# HOW WELL DO LAYERS DISCRIMINATE GIVEN CHOICES OF GRAIN AND PROTEIN CONCENTRATE?

D.J. Farrell*, W. Ball*, E. Thomson*, R.E. Abdelsamie**
and G.M. Pesti

## SUMMARY

An experiment was undertaken in which two strains of layers in multiple bird (6) cages were given in a 3-trough system choices of grain sorghum, wheat-13% CP and wheat-16% CP in combination with three 'protein packages' based on full-fat soybeans, sweet lupin meal and field peas in mash or pellet form. Shell grit was offered in a separate trough. A commercial 17% layer crumbles fed in a single trough was the control diet. Mortality, due mainly to vent pecking, was 24% for the SCWL (Red) birds and only 12% for the Black Australorp (SIROCB) (Black) birds. The latter strain consumed more feed than did the Red birds but the mean overall hen-day egg production (HDP) on the choice feeding system was 75% vs. 69%. There was wide variation in response to combinations with some individual treatments giving low intakes and performance eg. pelleted peas (25g/d) with sorghum fed to Red birds gave HDP of only 47%. Intake of the 'concentrate package' was consistently higher in mash (54g/d) form compared with pellets (38g/d). HDP was lowest on the sorghum-based combinations (70.2%) but it was not different on the 'protein package'-based combinations (72%). Total protein intakes were generally excessive and wide ranging, with all but two above 20g/d consequently lysine, methionine and total sulfur amino acids were invariably in excess of requirements.

The commercial diet gave mean productions of 76% for both strains. Black birds consumed 14g/d more than Red birds this included intakes of 7.6 and 4.1g/d respectively of shell grit. Gross margin per bird was $13.25 (Black birds) and $14.07 (Red birds) on the commercial diet. Individual combinations ranged from $15.50 to $8.34. It is concluded that there is considerable scope to fine-tune self-selection programs for layers in order to utilize this approach in a practical feeding system.

## INTRODUCTION

Providing broilers and layers with a choice of feed ingredients has been the subject of several investigations over many years (see Karunajeewa 1978; Tauson and Elwinger 1986; Rose et al. 1986; Cumming et al. 1987). Although there is some disagreement among workers about the possible benefits of a free-choice feeding system for poultry, there are several good theoretical reasons why it should be considered. First, there is normally no need to process grains in a self-selection program in which the choice is between a grain or a grain mixture and a protein concentrate supplement. Secondly, it

*Department of Biochemistry, Microbiology and Nutrition, University of New England, Armidale, NSW 2351
Present address: **P 0. Box 28, IDP/IPB Project, Bogor, Indonesia
+Department of Poultry Science, University of Georgia, Athens, GA 30602

is postulated that birds will adjust their nutrient intake according to level of production and environmental conditions particularly at hot temperatures (Scott and Balnave 1988; Scott and Balnave 1989). Thirdly birds can adjust to variation in grain protein by altering grain consumption. It follows that economic benefits will accrue from reduced energy input required to process the diets and from a likely reduction in the overconsumption of expensive dietary nutrients.

R. Horn (pers. comm 1987) reported that free-choice fed birds, using a single trough system (semi-choice feeding), gave an increased profit of $0.92 per bird over those fed a conventional layer mash diet at 70 weeks of age. Profit may be substantially more in warm weather (I. Littleton, pers. comm.).

The purpose of this paper is to report results of a self-selection experiment in which two strains of layers were given a choice of three grains and three protein concentrates in all combinations. Shell grit was provided separately. A commercial diet was used as the control.

## MATERIALS AND METHODS

One-day-old pullets were purchased from two commercial hatcheries and raised according to supplier recommendations on a 16% crude protein (CP) pullet starter mash (Fielders Agricultural Products, Tamworth, N.S.W.) in floor pens each holding about 80 birds. The two strains used were New Hampshire x single comb White Leghorns (Red) and a Black Australorp synthetic strain (SIRO CB).

Birds were fed restricted amounts of a pullet grower diet at about 12 weeks of age onward and were transferred to group battery cages (6 birds/cage) at 18 weeks. During the last two weeks of rearing some pens of pullets were offered whole grain sorghum and a protein concentrate in separate feed troughs to accustom them to a free-choice feeding system.

### Housing and management

The group cages were located in an enclosed sawtoothed layer shed running east-west (lengthways) and holding about 4,500 birds, ventilation was provided by an open space of 1 - 1.5 m between roof and walls. This space may be controlled by blinds which can be lowered to 6 cm above the ground. Birds were managed as far as possible according to standard commercial practice, Feed troughs were divided crossways into three sections per cage to allow separate feeding of whole grain, concentrate and shell grit. Control birds were offered a commercial diet with the addition of shell grit in a single feed trough. Water was provided by three nipple drinkers per cage.

### Diets

These were offered free choice. There were three grains: either a 13% CP wheat, a 16% CP wheat or grain sorghum (11% CP). The three 'protein packages' (concentrates) were based on either sweet lupins, extruded full-fat soybeans or field peas (Table 1) and formulated using a least cost computer program (Mixit II, version 2.4). The composition of the 'protein package' was estimated to complement the grains by contributing amino acids and all of the added yolk pigment, vitamins and minerals, except for calcium. These calculations were based on the assumption that intake of concentrate (g) would be 33% of the total predicted feed intake of 110g/d per bird. The concentrate package was offered in either a pelleted or mash form. Six group cages of each strain of bird were offered a standard commercial layer crumbled diet (17% CP) supplied by Fielders Agricultural Products, Tamworth, N.S.W.

TABLE 1. Ingredient (g/kg) and chemical composition of three 'protein packages' and three grains on an 'as is' basis.

| Protein package | Sweet lupins | Field peas | Full-fat soybean |
|---|---|---|---|
| Sweet lupins | 700 | | |
| Field peas | | 700 | |
| Full-fat soybeans | | | 705 |
| Meat & bone meal | 250 | 250 | 250 |
| D-L methionine | 5 | 5 | 5 |
| L-lysine | 5 | 5 | |
| Calcium carbonate | 35 | 35 | 35 |
| Mineral & vitamin pre mix | 5 | 5 | 5 |
| **Analysis** | | | |
| Metabolizable energy (MJ/kg) | 10.44 | 10.28 | 12.92 |
| Crude protein (g/kg) | 342 | 292 | 441 |
| Methionine (g/kg) | 7.8 | 8.0 | 10.7 |
| Total sulfur aa (g/kg) | 12.5 | 11.8 | 16.5 |
| Lysine (g/kg) | 23.7 | 21.5 | 24.4 |
| **Grain** | Wheat-13 | Wheat-16 | Sorghum |
| Metabolizable energy (MJ/kg) | 12.7 | 12.5 | 13.6 |
| Crude protein (g/kg) | 132 | 162 | 110 |
| Methionine (g/kg) | 2.0 | 2.4 | 1.7 |
| Total sulfur aa (g/kg) | 4.5 | 5.8 | 4.0 |
| Lysine (g/kg) | 3.4 | 4.4 | 2.9 |

## Measurements

Feed consumption was measured using specially designed metal scoops preweighed at least 10 times and checked regularly for each of the separate diet components. Residual feed in troughs was weighed back every 2 weeks. Egg numbers were recorded daily and weighed and graded once weekly according to the N.S.W. Egg Marketing Board's categories for 1987. Specific gravity was used to estimate shell quality in saline solutions (Voisey and Hamilton 1987) at intervals of 10 weeks.

Mortality was recorded daily and minimum and maximum shed temperatures were taken at three locations each day. Bodyweight was measured at the start and end of the experiment.

## Economic and statistical measurements

Dietary ingredients were priced at those reported in the Australian Poultry Digest (Richard Milne Pty. Ltd., Sydney) for May/June 1987, and eggs at the prices for the various grades paid to producers by the NSW Egg Marketing Board for August 1987. These prices were not varied throughout the experiment which ran for 40 weeks of lay.

Data were analysed using an analysis of variance. Duncan's multiple range test was used to separate differences ($P < 0.05$) between means (Steel and Torrie 1960).

The design of the experiment was 3 grains x 3 'protein packages' x 2 diet forms x 2 strains of birds x 6 replicates each of 6 birds. For each strain there were 6 additional replicates on a commercial diet.

Gross margin was calculated as the difference between the price of eggs minus feed costs. Estimates did not include cost of pelleting the concentrate packages nor any additional costs associated with self-selection programs.

## Chemical analysis

Metabolizable energy (ME) was determined on each grain and each 'protein package' using adult cockerels and the rapid method of Farrell (1978) and Farrell et al. (1988). Crude protein was determined for each grain and each 'protein package' using a micro Kjeldahl method. Except for grain sorghum, amino acid analysis was undertaken on each grain and each protein source including the meat and bone meal used (see Table 1). These values were used to calculate daily ME, crude protein and some amino acid intakes on the various dietary combinat ions. Tabled values were used to calculate amino acid content of the sorghum grain.

## RESULTS

The experiment commenced in late July 1987 and terminated 40 weeks later. Shed temperatures are shown in Fig. 1.
Mortality for each strain was much higher for the Red than for the Black birds (Fig. 2). During the entire experiment mortality was 12% for the Black birds and 24% for Red birds, The main cause of mortality in Red birds was vent pecking .

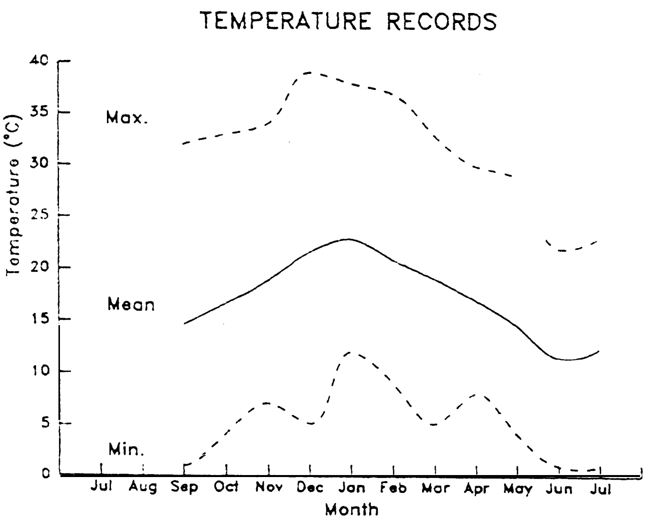


Fig. 1 Mean, minimum and maximum shed temperatures during the experiment which commenced in July 1987 and ran for 40 weeks.

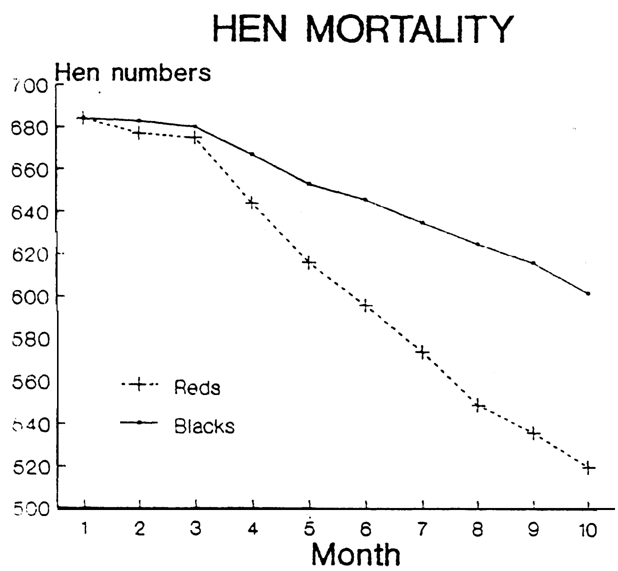


Fig. 2 Mortality of each strain during the 40 weeks of lay. Graph shows the decline in layer numbers.

Some difficulty was encountered in pelleting the full-fat sobyean meal 'package' and the pellets were fragile. Crumbling of pellets was reduced however by handling this feed with care.

Results of production performance, feed intake and gross margin for each strain for each ingredient combination are given in Table 2.

Overall means of the main effects of dietary ingredients on different parameters are given in Table 3. Analysis of variance of these data are given in Table 4.

TABLE 2 Daily intakes per bird of grain, protein concentrate and shell grit, liveweight change, egg production parameters, feed efficiency and gross margin of two strains of layers on various choices of grain and protein concentrate packages during 40 weeks of lay.

| Breed | Diet form | Grain | Protein | Feed intake Grain (g) | Feed intake Conc. (g) | Grit | total (g) | Live weight (kg) Start | Live weight (kg) Finish | Live weight (kg) Change | Hen day production (%) | Egg weight (g) | Specific gravity Start | Specific gravity Finish | Feed (kg) /12 eggs (g) | Feed (kg) egg/kg | Gross margin $/bird |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black | M | Wheat 12 | Lupins | 82.6 | 51.0 | 10.3 | 143.9 | 1.527 | 2.125 | 0.559 | 79.0 | 56.6 | 1.089 | 1.074 | 2.18 | 3.22 | 15.36 |
| Red | M | Wheat 12 | Lupins | 71.2 | 50.9 | 8.3 | 130.4 | 1.414 | 2.015 | 0.601 | 72.9 | 58.9 | 1.086 | 1.073 | 2.15 | 3.04 | 14.55 |
| Black | P | Wheat 12 | Lupins | 95.8 | 39.1 | 10.4 | 145.3 | 1.578 | 2.135 | 0.557 | 73.0 | 56.2 | 1.088 | 1.076 | 2.40 | 3.55 | 13.25 |
| Red | P | Wheat 12 | Lupins | 80.5 | 34.6 | 8.2 | 123.2 | 1.428 | 2.058 | 0.631 | 62.8 | 59.0 | 1.087 | 1.074 | 2.38 | 3.37 | 12.26 |
| Black | M | Wheat 12 | Peas | 69.8 | 63.1 | 7.4 | 140.3 | 1.554 | 2.237 | 0.682 | 79.1 | 56.0 | 1.089 | 1.076 | 2.13 | 3.17 | 14.70 |
| Red | M | Wheat 12 | Peas | 61.2 | 64.0 | 6.1 | 131.3 | 1.393 | 1.998 | 0.606 | 77.8 | 58.9 | 1.084 | 1.072 | 2.01 | 2.84 | 15.05 |
| Black | P | Wheat 12 | Peas | 90.5 | 35.9 | 9.5 | 135.9 | 1.569 | 2.033 | 0.465 | 73.2 | 56.1 | 1.088 | 1.073 | 2.23 | 3.32 | 13.94 |
| Red | P | Wheat 12 | Peas | 78.1 | 30.6 | 6.2 | 114.9 | 1.414 | 1.780 | 0.367 | 62.2 | 58.3 | 1.085 | 1.075 | 2.28 | 3.27 | 12.35 |
| Black | M | Wheat 12 | Beans | 75.4 | 39.8 | 9.0 | 124.1 | 1.543 | 2.078 | 0.535 | 75.1 | 56.1 | 1.087 | 1.075 | 1.99 | 2.95 | 11.99 |
| Red | M | Wheat 12 | Beans | 65.6 | 37.9 | 8.2 | 111.6 | 1.380 | 1.993 | 0.614 | 69.1 | 59.7 | 1.087 | 1.074 | 1.95 | 2.73 | 11.41 |
| Black | P | Wheat 12 | Beans | 86.3 | 36.9 | 11.1 | 134.3 | 1.559 | 2.120 | 0.561 | 75.6 | 57.3 | 1.090 | 1.072 | 2.15 | 3.13 | 12.23 |
| Red | P | Wheat 12 | Beans | 67.7 | 36.7 | 8.3 | 112.7 | 1.345 | 1.918 | 0.573 | 72.6 | 57.6 | 1.086 | 1.074 | 1.86 | 2.70 | 11.81 |
| Black | M | Wheat 16 | Lupins | 77.6 | 55.7 | 9.5 | 142.7 | 1.423 | 2.108 | 0.686 | 81.9 | 56.1 | 1.088 | 1.075 | 2.09 | 3.10 | 15.50 |
| Red | M | Wheat 16 | Lupins | 75.3 | 46.9 | 8.8 | 131.0 | 1.412 | 1.980 | 0.569 | 74.8 | 58.9 | 1.084 | 1.072 | 2.10 | 2.97 | 14.25 |
| Black | P | Wheat 16 | Lupins | 87.2 | 36.7 | 9.5 | 133.4 | 1.538 | 1.907 | 0.369 | 69.9 | 56.1 | 1.087 | 1.074 | 2.30 | 3.42 | 12.75 |
| Red | P | Wheat 16 | Lupins | 73.1 | 29.1 | 7.3 | 109.5 | 1.438 | 1.882 | 0.444 | 60.0 | 57.8 | 1.084 | 1.074 | 2.20 | 3.17 | 11.41 |
| Black | M | Wheat 16 | Peas | 70.2 | 67.6 | 8.3 | 146.1 | 1.557 | 2.228 | 0.671 | 81.2 | 55.3 | 1.087 | 1.074 | 2.16 | 3.25 | 14.26 |
| Red | M | Wheat 16 | Peas | 56.7 | 65.4 | 6.3 | 128.4 | 1.419 | 2.058 | 0.639 | 80.1 | 59.4 | 1.085 | 1.071 | 1.92 | 2.69 | 15.09 |
| Black | P | Wheat 16 | Peas | 80.3 | 42.5 | 9.1 | 132.0 | 1.554 | 2.208 | 0.654 | 68.3 | 55.1 | 1.087 | 1.076 | 2.36 | 3.58 | 11.89 |
| Red | P | Wheat 16 | Peas | 70.3 | 33.6 | 9.0 | 112.8 | 1.415 | 1.840 | 0.425 | 65.3 | 57.8 | 1.085 | 1.076 | 2.08 | 3.00 | 12.63 |
| Black | M | Wheat 16 | Beans | 75.1 | 38.3 | 9.1 | 122.5 | 1.621 | 2.145 | 0.525 | 75.0 | 56.8 | 1.088 | 1.074 | 1.96 | 2.87 | 11.84 |
| Red | M | Wheat 16 | Beans | 58.5 | 45.4 | 8.4 | 112.3 | 1.434 | 2.022 | 0.588 | 75.8 | 58.3 | 1.085 | 1.074 | 1.78 | 2.54 | 12.42 |
| Black | P | Wheat 16 | Beans | 77.8 | 41.4 | 11.8 | 131.0 | 1.555 | 2.077 | 0.522 | 76.2 | 56.5 | 1.088 | 1.076 | 2.06 | 3.04 | 11.60 |
| Red | P | Wheat 16 | Beans | 63.6 | 37.2 | 10.9 | 111.6 | 1.378 | 1.938 | 0.561 | 70.8 | 57.5 | 1.086 | 1.076 | 1.89 | 2.74 | 11.41 |
| Black | M | Sorg | Lupins | 73.3 | 62.8 | 12.4 | 148.5 | 1.505 | 2.103 | 0.599 | 77.6 | 55.8 | 1.089 | 1.076 | 2.29 | 3.42 | 14.21 |
| Red | M | Sorg | Lupins | 65.5 | 55.9 | 7.6 | 129.0 | 1.427 | 2.012 | 0.584 | 72.2 | 58.9 | 1.086 | 1.075 | 2.14 | 3.03 | 14.09 |
| Black | P | Sorg | Lupins | 77.3 | 53.6 | 9.6 | 140.4 | 1.506 | 2.175 | 0.669 | 77.0 | 57.1 | 1.087 | 1.075 | 2.18 | 3.19 | 15.07 |
| Red | P | Sorg | Lupins | 72.5 | 38.3 | 6.6 | 117.4 | 1.444 | 2.012 | 0.568 | 63.1 | 58.9 | 1.085 | 1.073 | 2.22 | 3.15 | 12.52 |
| Black | M | Sorg | Peas | 69.9 | 67.7 | 8.2 | 145.8 | 1.580 | 2.223 | 0.644 | 76.9 | 57.3 | 1.087 | 1.076 | 2.27 | 3.30 | 14.30 |
| Red | M | Sorg | Peas | 50.8 | 74.7 | 5.2 | 130.7 | 1.414 | 2.025 | 0.611 | 79.3 | 59.4 | 1.085 | 1.072 | 1.97 | 2.77 | 15.36 |
| Black | P | Sorg | Peas | 73.1 | 56.0 | 7.6 | 136.7 | 1.516 | 2.110 | 0.594 | 76.7 | 56.7 | 1.088 | 1.076 | 2.13 | 3.13 | 14.57 |
| Red | P | Sorg | Peas | 71.3 | 24.8 | 5.1 | 101.2 | 1.424 | 1.795 | 0.371 | 46.6 | 56.1 | 1.085 | 1.076 | 2.66 | 3.95 | 8.34 |
| Black | M | Sorg | Beans | 70.7 | 42.0 | 9.6 | 122.3 | 1.520 | 2.053 | 0.534 | 69.5 | 55.8 | 1.089 | 1.076 | 2.12 | 3.17 | 10.75 |
| Red | M | Sorg | Beans | 56.6 | 40.0 | 8.6 | 105.2 | 1.374 | 1.980 | 0.606 | 67.7 | 57.5 | 1.084 | 1.077 | 1.87 | 2.71 | 10.86 |
| Black | P | Sorg | Beans | 79.1 | 39.6 | 11.7 | 130.4 | 1.565 | 2.180 | 0.615 | 68.5 | 56.0 | 1.090 | 1.077 | 2.30 | 3.42 | 9.90 |
| Red | P | Sorg | Beans | 66.1 | 36.8 | 11.2 | 114.2 | 1.402 | 2.077 | 0.675 | 66.8 | 56.7 | 1.087 | 1.077 | 2.07 | 3.05 | 10.20 |
| SEM | | | | 3.69 | 3.61 | 0.89 | 4.42 | 0.012 | 0.019 | 0.015 | 3.15 | 0.70 | 0.003 | 0.003 | 0.09 | 0.11 | 0.28 |
| Black | Commercial Feed | | | 132.5 | 0.0 | 7.6 | 140.1 | 1.525 | 2.282 | 0.757 | 76.3 | 57.0 | 1.090 | 1.074 | 2.20 | 3.21 | 13.24 |
| Red | Commercial Feed | | | 121.9 | 0.0 | 4.1 | 126.0 | 1.428 | 2.075 | 0.647 | 76.4 | 59.5 | 1.086 | 1.074 | 1.98 | 2.77 | 14.07 |

TABLE 3. Mean (± SD) main effects of wheat (12% CP W-12, W-16% CP) (W-16), and sorghum (Sorg) when combined with three 'protein packages' based on extruded soybeans (SBM), sweet lupins (LUP) and field peas (PEA) in mash (M) or pelleted (P) form on intakes of grain, protein concentrate and grit and their effects on egg production and feed efficiency.

| Grain | Concen-trate | Grain intake (g/d) | Intake: Concentrate (g/d) | Intake: Grit (g/d) | Intake: Total (g/d) | Hen-day production (%) | Kg feed/ 12 eggs | Egg weight (g) | Feed (kg) /egg mass (kg) | Gross margin ($) |
|---|---|---|---|---|---|---|---|---|---|---|
| Sorg | SBM | 68.1 (11.4) | 36.9 ( 6.6) | 10.4 (2.4) | 118.1 (11.6) | 68.2 ( 7.1) | 2.1 (0.2) | 56.5 (1.9) | 3.1 (0.4) | 10.43 (1.53) |
| Sorg | LUP | 72.2 ( 7.9) | 52.6 ( 3.7) | 9.1 (3.7) | 133.8 (14.8) | 72.5 ( 7.6) | 2.2 (0.1) | 57.7 (1.9) | 3.2 (0.2) | 14.00 (1.40) |
| Sorg | PEA | 66.3 (12.4) | 55.8 (20.9) | 6.6 (1.8) | 128.7 (20.0) | 69.9 (14.8) | 2.3 (0.4) | 57.4 (2.1) | 3.3 (0.6) | 13.15 (3.12) |
| W-12 | SBM | 73.7 (11.9) | 37.8 ( 6.8) | 9.2 (1.8) | 120.7 (12.4) | 73.1 ( 7.2) | 2.0 (0.2) | 57.7 (1.8) | 2.9 (0.4) | 11.86 (1.45) |
| W-12 | LUP | 82.5 (10.0) | 43.9 (11.2) | 9.3 (1.8) | 135.7 (12.0) | 72.0 ( 9.5) | 2.3 (0.2) | 57.7 (1.9) | 3.3 (0.3) | 13.86 (2.09) |
| W-12 | PEA | 74.9 (14.1) | 48.4 (17.5) | 7.4 (1.8) | 130.5 (15.0) | 73.1 (10.2) | 2.2 (0.3) | 57.4 (2.0) | 3.2 (0.4) | 14.01 (2.11) |
| W-16 | SBM | 68.7 (11.9) | 40.6 ( 7.3) | 10.1 (2.2) | 119.4 (10.5) | 74.5 ( 4.8) | 1.9 (0.2) | 57.3 (1.2) | 2.8 (0.3) | 11.82 (1.13) |
| W-16 | LUP | 78.3 (9.6) | 42.1 (13.0) | 8.8 (1.8) | 129.2 (17.4) | 71.7 (11.1) | 2.2 (0.2) | 57.3 (1.8) | 3.2 (0.3) | 13.48 (2.33) |
| W-16 | PEA | 69.4 (11.7) | 52.3 (17.6) | 8.2 (3.0) | 129.9 (16.3) | 73.8 (11.1) | 2.1 (0.2) | 56.9 (2.5) | 3.1 (0.5) | 13.47 (2.29) |
| Concen -trate | form | | | | | | | | | |
| SBM | M | 67.0 (11.0) | 40.6 ( 6.7) | 8.7 (1.2) | 116.4 ( 9.4) | 72.1 ( 6.7) | 2.0 (0.2) | 57.4 (1.8) | 2.8 (0.3) | 11.54 (1.45) |
| SBM | P | 73.0 (11.9) | 38.1 ( 7.1) | 10.9 (2.5) | 122.4 (12.5) | 71.8 ( 7.2) | 2.1 (0.2) | 57.0 (1.6) | 3.0 (0.4) | 11.20 (1.58) |
| LUP | M | 74.2 ( 7.8) | 53.9 ( 9.6) | 9.5 (3.0) | 137.6 (10.6) | 76.5 ( 6.0) | 2.2 (0.1) | 57.6 (1.9) | 3.1 (0.2) | 14.68 (1.24) |
| LUP | P | 81.1 (11.0) | 38.6 (11.3) | 8.6 (2.0) | 128.2 (17.2) | 67.7 (10.2) | 2.3 (0.2) | 57.6 (1.8) | 3.3 (0.3) | 12.88 (2.08) |
| PEA | M | 63.1 (11.0) | 67.1 ( 8.4) | 7.0 (1.8) | 137.1 (11.9) | 79.1 ( 4.3) | 2.1 (0.2) | 57.8 (2.2) | 3.0 (0.3) | 14.80 (0.98) |
| PEA | P | 77.3 (11.1) | 37.2 (13.4) | 7.8 (2.7) | 122.3 (18.2) | 65.4 (13.6) | 2.3 (0.3) | 56.7 (2.1) | 3.4 (0.6) | 12.29 (3.00) |
| Wheat -12 | | $77.0^{a*}$ | $43.4^{b}$ | $8.6^{a}$ | $129.0^{a}$ | $72.8^{ab}$ | $2.15^{ab}$ | $57.6^{a}$ | $3.11^{ab}$ | $13.25^{a}$ |
| Wheat -16 | | $72.1^{b}$ | $45.0^{b}$ | $9.1^{a}$ | $126.2^{a}$ | $73.3^{a}$ | $2.08^{b}$ | $57.2^{a}$ | $3.04^{b}$ | $12.93^{a}$ |
| Sorghum | | $68.9^{c}$ | $49.4^{a}$ | $8.7^{a}$ | $126.9^{a}$ | $70.2^{b}$ | $2.19^{a}$ | $57.2^{a}$ | $3.19^{a}$ | $12.53^{b}$ |
| Lupins | | $77.6^{a}$ | $46.2^{b}$ | $9.1^{b}$ | $132.9^{a}$ | $72.1^{a}$ | $2.22^{a}$ | $57.6^{a}$ | $3.22^{a}$ | $13.78^{a}$ |
| Beans | | $70.2^{b}$ | $39.3^{c}$ | $9.9^{a}$ | $119.4^{b}$ | $71.9^{a}$ | $2.00^{b}$ | $57.2^{a}$ | $2.93^{b}$ | $13.45^{a}$ |
| Peas | | $70.2^{b}$ | $52.2^{a}$ | $7.4^{c}$ | $129.7^{a}$ | $72.3^{a}$ | $2.18^{a}$ | $57.3^{a}$ | $3.20^{a}$ | $11.37^{b}$ |
| Commercial diet (Black strain) | | | | 7.6 | 140.0 | 76.4 | 2.20 | 57.1 | 3.22 | 13.25 |
| Commercial diet (Red strain) | | | | 4.1 | 126.0 | 76.5 | 1.98 | 59.6 | 2.77 | 14.07 |

*Values with the same superscripts are not significantly different (P<0.05).

TABLE 4. Analysis of variance of main effects and interactions

| Source | DF | Intake: Grain | Intake: Concentrate | Intake: Shell grit | Intake: Feed | Hen day prod | Feed/ 12 eggs | Egg-weight | Feed/egg mass |
|---|---|---|---|---|---|---|---|---|---|
| Strain | 1 | ***[*] | *** | *** | *** | *** | *** | *** | *** |
| Grain | 2 | *** | *** | NS | NS | * | ** | NS | * |
| Concentrate | 2 | *** | *** | *** | *** | NS | *** | NS | *** |
| Form | 1 | *** | *** | * | *** | *** | *** | * | *** |
| Grain x conc. | 4 | NS | * | * | NS | NS | NS | NS | NS |
| Conc. x form | 2 | ** | *** | *** | *** | *** | NS | NS | NS |

[*] *** = P<0.001, ** = P<0.01, * = P<0.05, NS = not significant

Daily intakes of ME, protein and of some critical amino acids are given in Table 5.

Feed intake was consistently higher for the Black compared with the Red layers (Table 2). In most cases there was good agreement for the intakes of grain and protein concentrate for both strains on the same grain/protein combination. However there were some very low intakes. Red birds consumed only 24.8g/d of the field pea package in pelleted form with sorghum. The reason for this is unknown but is unlikely to be due to poor acceptability because of the high intake by Black birds on this ingredient combination. Hen day egg production was only 47% and this treatment should be ignored.

It is interesting that intake of the protein concentrate was consistently higher when in mash (53.9+2.8) than in pelleted (38.0+1.86) form.

Mean hen-day egg production varied from 60% on the Wheat-16 lupin (pellets) ingredient combination for Red birds to 82% on the Wheat-16 lupin ingredient combination (mash) for Black birds. Wheat-16 and field peas in mash form gave over 80% production for both strains. Egg production on the commercial diet was identical for both strains (76.5%) and this was higher than on any of the self selection corrbinations (main effects) shown in Table 3 When all self-selection treatment combinations are combined, Black birds produced more eggs (75.3+0.9%) compared to the Red birds (69.3+1.9%).

On the grain/concentrate combinations, intake of the full-fat soybean 'package' was consistently less than on the field peas and the sweet lupins (Table 3) due, in part to its higher determined ME content of 12.9 MJ kg compared to 10.4 and 10.3 MJ kg for sweet lupins and field peas respectively. Grain intake was highest with the sweet lupin 'package' and total feed intake was least on the soybean diets, Grain intakes were different, these ranged from 77g/d for Wheat 12 to 70g/d for sorghum. Mean total feed intakes for the three grain combinations were the same (Table 3). Shell grit varied between 7g and 10g/d. It did not differ on the grain combinations but was least on the field pea combinations (7.4g/d) and highest on the soybean corrbinations (9.9g/d). These grit intakes translate into about 2.6 to 3.5g calcium.

Hen-day egg production on the sorghum-based diets (70.2%) was lower than on the Wheat-16 based diets (73.3%) but did not differ for the three protein combinations.

Feed efficiency expressed either per kg or per 12 eggs was best for the Wheat-16 based combinations and the soybean corrbinations (Table 3).

Given the variation in gross margins, there was generally no clear

TABLE 5 Daily energy intakes (kJ/bird) from grain, protein concentrate package, and the contribution of lysine, methionine and sulfur amino acids from various choices of grain and protein concentrate packages for two strains during 40 weeks of lay.

| Breed | Diet form | Grain | Protein | ENERGY Grain ME (kJ) | Conc ME (kJ) | ME % grain | Total ME (kJ) | PROTEIN Grain (g) | Concentrate (g) | Concentrate (%) | Total (g) | LYSINE Grain (g) | Concentrate (g) | Concentrate (%) | Total (g) | METHIONINE Grain (g) | Concentrate (g) | Concentrate (%) | Total (g) | SULFUR AMINO ACIDS Grain (g) | Concentrate (g) | Concentrate (%) | Total (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black | M | Wheat 12 | Lupins | 1046 | 533 | 66 | 1579 | 10.9 | 17.5 | 62 | 28.4 | 0.28 | 1.21 | 82 | 1.49 | 0.17 | 0.40 | 71 | 0.56 | 0.37 | 0.64 | 63 | 1.01 |
| Red | M | Wheat 12 | Lupins | 901 | 532 | 63 | 1433 | 9.4 | 17.4 | 65 | 26.8 | 0.23 | 1.21 | 84 | 1.44 | 0.14 | 0.40 | 74 | 0.54 | 0.32 | 0.64 | 66 | 0.96 |
| Black | P | Wheat 12 | Lupins | 1213 | 408 | 75 | 1621 | 12.6 | 13.4 | 51 | 26.0 | 0.33 | 0.93 | 74 | 1.25 | 0.19 | 0.30 | 61 | 0.50 | 0.43 | 0.49 | 53 | 0.92 |
| Red | P | Wheat 12 | Lupins | 1019 | 361 | 74 | 1380 | 10.6 | 11.8 | 53 | 22.5 | 0.26 | 0.82 | 76 | 1.08 | 0.16 | 0.27 | 63 | 0.43 | 0.36 | 0.43 | 54 | 0.79 |
| Black | M | Wheat 12 | Peas | 884 | 649 | 58 | 1533 | 9.2 | 18.4 | 67 | 27.6 | 0.24 | 1.36 | 85 | 1.60 | 0.14 | 0.50 | 78 | 0.64 | 0.31 | 0.75 | 70 | 1.06 |
| Red | M | Wheat 12 | Peas | 775 | 659 | 54 | 1433 | 8.1 | 18.7 | 70 | 26.8 | 0.20 | 1.38 | 87 | 1.58 | 0.12 | 0.51 | 81 | 0.63 | 0.28 | 0.76 | 73 | 1.03 |
| Black | P | Wheat 12 | Peas | 1146 | 370 | 76 | 1515 | 11.9 | 10.5 | 47 | 22.4 | 0.31 | 0.77 | 72 | 1.08 | 0.18 | 0.29 | 61 | 0.47 | 0.41 | 0.43 | 51 | 0.83 |
| Red | P | Wheat 12 | Peas | 989 | 314 | 76 | 1303 | 10.3 | 8.9 | 46 | 19.2 | 0.26 | 0.66 | 72 | 0.91 | 0.16 | 0.24 | 61 | 0.40 | 0.35 | 0.36 | 51 | 0.71 |
| Black | M | Wheat 12 | Beans | 954 | 514 | 65 | 1468 | 9.9 | 17.7 | 64 | 27.6 | 0.26 | 0.97 | 79 | 1.23 | 0.15 | 0.43 | 74 | 0.58 | 0.34 | 0.66 | 66 | 1.00 |
| Red | M | Wheat 12 | Beans | 831 | 489 | 63 | 1320 | 8.7 | 16.8 | 66 | 25.5 | 0.22 | 0.92 | 81 | 1.14 | 0.13 | 0.40 | 76 | 0.54 | 0.30 | 0.63 | 68 | 0.92 |
| Black | P | Wheat 12 | Beans | 1093 | 477 | 70 | 1570 | 11.4 | 16.4 | 59 | 27.8 | 0.29 | 0.90 | 75 | 1.19 | 0.17 | 0.39 | 70 | 0.57 | 0.39 | 0.61 | 61 | 1.00 |
| Red | P | Wheat 12 | Beans | 857 | 474 | 64 | 1332 | 8.9 | 16.3 | 65 | 25.2 | 0.22 | 0.90 | 80 | 1.12 | 0.14 | 0.39 | 74 | 0.53 | 0.30 | 0.61 | 67 | 0.91 |
| Black | M | Wheat 16 | Lupins | 972 | 582 | 63 | 1553 | 12.6 | 19.0 | 60 | 31.6 | 0.34 | 1.32 | 79 | 1.66 | 0.19 | 0.43 | 70 | 0.62 | 0.45 | 0.70 | 61 | 1.15 |
| Red | M | Wheat 16 | Lupins | 943 | 490 | 66 | 1433 | 12.2 | 16.1 | 57 | 28.2 | 0.33 | 1.11 | 77 | 1.44 | 0.18 | 0.37 | 67 | 0.55 | 0.44 | 0.59 | 57 | 1.02 |
| Black | P | Wheat 16 | Lupins | 1092 | 383 | 74 | 1475 | 14.1 | 12.6 | 47 | 26.7 | 0.38 | 0.87 | 69 | 1.25 | 0.21 | 0.29 | 58 | 0.49 | 0.51 | 0.46 | 48 | 0.96 |
| Red | P | Wheat 16 | Lupins | 916 | 304 | 75 | 1220 | 11.8 | 10.0 | 46 | 21.8 | 0.32 | 0.69 | 68 | 1.01 | 0.18 | 0.23 | 56 | 0.40 | 0.42 | 0.36 | 46 | 0.79 |
| Black | M | Wheat 16 | Peas | 879 | 695 | 56 | 1574 | 11.4 | 19.7 | 63 | 31.1 | 0.31 | 1.46 | 83 | 1.76 | 0.17 | 0.54 | 76 | 0.71 | 0.41 | 0.80 | 66 | 1.21 |
| Red | M | Wheat 16 | Peas | 710 | 672 | 51 | 1383 | 9.2 | 19.1 | 68 | 28.3 | 0.25 | 1.41 | 85 | 1.66 | 0.14 | 0.52 | 79 | 0.66 | 0.33 | 0.77 | 70 | 1.10 |
| Black | P | Wheat 16 | Peas | 1006 | 437 | 70 | 1443 | 13.0 | 12.4 | 49 | 25.4 | 0.35 | 0.92 | 72 | 1.27 | 0.19 | 0.34 | 64 | 0.53 | 0.47 | 0.50 | 52 | 0.97 |
| Red | P | Wheat 16 | Peas | 880 | 345 | 72 | 1226 | 11.4 | 9.8 | 46 | 21.2 | 0.31 | 0.72 | 70 | 1.03 | 0.17 | 0.27 | 61 | 0.44 | 0.41 | 0.40 | 49 | 0.81 |
| Black | M | Wheat 16 | Beans | 941 | 495 | 66 | 1435 | 12.2 | 17.0 | 58 | 29.2 | 0.33 | 0.94 | 74 | 1.27 | 0.18 | 0.41 | 69 | 0.59 | 0.44 | 0.63 | 59 | 1.07 |
| Red | M | Wheat 16 | Beans | 733 | 587 | 56 | 1320 | 9.5 | 20.2 | 68 | 29.6 | 0.26 | 1.11 | 81 | 1.37 | 0.14 | 0.49 | 78 | 0.63 | 0.34 | 0.75 | 69 | 1.09 |
| Black | P | Wheat 16 | Beans | 975 | 535 | 65 | 1510 | 12.6 | 18.4 | 59 | 31.0 | 0.34 | 1.01 | 75 | 1.35 | 0.19 | 0.44 | 70 | 0.63 | 0.45 | 0.68 | 60 | 1.14 |
| Red | P | Wheat 16 | Beans | 797 | 480 | 62 | 1277 | 10.3 | 16.5 | 62 | 26.8 | 0.28 | 0.91 | 76 | 1.19 | 0.15 | 0.40 | 72 | 0.55 | 0.37 | 0.61 | 62 | 0.98 |
| Black | M | Sorg | Lupins | 994 | 667 | 60 | 1660 | 8.1 | 21.8 | 73 | 29.9 | 0.22 | 1.51 | 88 | 1.73 | 0.12 | 0.50 | 80 | 0.62 | 0.29 | 0.80 | 73 | 1.09 |
| Red | M | Sorg | Lupins | 887 | 584 | 60 | 1472 | 7.2 | 19.1 | 73 | 26.3 | 0.19 | 1.33 | 87 | 1.52 | 0.11 | 0.44 | 80 | 0.55 | 0.26 | 0.70 | 73 | 0.96 |
| Black | P | Sorg | Lupins | 1048 | 559 | 65 | 1607 | 8.5 | 18.3 | 68 | 26.8 | 0.23 | 1.27 | 85 | 1.50 | 0.13 | 0.42 | 76 | 0.55 | 0.31 | 0.67 | 68 | 0.98 |
| Red | P | Sorg | Lupins | 983 | 399 | 71 | 1383 | 8.0 | 13.1 | 62 | 21.1 | 0.21 | 0.91 | 81 | 1.12 | 0.12 | 0.30 | 71 | 0.42 | 0.29 | 0.48 | 62 | 0.77 |
| Black | M | Sorg | Peas | 947 | 696 | 58 | 1643 | 7.7 | 19.8 | 72 | 27.5 | 0.21 | 1.46 | 88 | 1.66 | 0.12 | 0.54 | 82 | 0.66 | 0.28 | 0.80 | 74 | 1.08 |
| Red | M | Sorg | Peas | 689 | 768 | 47 | 1457 | 5.6 | 21.8 | 80 | 27.4 | 0.15 | 1.61 | 91 | 1.76 | 0.09 | 0.60 | 87 | 0.68 | 0.20 | 0.88 | 81 | 1.09 |
| Black | P | Sorg | Peas | 991 | 576 | 63 | 1567 | 8.0 | 16.4 | 67 | 24.3 | 0.22 | 1.21 | 85 | 1.42 | 0.12 | 0.45 | 78 | 0.57 | 0.29 | 0.66 | 69 | 0.96 |
| Red | P | Sorg | Peas | 967 | 255 | 79 | 1222 | 7.8 | 7.2 | 48 | 15.1 | 0.21 | 0.53 | 72 | 0.74 | 0.12 | 0.20 | 62 | 0.32 | 0.29 | 0.29 | 51 | 0.58 |
| Black | M | Sorg | Beans | 959 | 542 | 64 | 1501 | 7.8 | 18.6 | 71 | 26.4 | 0.21 | 1.03 | 83 | 1.23 | 0.12 | 0.45 | 79 | 0.57 | 0.28 | 0.69 | 71 | 0.98 |
| Red | M | Sorg | Beans | 767 | 517 | 60 | 1284 | 6.2 | 17.8 | 74 | 24.0 | 0.17 | 0.98 | 85 | 1.14 | 0.10 | 0.43 | 82 | 0.52 | 0.23 | 0.66 | 75 | 0.89 |
| Black | P | Sorg | Beans | 1072 | 512 | 68 | 1584 | 8.7 | 17.6 | 67 | 26.2 | 0.23 | 0.97 | 81 | 1.20 | 0.13 | 0.42 | 76 | 0.56 | 0.32 | 0.65 | 67 | 0.97 |
| Red | P | Sorg | Beans | 896 | 476 | 65 | 1372 | 7.3 | 16.4 | 69 | 23.6 | 0.19 | 0.90 | 82 | 1.09 | 0.11 | 0.39 | 78 | 0.50 | 0.26 | 0.61 | 70 | 0.87 |
| Black | Commercial Feed | | | | | | 1396 | | | | | | | | | | | | | | | | |
| Red | Commercial Feed | | | | | | 1284 | | | | | | | | | | | | | | | | |

economic advantage of choice feeding compared to feeding a single diet (Table 3). However it should be restated that prices were fixed at the start of the experiment and these would have changed over the 40 week period, However on some of the individual ingredient combinations gross margin was over $2/bird above that on the commercial diet. Conversely there were frequently gross margins substantially below those observed on the commercial diet (Table 2).

The Black strain on the commercial diet consumed 10g/d more feed than did the Red birds. This strain was about 200g heavier than the Red bird at the end of 40 weeks of lay. Because egg size was about 2.5g more for the Red strain feed efficiency was poorer for the Black strain. Specific gravity was similar at the start and finish of the experiment on all diet combinations. All groups gained about 500g during that period with variation due to diet but did not generally reach final bodyweights observed on the commercial diet.

Intakes of ME, protein, lysine, threonine and total sufur amino acids (TSS) are given in Table 5. Daily ME intakes varied from 1.22 MJ Wheat-16/lupins (pelleted) for Red birds to 1.62 MJ Wheat-12/lupins (pelleted) for Black-birds. In all cases grain provided the majority of the total energy (51 to76%). There was wide variation depending on the grain/protein combination, and its form but there was remarkably good agreement between strains for the same ingredient combination (Table 5). The difference in ME intake between the two strains on the commercial diet was 112 kJ/d. These ME intakes were generally below those observed on the self-selection diet combinations and may reflect some spillage on the self-selection treatments.

Protein intake was unusually high (Table 4). On the Wheat-X/lupin combination (mash) it was 31.6g/d for the Black strain with the lowest 15 .1g/d. The combination of sorghum and field peas (pelleted) for Red birds gave an unusually low protein intake, with the peas contributing less than 50% to the total protein and giving a low egg production (Table 2) as already discussed. With this exception total protein consistently gave adequate intakes of lysine, methionine and total sulfur amino acids. In only two cases was total lysine intake below 1g/d, while methionine was generally above 500mg/d giving TSS of at least 800 mg/d.

## DISCUSSION

Choice feeding is an extremely complicated area of research because of the many interactions, some of which are not well understood. Not only is there an effect of trough design, position in the trough compartments of feeds offered, time of introduction to the self-selection system, (Karunajeewa 1978) but in the present study strain of bird is also a factor. Form of 'protein package' concentrate appears to influence its consumption. Cumming et al. (1987) suggested that mash, crumbles or pelleted concentrates give similar results but from the observations of Calet (1965) increased intakes of concentrate when pelleted rather than in mash form be predicted. It is also evident the numbers of birds per cage may be a factor since there was high mortality for the Red birds and reduced egg production compared to the Black strain,

Another interesting feature of this study was the generally high intake (4.1-7.6g/d) of additional calcium as shell grit by birds on the commercial diet, This suggests the layers have a specific calcium appetite which they satisify often by consuming a pure source of calcium if available independent of other nutrients (Cumming 1989). Although Cumming (1989) has recommended for good reasons the feeding of calcium separately and in a course form (shell grit or limestone chips), others have found this to be unnecessary. For example Tauson and Elwinger (1986) used 13% calcium as part of their concentrate in a self-selection experiment using mechanical feeders, with no decline in production parameters. In the present study the concentrate 'packages' provided about 30g of calcium/kg. Mean daily intakes were 39 to 52g (Table 3); these would contribute 1.2 to 1.5g of calcium. Shell grit provided 7.4 - 10g/d or 2.6 to 3.5g (Table 3) giving total intakes of calcium of 4 to 5g/d and sufficient to meet an egg mass of 50g/d (SCA 1987).

There is some disagreement in choice of a single or a divided feed trough. The former is sometimes referred to as a semi-choice feeding system (Tauson and Elwinger (1986). Cumming et al. (1987, and pers com.) has recommended the use of a single trough because of over consumption of feed particularly of protein concentrate if the trough is divided. In the present experiment there was on most ingredient combinations over consumption of protein and therefore of essential amino acids. Energy intakes were generally in excess of those on the commercial feed. Despite these high nutrient intakes, Red birds in particular, did not give maximum production on the majority of dietary combinations, although egg weight was consistently higher for Red than for Black birds on all dietary combinations (Table 2). Recently Scott and Balnave (1988) showed that at high temperatures (25 to 35°C) during early lay choice-fed hens were better able to maintain egg production and body weight than those offered a complete diet. At cold temperatues (6 to 16°C) birds over consumed protein but egg output did not increase when allowed to select their ration.

Over consumption of dietary protein is a problem with choice-fed birds particularly when offered feed in a two-trough system. Horn (pers. comm.) recorded mean daily protein intakes of 30.2g/d from two compartments compared with 22.5g in a selection of the same grain and concentrate from a single trough. In the present study only a few treatments exceeded 30g/d (Table 5). But in almost all cases lysine, methionine and total sulfur amino acids exceeded specifications (SCA 1987) for maximum egg production. For lysine and methionine these are 830 and 389mg/d respectively assuming 90% availability in the diet.

The significantly lower consumption of sorghum compared to the two wheat (Table 3) is contrary to the observations of Cumming (1984). He found that both broilers and hens preferred sorghum to wheat when offered both grains free choice.

Seeman (1982), cited by Tauson and Elwinger (1986), also observed that kind of grain and strain of layer influenced performance. However one of the major benefits of a choice feeding system is the opportunity of grain producers to use surplus grain in whole form for poultry production without the need to allocate the grain in exact amounts.

## CONCLUDING REMARKS

Like many previous choice-feeding experiments the results are equivocal. The over consumption of protein and amino acids is clearly undesirable and a semi-choice feeding system may be appropriate, On the other hand it does seem that the two strains of birds used respond to choice-feeding system some what differently in terms of mortality and egg production. Layers under the semi-commercial conditions of this study do not have the capacity to 'fine-tune' their intake of nutrients to the same extent on all dietary combinations. Further experiments are underway in which single and multiple compartment troughs are being compared with the same diet combinations. A big question in the present experiment is the effects of 6 birds per cage. It would be of interest to reduce this number to 3 or 4 and then impose self-selection feeding regimes.

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