NAKED OATS: THEIR POTENTIAL AS A COMPLETE FEED FOR POULTRY

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SUMMARY

Chemical analyses of cultivars of naked oats (NO) gave oil contents ranging from 3.1–11.8% and crude protein from 9.8–18.1% (DM basis). There was a linear relationship between crude protein and lysine or threonine in NO samples.

Broiler experiments showed that there was a need to pellet diets for maximum intake. Further improvement was achieved by the addition of exogenous enzymes such that at 84% NO inclusion, chick performance was similar to that on a wheat-based diet. Metabolizable energy (ME) and fat digestibility of NO was less for chicks than for adult birds. Addition of appropinate exogenous enzymes (1g/kg) improved substantially ME of NO diets in broiler chicks at two ages but not in adult cockerels. Only when chicks were aged 4-8 days was there a response of enzyme addition to wheat. A depression in ME was observed with adult birds for one enzyme addition.

A self-selection experiment showed that one combination of whole NO and a concentrate package could support similar mean egg production to that of layers on a commercial diet. Egg size tended to be higher on diets with NO. In another layer experiment the need to pellet **NO** diets was confirmed. At inclusion rates above 50% or oat groats at 75%, laying performance was reduced irrespective of whether diets were pelleted or not.

INTRODUCTION

Naked oats (Avena nuda) have been tested in Australian breeding programs for many years but yields have generally been disappointing. It is only recently that genotypes have been selected that yield a similar dry matter equivalent to conventional, hulled oats when the hull has been removed (Barr et. al. 1988; Barr 1990). These naked oat (NO) cultivars have appeal to the stock feed industry. Firstly, they are normally high in oil and in crude protein. Unlike other grains, when the crude protein (CP) content of NO increases so too do the essential amino acids and in direct proportion. One line of **NO** is due for commercialisation soon (see Barr 1991).

Naked oats are particularly attractive to the poultry industry. The oil is rich in linoleic acid (Maurice et al. 1985) which increases egg size, and they have a high metabolizable energy (ME) and are therefore useful in broiler diets.

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One of the problems with naked oats is that like hulled oats they probably have a high content of beta glucans (Barr 1990). Levels of beta glucans in hulled oats range from 3.4 to 5.9%. Recently Cave et al (1990) attempted to overcome growth depressions frequently observed in broilers given diets with naked oats (Cave and Burrows 1985; Maurice et al. 1985) with some success.

The object of this report is to detail analyses of various cultivars of naked oats used in selection trials and to give results showing the usefulness of naked oats in broiler and layer diets.

MATERIALS AND METHODS

Chemical analysis

Standard analytical procedures were used to measure nitrogen and ether extract of naked oat samples and dietary ingredients (Association of Official Analytical Chemists 1980). Amino acid analysis were undertaken by Degussa Corporation, Germany. Metabolizable energy (ME) was determined with adult cockerels using the rapid assay of Farrell (1978) with modifications (Farrell et al. 1991), and with growing chickens using the conventional total collection method over 4-5 days.

Broiler experiments

These experiments were confined to the starter phase of growth. They were undertaken in conventional, electrically-heated brooders with wire floors or in small wire-mesh cages (Sathe et al 1964) in a heated room. Illumination was continuous and feed and water were provided ad libitum.

Diets were formulated using a least cost computer program and using nutrient specifications for broilers and layers as recommended by the Standing Committee on Agriculture (1987).

Experiment 1 The diets contained either 710 g/kg of wheat as the sole grain source, or 200, 400, 600 and 840 g of NO instead of wheat. Other major ingredients were meat and bone meal and soybean meal. Diets were fed in mash form to 4 replicates of 10 male broiler chicks grown from 10 to 22 days.

Experiment 2 The diets used in this experiment were bulked from experiment 1 to provide diets with 300 g and 720 g NO/kg in mash or pelleted form. The same wheat-based diet (710 g/kg) was used as a control. There were 3 replicates each of 10 male broiler chickens grown from 4 to 18 days.

Experiment 3 In this experiment a ß-glucanase enzyme or an enzyme cocktail was added (1 g/kg) to diets containing 600 and 840 g NO/kg. Diets contained soybean meal and meat and bone meal with additions of synthetic lysine and methionine. They were calculated to be equal in ME and CP.

Layer experiments

Experiment 1 A self selection trial was undertaken at Armidale to determine if naked oats could be used successfully as the sole grain in the diet. There were three diets: (i) a commercial 17% CP layer diet, (ii) whole NO and a low-protein concentrate package (L, CP 29.1%), (iii) whole NO and a high-protein concentrate package (H, CP 37.0%). The concentrate was pelleted and fed with the NO in a single trough; it contained the mineral and vitamin premix, free lysine and methionine and some of the calcium. Shell grit was sprinkled over the feed at frequent intervals. It was estimated that the daily intake of concentrate would be about 33% of the total feed consumption. For each bird there were two 1.5kg containers, one holding the concentrate the other the oats. Feed troughs were replenished from these containers.

A bantamised hybrid strain of layer (Stanhope and Parkinson-1988) was used. For each treatment ten pullets, aged 18 weeks, were placed in individual cages each with a feed trough and a nipple drinker. The cages were located in a conventional, wooden layer shed holding about 650 birds in total. There were two batches of similar pullets that differed in age by 5 weeks. On the diet with the H concentrate, 10 pullets from a second batch of birds were used and this treatment was identified as H_2.

Egg numbers, egg weight, egg specific gravity, feed consumption, mortality and body weights were measured at regular intervals.

TABLE 1 Ingredient and chemical composition (g/kg) of naked oat (NO) diets fed as mash and pellets in layer Experiment 2

	NO 50%	NO 75%
Naked oats	500	750*
Wheat (12.5% CP)	140	
Meat meal	111	115.5
Field peas	105	28
Soybean meal	34	31
Calcium carbonate	75	74
Vegetable oil	36	
Lysine (g/kg)		0.6
Methionine (g/kg)	1.1	0.9
Vitamin & mineral premix (5 g/tonne)		
Calculated analysis ('air dry' basis)		
Metabolizable energy (MJ/kg)	13.35	13.35
Crude protein (g/kg)	181	183
Lysine (g/kg)	8.9	8.9
Methionine (g/kg)	3.7	3.7
Total sulphur amino acids (g/kg)	7.3	7.3

*Oat groats replaced naked oats in diet 6

Experiment 2 This was conducted at Parafield, S.A. between July and October, 1990. The birds were Tegel White ST and were aged 30 weeks at the start of the experiment. There were 4 replicates per diet each of 10 birds. Egg production was measured daily, egg size and feed intake were measured weekly. There was a commercial layer diet (16.5% CP, 11.14 MJ ME/kg DM), a diet with 50% NO in mash or pellet form, and with 75% NO in mash or pellet form. Oat groats were included at 75% in a sixth pelleted diet. The cultivar of NO was Terra 11/1 containing 13.9% CP with a lysine content of 0.57% ('as is' basis) and an ME of 15.63 MJ/kg DM. The composition of the diet is given in Table 1.

RESULTS

Analyses

The crude protein (CP, % DM) contents of a range of experimental cultivars of NO varied from 9.8 to 18.1 with oil contents (% DM) from 3.1 to 11.8. Terra 11-1, the soon to be released NO cultivar, had an average CP content of 14.3% (9.8-18.3%) (n = 45) and an average oil content of 9.2% (7.4 - 11.6%) (n = 20) measured at different sites in South Australia and Western Australia.

The amino acid profile of seven cultivars of NO from 13.0 to 18.6% CP is given in Table 2.

Table 2 The amino acid profiles (% DM) of seven different cultivars of naked oats

	Naked oat cultivar						
Amino acid	1	2	3	4	5	6	7
MET	0.22	0.25	0.24	0.30	0.28	0.31	0.32
CYS	0.36	0.40	0.40	0.47	0.45	0.50	0.41
M+C	0.58	0.65	0.64	0.77	0.72	0.80	0.73
LYS	0.58	0.64	0.58	0.71	0.70	0.79	0.74
THR	0.45	0.50	0.47	0.59	0.58	0.66	0.62
TRP	0.20	0.18	0.15	0.24	0.25	0.24	0.20
ARG	0.84	0.93	0.84	1.15	1.11	1.24	1.59
VAL	0.64	0.74	0.70	0.86	0.78	0.95	0.96
PRO	0.68	0.81	0.91	0.98	0.99	1.42	ND
PHE	0.64	0.72	0.68	0.86	0.84	0.94	0.95
TYR	0.42	0.47	0.42	0.54	0.59	0.62	0.58
LEU	0.95	1.03	0.99	1.28	1.22	1.37	1.31
ILE	0.48	0.54	0.50	0.62	0.57	0.67	0.74
ASP	1.11	1.21	1.16	1.51	1.50	1.66	1.49
GLU	2.39	2.73	2.58	3.38	3.25	3.73	3.62
ALA	0.61	0.67	0.64	0.81	0.80	0.88	0.76
HIS	0.28	0.31	0.28	0.38	0.37	0.40	0.42
GLY	0.64	0.69	0.68	0.84	0.80	0.91	0.83
SER	0.64	0.70	0.67	0.87	0.84	0.94	0.85
Crude protein	13.0	14.1	13.3	17.3	16.7	18.6	17.3

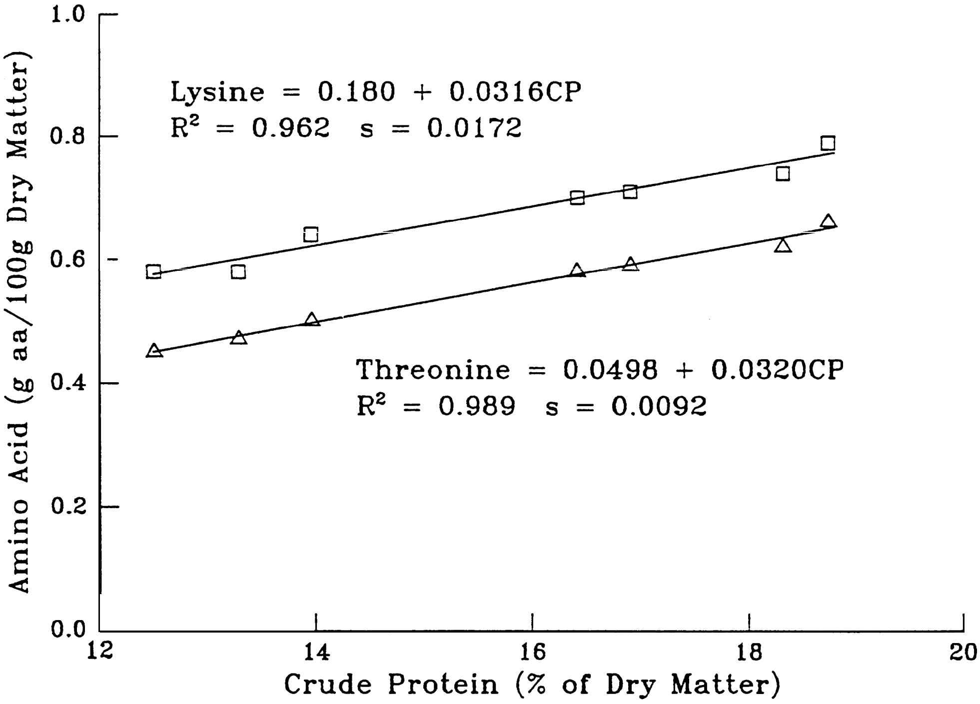

Fig. 1 The relationship between crude protein in naked oats and the concentrations of lysine or threonine

The linear relationships between crude protein and lysine and threonine are shown in Fig. 1. It is apparent that these amino acids can be predicted accurately from CP of **NO**

The crude protein, fat, fat digestibility and **ME** values measured with chicks (7-20d) and adult cockerels is shown in Table 3

TABLE 3 Protein and fat contents (DM basis) of cultivars of naked oats (A-F) and hulled oats (G-H) and metabolizable (ME) energy and digestible fat measurements made with cross-bred chicks from 7-20 days and adult cockerels

Cultivar	CP (%)	Fat (%)	Fat dig. (%)		ME (MJ/kg)	
			Chicks	Cockerels	Chicks	Cockerels
A	15.3	8.4	77.4	86.4	15.0	16.0
B	17.0	7.2	69.3	88.7	14.8	15.8
C	14.8	8.1	74.2	89.3	14.8	15.7
D	14.7	9.6	65.5	88.4	14.7	16.2
E	14.1	8.7	77.2	88.3	15.2	15.8
F	15.6	8.4	55.1	80.6	14.8	15.6
G	10.8	6.2	78.5	91.6	12.1	12.8
H	12.8	5.9	86.3	91.5	12.2	12.9

A paired 't test' showed that there were consistent differences ($P<0.01$) in that fat digestibility of NO was less with chicks than adult cockerels giving correspondingly lower ($P<0.01$) ME values.

TABLE 4 The metabolizable energy of a broiler starter diet, naked oats (NO) and their combination (%) in broilers at two different ages

	Metabolizable energy (MJ/kg 'as is')			
Age (d)	Starter	NO (11/1)	Starter (50) NO (50) Found	Predicted
15-20	13.18	13.23	13.13	13.20
39-44	13.39	13.79	13.22	13.59
LSD (P<0.05)	0.142	0.200	0.101	

When NO and a broiler starter diet were fed separately there were differences in ME at 15-20 and 39-44 days in both the broiler and **NO** diets. This was not seen when the feeds were then combined in equal amounts at 39-44 days (Table 4).

Broilers

Experiment 1 Increasing inclusion of NO depressed growth and increased FCR. This was largely due to a decrease in feed intake with increasing inclusions of NO in the diet (Table 5).

TABLE 5 Results of male broiler chickens grown from 10-22 days on starter mash diets containing either wheat or naked oats (20 - 84%)

	Wheat (%)	Naked oats (%)				LSD
	71	20	40	60	84	(P<0.05)
Gain (g/d)	20.3	15.6	12.1	9.0	7.6	2.00
FCR	1.22	1.40	1.31	1.42	1.47	0.103

Experiment 2 These results are shown in Table 6.

TABLE 6 Growth rate and **FCR** of male broiler chickens grown from 4-18 days on mash **(M)** or pelleted **(P) NO** based diets with wheat as the control

	Wheat (%)	Naked oats (%)				
	71	30		72		LSD
	(P)	(M)	(P)	(M)	(P)	(P<0.05)
Gain (g/d)	28.6	17.0	29.1	10.5	25.1	2.67
FCR	1.45	1.75	1.54	1.98	1.55	0.176

There was a significant improvement as a consequence of pelleting the NO-based diets. Compared to the wheat-based diet, only the pelleted NO at 30% equalled the performance of the control chickens.

Experiment 3 Addition of enzymes to the NO diet improved growth and FCR significantly such that they were the same on the 84% NO as on the wheat-based diet (Table 7). Thus the previously observed depressions in Experiments 1 and 2 were overcome particularly when the enzyme cocktail (++) was included. Enzymes had little effect on the wheat-based diet although FCR was improved ($P<0.05$) with the addition of the enzyme cocktail.

TABLE 7 Effects of enzyme (o, + ß glucanase or ++ enzyme cocktail) additions to pelleted diets fed to male broilers grown from 3 to 17 days

	Wheat (71%)			Naked oats (60%)			Naked oats (84%)			LSD
	o	+	++	o	+	++	o	+	++	(P<0.05)
Gain (g/d)	22.6	22.4	24.6	13.8	23.6	21.5	17.5	20.7	23.4	2.61
FCR	1.68	1.60	1.54	2.07	1.58	1.65	1.85	1.67	1.53	0.113

Metabolizable energy was measured on these same diets with three groups of 8 broiler chicks per diet aged 4-8 d, 8-12 d and on 5 individual adult cockerels per diet. The results are given in Table 8.

TABLE 8 Mean metabolizable energy (MJ/kg) measured on pelleted diets and with and without enzymes with (i) chicks 4-8 d (ii) chicks 8-12 d and (iii) individual adult cockerels (n = 5/diet). Overall SEM = 0.194 (+ ß glucanase, ++ cocktail)

	Wheat (71%)			Naked oats (%) 60			Naked oats (%) 84			LSD
Age (d)	o	+	++	o	+	++	o	+	++	(P<0.05)
4-8	10.4	11.2	11.4	9.3	12.0	12.0	9.2	11.7	11.9	0.91
8-12	13.4	13.3	13.4	11.6	13.5	13.4	11.7	13.1	13.3	
Adult	14.1	14.6	13.6	13.9	14.3	14.3	13.9	14.1	13.9	0.31

There were significant ($P<0.05$) effects of age, grain and enzyme on ME values. There were age x enzyme, grain x enzyme and age x grain x enzyme interactions ($P<0.05$).

For the broiler chicks at two ages, enzyme addition significantly improved ME yield on the NO diets, by almost 2 MJ/kg diet (Table 8). Improvement on the wheat-based diet occurred only when chicks were 4-8 days of age. For adult cockerels, enzyme additions had small effects on ME of NO based diets. On the wheat-based diet the ß-glucanase improved ($P<0.05$) ME but the enzyme cocktail reduced ($P<0.05$) ME compared with the controls (o enzyme).

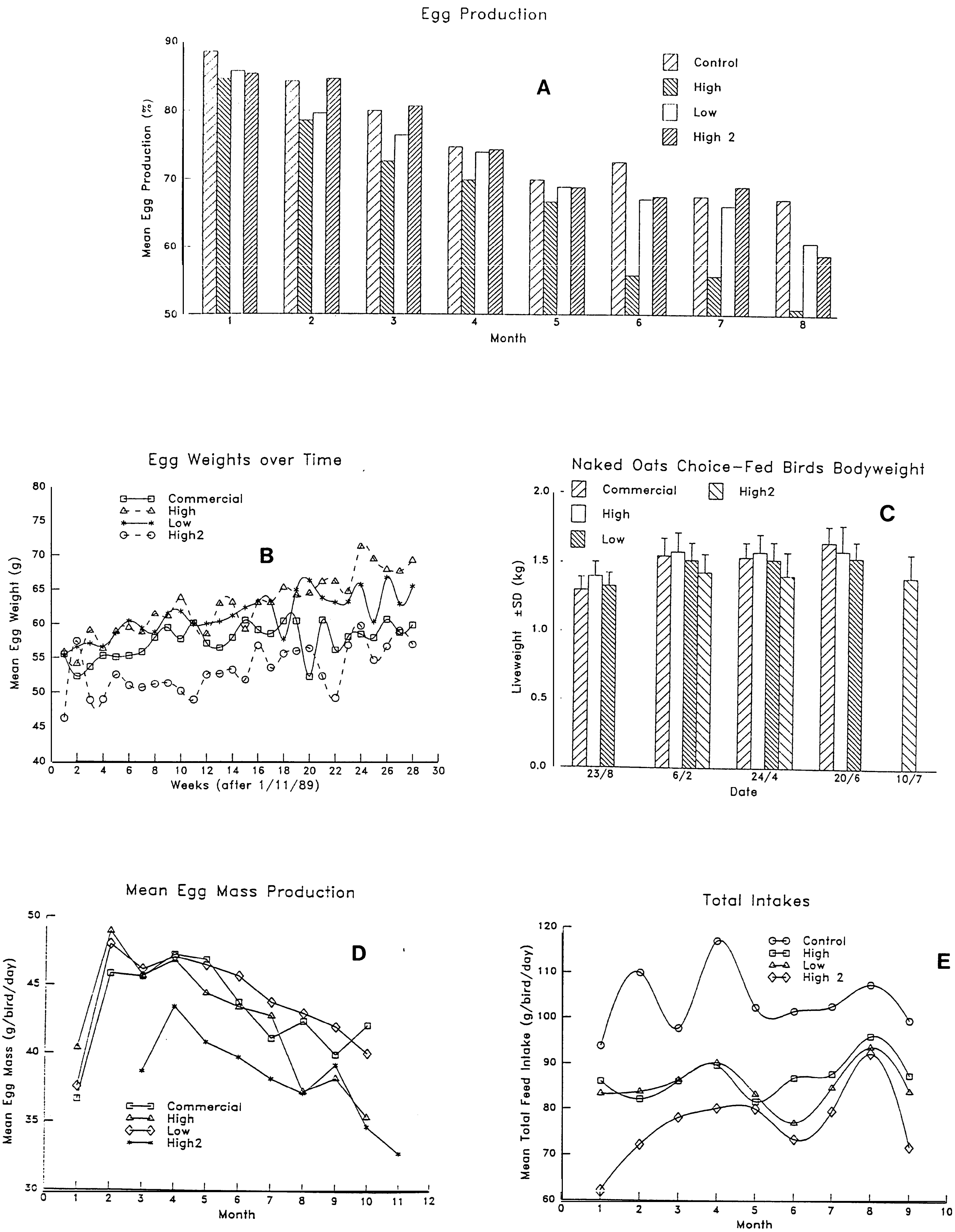

Fig. **2** Mean monthly egg production (A), egg weights **(B)** and bodyweights (C), egg mass (D) and total feed intake (E) of 10 individually caged birds on a commercial diet and self selection of naked oats and high (H) or low (L) protein concentrates. H_2 is a second group of birds on diet H.

Layer experiments

Experiment 1 The mean (±SEM) metabolizable energy (MJ/kg DM) of the NO was 14.77 (±0.089), of the concentrate H, 11.24 (±0.155) and of the concentrate L, 12.54 (±0.098). Crude protein contents (%) were 16.8, 35.4 and 28.0 ('as is' basis) respectively.

There was a significant effect ($P<0.01$) of diet and month on egg production. The control diet gave a significantly higher overall mean production (72.9%) than did diets H (65.3%) and H_2 (63.6%) but similar to L (70.7%). Peak production (%) was 87 (control), H, 91; L, 86 and H_2, 84.

Mean monthly egg production is given in Fig. 2A. This was consistently lower on the H_2 diet and declined rapidly on diet H during the last 3 months of production.

The pattern of egg weights for the final 30 weeks of production is shown in Fig. 2B. Eggs from birds on the H and L diets were consistently heavier than eggs from hens on the control diet and also on the H2 diet. The likely reason for this is (1) that NO are high in oil and in linoleic acid and (2) birds on the H_2 diet were consistently lighter in bodyweight than other groups. On the 24/4 they weighed 1.4 kg and about 200 g less than the other groups. H_2 birds had lost weight between 6/2 and the end of the experiment (Fig. 2C).

When data are calculated as daily egg mass output (Fig. 2D), it can be seen that egg mass on the commercial diet and the L diet was similar. H2 was consistently below that of other diets, and the decline in egg mass output on diet H was substantial after month 7 and after month 9 on diet H2.

There were overall differences ($P<0.05$) in daily intakes of naked oats by choice-fed birds between treatments. Birds on diets H and H_2 had similar mean daily intakes of 53.9 and 53.2 g and birds on diet L the lowest ($P<0.05$) of 49.8. Intake of concentrate was highest on L (26.7 g) and similar on H and H2 (24.5 and 24.1 g).

Mean total daily feed intakes (g) over the 10 months were 93.1, 78.3, 76.5 and 77.2 for birds on the commercial diet, and on H, L and H2 diets respectively. These correspond to daily ME (MJ) intakes of 1.02, 0.96, 0.97 and 0.95. The commercial diet and diet H_2 were different ($P<0.05$) from the other two diets; diets H and L, were similar. Average daily feed intakes for each month are shown in Fig. 2E.

Interestingly the contribution of the concentrates H and H2 to the total ME intake were 25.6 and 24.7% respectively. The contribution of the concentrate L which had a higher ME than H, was 31.3%. There was a diet x month interaction.

The intakes of crude protein (g/d) were significantly more ($P<0.05$) on choice feeding regimes than on the commercial diet (17.2 g/d). Of the NO diets, H (22.0 g) was more ($P<0.05$) than L (20.2 g) or H_2 (19.3 g). These latter

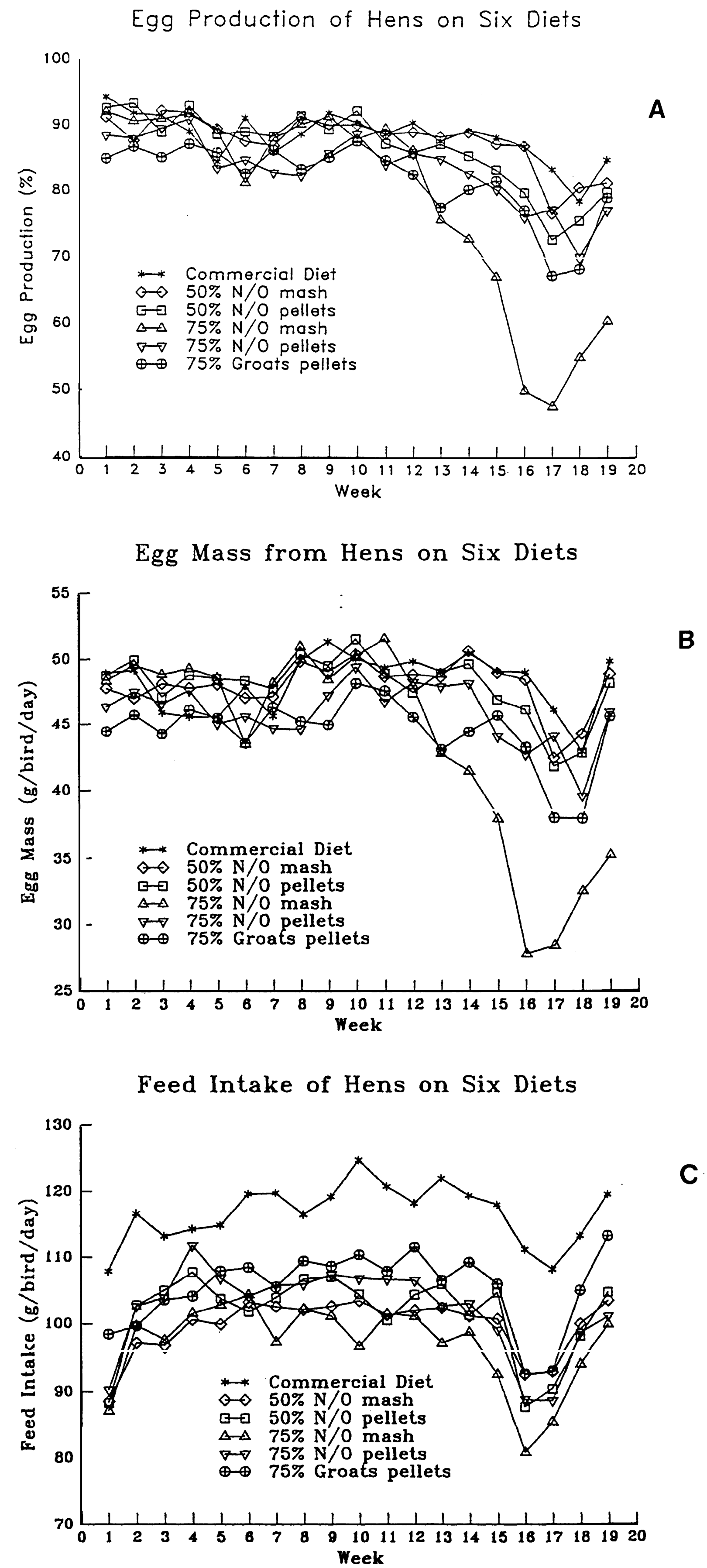

Fig. 3 Egg production (A), egg mass (B) and daily feed intake (C) of groups of 4 replicates each of 10 birds on one of six diets (See Table 1 for details) from 30 to 49 weeks of age.

differences were in part due to differences in NO consumption (g/d) as well as to the higher ($P<0.05$) daily concentrate intake of birds on H diet (12.5 g **CP)** compared with diets L (10.9 g CP) and H2 (10.3 g CP) which were the same.

Specific gravity (SG) of eggs measured monthly did not show any differences due to treatment. However for all diets, SG declined gradually with time and to below 1.07 during month 6 At the end of the experiment the overall mean SG was 1.077 compared to 1.087 at the start.

Statistical analyses are shown for each parameter in Table 9.

TABLE 9 Statistical data for layer Experiment 1

Parameter	Statistical significance		
	Month	Diet	Month x Diet
Egg production	***	***	NS
Egg mass	***	***	NS
Feed intake			
Oats	**	***	NS
Concentrate	***	***	**
Total	***	***	-
Crude protein intake			
Oats	***	***	NS
Concentrate	***	***	***
Total	***	***	***
Metabolizable energy intake			
Oats	***	***	NS
Concentrate	***	***	**
Total	***	***	NS
Concentrate (% total)	***	***	***

Layer experiment 2 The experiment ran for 19 weeks and mean production parameters are shown in Table 10. Pattern of egg production is shown in Fig. 3A. It is evident that the NO 75% diet in mash form gave a marked reduction in egg production after week 12. This was much less evident on the diets with 75% NO or 75% oat groats when pelleted. Mean egg production exceeded 86% on the commercial and on the 50% NO diet in mash and pelleted form but was reduced to 78-83% on the other diets. Average daily intake was higher ($P<0.01$) on the commercial diet (116 g/d) compared to the other diets (Table 10). Mean intakes were 100 g/d on the 50% NO diet (mash) and 105 g/d on the 75% oat groat diet (pellets). Mean intake tended to be higher on the NO in pelleted compared to mash form by 2-5 g/d (Table 10). Weekly pattern of egg mass and feed intake are shown in Fig 3B and 3C respectively.

Table 10 Mean production parameters of layers over 19 weeks given diets containing naked oats in mash (M) or pelleted (P) form and compared with a commercial layer diet and a diet containing 75% oat groats

	Commercial	Naked oats (%)				Groats	LSD
		50%		75%		75%	
	(M)	(M)	(P)	(M)	(P)	(P)	(P<0.05)
Feed intake (g/d)	117	100	102	97	102	105	2.13
Egg production (%)	88.2	87.6	86.4	78.8	83.2	81.6	1.66
Egg weight (g)	54.7	54.8	55.6	55.8	55.2	54.5	0.60
Egg mass (g)	48.2	48.0	48.0	43.8	45.9	44.5	1.04
Feed efficiency (kg/kg)	2.4	2.1	2.1	2.3	2.2	2.4	0.06

Egg size was significantly larger ($P<0.05$) on NO 50% (mash) and NO 75% (mash and pellets) but not on the oat groats diet. However daily egg mass (g/d) was 48.2 on the commercial diet. This was similar to the NO 50% diets but greater ($P<0.01$) than on the 75% NO and groat-based diets (Table 10).

Feed efficiency was better ($P<0.05$) on all diets except for oat groats compared to the commercial diet. NO 50% diets had a significantly lower ($P<0.05$) feed efficiency in both mash (2.08) and pelleted (2.12) form compared to other NO and oat groat diets (Table 10).

DISCUSSION

The chemical composition of NO is attractive, particularly the high levels of oil and the constant linear relationship between lysine or threonine and crude protein in NO (Fig. 1). This is unlike many other cereal grains in which several essential amino acids, when expressed as a percent of crude protein, decrease (Johnson et al. 1970) with increasing protein content.

The levels of naked oats used in these experiments are generally higher than would be used in commercial practice. These high levels are necessary in order to identify any difficulties related either to anti-nutritive factors or to the incorporation of NO in poultry diets. It is clear that at high levels of inclusion, pelleting NO diets improves intake and hence performance, while for broilers pelleting at any inclusion level enhanced performance over mash diets.

Although diets for chick growth experiments were cold-pelleted, it is possible that the heat generated may have partially inactivated some anti-nutritive factor in the NO. In addition, the inclusion of NO in mash diets may reduce their acceptability since the NO when milled seemed to form a fine powder.

The increase in ME of NO as chickens get older is apparently due in part to their improved ability to digest the oil in the NO (Tables 3 and 4) and perhaps to other factors. The ME of wheat, without enzyme, also increased with age (Table 8), probably due to increased capacity of birds to ferment the non-starch polysaccharides (Annison 1990). Johnson (1987) showed quite clearly a similar trend for a wide range of feedstuffs.

Maurice et al. (1985) reported a ME value for NO of 13.31 MJ/kg DM. This is less than reported here (Table 3) where they ranged between 14.8 and 15.2 MJ/kg for young chickens. When Maurice et al. (1985) fed broilers incremental amounts of NO in broiler diets, a growth depression was observed in birds at inclusion rates in excess of 40% at 3 and 7 weeks of age. However FCR was unaffected. It was not stated if the diets were in mash form but it appears that this was the case. The authors ascribed this depression in growth to a high phytic acid content of the NO soybean diet causing a phosphorus deficiency. Cave and Burrows (1985) also observed a depression in broiler chickens grown 28 to 48 days on diets with 0, 30% and 60% No. Again a depression in growth rate and FCR was observed at the highest inclusion of NO.

A detailed study of NO was undertaken recently by Cave et al. (1990). When broilers were grown on mash NO based diets there was a significant decline in feed intake, weight gain and an increase in FCR of broilers grown for 1-28 days. The addition of ß-glucanase (2.5g/kg diet) improved growth rate of broilers (8-20 days) on a diet containing 60% NO, but other additions of penicillin, EDTA or autoclaving the oats did not improve performance convincingly. Cave et al. (1990) were unable to demonstrate any increase in ME of NO with enzyme addition measured as true metabolizable energy. Nevertheless they concluded that the ß-glucans were responsible for the depression in growth and that phytase was not a factor.

There is little published information on the use of oat groats in the diets of layers. Karunajeewa and Tham (1987) reported on the changes in fatty acid content of eggs from hens on diets with up to 700g/kg of oat groats but not on production parameters.

The use of an experimental bantamised layer may have obscured the true picture in Experiment 1. There were marked differences between the performance of the two batches of birds given the same concentrate package (H). W.S. Stanhope (pers. comm 1989) indicated that differences in bodyweight of pullets at point-of-lay can result in differences in subsequent laying performance.

Our findings here suggest that the prospects of using NO as a complete feed for poultry are considerable. One of the difficulties is the imbalance between the very high ME value of NO and amino acid concentrations. This reduces feed intake in layers resulting in a decrease in the intake of several essential amino acids. These are not insurmountable constraints. In broilers it is unlikely that, in practice, NO would be used as the sole grain source. We have demonstrated that by pelleting the NO diet and by adding appropriate enzymes, NO can be the sole grain source. We stress that there is a need for more extensive production trials.

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