THE BULK CONSTRAINT AND COMPUTER FORMULATIONS OF LEAST-COST FEED MIXES

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Conventional linear programming practice in least-cost feed formulation is to introduce a "bulk constraint" row of 100 units and a diet specified in percentage terms. This procedure places an arbitrary density or concentration level on the available nutrients and metabolizable energy within the resultant feedmixes, which is not necessarily consistent with the birds' consumption capacity. In fact, animals and birds have quite flexible consumption patterns and capacities. Growing pullets fed "low-energy" feedmixes can, in pursuit of their energy requirements, consume up to 150 per cent of their "normal" feed intake. Diet specification for growing birds should be in terms of so many ounces of nutrients per day or week rather than in conventional terms of the percentage nutrient composition of the diet.

1 INTRODUCTION

The conventional procedure in computer formulations of least-cost feedmixes has been to specify a diet in percentage terms and to place a bulk constraint or weighing row restraint of 100 units on the resultant feed formulation. This convenience measure, however, has caused an arbitrary nutrient density or concentration level per unit of weight to be placed on feedmixes which is unrelated to the bird or animal's real consumption capacity. In practice, birds are able to consume a much greater bulk than is normally specified. This enables a reduction in the percentage of each nutrient in the diet and yet still allows the bird to obtain the same overall quantity of nutrients by weight. In this paper we will show that this allows for a significant reduction in the cost of the feedmixes computed. As a consequence, it is recommended that when compiling feedmixes for a bird or animal having flexible dietary requirements and capacities, parametric linear programming of the bulk constraint should be one of the first alternatives in the sensitivity analyses performed.

2 THE BULK CONSTRAINT

The bulk constraint regulates the concentration of available nutrients and metabolizable energy (ME) in terms of pounds or grammes weight per unit weight of feedmix. Conventionally, the bulk constraint is held at

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100 units by weight while the individual ingredients (inputs) are specified as one unit (see table 1).[1] This allows the individual ingredients (inputs) equal weight or value in the computer compilation of the resultant feedmix. In the computer output, the individual ingredients in the feedmix are presented in convenient percentage terms or parts of 100 units.

Under normal conditions, a 16-weeks-old growing pullet consumes on an average 3 oz. of feedmix per day. If the bulk constraint was set at 125 units instead of the conventional 100 units, the 16-weeks-old growing pullet would need to consume 3·75 oz. of feedmix per day to receive its nutrient and energy requirements.

2.1 DIET SPECIFICATION AND THE BULK CONSTRAINT

In considering least-cost feed formulations for growing pullets the linear programmer is faced with a stated *diet* (defined as the birds' nutrient and energy requirements) or set of restraints to which, with the aid of a computer, he must fit a least-cost feedmix (defined as the ingredient formulation).

Growing pullets require a certain uptake of nutrients and energy (calories) to remain on a given future production surface.[2] The uptake of the required nutrients (e.g., ounces of protein per day) is regulated by the energy level of the feedmix. With a low energy feedmix the bird will consume a greater quantity of feedmix to obtain its energy and nutrient requirements; conversely with a high energy feedmix the bird will consume a smaller quantity of feedmix.[3] Growing pullets can obtain their nutritional requirements from various size "packages" or quantities of feedmix, and the range (quantities) can be defined for a specified diet.

In the present study, if a protein level of 15 per cent is recommended for growing pullets consuming 3 oz. of a given energy level feedmix per day, the available protein consumed would be 0·45 oz. Depending on the strain of bird, stage of growth, growth purposes, etc., the growing pullet will perform in an equivalent manner when it consumes 0·45 oz. of protein in 3 oz. to 3·75 oz. of feedmix. To use a percentage specification restricts the growing pullets to a single arbitrary consumption level.

When the bulk constraint is varied, the nutrients and calories (energy) of the diet remain in the same proportion to one another. By consuming different quantities of feedmix the bird still consumes the same nutrients by weight and the same number of calories (energy). Hence the bird is

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[1] R. A. Powell and B. J. Dent, "Computers, Feed and Profit in Intensive Livestock Units", *Journal of Australian Institute of Agricultural Science*, Vol. 35, No. 4 (December, 1969), p. 228.

[2] There is an element of flexibility allowable in the feeding of growing birds, as they consume feed now and produce over a future time period. Unlike laying hens where present feed consumption immediately affects production, growing pullets can bear a degree of change in their feeding patterns without adversely affecting future production.

[3] T. R. Morris, "The Effect of Dietary Energy Level on the Voluntary Calorie Intake of Laying Birds", *British Poultry Journal*, Vol. 9, No. 3 (July, 1968).

consuming an equivalent diet. To vary the proportion of nutrients and energy results in a different diet being specified.

2.2 THE ENERGY RESTRAINT

Energy (ME) is expressed as calories per unit weight (k cal/lb). In diet specification a fixed energy level is usually stipulated. However, for successful ranging of the bulk constraint, the energy level and consequently the consumption level must be allowed to vary. The level of calories available for intake will be the same, but may be in the form of a low, medium or high energy feedmix. In this treatment of energy, the calorie level ceases to be a fixed proportion of the weight of feed consumed.

In the restraints column (table 1), the birds' energy requirements are expressed as the number of calories available for intake. With a bulk constraint level of 100 units there are 129,390 calories in 100 lb; with a bulk constraint level of 125 units there are 129,390 calories in 125 lb.

2.3 THE EFFICIENCY OF RANGING THE BULK CONSTRAINT

The diet problem is, within the bounds of the birds' consumption capacity, to ascertain the least cost method of providing the bird with quantities of available nutrients (e.g., ounces of protein) for a given calorie intake. Least cost linear programming of the basic diet and ranging of the bulk constraint is the most efficient procedure to implement, in terms of computer usage, to achieve this end.

It is possible to specify a diet problem without a bulk constraint row. The least cost solution obtained would be identical to the least cost solution using the free ranging bulk constraint. However, in practice, a feasible solution point close to the least cost solution may prove more acceptable. Also the least cost solution may occur outside the bird's consumption capabilities, which would necessitate re-designing the problem and extra computer time.

A linear programme with a series of discrete proportional restraints columns, representing high to low energy diets, could achieve solutions and information similar to the solutions achieved with a free ranging bulk constraint. This method is inefficient and costly, both in terms of computing time and matrix preparation time. Instead of discrete computer runs, the iterative procedure involved in varying the bulk constraint level achieves optimal solutions in a single computer run.

3 THE LINEAR PROGRAMMING MATRIX

The complete matrix is presented in table 1. Salient aspects of the quantitative components are presented below.

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[4] Metabolizable energy (ME) "is the energy in the food, less the energy in the excrement, both faecal and urinal (sic!)—It includes all the energy in the food which can be used by the animal—", H. W. Titus, *The Scientific Feeding of Chickens* (Illinois; Interstate Printers, 1961), pp. 246–248.

3.1 ACTIVITY CO-EFFICIENTS

(a) In one unit of wheat there is 12 per cent protein available to the bird. That is, in 1 lb of wheat, 0·12 lb is available protein.

(b) Energy, for the individual ingredients, is expressed in k cal/lb.

(c) There is a dietary limit of 3 per cent linseed meal and 3 per cent cottonseed meal allowable in the final feedmix. For example, as the bulk constraint is varied, under the programming specification used in table 1, the maximum limit of 3 per cent linseed meal allowable in the resultant least-cost feedmix will strictly apply.

3.2 OBJECTIVE FUNCTION

The prices for the ingredients (inputs) were based upon 1970–71 average prices derived from the State Marketing Bureau records.

3.3 RESTRAINTS COLUMN[5]

The dietary requirements of the growing pullets were originally specified in percentage terms, parts by weight of 100 units, but become as the bulk constraint is varied, parts by weight of the bulk constraint level. The energy requirements are treated as calories available at a stated bulk constraint level.

4 RESULTS

The results of the parametric linear programming of the bulk or weighing row constraint are shown in table 2 and figure 1. It will be noted, solution B was an optimal solution with the bulk constraint set at 100 units. However, with the free ranging bulk constraint, B would not appear as an optimal solution point; feedmix B is a forced feasible solution between optimal solution points A and C.

With the bulk constraint level set at 100 units by weight, the least cost feedmix was $1·86 per 100 lb. With the variable bulk constraint level, the least cost feedmix was $1·69 per 124·3 lb. The minimum cost for the specified equivalent diet was $1·69 (at a bulk constraint level of 124·3), which represented a cost savings of 9·3 per cent over the least cost diet obtained when a fixed bulk constraint level of 100 was implemented. Subtracting the estimated additional handling, manufacturing, storage and transportation costs for delivery within the metropolitan area, the savings at the farm level will amount to approximately 7 per cent.

The magnitude of the cost savings is dependent on the diet stipulated and the input cost structure. The original diet was a medium energy diet, with a higher or lower energy diet specified, the cost savings would be greater or smaller respectively. From the parametric linear programming conducted, as shown in figure 1, the range of the total costs for the various diet densities is depicted. When the bulk constraint level is varied there is an inverse proportionate change in the density of the diets.

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[5] Also referred to as the "B" column (Basis) or the "right-hand side" (R.H.S.).

TABLE 1

*Linear Programming Matrix and Specification for Growing Pullets Feedmix**

Restraints ↓ / Ingredients →	B		Wheat	Oats	Maize	Sorghum	Barley	Bone meal	Coconut meal	Lucerne meal
Protein minimum ..	15·00	≤	·12	·1	·1	·08	·09	..	·2	·18
Calcium maximum ..	1·5	≥	·0012	·0015	·0008	·0015	·0015	·304	·0014	·0112
Calcium minimum ..	1·0	≤	·0012	·0015	·0008	·0015	·0015	·304	·0014	·0112
Phosphorus minimum ..	0·8	≤	·0035	·0035	·0027	·0028	·004	·14	·006	·0025
Phosphorus inorganic minimum	0·45	≤	·00105	·00105	·00081	·00084	·0012	·14	·0018	·00075
Sodium maximum ..	0·25	≥	·0002	·00035	·00014	·00019	·0003	·0056	·0007	·0007
Sodium minimum ..	0·15	≤	·0002	·00035	·00014	·00019	·0003	·0056	·0007	·0007
Fibre maximum	15·00	≥	·0275	·11	·025	·025	·065	·02	·14	·22
Lysine minimum	0·55	≤	·0041	·0044	·0024	·0017	·0036	..	·0072	·009
Methionine and cystine minimum	0·5	≤	·0058	·0044	·0027	·0027	·0036	..	·006	·0048
Linseed maximum ..	0	≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Cottonseed maximum ..	0	≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Weighing row bulk constraint	100	=	1	1	1	1	1	1	1	1
Energy (ME) (k cal/lb) ..	129,390	=	1,430	1,180	1,156	1,543	1,248	..	749	590
Cost per 100 lb		$	2·43	1·43	2·09	1·71	1·41	4·85	2·7	2·50

TABLE 1—*continued Linear Programming Matrix and Specification for Growing Pullets' Feedmix*—continued*

Ingredients → / Restraints ↓	B		Bran	Pollard	Hominy	Meat meal	Meat and bone meal	Soyabean meal	Cotton-seed meal	Low protein safflower
Protein minimum ..	15·00	≤	·16	·16	·1	·5	·45	·5	·4	·22
Calcium maximum ..	1·5	≥	·0016	·0015	·0009	·0954	·1174	·004	·003	·0039
Calcium minimum ..	1·0	≤	·0016	·0015	·0009	·0954	·1174	·004	·0033	·0039
Phosphorus minimum ..	0·8	≤	·011	·008	·005	·0475	·055	·006	·012	·0071
Phosphorus inorganic minimum	0·45	≤	·00033	·0024	·0015	·0475	·055	·0018	·00036	·00213
Sodium maximum ..	0·25	≥	·00008	·00006	·00005	·006	·0067	·0012	·0003	·0003
Sodium minimum ..	0·15	≤	·00008	·00006	·00005	·006	·0067	·0012	·0003	·0003
Fibre maximum	15·00	≥	·1	·07	·005	·025	·03	·03	·12	·31
Lysine minimum	0·55	≤	·007	·0057	·0041	·032	·0284	·035	·0208	·0073
Methionine and cystine minimum	0·5	≤	·007	·00788	·0055	·013	·0108	·02	·0144	·0071
Linseed maximum ..	0	≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Cottonseed maximum ..	0	≥	—·03	—·03	—·03	—·03	—·03	—·03	+·97	—·03
Weighing row bulk constraint	100	=	1	1	1	1	1	1	1	1
Energy (ME) (k cal/lb) ..	129,390	=	681	862	1,362	1,021	1,089	1,135	1,044	431
Cost per 100 lb		$	1·2	1·3	2·00	4·6	4·00	6·45	3·47	1·8

TABLE 1—*continued Linear Programming Matrix and Specification for Growing Pullets' Feedmix*—continued*

Restraints ↓ / Ingredients →	B	High protein safflower	High protein sunfflower	Peanut meal	Beef tallow	Blood meal	Fish meal	Skim milk
Protein minimum	15·00 ≤	·43	·41	·43	..	·85	·65	·33
Calcium maximum ..	1·5 ≥	·0065	·004	·0018	..	·003	·0542	·0142
Calcium minimum ..	1·0 ≤	·0065	·004	·0018	..	·003	·0542	·0142
Phosphorus minimum ..	0·8 ≤	·012	·01	·005	..	·0035	·028	·011
Phosphorus inorganic minimum	0·45 ≤	·00036	·0003	·0015	..	·0035	·028	·011
Sodium maximum ..	0·25 ≥	·0001	·001	·0004	..	·0089	·0094	·0058
Sodium minimum ..	0·15 ≤	·0001	·001	·0004	..	·0089	·0094	·0058
Fibre maximum	15·00 ≥	·09	·14	·12	..	·01	·01	·001
Lysine minimum	0·55 ≤	·0138	·016	·0195	..	·0191	·0597	·0394
Methionine and cystine minimum	0·5 ≤	·0138	·0168	·0145	..	·0204	·0286	·0139
Linseed maximum ..	0 ≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Cottonseed maximum ..	0 ≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Weighing row bulk constraint	100 =	1	1	1	1	1	1	1
Energy (ME) (k cal/lb) ..	129,390 =	930	794	1,248	3,268	1,248	1,362	1,225
Cost per 100 lb	$	4·2	4·25	4·9	7·58	6·00	9·82	9·5

TABLE 1—*continued Linear Programming Matrix and Specification for Growing Pullets' Feedmix*—continued*

Restraints ↓ / Ingredients →	B		Liver meal	Linseed meal	Christmas phosphate	Sel grit	Limestone	Salt	Pure methionine
Protein minimum ..	15·00	≤	·65	·33	..	..	..	..	..
Calcium maximum ..	1·5	≥	·0048	·0041	·34	·34	·34	..	..
Calcium minimum ..	1·0	≤	·0048	·0041	·34	·34	·34	..	..
Phosphorus minimum ..	0·8	≤	·008	·008	·145	..	..	..	..
Phosphorus inorganic minimum	0·45	≤	·008	·0024	·145	..	..	..	..
Sodium maximum ..	0·25	≥	·0038	·0012	..	..	..	..	..
Sodium minimum ..	0·15	≤	·0038	·0012	..	..	..	..	..
Fibre maximum	15·00	≥	·02	·009	..	..	..	..	..
Lysine minimum	0·55	≤	·0572	·0142	..	..	..	..	..
Methionine and cystine minimum	0·5	≤	·0334	·0116	..	..	..	..	·98
Linseed maximum ..	0	≥	—·03	+·97	—·03	—·03	—·03	—·03	—·03
Cottonseed maximum ..	0	≥	—·03	—·03	—·03	—·03	—·03	—·03	—·03
Weighing row bulk constraint	100	=	1	1	1	1	1	1	1
Energy (ME) (k cal/lb) ..	129,390	=	1,293	794	..	..	..	..	..
Cost per 100 lb		$	7·5	3·55	1·96	0·915	0·82	1·96	75·0

* Major Source: Poultry Research Station, Seven Hills.

TABLE 2

Optimal Solution Points for the Free Ranging Bulk Constraint

Optimal formulations	Varying bulk levels	Total costs for an equivalent diet	
	(lb)		($)
—	90·00	1·99	
—	95·96	1·90	
—	97·19	1·89	
A	99·24	1·87	
B*	100·00	1·86	Rate and magnitude of fall is dependent upon relative input costs.
C	100·64	1·86	
D	104·29	1·82	
E	108·99	1·79	
F	111·37	1·77	
G	123·50	1·70	
H	124·30	1·69	Minimum total cost.
I	129·58	1·73	
J	131·05	1·74	
—	150·00	1·92	

* B is a forced solution point.

As the bulk constraint level increases the diet density decreases and so the least cost feedmix has a low energy and nutrient density.

The minimum cost area (bulk constraint level of 124·3 units) may not be the ultimate least cost operating point. Problems arising from the greater physical weight and in most cases the volume of the feedmixes may preclude the use of the lowest density feedmixes. The cost of large discrete capital items in the form of new storage facilities, the transportation costs resulting from the greater number of trips to fill on farm storage bins, the cost of extra labour units to handle a greater volume of feedmix and the distribution of feed to the growing pullets may modify the solution. Particular circumstances may force a revision of the problem at a given bulk constraint level or cause a shift to another bulk constraint level. A bulk constraint level of 104·29 units with a cost savings of 2·2 per cent obtainable or a bulk constraint level of 108·99 units, with a 3·76 per cent cost savings may be preferable in circumstances where, for example, a limited storage capacity exists.

As the bulk constraint level is increased from 100 units to the least cost point of 124·30 units, there is a substantial increase in the levels of the relatively low-energy ingredients, barley and pollard, as shown in table 3. At the higher bulk constraint levels, bran is introduced. As the bulk constraint varies upwards, the low energy ingredients cease to be penalized and are able to provide calories and nutrients (in particular, protein) in a cheaper form than the high energy ingredients, sorghum, maize, wheat, etc. Pollard, bran and, to a lesser extent, barley, provide adequate amounts of available protein, and so at the higher bulk constraint levels. the protein concentrate ingredients, meat and bone meal, blood meal, etc., can be eliminated. Where protein concentrates (animal by-products) are stipulated, movement to the 111·37 bulk constraint level is feasible.

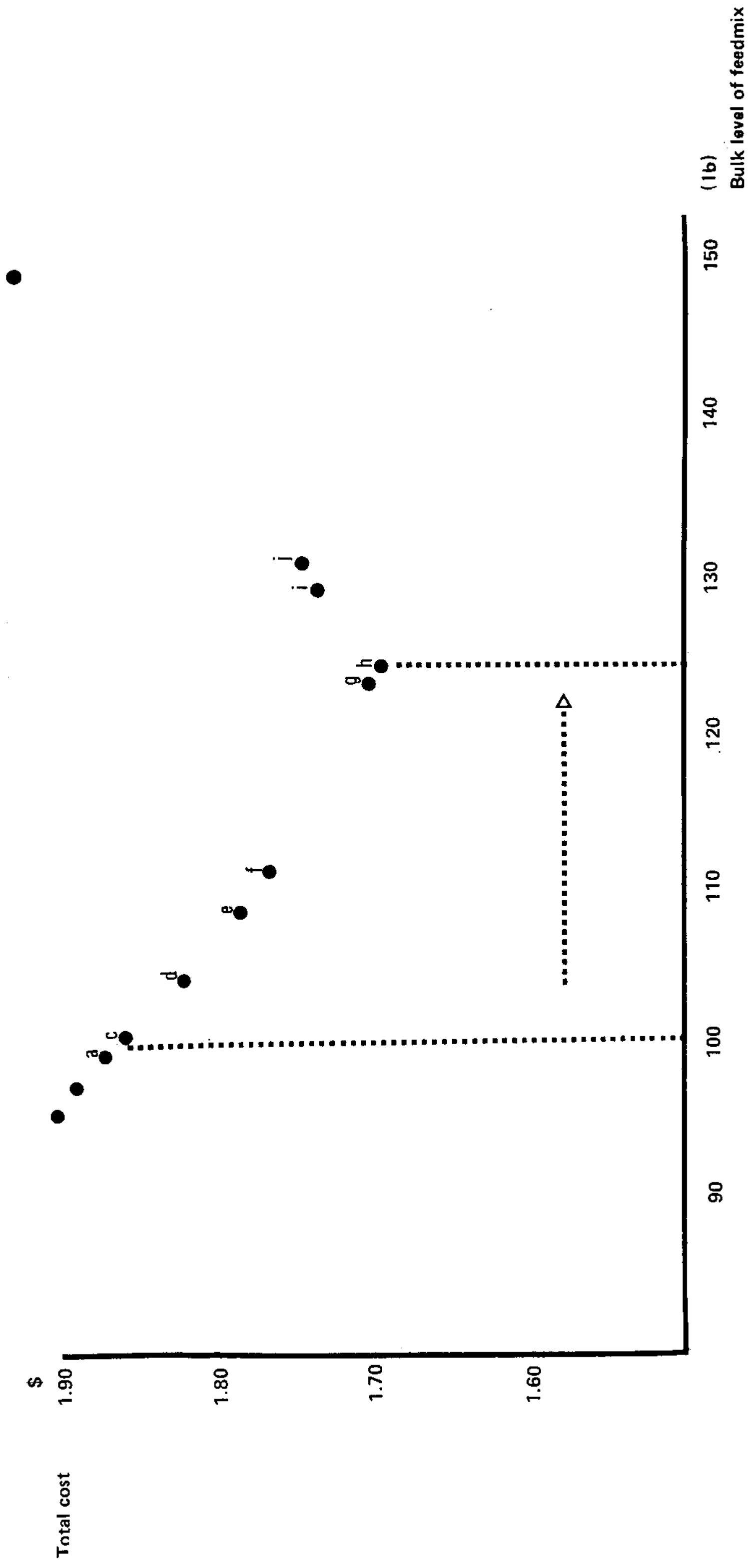

FIGURE 1: *Total costs for a stated Metabolizable Energy and Nutrient Level.*
The lettering indicates a series of optimal solutions, resulting from the *free ranging* bulk constraint.

TABLE 3

Optimal Solutions for the Free Ranging Bulk Constraint

Constituent	Amount in feedmix (lb)									
	A	B*	C	D	E	F	G	H	I	J
Sorghum	45·11	44·30	43·6	55·28	50·88	43·47	5·47	..	..	..
Bran	..	..	..	..	..	..	..	..	51·1	51·12
Barley	26·31	26·38	26·44	..	..	9·08	55·67	63·65	75·78	75·78
Pollard	16·53	18·44	20·05	40·58	51·44	52·79	59·69	57·94	..	..
Meat and bone meal (45 | ptn)	7·7	7·48	7·28	7·26	5·99	5·01	..	..	..	..
Blood meal	3·4	3·25	3·10	0·95	..	..	..	..	..	..
Salt	0·12	0·13	0·14	0·20	0·24	0·26	0·32	0·32	0·31	0·31
Christmas phos.	..	..	..	..	..	..	1·62	1·61	2·35	2·35
Limestone	..	..	..	..	0·41	0·74	0·78	0·78	0·006	1·47
Total bulk (lb)	99·24	100·00	100·64	104·29	108·99	111·37	123·50	124·30	129·58	131·03

* B is a forced feasible solution.

5 FEEDMIX COMPOSITION

Computer formulation of least-cost feedmixes depend, for their significance, upon the accuracy and relevance of the physical scientist's specification of the bird's dietary requirements. Never is this aspect more important than when parametric linear programming begins to stretch the physical scientist's defining of the bird's consumption and production tolerances to extremes. Unfortunately nutrition theory is not an exact science, and there remains a great deal of conflict as to the influence of certain ingredients in the feedmix upon the performance of the growing pullet, even though the feedmixes contain the same minimum nutrients by analysis.[6]

The edibility of a diet and the availability of certain ingredients over a given time period may cause problems. To increase the feasibility of the computed feedmixes, alternative ingredients must be available at a particular bulk constraint level and have a low opportunity cost, so that cost reduction benefits are not sacrificed by remaining at the desired bulk constraint level. The sensitivity analyses carried out indicate a number of feasible alternative feedmixes at the various bulk constraint levels. There is a variety in feedmix ingredient formulation as the bulk constraint level increases (table 3), as well as feasible alternative ingredient formulations available at particular bulk constraint levels (table 4a, 4b).

Tables 4a and 4b show a selection of the smallest marginal opportunity costs for grains, grain by-products and protein concentrates for substitution into the feedmixes. At a bulk constraint level of 124·3 units by

[6] There is nothing in the construction of the diet problem to ensure palatibility and little reason to expect that even with a dozen nutritional requirements a minimum-cost diet would be edible. See R. Dorfman, P. Samuelson and R. Solow, *Linear Programming and Economic Analysis* (New York: McGraw-Hill, 1958), p. 15.

weight, if the quantity of pollard in the feedmix was impairing the performance of the bird, then a reduction in the quantity of pollard may be warranted. For example, a maximum limit of not more than 30 per cent pollard may be allowable in the final mix, and so for the reduced pollard, oats or bran would be substituted. Because of the low opportunity costs for oats and bran at this particular bulk constraint level, the least cost figure will not alter significantly.

TABLE 4

Table 4a

Bulk Constraint Level of 100 *Units by Weight*

Constituent	Amount in feedmix	Marginal opportunity costs	(Cost/lb)
			$
Sorghum	44·30	Wheat	0·0025
Barley..	26·38	Maize	0·0021
Pollard	18·44	Oats	0·0003
Meat and bone meal (45%)..	7·48	Meatmeal (50% ptn) ..	0·00031
Blood meal	3·25	Bran	0·0011
Salt	0·13	Cottonseed meal	0·0012
Total bulk (lb)	100·0		
Total cost	$1·86		

Table 4b

Bulk Constraint Level of 124·3 *Units by Weight*

Constituent	Amount in feedmix	Marginal opportunity costs	(Cost/lb)
			$
Barley..	63·65	Wheat	0·0032
Pollard	57·94	Oats	0·0004
Salt	0·32	Bran	0·0007
Christmas phosphate ..	1·61	Low protein safflower ..	0·0068
Limestone	0·78	Sel grit	0·0009
		Hominy	0·0045
		Meat and bone meal (45% ptn)	0·0084
Total bulk (lb)	124·3		
Total cost	$1·69		

6 INPUT PRICE CHANGES

Ranging of the bulk constraint is economically feasible while there remains a price differential between the grains, within the various grades of grains and between grains and grain by-products, which is not directly proportional to the nutrient composition and energy (calorie content) of these inputs. Grains and grain by-products are the most significant, as they constitute the major portion of feedmixes. Under the present price structure, the grains and grain by-products such as bran, barley, oats and pollard provide absolute quantities of protein and calories available for intake in a cheaper form than the so-called "quality grains", such as sorghum and wheat, etc.

For individual ingredient price rises, the effect upon the feasibility of ranging the bulk constraint will be negligible, as the low opportunity costs evident at all bulk constraint levels will ensure immediate substitution of the ingredient at a non-significant alteration to the structure of total costs. The structure of total costs for this study is shown in figure 1. At certain times of the year, if the price of sorghum or one of its close substitutes were to drop substantially, then the cost savings associated with the ranging of the bulk constraint would diminish, while the optimal bulk constraint level would be closer to 100. Conversely, if the price of a grain by-product (bran or pollard) were to drop, the cost savings would increase, while the optimal bulk constraint level would shift further away from 100.

7 THE INFLUENCE OF DIET SPECIFICATION

The production parameters protein and energy, have the most influence upon the structure of total cost. Nutrients such as phosphorus, calcium, sodium, etc., are available in sufficient quantities in the majority of ingredients, while the concentrated forms, limestone, Christmas phosphate, salt, etc., are relatively inexpensive.

The cost reducing benefits associated with the varying of the bulk constraint are obtainable because the available nutrients and energy are in a diluted form. Available protein and energy (calories) in particular, must vary in concentration for ranging of the bulk constraint level to be successful. To have the protein restraint specified as a percentage, for example 15 per cent protein at all bulk constraint levels, results in non-significant cost savings. To require a constant metabolizable energy level, for example, 1,293·90 k cal/lb at all bulk constraint levels, results in no cost savings. However, with restraints calcium, phosphorus, sodium, etc., a constant percentage inclusion at various bulk constraint levels may be specified while still maintaining significant cost savings.

8 CONCLUSION AND SUMMARY

Parametric linear programming of the bulk constraint for feedmix design provides a number of feasible solutions and a least-cost solution to help solve the diet problem. In this study, by allowing the bulk constraint level to vary over a defined range representing the growing pullets' consumption capacity for a given calorie intake level, a computed cost savings of 9·2 per cent was obtainable over the conventional procedure of a fixed bulk constraint level and hence consumption capacity for the stated diet.

Under the input price relationship and diet specification used, a reduction of the bulk constraint level below 100 units by weight (higher density diet) was not economically feasible. A reduction in the per unit costs for nutrients and energy (calories) was only evident at the higher bulk constraint levels.

To have a diet specified in percentage terms and a constant energy level stipulated, allows the programme little flexibility in devising meaningful feedmixes. A feedmix derived from a stated diet with a fixed bulk constraint of 100 units by weight, may be the optimal feedmix, but until a parametric linear programme of the bulk constraint is completed this cannot be confirmed.