diets (as oleic acid) caused an increase in egg weight. This finding is in accord with the results of Whitehead (32), who concluded that egg weight responded to higher dietary and absorbable fatty acids, and that other unsaturated fatty acids such as oleic acid may increase the amount of readily absorbable fatty acid content of the diet. Also the results support the findings of other investigators, who indicated better utilization of the dietary fat due to supplemental unsaturated fats (2, 25).

The improved egg weight, egg output and protein and TSAA utilization indicated a synergistic effect between some fats and dietary protein and TSAA, specially when the diets were inadequate in protein and TSAA. The synergistic effects of fat is influenced by the nature and the rate of inclusion of the fat. Lipid increases food passage time which results in increased utilization of non-lipid components of the diet (16, 17). Increased food transit time increases fat, carbohydrate and protein digestion and more nutrients would be available for absorption. Absorption of some nutrients may increase as the result of longer food transit time. This, together with lower heat increment of the fat, leads to an increase in ME intake from both carbohydrate and fat, the consequence of which is an increase in egg output. This result is in agreement with the report of Reid (22).

All the increase in egg weight is not due to increase in yolk weight as a consequence of yolk lipid deposition.

Increased yolk weight stimulates more albumen secretion which in turn increases protein output. Griffin *et al.* (13) indicated that increase in egg weight was contributed by increased yolk and albumen weights and that albumen made a greater contribution than yolk in this regard. The larger ova produced, resulting from greater lipid deposition in yolk, stimulates more albumen secretion. Therefore, both egg lipid and protein output increase and egg composition almost remains constant.

The improved egg output response may be partly due to increases in daily intakes of TSAA due to added fats, but comparing diets 4 and 7 with diets 2, 3, 5 and 6 in experiment II suggests that other factors are involved. It seems that the improved protein and TSAA utilization as the result of added fat was involved. Such nitrogen utilization due to supplemental fat has been reported by Biely and March (4, 5).

Supplemental fats may exert their effects in several ways as far as its sparing action on protein and amino acids utilization is concerned. Added fat increases the passage time of food through the gastrointestinal tract and consequently exposes food for more time to the digestive enzymes, which causes better digestion of dietary proteins. Also amino acid absorbability may increase due to the slower transport of food through the gut. In addition lipid supplementation increases fat, protein and amino acid retention in laying hens (22).

It is clear that amino acid absorption is an active process and readily available energy enhances the process (7, 11, 21). Therefore, it is possible that fats exert a direct effect on amino acid absorbability by increasing ME utilization. Improved ME utilization after the addition of fat has been demonstrated (8, 9).

It seems that the role of feed lipids is to improve the utilization of protein and limiting amino acids. It is possible that by adding fats to the diet of laying hens one can reduce the amounts of dietary protein and limiting amino acids to some extent, without any adverse effect on the performance. In this case, the cost of feed will be reduced, particularly for those countries which produce a considerable amount of lipid but need to import their high protein ingredients.

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