MAINTAINING SHEEP DURING DROUGHT WITH COMPUTER FORMULATED RATIONS

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The use of a linear programming model for the determination of least-cost feed mixes for the drought maintenance of dry adult sheep is reported in this paper. A ration is suggested whereby sheep can be fully maintained at an approximate cost of one cent per head per day, representing a considerable reduction in the cost of feeding by the currently recommended standards. The importance of including the mineral additives, salt, sulphur and calcium is stressed throughout.

1 INTRODUCTION

Linear programming enables the formulation of drought rations designed to provide sheep maintenance requirements at the least possible cost. The ease with which the programmed solution can be adjusted to new price situations is one of the major advantages of the technique. All feeds can be evaluated solely on their respective costs and ability to meet the stipulated requirements of the animal.

The linear programming technique has been widely used for compounding least-cost rations for application in intensive livestock production enterprises such as poultry and pig raising.

Research has shown that the monogastric nature of these animals gives rise to predictable input/output relationships. However, such direct relationships cannot be realistically assumed to hold under intensive ruminant feeding conditions. Because of microbial activity in the rumen, injected nutrients undergo considerable change before they become available to the animal in the abomasum. The protein content of a particular input is of little consequence for ruminant drought maintenance because it is the bacterial protein synthesized within the rumen that is utilized by the animal. Therefore, protein quality and not quantity is the major consideration. Protein inputs are particularly susceptible to microbial degradation whilst energy concentrates are not. Because energy is the prime concern in drought maintenance, microbial activity should not adversely affect the nutritional balance of the ration.

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2 MODEL FORMULATION FOR COST MINIMIZATION

2.1 FORMULATING THE OBJECTIVE FUNCTION

An important consideration confronting the producer operating under drought conditions is how to minimize the financial costs involved with drought management. As feed costs comprise the main operating expenditure involved in the survival of the sheep flock, the objective function in this model is the determination of the least cost maintenance ration which is capable of satisfying the animal's nutritional requirements. If there are n inputs and m nutritional constraints in the programme, the cost minimization problem can be written:

Minimize

(i) $C = \sum_{j=1}^{n} p_j q_j$

Subject to

(ii) $x_i \geqq y_{ij} p_j$

and

(iii) $q_j > 0$, for all j

where

j = 1,2, . . . , n inputs

i = 1,2, . . . , m nutritional requirements

p_j = the net cost per unit of the jth input

q_j = the quantity of the jth input in the ration

C = the total cost of the ration

x_i = the level of the ith requirement

y_{ij} = the level of the ith requirement met by a unit of the jth input.

2.2 ASSUMPTIONS IN THE MODEL

The model is built on several implicit assumptions:

(i) that the animal cannot obtain any significant nutritive value from the environment;

(ii) that all nutrient sources are additive in their ability to meet the stipulated requirements;[1]

(iii) that all inputs can be used in quantities which are fractional units;

[1] Conjecture may arise when using linear programming as to the validity of the additivity assumption with respect to nutrient availability to the animal. Basically, this assumption infers that nutrients from various sources (or activities) are available in aggregate in the final solution; thereby discounting the possibility of nutrient interaction. Dent [1] remarks that in the absence of quantitative information to the contrary the assumption is deemed to hold.

(iv) that there is a limit to the number of inputs and constraints which can be considered; and

(v) that error introduced due to microbial activity within the rumen is minimal and non-constraining (bodyweight maintenance through the provision of energy sources is the major consideration with total drought feeding).

2.3 DATA REQUIREMENTS

In terms of the above model, the following data are required:

(i) the nutritional requirements of the animal;

(ii) the feedstuffs available to satisfy these requirements;

(iii) the nutritional composition of the available feedstuffs; and

(iv) the cost of such feeds.

(i) *Nutritional requirements*

Since the objective function requires animal maintenance at least cost, minimum requirements were the main constraints considered. However, the nutritional needs of the animal were not strictly stated; the derived solution was permitted to supply some requirements in excess of the stipulated minimum levels. Table 1 provides the estimated nutritional requirement levels for the total maintenance of dry adult sheep.

TABLE 1

Daily Nutrient Requirements for Maintenance of Dry Adult Merino Sheep

Requirements		Unit	Level required per day
Protein	MAX	gram	60·00
Protein	MIN	gram	40·00
Calcium	MIN	gram	3·00
Phosphorus	MIN	gram	1·50
Sodium	MIN	gram	0·50
Iodine	MIN	gram	0·0006
Magnesium	MIN	gram	0·400
Copper	MIN	gram	0·02
Sulphur	MIN	gram	1·00
Potassium	MIN	gram	0·35
Iron	MIN	gram	0·01
Fibre	MAX	gram	250·00
Fibre	MIN	gram	..
Energy	MAX	k cal	1,200.00
Energy	MIN	k cal	1,000·00

Source: Data supplied by research personnel at the Drought Feeding Unit, Glenfield Veterinary Research Station, Sydney.

(ii) *Feedstuffs considered in model*

Twenty-three feeds comprising five major cereal grains and eighteen protein concentrates were considered in the model. Three mineral additives, salt, limestone and pure sulphur, were also included. Only those feeds which were considered to be generally available throughout periods of drought were made available to the solution. For instance, roughages were not considered as it was felt that they would normally be too highly priced under drought conditions to be economically feasible.

(iii) *Feedstuff nutritional composition*

The particular nutrient levels of some feeds used in the matrix will be open to debate. Data relevant to the Australian situation has not been readily obtainable and in some cases estimates of nutritional composition had to be based on North American data, adjusted in accordance with local opinion. Appendix I, which gives the nutritional composition of the various feedstuffs, comprises the basic technical matrix upon which this model was built.

(iv) *Feedstuff prices*

Prices were based on a 12-month average of statistics obtained from a sample of retailers throughout the Sydney metropolitan area, for the period ending June, 1971.[2]

Transport costs will impose a further cost on the producer where inputs cannot be obtained locally. However, in areas which have been declared drought stricken, substantial freight rebates apply which largely offset the costs of obtaining feeds from elsewhere.[3] To test the net effect of imposing transport costs and freight rebates on the optimal solution, the basic programme was modified to consider the increased costs of obtaining feedstuffs for distances up to 500 miles from Sydney.[4]

Appendix II provides the prices of all feed inputs considered in the model.

3 RESULTS

3.1 COMPOSITION OF THE LEAST COST SOLUTION

Using the data contained in appendices I and II and table 1, and including both salt and limestone as mineral additives, the least-cost ration described in table 2 was obtained. This ration provides for total dry sheep maintenance at a daily cost of 1·64 cents; or 11·48 cents per week.

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[2] Price quotations operating over previous drought periods (e.g., 1965–66, 1967–68) were not used in lieu of current price levels because a greater variety of feedstuffs at competitive price levels are currently available on the market than during prior periods. The significant expansion of oil seed production, and the resultant increased availability of protein concentrate meals, attest to this.

[3] Rebates of up to 50 per cent of freight costs are available to farmers in drought declared areas, provided the applicant has an established patronage with rail transport.

[4] Although cost increases per unit weight (10 kg) ranged from 4 to 6 cents for feed grains and from 5 to 7 cents for concentrate feeds, no change in the optimal mix was experienced. This was due to the high degree of price stability of the solution.

TABLE 2

Daily Maintance Ration 1 for Dry Adult Sheep

Feed	Weight (gms)	Per cent of ration	Daily cost (cents)	Cost/10 kg (cents)
Oats	269·84	55·81	0.92	0.39
Bran	206·35	42·68	0.70	0.28
Limestone	6·66	1·38	0.023	0.18
Salt	0·62	0·13	0.002	0.43
Total	483·46	100·00	1.64	..

One of the major purposes of this study was to investigate the significance of providing additional minerals in drought maintenance rations. The importance of supplying minerals such as calcium and salt is emphasized by the significant cost reduction generated through their inclusion in the solution from an initial ration not containing these inputs. As a result of the inclusion of mineral supplements, the bulk weight of the ration was increased by 13 per cent and the daily cost per head was reduced by 17 per cent.

As it was apparent that the sulphur element was an effective constraint, pure sulphur was included as an additional activity. The optimal solution which resulted is shown in table 3.

TABLE 3

*Daily Maintenance Ration 2 for Dry Adult Sheep**

Feed	Weight (gms)	Per cent of ration	Daily cost (cents)	Cost/10 kg (cents)
Pollard	333·34	97·53	1.05	0.32
Limestone	7·35	2·15	0.033	0.18
Salt	0·79	0·23	0.003	0.43
Sulphur	0·33	0·10	0.001	0.99
Total	341·78	100·00	1.087	..

* Includes pure sulphur (100 per cent fine ground).

The use of pure sulphur had the effect of reducing the daily cost per head to 1·08 cents/head/day, or 7·56 cents/week—a reduction of 34 per cent on the cost of ration 1. Although the bulk weight of the ration was reduced by 29 per cent to 342 g/head/day (approximately 0·75 lb), it is doubtful whether this will have an adverse effect on the animal under drought conditions.[5]

3.2 SENSITIVITY ANALYSIS

The provision of a sensitivity analysis shows the ranges over which price and nutritional constraint specifications can vary and still remain in the optimal solution. Although the numerical values which have been assigned to both feed price and nutritional constraint ranges in table 4 and table 5 respectively should not be interpreted to represent precise levels of possible variation, they are useful in indicating both the general magnitude and the direction of such variation in the solution inputs.

TABLE 4

Price Sensitivity Analysis for Selected Feeds

Feed	Cost per 10 kg (cents)	Minimum cost per 10 kg (cents)	Maximum cost per 10 kg (cents)
Pollard	0·32	0·27	0·42
Limestone	0·18	No bound	1·12
Salt	0·43	No bound	No bound
Sulphur	0·99	No bound	No bound

In table 4 the importance of the mineral additives to the ration is emphasized by the "boundless" cost ranges, indicating that the cost of the particular input can rise by a very large margin before it becomes excluded from the optimal solution. Therefore, if a particular input is bounded by wide cost ranges, it is assumed to be reasonably insensitive to price variation and will be selected in any solution derived from a given set of price co-efficients. Cost ranges for a particular input in any optimal solution are derived on the basis that the costs of all other inputs remain constant.

Table 5 represents the sensitivity analysis for the values of the nutritional requirements specified in the model, showing the levels to which the various requirements can vary without adversely affecting the animal. Noteworthy (as with price variations for selected feeds) is the wide variation permitted for those requirements imposing particular constraint on the solution.

It is also important to provide a price sensitivity analysis on those feeds which are excluded from the ration as this indicates the prices to which these feeds must drop before they will be considered in the optimal solution. Table 6 provides this analysis.

[5] Technical opinion suggests that bulk should not be an important consideration for drought maintenance, so long as the nutritional needs of the animal can be adequately satisfied by the ration. Bulk could prove to be advantageous in cases where nutritional sources within the mix release nutrients at a suboptimal rate; thereby causing a poor utilization of the available nutrients by bacteria within the rumen.

TABLE 5

Daily Nutritional Requirements Sensitivity Analysis for Ration 2

Row		Unit	Current RHS level (gms)	Minimum level (gms)	Maximum level (gms)
Protein	MAX ..	gram	60·00	49·70	60·00
Protein	MIN ..	gram	40·00	40·00	60·00
Calcium	MIN ..	gram	3·00	0·73	3·21
Phosphorus	MIN ..	gram	1·50	1·50	3·21
Sodium	MIN ..	gram	0·50	0·26	No Bound
Iodine	MIN ..	gram	0·0006	0·0006	0·31
Magnesium	MIN ..	gram	0·400	0·400	1·59
Copper	MIN ..	gram	0·002	0·002	0·46
Manganese	MIN ..	gram	0·020	0·020	3·52
Sulphur	MIN ..	gram	1·00	0·10	1·08
Potassium	MIN ..	gram	0·35	0·35	3·70
Iron	MIN ..	gram	0·01	0·01	1·77
Fibre	MAX ..	gram	250.00	50·59	No Bound
Fibre	MIN ..	gram	..	..	50·59
Energy	MAX ..	k cal	1,200·00	1,011·00	No Bound
Energy	MIN ..	k cal	1,000·00	1,000·00	1,011·00

TABLE 6

Cost Analysis of Excluded Inputs for Ration 2

Input	Cost/10 kg (cents)	Opportunity cost of having input in solution (cents/10 kg)	Price at which input enters solution (cents/10 kg)
Wheat	0·53	0·22	0·31
Oats	0·39	0·11	0·28
Maize	0·46	0·08	0·38
Sorghum	0·38	0·02	0·36
Barley	0·31	0·02	0·29
Coconut meal	0·59	0·41	0·18
Lucerne meal	0·55	0·40	0·15
Meat meal (50 per cent protein)	1·00	0·70	0·30
Meat meal (45 per cent protein)	0·91	0·58	0·33
Soybean meal	1·42	1·13	0·29
Cottonseed meal	0·76	0·51	0·25
High protein safflower	0·39	0·28	0·11
Low protein safflower	0·95	0·73	0·23
High protein sunflower	0·96	0·77	0·19
Peanut meal	0·99	0·70	0·29
Fish meal (65 per cent protein) ..	2·32	1·96	0·36
Livermeal	1·65	1·34	0·31
Linseed meal	0·89	0·70	0·19
Blood meal	1·32	1·01	0·51
Bone meal	1·01	0·84	0·17
Bran	0·28	0·12	0·16
Hominy	0·53	0·29	0·24

The levels to which the prices of the major feed grains must fall are particularly low in most cases. For example, the price of wheat must fall below 31 cents/10 kg (90 cents/bushel) before it becomes economical whilst oats must be obtained at no more than 28 cents/10 kg (50 cents/bushel) to be included in the optimal solution. Similarly, the prices of the protein concentrates must experience significant reductions to permit economic usage.

3.3 SHADOW PRICE ANALYSIS

In the formulation of any cost minimizing ration, certain elements will be more constraining to the solution than others and thus impose a special cost on the ration. These costs or shadow prices indicate the potential cost reduction generated by the addition or subtraction of the marginal unit of the particular requirement (depending on whether the relevant constraint is a maximum or a minimum).

As minimum constraints were the major concern in this model, it is important to note the magnitude of the cost reduction indicated by the shadow price of each constraint. For instance, it was found that when grain price variations were considered with ration 1, the resultant optimal solution contained significant percentages of coconut meal. As this feed exhibits a high sulphur content (see appendix I) and sulphur exhibits a high shadow price, the use of pure sulphur as a mineral additive had the effect of reducing the daily cost per head from 1·64 cents to 1·08 cents—a reduction of 34 per cent. This is illustrated in table 7.

TABLE 7

Shadow Price Analysis of Constraining Requirements

Constraining elements ration 1 (without sulphur)	Shadow price (cents)	Constraining elements ration 2 (with sulphur)	Shadow price (cents)
Protein MAX	+ ·0184	Calcium MIN ..	— ·0053
Calcium MIN	— ·0053	Sodium MIN ..	— ·0110
Sodium MIN	— ·0110	Sulphur MIN ..	— ·0099
Sulphur	−2·7300	Energy MIN ..	— ·0011

Column 2 shows the high shadow price of sulphur in ration 1, indicating that the satisfaction of the sulphur requirement is significantly constraining the attainment of the optimal least-cost mix. Therefore, a cost advantage can be realized by making sulphur directly available to the solution, thereby minimizing the opportunity cost (shadow price) of making it available via other feeds. The very small shadow prices for the constraining requirements in ration 2 indicate that no additional advantage can be derived by a further marginal reduction of the constraining requirement (see column 4).

4 COMPARISON WITH WHEAT FEEDING

This section compares the relative merits of feeding the computed rations with the commonly adopted practice of total wheat feeding during drought periods. Wheat has been previously recommended for drought feeding on the basis that it provides a relatively cheap cost per unit energy and enjoys ready availability and price stability during drought periods. The basis of this comparison assumes that the usual feeding rate is approximately 1 lb/head/day (0·454 kg).

At the current Australian Wheat Board price for feed wheat of $1.52/ bushel, significant savings are generated through the use of the sulphur inclusive ration 2, in preference to total wheat feeding.[6] To be economically comparable with ration 2, wheat must be obtained at a price significantly below the A.W.B. level. Table 8 indicates that for wheat feeding to be considered an economic strategy, feed wheat must be obtained for 65 cents/bushel or less—a drop of 90 cents below the current A.W.B. price.

TABLE 8

Potential Savings Using Ration 2 Instead of Wheat Feeding

Cost/bus wheat ($)	Daily cost wheat ration (cents)	Daily cost ration 2 (cents)	Daily savings (cents)	Potential Weekly saving 1,000 dry sheep ($)
1.50	2.50	1.08	1.42	99.40
1.45	2.42	1.08	1.34	93.80
1.30	2.17	1.08	1.09	76.30
1.20	2.00	1.08	0.92	64.40
1.00	1.67	1.08	0.59	41.30
0.90	1.50	1.08	0.42	29.40
0.80	1.33	1.08	0.25	17.50
0.70	1.17	1.08	0.09	6.30
0.65	1.08	1.08	..	..

[6] The results of some preliminary experiments recently undertaken at the Glenfield Veterinary Research Station have shown significant body weight increases in lambs fed various wheat-based diets. Five pens of weaner lambs were subjected to four basic total feeding treatments:

(i) wheat + limestone,
(ii) wheat + limestone + sodium buffer mixture,
(iii) wheat + limestone + single sodium buffer,
(iv) wheat + limestone + salt.

These rations were fed over a period of 13 weeks following a 6 week adaptation period. From an initial liveweight of 38 kg, those fed treatment (i) showed a body weight increase of 3·91 kg (10·28 per cent), whilst those on the remaining sodium treatments showed a weight increase of 13·45 kg (35·39 per cent). Total wheat consumption (on an ad libitum basis) varied from 72·36 kg for the first treatment to 94·18–94·64 kg for the remaining treatments. Total buffer consumption over the experimental period was approximately 1·5 kg.

Further computation showed that a wheat-based solution would prove optimal if wheat could be obtained for 80 cents/bushel or less and calcium, salt and limestone were included as mineral additives. The inclusion of mineral additives has a cost depressing effect on the computed solution as essential minerals are supplied in bulk and not through the grain input. Without these minerals, the bulk of wheat required to satisfy the nutritional requirements would be greater as would be the cost of supplying the ration; necessitating feed wheat grain being obtained at very low prices.

Some consideration needs to be given to the relative merits of using home-grown wheat in preference to buying in feed grain. Where home-grown wheat is used for drought feeding purposes, an opportunity cost is involved. This is equal to the net return realized by the farmer through the sale of quota wheat to the A.W.B. and will approximate 80–90 cents/bushel in most cases.[7]

5 SUMMARY AND QUALIFICATIONS

This paper reports an application of linear programming to the field of ruminant nutrition and concerns the problem of total dry sheep maintenance under drought conditions. The relative economics of the grain and protein concentrate feeding of sheep during drought is investigated. Also, conclusions are drawn as to the importance of mineral supplements in drought feeding rations.

The underlying assumption throughout is that total hand feeding is the practice and that the animal gains negligible nutritional benefit from the environment. Total dry sheep maintenance can be effected at an approximate cost of 1 cent per head per day through the use of a mix containing pollard, salt, sulphur and limestone. A wheat-based mix will prove optimal if wheat grain can be obtained for less than 80 cents per bushel and the above minerals are included. Consideration needs to be given to the opportunity cost involved with on-farm feed wheat production.

The determination of drought prices for practical drought planning is a complex problem. Wheat, a major feed grain, lends a degree of seasonal price stability to the market. In recent years an increased range of feedstuffs such as oilseed meals has become available. The approach adopted here was to use 1970–71 average prices, and to test the price stability of the optimal solution using sensitivity analysis.

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[7] The benefits to be derived through feeding home-grown wheat will largely depend on the frequency of the periods in which drought feeding becomes necessary. Where supplementary feeding is a regular part of flock management, home grown reserves will prove economical. However, in areas where the practice is infrequent, the opportunity costs of on-farm storage will need to be considered.

In areas where production costs per bushel are high, it would be advantageous to consider storage of home-grown wheat. Such areas are likely to experience more frequent drought periods and the need for hand feeding.

The selection of pollard as the basis of the programmed solution may surprise, as little consideration has been given to this feed as a practical source of drought maintenance. Pollard is a wheat derivative and must, therefore, have the same degree of price stability even under possible large-scale use in droughts. Alternatively, the wheat-based diets which were closest to the optimal pollard-based diet must receive favourable attention under drought conditions.

The accuracy of the results obtained from any linear programming model depends entirely on the accuracy of the specified data comprising the basic matrix. Although price levels for most feeds are readily obtainable at regular intervals, the nutritional composition of the feed and its variability from sample to sample remains a problem to accurate programme formulation. Thus, because certain assumptions have to be made concerning these variables, considerable scope exists for more efficient mix formulation through the use of more accurate data.

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APPENDIX I

Matrix of Feedstuff Composition and Maintenance Requirements

Activity constraints		B	Weight unit	Wheat	Oats	Maize	Grain Sorghum	Barley	Coconut meal
Cost	.. ..	....	$/10 kg	0·56	0·39	0·46	0·38	0·31	0·59
Protein	MAX ..	60·00	gram	0·1200	0·1000	0·1000	0·0800	0·0900	0·2000
Protein	MIN ..	40·00	gram	0·1200	0·1000	0·1000	0·0800	0·0900	0·2000
Calcium	MIN ..	3·00	gram	0·0012	0·0015	0·0008	0·0015	0·0015	0·0014
Phosphorus	MIN ..	1·50	gram	0·0035	0·0035	0·0027	0·0028	0·0040	0·0060
Sodium	MIN ..	0·50	gram	0·0002	0·00035	0·00014	0·00019	0·0003	0·0007
Iodine	MIN ..	0·0006	gram	0·00065	0·00065	0·00065	0·00065	0·00065	0·0015
Magnesium	MIN ..	0·40	gram	0·0014	0·0014	0·0057	0·0031	0·0013	0·0031
Copper	MIN ..	0·002	gram	0·0008	0·0008	0·0046	0·00031	0·0013	0·0025
Manganese	MIN ..	0·02	gram	0·0033	0·0044	0·0025	0·0044	0·0017	0·0043
Sulphur	MIN ..	1·00	gram	0·0020	0·0021	0·0009	0·0011	0·0015	0·0034
Potassium	MIN ..	0·35	gram	0·0042	0·0043	0·0054	0·00035	0·0049	0·0005
Iron	MIN ..	0·01	gram	0·0055	0·0064	0·0045	0·0044	0·0105	0·0164
Fibre	MAX ..	250·00	gram	0·0275	0·1110	0·0250	0·0250	0·0650	0·1400
Fibre	MIN ..	....	gram	0·0275	0·1110	0·0250	0·0250	0·0650	0·1400
Energy	MAX ..	1,200·00	k cal/g	3·1500	2·6000	3·5400	3·4000	2·7500	1·6500
Energy	MIN ..	1,000·00	k cal/g	3·1500	2·6000	3·5400	3·4000	2·7500	1·6500

APPENDIX I—*continued*

Matrix of Feedstuff Composition and Maintenance Requirements—continued

Activity constraints		B	Weight unit	Lucerne Meal	Meat Meal 50 per cent	Meat Meal 45 per cent	Soybean Meal	Cottonseed meal	Low protein safflower
Cost	.. ..	....	$/10 kg	0·55	1·00	0·91	1·42	0·76	0·39
Protein	MAX ..	60·00	gram	0·1800	0·5000	0·4500	0·5000	0·4000	0·2200
Protein	MIN ..	40·00	gram	0·1800	0·5000	0·4500	0·5000	0·4000	0·2200
Calcium	MIN ..	3·00	gram	0·0112	0·0954	0·1174	0·0400	0·0033	0·0039
Phosphorus	MIN ..	1·50	gram	0·0025	0·0475	0·0550	0·0060	0·0120	0·0071
Sodium	MIN ..	0·50	gram	0·0007	0·0060	0·0067	0·0012	0·0003	0·0003
Iodine	MIN ..	0·0006	gram	0·0015	0·0015	0·0015	0·0015	0·0015	0·0015
Magnesium	MIN ..	0·40	gram	0·0040	0·0055	0·0049	0·0026	0·0055	0·0021
Copper	MIN ..	0·002	gram	0·0132	0·00082	0·0008	0·0014	0·0024	0·0190
Manganese	MIN ..	0·02	gram	0·0042	0·0012	0·0011	0·0031	0·0021	0·0200
Sulphur	MIN ..	1·00	gram	0·0027	0·0048	0·0042	0·0033	0·0048	0·0020
Potassium	MIN ..	0·35	gram	0·0206	0·0042	0·0038	0·0080	0·0145	0·0080
Iron	MIN ..	0·01	gram	0·0196	0·0720	0·0643	0·0105	0·0111	0·0105
Fibre	MAX ..	250·00	gram	0·2200	0·0300	0·0300	0·0300	0·1200	0·3100
Fibre	MIN ..	....	gram	0·2200	0·0300	0·0300	0·0300	0·1200	0·3100
Energy	MAX ..	1,200·00	k cal/g	1·3000	2·2500	2·4000	2·5000	2·3000	0·9500
Energy	MIN ..	1,000·00	k cal/g	1·3000	2·2500	2·4000	2·5000	2·3000	0·9500

APPENDIX I—*continued*

Matrix of Feedstuff Composition and Maintenance Requirements—continued

Activity constraints		B	Weight unit	High protein safflower	High protein sunflower	Peanut meal	Fish meal 65 per cent	Liver meal	Linseed meal	Blood meal
Cost	..	....	$/10 kg	0·95	0·96	0·99	2·32	1·65	0·89	1·32
Protein	MAX	60·00	gram	0·4300	0·4100	0·4300	0·6500	0·6500	0·3300	0·6000
Protein	MIN	40·00	gram	0·4300	0·4100	0·4300	0·6500	0·6500	0·3300	0·6000
Calcium	MIN	3·00	gram	0·0065	0·0040	0·0018	0·0542	0·0048	0·0041	0·0030
Phosphorus	MIN	1·50	gram	0·0071	0·0100	0·0050	0·0280	0·0080	0·0080	0·0025
Sodium	MIN	0·50	gram	0·0003	0·0010	0·0004	0·0094	0·0038	0·0012	0·0089
Iodine	MIN	0·0006	gram	0·0015	0·0015	0·0015	0·0015	0·0015	0·0015	0·0015
Magnesium	MIN	0·40	gram	0·0025	0·0038	0·0031	0·0032	0·0047	0·0055	0·0005
Copper	MIN	0·002	gram	0·0028	0·0035	0·0023	0·0012	0·0092	0·0026	0·0175
Manganese	MIN	0·02	gram	0·0032	0·0022	0·0644	0·0030	0·0008	0·0041	0·0152
Sulphur	MIN	1·00	gram	0·0035	0·0038	0·0029	0·0055	0·0040	0·0038	0·0028
Potassium	MIN	0·35	gram	0·0082	0·0066	0·0115	0·0040	0·0038	0·1024	0·0021
Iron	MIN	0·01	gram	0·0240	0·00003	0·0098	0·0645	0·0970	0·0159	0·0049
Fibre	MAX	250·00	gram	0·0900	0·1400	0·1200	0·0100	0·0200	0·0090	0·0010
Fibre	MIN	....	gram	0·0900	0·1400	0·1200	0·0100	0·0200	0·0090	0·0010
Energy	MAX	1,200·00	k cal/g	2·0500	1·7500	2·7500	3·0000	2·8500	1·7500	2·7500
Energy	MIN	1,000·00	k cal/g	2·0500	1·7500	2·7500	3·0000	2·8500	1·7500	2·7500

APPENDIX I—*continued*

Matrix of Feedstuff Composition and Maintenance Requirements—continued

Activity constraints		B	Weight unit	Bone meal	Bran	Pollard	Hominy	Limestone	Salt	Pure Sulphur
Cost	..	....	$/10 kg	1·01	0·28	0·32	0·53	0·18	0·43	0·99
Protein	MAX	60·00	gram	0·1300	0·1600	0·1600	0·1000	..	..	..
Protein	MIN	40·00	gram	0·1300	0·1600	0·1600	0·1000	..	..	..
Calcium	MIN	3·00	gram	0·3040	0·0016	0·0015	0·0009	0·3400	..	..
Phosphorus	MIN	1·50	gram	0·1400	0·0110	0·0080	0·0050	..	..	..
Sodium	MIN	0·50	gram	0·0026	0·0008	0·0006	0·0005	..	0·3900	..
Iodine	MIN	0·0006	gram	0·0015	0·00065	0·00065	0·00065	..	..	..
Magnesium	MIN	0·40	gram	0·0024	0·0056	0·0032	0·0040	..	..	..
Copper	MIN	0·002	gram	0·0013	0·0012	0·0009	0·0013	..	..	..
Manganese	MIN	0·02	gram	0·0020	0·0113	0·0159	0·0015	..	..	..
Sulphur	MIN	1·00	gram	0·0017	0·0021	0·0020	0·0002	..	..	1·0000
Potassium	MIN	0·35	gram	0·0023	0·0123	0·0089	0·0061	..	..	..
Iron	MIN	0·01	gram	0·1290	0·00019	0·0001	0·00027	..	..	..
Fibre	MAX	250·00	gram	0·0200	0·1000	0·0700	0·0050	..	..	..
Fibre	MIN	....	gram	0·0200	0·1000	0·0700	0·0050	..	..	..
Energy	MAX	1,200·00	k cal/g	..	1·5000	3·0000	2·2500	..	..	..
Energy	MIN	1,000·00	k cal/g	..	1·5000	3·0000	2·2500	..	..	..

APPENDIX II

Inputs Available to Compound Solution

Input	Cost/10 kg	Cost per long ton
	$	$
Wheat	0.53	53.96
Oats	0.39	39.70
Maize	0.46	51.92
Sorghum	0.38	39.70
Barley	0.31	44.80
Coconut meal	0.59	60.00
Lucerne meal	0.55	56.00
Meat meal (50 per cent protein)	1.00	101.00
Meat meal (45 per cent protein)	0.91	92.65
Soybean meal	1.42	144.58
Cottonseed meal	0.76	77.38
Low protein safflower	0.39	39.71
High protein safflower	0.95	96.73
High protein sunflower	0.96	97.74
Peanut meal	0.99	101.00
Fish meal (65 per cent protein)	2.32	236.20
Liver meal	1.65	168.00
Linseed meal	0.89	90.62
Blood meal	1.32	134.40
Bone meal	1.01	102.83
Bran	0.28	28.50
Pollard	0.32	32.58
Hominy	0.53	53.96
Limestone	0.18	18.32
Salt	0.43	43.78
Sulphur	0.99	101.00