THE IMPORTANCE OF LINOLEIC ACID IN POULTRY DIETS

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SUMMARY

Linoleic acid is an essential nutrient for growing and adult poultry and a deficiency will adversely influence growth and the reproductive performance of male and female birds. The requirement for linoleic acid during growth and lay in birds fed an adequate diet is approximately 10 g/kg of diet but conventional Australian diets based on wheat, sorghum and meat meal do not normally meet this requirement.

At Camden dietary supplementation with a vegetable oil containing a high concentration of linoleic acid was found to give markedly improved broiler growth arid feed conversion compared with similar supplements of an oil containing the same concentration of total unsaturated fatty acids but a low concentration of linoleic acid.

The use of linoleate-rich rice pollard in layer diets has also been shown to improve mean egg weight by 2-2.5 g and to increase the number of eggs of 60 g weight and above by 35-67 per cent between 20 and 48 weeks of age. This was reflected in an increased mean weekly income of approximately 2.5 cents per bird over this period.

INTRODUCTION

Although a number of acids with essential fatty acid activity have now been identified, by far the most important from a nutritional standpoint is linoleic acid. This fatty acid is present at high concentrations in vegetable oils and can be converted in the body to other fatty acids with essential-like activity.

Studies into the essential fatty acid requirements of poultry only commenced in 1950 when Reiser (1950) reported high mortality and marked retardation of growth at 4 weeks of age in chicks fed fat-free purified diets. Dietary supplementation with fat overcame this growth depression although the source of fat was shown to have an important influence in this respect (Hopkins et al., 1960; Marion et al., 1961). Experimental evidence accumulated to indicate that the chick had a specific requirement for linoleic acid in that dietary supplementation with methyl linoleate or linoleic acid concentrates was shown to improve the growth rate of chicks previously receiving a low-fat, purified diet (Machlin and Gordon, 1960a,b; 1961). In this work the addition of saturated fatty acids to the low-fat diet did not improve growth rate and although Edwards (1967) showed that methyloleate could stimulate the growth of young cockerels fed fat-free diets this effect was only observed for a short period, whereas the response to methyl linoleate continued for anextended period. Edwards (1967) and Hopkins and Nesheim (1967) found that a linoleic acid deficiency resulted in enlarged livers and increased liver fat as well as reduced growth.

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Research studies in the 1960's showed that the essential fatty acid-deficient chick had a reduced resistance to disease. Fungal diseases of the respiratory and digestive tracts were reported in chicks fed diets containing low levels of essential fatty acids (Ross and Adamson, 1961; Hopkins and Nesheim, 1962; Hopkins et al., 1963; Edwards, 1967). Boyd and Edwards (1966) also reported an increased susceptibility to E. coli infection.

REQUIREMENTS

Estimates of the linoleic acid requirement of the growing chick range from 4 to 14 g/kg of diet (Hill, 1966; Bieri and Prival, 1966; Hill et al., 1967; Hopkins and Nesheim, 1967; Menge, 1970). The use of different parameters to estimate the requirement results in differing estimates but it would appear that the linoleic requirement of the growing chick is approximately 8-10 g/kg of diet.

In laying hens the greatest requirement for linoleic acid is for the maintenance of maximum egg weight. When pullets are fed linoleate-adequate diets during growth the subsequent requirement during lay is 9-12 g/kg of diet (Balnave, 1971a; Agricultural Research Council, 1975) although this adult requirement increases when pullets are reared on low-linoleate diets (Agricultural Research Council, 1975).

GROWING BROILERS

Few research studies have examined the importance of dietary linoleic acid concentration in broiler diets. In studies at Camden MacAlpine (1980) observed that a dietary linoleic acid level of 7 g/kg was associated with depressed ME intake and weight gain. Conventional Australian diets based on wheat, sorghum and meat meal do not satisfy the bird's dietary linoleic acid requirement of 8-10 g/kg. Such diets contain on average between 6 and 7 g linoleic acid/kg diet although occasionally high and low values are observed. It is, therefore, likely that dietary supplementation with linoleic acid will improve the growth rate and general performance of broilers.

We have recently examined the responses of growing broilers to various levels of dietary linoleate supplementation. Sunflower oil was used as a source of linoleic acid and comparisons were made with similar supplements of olive oil. Both these oils contain similar concentrations of total unsaturated fatty acids but sunflower oil is a rich, and olive oil a poor, source of linoleic acid. The oils were included at levels of 10, 30, 60 and 90 g/kg diet and at each dietary inclusion level the ME : protein ratio and the dietary'amino acid balance were kept constant. The results from two growth trials are shown in Table 1.

In Experiment 1 the growth rate increased continually with increasing dietary sunflower oil supplementation. In contrast, live-weight gain was reduced at the two highest levels of dietary olive oil supplementation so that at the 9 per cent level of oil inclusion the difference in growth rate between the two oils was very highly significant ($P<0.001$). The food conversion efficiency improved continually with increasing supplementation with both oils and the difference between the two oils was again highly significant ($P<0.01$) at the highest dietary inclusion level. The ME's of the diets were similar at each inclusion level indicating that the digestibilities of the oils, 'TABLE 1 The effect of supplementing broiler diets with olive oil and sunflower oil (Alao, Balnave and Annison, Unpublished results)

	Supplement (g/kg diet)	Experiment 1 (49d)			Experiment 2 (47d)	
		B'wt gain (g)	FCE (g food/g gain)	Body fat (g/kg)	B'wt gain (g)	FCE (g food/g gain)
Olive oil	10	1843	2.06	169	-	-
	30	1898	1.96	164	1836	1.91
	60	1881	1.92	159		-
	90	1809	1.91	152	1945	1.82
Sunflower oil	10	1853	2.05	171		-
	30	1923	1.98	168	1896	1.88
	60	1961	1.88	160		-
	90	1989	1.83	156	2060	1.71
Tallow + Olive oil	10	-	-	-	-	-
	30	-	-	-	1797	1.92
	60	-	-	-	-	-
	90	-	-	-	1992	1.80
S.E.M.		34.8	0.026	1.74	33.4	0.020

were similar. The improvement in liveweight gain with increasing dietary sunflower oil supplementation was not due to an increase in body fat deposition as a continuous reduction in carcass fat was observed with increasing dietary supplementation with both oils.

These results were confirmed in the second study where sunflower oil and olive oil were compared at two dietary inclusion levels with a third treatment consisting of 20 per cent olive oil and 80 per cent tallow. Again the maximum growth rates and best feed conversion efficiencies were observed with birds fed diets supplemented with sunflower oil. At the 9 per cent dietary inclusion level the feed conversion efficiency of the birds fed sunflower oil was significantly better than for birds fed olive oil ($P<0.001$) or tallow ($P<0.01$).

COCKERELS

Early studies showed that cockerels fed diets containing extremely low levels of linoleic acid showed retarded sexual development (Bieri et al., 1956, 1957; Edwards, 1963, 1967). This results in a reduced adult fertility.

LAYING HENS

Research into the essential fatty acid requirements of adult hens was initiated by Jensen et al. (1958) who reported that an unidentified factor in maize oil was responsible for increasing egg weight. This work was extended to include other vegetable oils (Shutze et 'al., 1959, 1962; Shutze and Jensen, 1963). These studies showed that vegetable oils high in linoleic acid were most effective in improving egg weight and that the linoleic acid component of the oils was the factor responsible for this response. Initially suggestions were made that the beneficial egg weight response observed as a result of dietary supplementation with these oils was possibly due to the increased energy concentration of the diet. However, later experimental work showed that linoleic acid *per se* significantly'influenced egg weight (Edwards and Morris, 1967; Menge, 1968) principally through an effect on yolk weight and lipid content (Calvert, 1967; Balnave, 1969). Later work by Balnave (1971b) showed that the laying hen utilizes different energy sources in different ways. Hens fed diets supplemented with maize oil gave similar total egg yields to hens fed equivalent levels of metabolisable energy from maize starch, but the latter birds responded by increasing egg numbers whereas the former birds responded by increasing egg weight.

Other explanations to explain the beneficial responses in egg weight from dietary supplementation with linoleate-containing oils have included the effects of total dietary lipid and total dietary unsaturated fatty acid content, These suggestions were reinforced by the suggestion of Shannon and Whitehead (1974) that the responses observed from feeding vegetable oils rich in linoleic acid could possibly have been induced by other unsaturated fatty acids. This conclusion resulted from studies which failed to show any significant differences in egg weight at different dietary linoleate concentrations when the total dietary fat and unsaturated fatty acid concentrations remained constant. However, in this study the minimum dietary linoleic acid concentration used during growth and lay was 8 g/kg of diet and this dietary concentration would have essentially satisfied the bird's requirement for this nutrient during growth. Therefore, since the birds should have had adequate reserves of linoleic acid at the commencement of lay the use of a minimum dietary concentration as high as 8 g linoleate/kg diet during lay would not have been expected to exert any major detrimental effect on egg weight, as confirmed by these workers. The observation that supplements of linoleic acid in excess of requirements had little influence on egg weight in birds with adequate linoleate reserves had been reported previously by Balnave (1971a) who found in ^{14}C-linoleate turnover studies that although 98 per cent of the linoleic acid was absorbed from such diets, most of this was subsequently oxidised to carbon dioxide or used in the synthesis of other compounds.

Marion and Edwards (1964) showed conclusively that supplementing a layer diet with 50 g maize oil/kg produced significant increases in egg weight compared with controls whereas no significant responses were observed with similar dietary supplements of coconut oil and menhaden oil. Furthermore, since menhaden oil contains approximately 60 per cent unsaturated fatty acids compared with 86 per cent in maize oil and only 8 per cent in coconut oil, the results indicate that the total unsaturated fatty acid content of the oils was unimportant. Similar conclusions may be reached from the report of Menge et al. (1965) where comparable egg weights were obtained at similar intakes of linoleic acid but vastly different intakes of total unsaturated fatty acids when menhaden and safflower oils were used as dietary supplements. Also, egg weight was significantly increased at high linoleic acid intakes from safflower oil although the total unsaturated fatty acid intake was similar to that from the much lower linoleate-containing menhaden oil. Therefore, it appears unlikely that the egg weight response from feeding vegetable oils is a specific reflection of total fat or total unsaturated fatty acid intake.

An important nutritional problem in conventional Australian layer, as well as grower, diets is that dietary linoleic acid concentration often fails to meet the bird's requirement for this nutrient and this effect is accentuated if the grower diet is also deficient in linoleic acid., Although increasing the dietary linoleic acid concentration in layer diets above the recognised requirement level does not normally produce corresponding increases in egg weight, some reports have indicated that further increases may sometimes be obtained (Balnave and Brown, 1968). This response may be related to the body reserves of linoleic acid in individual flocks and be dependant on genotype since comparisons of egg weight gradings from recent. New South Wales random sample layer tests show a large range in the percentage of 60 g eggs of different WL x AO stock maintained on the same diets in the same environment.

At Camden we have recently examined the benefits of including linoleate-rich rice pollard in conventionally formulated Australian layer diets. Two studies have been completed in which Hyline WL x AO pullets and second year hens and Hazlett Tinted and Brown egg layers were used. The responses obtained from each of these three strains were essentially similar and indicate that diets based on wheat, sorghum and meat meal do not optimise egg weight.

Some results from the first study are shown in Table 2. These indicate that substantial increases of the order of 1-2 g in mean egg weight may be obtained by suitable modification of conventional layer diet formulations. The improvement in egg weight in this experiment was

TABLE 2 The effect of rice pollard supplementation of a conventional layer diet from 38-61 weeks of age (Srichai and Balnave, 1981)

Dietary rice pollard (g/kg)	0	85	420
Egg Production (egg/bd)	0.81	0.83	0.80
Egg Weight increase (g)	3.04	3.79	4.82
Liveweight increase (g/bd)	1.01	1.01	0.69
Food intake (g/bd)	119.2	119.0	110.5
Nutrient intake			
ME (kJ/bd)	1480	1470	1387
Linoleic acid (mg/bd)	655	1059	2708
Lysine (mg/bd)	906	892	1017
Methionine (mg/bd)	369	333	354
Methionine + Cystine (mg/bd)	620	500	574

associated with increases in dietary linoleic acid concentration and' intake but not with the intakes of other major nutrients, including metabolisable energy and essential amino acids. However, it is possible that some other factor in the rice pollard could have contributed to the improved egg weight.

The results of Experiment 2 are shown in Table 3. These confirm the results of the initial study and show that the marked increases in mean egg weight are associated with improved egg gradings and, increased numbers of eggs above 60 g weight. The egg gradings suggest that the Brown pullets had a lower requirement for linoleic acid than the Tinted pullets.. The beneficial responses were observed within three weeks of feeding the diets at 20 weeks of age and maximum differences in mean egg weight of 2.0-2.5 g were observed. The differentials in mean egg weight and in egg gradings were reduced when birds from all treatments were placed on the basal diet at 48 weeks of age.

The results of these studies indicate that substantial increases in mean egg weight and in egg gradings may be obtained by simple dietary manipulation. In these layer studies the improvement in economic returns was accentuated by the use of a relatively cheap raw ingredient and amounted to approximately 50-77 cents per bird to 48 weeks of. age (see Table 4). These returns would have been greater had it been possible to arrange for the bulk supply of rice pollard.

TABLE 3 The effect of rice pollard supplementation of a conventional layer diet from 20-48 weeks of age
(Balnave, Unpublished results)

	Hazletts Tinted			Hazletts Brown		
Dietary rice pollard (g/kg)	0	85	420	0	85	420
Food intake (g/bd)	106.9	111.0	106.1	108.4	113.2	108.0
Egg Production (egg/bd)	0.81	0.81	0.79	0.78	0.78	0.79
Mean egg weight (g)	54.6	56.1	56.9	55.4	56.8	57.2
Mean % egg gradings						
<45 g	3.7	2.6	1.4	3.9	2.4	2.4
45-50 g	11.3	7.6	5.4	8.6	7.1	6.3
50-55 g	32.9	27.0	24.8	29.0	21.6	22.7
55-60 g	30.6	31.1	32.6	29.7	29.8	30.1
>60 g	21.4	31.7	35.8	28.8	39.0	38.6

TABLE 4 Economic evaluation of dietary linoleic acid supplementation of a conventional layer diet from 20-48 weeks of age

	Hazletts Tinted			Hazletts Brown		
Dietary Rice Pollard (g/kg)	0	85	420	0	85	420
Feed Costs ($/tonne)	185	185*	185*	185	185*	185*
Feed costs ($/bird)	3.88	4.03	3.85	3.93	4.10	3.91
Egg returns ($/bird)	11.47	12.15	12.21	11.41	12.08	12.09
Egg returns - Feed costs ($/bird)	7.59	8.12	8.36	7.48	7.98	8.18

*The feed costs for diets containing rice pollard would be reduced if this were supplied in bulk. This would result in reductions of approximately $2 and $9 per tonne respectively in the diets containing 85 and 420 g rice pollard/kg.

The use of other ingredients rich, in linoleic acid would need to be assessed economically before dietary inclusion in layer diets.. At present costings the use of pure vegetable oils at a 1 per cent dietary inclusion level would mean an increased cost of approximately $10 per tonne of feed. Using the feed intake and egg production data from Experiment 2 this would still result in an increased return of approximately 30 cents per bird to 48 weeks of age. However, supplementation . at a 3 per cent dietary oil inclusion level to approximate the dietary linoleic acid concentration of the high-rice pollard ration would not prove economical.

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