OPPORTUNITIES FOR SAVINGS IN MIXING LEBANESE POULTRY FEEDS

BY

ZAFAR YAB HUSAIN

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ZAFAR YAB HŪSAIN

Approved:

Donald C. Taylor

Donald C. Taylor: Assistant Professor of Agricultural Economics. Advisor

Nuhad J. Daghir

Nuhad J. Daghir: Associate Professor of Poultry. Member of Committee

Emile Ghattas

Emile Ghattas: Professor of Business Administration. Member of Committee

Gordon H. Ward

Gordon H. Ward: Professor of Agricultural Economics. Member of Committee

W. W. Worzella

Wallace W. Worzella: Professor of Agronomy, and Coordinator of Graduate Studies

Date thesis is presented: June 7, 1968

SAVINGS IN MIXING FEEDS

HUSAIN

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AN ABSTRACT OF THE THESIS OF

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This case study was conducted to compare the costs of Lebanese poultry feeds formulated under conventional and linear programming methods. The layer rations in the case firm were studied in 1967. Three kinds of basic data were collected: the prices of the ingredients available in the inventory of the firm during 1967, the nutrient compositions of these ingredients, and the ration specifications used by the firm. Information on the formulae of the actual rations developed and sold by the firm in 1967, the costs of the formulae, and the amount marketed under each formula was also collected.

A linear programming model involving 30 restrictions and 57 variables was developed to determine the least-cost rations. Solutions were obtained on the IBM 1620 Computer at the AUB Computer Center. The costs of the linear programmed rations were compared to those of the conventionally formulated rations. The differences between the two gave the savings per kilogram which, when multiplied by the volume of each formula produced, yielded the over all gross savings for the firm during 1967 if it had used linear programming in formulating its rations. The savings amounted to LL. 46,338.62.

In addition to determining the least-cost formulae, supplementary information on the following items was generated: analysis of least-cost rations, price stability ranges of the included ingredients, and shadow prices of excluded ingredients and exactly met specifications. Some practical uses to feed firms of this information were also suggested.

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I. INTRODUCTION

Commercial egg production has expanded rapidly in Lebanon over the past decade. This is substantiated both by production and trade statistics. Egg production increased from an average of 2.1 thousand metric tons during 1954-56 to 18.5 thousand metric tons in 1964-66(and to 31.9 thousand metric tons in 1967). The exports increased from 0.4 thousand metric tons during 1954-56 to 7.3 thousand metric tons in 1964-66, accompanied by a decrease in imports from 1.8 thousand metric tons during 1954-56 to 0.1 thousand metric tons in 1964-66.(Cortas and Sattar, 1968, p 100)

Feed constitutes a high proportion of the total cost of producing eggs. For example, Ward and Fuleihan (1962, p 43) estimated feed costs to be 68 percent of total egg production costs in Lebanon compared to labor and fixed costs which accounted for 11.5 and 14 percent of total costs, respectively. The high proportion of feed cost calls for studies to determine how per unit costs of feed can be reduced.

Feed is produced by mixing different feedstuffs in certain proportions so that the nutritional requirements, as determined through nutrition research, are met. Literally thousands of combinations of feedstuffs available to feed mixers can meet the nutritional requirements of any particular ration. A feed mixer is interested in finding that specific combination which is nutritionally adequate and at the same time the least-cost possible. The present method used by most feed mixers in Lebanon represents a combination of past experience, common sense, and "systematic" trial and error. While vast experience and "good" common sense may yield reasonably "good" results, a feed mixer using such a procedure has no guarantee that all nutritional requirements are met or that ration costs are absolutely minimum.

Fortunately, a technique called linear programming exists which, when applied to feed mixing problems, can provide both such guarantees. This technique has received relatively widespread use, particularly in the U.S. , in recent years. It is a mathematically systematic procedure whereby the least-cost combination of feedstuffs can be obtained while meeting all the nutritional requirements incorporated into the system.

The general purpose of this study was to gain quantitative insights on how much the costs of Lebanese poultry feeds could be reduced if linear programming were used in formulating rations rather than the conventional methods which have been used. To gain these insights, a case study of a feed mixing firm in Lebanon was undertaken.

II. REVIEW OF LITERATURE

Linear Programming in General

Linear programming is a mathematical technique for solving problems involving a number of linear inequalities, subject to the maximization or minimization of a linear objective function. Problems can be solved by either transportation and/or simplex method. The discussion of linear programming in this chapter is restricted to the simplex method since this method was used in this study.

First, a problem involving two unknowns is solved geometrically, later a simplex model is developed for a problem involving four unknowns and finally a general algebraic form is shown for problems involving n-unknowns.

Geometrical Solution

Consider the following problem:

A certain firm is producing two products, X_1 and X_2. X_1 needs two units of input A and five units of input B; X_2 needs six units of input A and three units of input B. Input A has a maximum availability limit of 24 units and input B of 30 units. The profit per unit is \$ 5.00 for X_1 and \$ 8.00 for X_2. The problem is to find the combination of X_1 and X_2 such that profit is maximum. This problem can be written as follows:

$$\text{Maximize} \quad Z = 5X_1 + 8X_2 \qquad \text{(II-1)}$$

subject to

$$2X_1 + 6X_2 \leq 24$$

$$5X_1 + 3X_2 \leq 30 \qquad \text{(II-2)}$$

$$X_1, X_2 \geq 0 \qquad \text{(II-3)}$$

Since this problem involves only two unknowns, it can be solved geometrically as shown below:

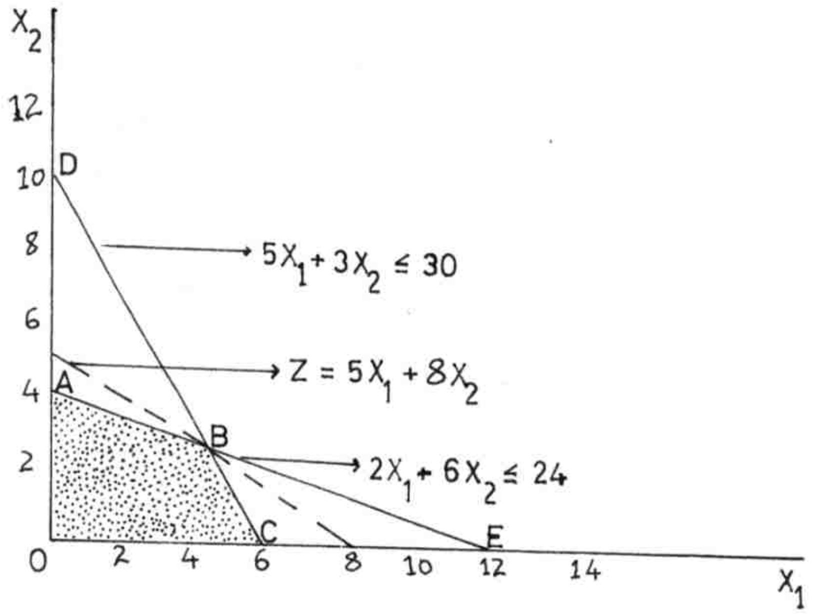

Figure 1. Feasible solution set for the product mix problem.

The restriction equations (II-2) are shown by solid lines while the objective function is indicated by a dotted line with a slope of $- 5/8$. Equation (II-3) indicates that the variables in the solution cannot be negative. Since the restrictions are in the form of "less than or equal to", the area of feasible solution from the first restriction in (II-2) is given by AOE and from the second restriction in (II-2) by DOC. $AOE \cap DOC$ gives convex set OABC as the area of feasible solution when both restrictions in (II-2) are considered. The feasible points are the one at which the objective function is tangent or intersects the convex set OABC. Maximization of the objective function requires that the feasible point be the highest point in the convex set OABC. Point B(4.5, 2.5) is the highest point in this convex set. It gives a profit of $ 42.50 as compared to, for example, a profit of $ 32.00 at point A(0, 4) and a profit of $ 30.00 at point C(6, 0).

Algebraic Form in Four-unknowns

When the number of unknown variables increases to more than three, the graphical method ceases to be helpful in providing solutions. Algebraic methods are well suited to problems involving more than three unknowns. The simplex method was developed by Dantzig(1951, pp 339-347) to handle a problem of any finite number of unknowns in a mathematical way. The following example illustrates the setting up of a simplex linear programming model. (Heady and Candler, 1958, pp 54-68)

A farmer has the alternative of growing four crops: corn, oats, soybean and wheat. To keep the problem simple, it is assumed that only three kinds of inputs, namely land, March labor, and July labor are used in production. The farmer wants to use a minimum of 50 acres of his land. He has a maximum of 100 hours of March labor and 80 hours of July labor. One acre of corn(X_1) is assumed to require no March labor but one hour of July labor. Similarly, one acre of oats(X_2) requires one hour of March labor and none of July labor, one acre of soybean(X_3) requires half an hour of March labor and none of July labor. The profits per acre from corn, oats, soybean, and wheat are $ 30.00, $ 10.00, $ 40.00 and

$ 12.00, respectively. The problem of the farmer is how to allocate his limited resources without violating the availability restrictions and at the same time to maximize his profits. This problem can be stated in algebraic form as follows:

$$\text{Maximize } Z = 30X_1 + 10X_2 + 40X_3 + 12X_4 \qquad \text{(II-4)}$$

subject to

$$1X_1 + 1X_2 + 1X_3 + 1X_4 \geq 50$$

$$0X_1 + 1X_2 + 0X_3 + .5X_4 \leq 100 \qquad \text{(II-5)}$$

$$1X_1 + 0X_2 + 2X_3 + 0X_4 \leq 80$$

$$X_1, X_2, X_3, X_4 \geq 0 \qquad \text{(II-6)}$$

The next step in setting up a linear programming model is to convert the inequalities into equalities. This can be achieved by adding slack variables to the inequalities. The minimum restrictions are converted into equalities by adding slack variables which indicate the amount of surpluses. Maximum restrictions are converted into equalities by adding slack variables which indicate the amount of deficits. Artificial variables with " +1 " coefficients are then added to those equations which lack " +1 " coefficients, to complete a unit matrix. The inclusion of artificial variables assists the computer in solving problems but it has no economic significance. These slack and artificial variables are also added to the objective(profit) function. Since slack variables contribute nothing to profit, they are given zero coefficients, and since artificial variables are not wanted in the final solution, they are given very high coefficients, denoted by - M. The addition of slack and artificial variables to (II-4) and (II-5) yields the following:

$$\text{Maximize } Z = 30X_1 + 10X_2 + 40X_3 + 12X_4 + 0X_5 + 0X_6 + 0X_7 - MX_8 \qquad \text{(II-7)}$$

subject to

$$1X_1 + 1X_2 + 1X_3 + 1X_4 - 1X_5 + 0X_6 + 0X_7 + 1X_8 = 50$$
$$0X_1 + 1X_2 + 0X_3 + .5X_4 + 0X_5 + 1X_6 + 0X_7 + 0X_8 = 100 \qquad \text{(II-8)}$$
$$1X_1 + 0X_2 + 2X_3 + 0X_4 + 0X_5 + 0X_6 + 1X_7 + 0X_8 = 80$$

The real variables are X_1 to X_4, the slack variables are X_5 to X_7 and the artificial variable is X_8. The equations in (II-7) and (II-8) are in the linear programming form which can be solved by the simplex method.

General Algebraic Form in n-unknowns

A linear programming problem involving n-unknowns can be stated in a general algebraic form as follows:

$$\text{Maximize } Z = C_1X_1 + \dots + C_jX_j \dots + C_nX_n \qquad \text{(II-9)}$$

subject to

$$a_{11}X_1 + \dots a_{1j}X_j \dots a_{1n}X_n \geq b_1$$
$$a_{i1}X_1 + \dots a_{ij}X_j \dots a_{in}X_n \leq b_i \qquad \text{(II-10)}$$
$$a_{m1}X_1 + \dots a_{mj}X_j \dots a_{mn}X_n \leq b_m$$
$$X_j \geq 0 \qquad (j = 1, \dots n) \qquad \text{(II-11)}$$

The above linear programming problem can be set up in a simplex model as follows:

$$\text{Maximize } Z = C_1X_1 + \dots + C_jX_j + \dots + C_nX_n + \dots \qquad \text{(II-12)}$$
$$+ 0X_{n+1} + \dots + 0X_{n+j} + \dots + 0X_{n+m} - MX_{n+m+1}$$

subject to

$$a_{11}X_1 + \dots + a_{1j}X_j + \dots + a_{1n}X_n + X_{n+1} + \dots - X_{n+m+1} = b_1$$

$$a_{i1}X_1 + \dots + a_{ij}X_j + \dots + a_{in}X_n + 0X_{n+1} + \dots + X_{n+j} + \dots + 0X_{n+m+1} = b_i \qquad \text{(II-13)}$$

$$a_{m1}X_1 + \dots + a_{mj}X_j + \dots + a_{mn}X_n + \dots + X_{n+m} + \dots + 0X_{n+m+1} = b_m \qquad \text{(II-13)}$$

$$X_j \geq 0 \qquad \text{(II-14)}$$

where,

$X_1 \dots X_n$ are real variables,

$X_{n+1} \dots X_{n+m}$ are slack variables,

and X_{n+m+1} is an artificial variable.

Evolution of Linear Programming As Applied to Feed Mixing Problems

This part of the chapter traces the history of the development of linear programming as applied to feed mixing problems. Methodological improvements are emphasized, but only those which contribute directly to the methodology used in this study.

Stigler was first to attempt to compute a "minimum-cost" diet. His classical work(1945) showed that a human being could survive in the United States on a ration consisting of wheat flour, evaporated milk, cabbages, spinach, and dried navy beans at an annual cost, in August 1939 prices, of $ 39.93. Since his study preceded the development of linear programming, his computations relied on "systematic" trial and error. And, as he acknowledged, his so-called "minimum cost" diet was not necessarily the diet of absolute minimum cost. In addition to determining the composition and value of the minimum-cost diet, Stigler also computed the actual amounts of the different nutrients in the diet as percentages of the minimum requirements.

The first attempt to compute minimum cost animal feeds was made by Waugh (1951). He computed minimum cost dairy rations with two levels of protein and with and without weight controls. Since matrix algebra was used in solving this problem, Waugh was restricted to considering identical numbers of ingredients and ration restrictions. The solutions gave the minimum cost combinations of the ingredients and the costs of the rations.

The post-Waugh attempts to compute least-cost feed rations were not limited to problems with identical numbers of ingredients and ration restrictions. The development of the simplex method of solution made it possible to solve problems involving larger numbers of unknowns than numbers of equations. Also, development and use of electronic computers permitted the handling of much larger problems than was formerly possible with desk calculators.

Swanson (1955) made use of linear programming in formulating a least-cost hog feed with two levels of protein and with 17 minimum restrictions. Twenty ingredients were considered under two different price situations. Katzman (1956) computed a least-cost broiler ration with seven minimum restrictions and one weight control restriction. Eight ingredients were considered in this case. The surplus quantities of nutrients were shown in addition to the least-cost combinations of ingredients and the cost of the formula.

With the gain in experience in using linear programming, additional information was generated and its uses are illustrated in the studies cited below:

Hutton et al.(1958) developed a simplex model to formulate a least-cost broiler feed formula meeting 12 restrictions from 34 ingredients. The solution provided the least-cost formula, its cost and the amounts of nutrients and feedstuff surpluses and deficits. Additional information regarding displacement rates of ingredients and nutrient restrictions and the changes in the feed formula and its cost was also provided. It was shown how this information could be used to modify the least-cost formula when changes in specifications, in ingredient composition and in ingredient prices, take place. Bishop (1962) computed a least-cost broiler starter ration with and without a calorie-protein ratio restriction. Other information generated included the price ranges of included ingredients within which the ration remained unchanged, and the necessary reduction in the prices of the excluded ingredients in order that such ingredients could be included in the least-cost ration. Maddy et al.(1963) and Seagraves (1963) included the price ranges for included ingredients and the shadow prices of excluded ingredients and restrictions exactly met in their least-cost solution. Seagraves also showed how the computation cost on electronic computers could be reduced if the size of problem were made less by prior calculations. Stafford (1965), and Taylor and Daghir (1968) showed how the price ranges of included ingredients and the shadow prices of excluded ingredients could be used as guide lines for purchasing ingredients.

Assumptions Underlying Linear Programming with Particular Reference to Feed Mixing Problems

Linear Programming is based on certain assumptions. A thorough acquaintance with these assumptions is essential for one to know if linear programming represents a valid analytical framework for solving problems. Otherwise, the results obtained from linear programming may be misleading. The various assumptions basic to the linear programming technique are widely discussed in the literature. (Heady and Candler, 1958, pp 17-18, Dorfman, et al., 1958, p 10, Ferguson and Sargent, 1958, pp 78-79). The most important relative to least-cost feed formulation problems are discussed below:

Linearity and Additivity Assumption

This assumption applies to both the objective function and the equations reflecting the restrictions. Linearity of any function implies that the function is a straight line.

A firm whose objective function (either profit or cost) is linear is operating in a perfect market in that a given price applies to all possible quantities that the firm could sell or buy. For a profit function, the linear assumption implies that regardless of how much the firm produces, all units sell at the given market price. For a cost function, it implies a perfect raw materials market in that the firm pays the same price regardless of the quantity purchased, i.e.the input price is not affected by the amount that any single firm buys.

The linearity and additivity assumption on restriction equations, indicate in economic terms that there exists "constant returns to scale". It assumes, for example, that if one kg of corn supplies 3,373 calories, ten kg of corn will provide 33,730 calories. The linearity assumption is closely related to an "independence" assumption. In this case, the independence assumption indicates that the amount of individual nutrients physically available from a given ingredient is independent of the quantities of that ingredient used in a ration. Another implication of independence is in terms of physiological availability of nutrients from different ingredients. The physiological independence assumption implies that nutrients from given ingredients are physiologically available irrespective of what other ingredients are present in the ration formula.

Divisibility

This assumption implies that the restrictions and the objective of the problem can be represented by continuous functions rather than discontinuous points in space. It implies that a feed mixer can mix the different ingredients in any proportion and also produce the feed in any proportion.

Single Valued Specification Levels

Only one minimum or maximum level is assumed for any given nutrient and feedstuff specification in a feed mixing problem. The levels are usually those which have been shown to support the maximum possible physical preformance of the chicken. But the "law" of diminishing returns implies the possible inappropriateness of this assumption. In particular, it suggests the possibility of greater economy in production if the levels used of certain specifications are less than those which support maximum possible physical performance.

III. METHODOLOGY

The general objective of this study, as stated above, was to compare, for a specific feed mixing firm, the costs of poultry rations formulated with (a) conventional and (b) linear programming methods. To achieve this general objective, the following specific objectives were considered:

Specific Objectives of the Study

1) To find the actual cost of the mixed feeds when the conventional method was used.

2) To find the cost of the mixed feeds if linear programming had been used under identical feedstuff market conditions and with nutrient specifications identical to those used in the conventional formulations.

3) To compare the ration costs under the two systems and to compute the savings if the feed mixing firm had used linear programming during 1967 to formulate its layer rations.

4) To generate additional information such as: analysis of least-cost rations, price stability ranges of included ingredients, shadow prices of excluded ingredients, shadow prices of exactly met specifications, and to show their practical uses to poultry feed mixers.

Description of Case Study

This study was restricted to one firm and one product. Its main purpose was simply to demonstrate the potential for savings from the use of linear programming in formulating least-cost poultry feed formulae.

Criteria for Selection of Firm and Product

The firm under study was selected on the basis of three criteria: the willingness of its management to supply necessary data, the completeness and apparent accuracy of the information in its records and the frequency of reviews of its feed formulae.

The importance of the first two criteria is self-explanatory. The frequency of reviews is closely related to the period of time over which the study was made. More than one review is needed to guard against the possibility of studying a ration formulation situation which for some reasons might have been atypical. In this case, the firm reviewed its formulae ten times in 1967.

The product was selected on the basis of production volume. The larger the volume of production, the larger is the likely saving if an improved method of ration formulation is adopted, and the greater should be the interest of a feed mixing firm in changing its formulation procedures. The firm under study produced both layer and broiler feed. The volume of the former was twice that of the latter; accordingly, feed for layers was selected for this study. The firm produced two kinds of layer feeds: a high protein feed and a low protein feed. These two feeds are henceforth referred to in the study as L-1 and L-2.

Collection of Required Data

The following seven kinds of information were collected through personal interview from one of the responsible employees of the firm:

1) Ingredients available in the inventory of the firm during the period of study, January to December, 1967.

2) Prices of the ingredients available for each month for the same period.

3) The nutrient composition of each of the ingredients available in the inventory of the firm.

4) Nutrient and ingredient specifications considered by the firm when formulating its rations.

5) The number of different formulae used throughout the year and the period over which each was used.

6) The ingredient mix of the actual formulae used by the firm and the cost of each.

7) Volume of feed produced for each feed formula used by the firm.

The firm placed primary reliance on the nutrient compositions from "Analysis Table for Feed Ingredients". (Hubell, 1965) For locally produced ingredients, however, the firm supplied modified nutrient compositions.

Adjustments Made to the Original Data

The actual amounts of the nutrients present in each feed formula used by the firm were first computed and compared with the nutrient specifications reported by the firm. This analysis revealed that some of the nutrient specifications were not met. But a valid cost comparison of the rations formulated under two different methods requires that the basic data used in both calculations be the same. Therefore, the reported specifications were modified, when necessary, to be consistent with the actual feed formula produced. The most important modifications were first discussed with the management of the feed firm. These revised restrictions were then used in the least-cost formulation with linear programming.

One additional modification was made. In the original feed formulae, yellow corn was used at a level high enough to insure an adequate amount of xanthophyll, and so no explicit xanthophyll requirement was reported by the firm. But, for the programmed formulae in which white sorghum was available, a minimum specification for xanthophyll at 5.00 mg/kg was required to prevent the relatively lower cost, but also xanthophyll-free white sorghum from completely replacing yellow corn in the ration.

Linear Programming Applied to Case Study

In chapter II, the linear programming (simplex) method was explained in general and as it applies to least-cost feed formulations. This part of the methodology focuses on the specific adaptation of linear programming to the feed mixing firm under study. This involved setting up a linear programming model and a reprogramming schedule. A discussion of each follows.

Setting up the Linear Programming Model

As mentioned above, the firm under study produced two kinds of layer feeds. The linear programming models for the two layer feeds, L-1 and L-2, are described separately as follows:

1) L-1: The setting up a linear programming model requires three kinds of data, namely prices of ingredients, nutrient composition of ingredients and nutrient and ingredient specifications. Table 1 shows the ingredients available with their prices for the months of January to December, 1967. The 11 ingredients available to the firm during 1967 are numbered in the linear programming model X_{31} to X_{41}. Some of these ingredients were not available during certain months of the year. In such instances, the ingredients were assigned artificially high prices of 10,000 L.P./kg to insure that they would not be included in the least-cost solutions. The objective function for each of the ten feed formulae for L-1 and L-2 was established as follows:

$$\text{Minimize } Z = \sum_{i=1}^{10} C_{ij}X_j, \qquad (j = 1, \ldots\ldots 57) \quad \text{(III-1)}$$

where,

C_{ij} = cost of variable j in L-1.i or L-2.i

X_j = amount of variable j in least-cost feed formula

Table 2 shows the nutrient composition of the 11 ingredients. These are shown in the linear programming model in Appendix B in col 31 to col 41.

Table 3 shows a total of 30 specifications for each of the ten L-1 rations. The 30 specifications include 16 minimum restrictions (made up of 14 nutrient and two ingredient specifications), 13 maximum restrictions (made up of 10 nutrient and three ingredient specifications) and one "equal to" restriction for weight control. The 13 minimum restrictions are shown in the first 13 rows while one minimum restriction is shown in row 28. The two minimum ingredient restrictions are shown in

Table 1. Monthly prices (L.P./kg) of ingredients available in the inventory of the firm during 1967.

Ingredients	Var. No.	Jan.	Feb.	Mar.	Apr.	May	June
Yellow corn (U.S.A.)	X_{31}	25.00	25.00	25.00	25.00	25.00	25.00
Wheat bran (Local)	X_{32}	14.50	14.50	14.50	14.50	14.50	14.50
Feather meal (Local)	X_{33}	41.00	41.00	41.00	41.00	41.00	41.00
Soymeal (50%, U.S.A.)	X_{34}	62.70	62.70	62.70	47.80	47.80	47.80
Oats (Pac. Coast, U.S.A.)	X_{35}	19.00	19.00	19.00	19.00	19.00	19.00
St. bone meal (Egypt)	X_{36}	30.00	30.00	30.00	30.00	30.00	30.00
Limestone (Local)	X_{37}	2.70	2.70	2.70	2.70	2.70	2.70
L.M.A.P.	X_{38}	51.40	50.04	49.09	48.97	48.69	48.69
Mav-12-A	X_{39}	-	-	-	-	-	-
L.M.A.C. #	$X_{39\#}$	53.62	53.62	53.62	53.62	53.62	53.62
White sorghum (Local)	X_{40}	-	-	-	-	-	-
Barley (Local)	X_{41}	-	-	24.30	25.70	24.40	24.40

Table 1. (Continued)

Ingredients	July	Aug.	Sept.	Oct.	Nov.	Dec.
Yellow corn (U.S.A.)	25.00	25.00	25.00	23.00	23.00	23.00
Wheat bran (Local)	14.50	14.50	14.50	15.50	14.50	14.50
Feather meal (Local)	41.00	41.00	41.00	41.00	41.00	41.00
Soymeal (50%, U.S.A.)	40.70	40.70	40.70	39.10	39.10	39.10
Oats (Pac. Coast, U.S.A.)	19.00	19.00	19.00	17.00	17.00	17.00
St. bone meal (Egypt)	30.00	30.00	30.00	25.00	25.00	25.00
Limestone (Local)	2.70	2.70	2.70	2.70	2.70	2.70
L.M.A.P.	48.69	49.50	49.54	47.83	47.26	47.26
Mav-12-A	-	-	57.43	57.43	57.43	-
L.M.A.C.#	-	-	-	-	-	-
White sorghum (Local)	-	22.00	22.00	-	-	-
Barley (Local)	28.20	28.20	24.70	24.70	-	-

See page 26 for explanation.

Table 2. Nutrient composition of ingredients available in the inventory of the firm during 1967.

Nutrients	Unit	Yellow corn (X_{31})	Wheat bran (X_{32})	Feather meal (X_{33})	Soymeal (X_{34})	Oats (X_{35})
Metabolizable energy	Cal/kg	3373.0	1124.0	2227.0	2535.0	2645.0
Fat	%	3.50	4.00	1.10	0.50	6.30
Protein	%	8.80	13.80	85.00	50.00	12.50
Lysine	%	0.21	0.55	1.80	3.20	0.38
Methionine	%	0.18	0.16	0.56	0.77	0.13
Methionine plus Cystine	%	0.34	0.40	3.37	1.51	0.29
Calcium	%	0.010	0.180	0.250	0.200	0.100
Phosphorus (Available)	%	0.075	0.274	0.250	0.195	0.099
Vitamin A	1000 IU	0.992				
Riboflavin	mg/kg	1.102	2.205	1.764	2.646	1.102
Pantothenic acid	mg/kg	4.850	26.455	7.716	13.228	12.125
Niacin	mg/kg	19.841	143.299	17.637	20.944	14.330
Choline	mg/kg	441.0	1014.0	882.0	2866.0	882.0
Crude fiber	%	2.90	14.60	1.00	3.00	11.20
Arginine	%	0.40	0.69	5.10	3.80	0.60
Glycine	%	3.50	0.69	5.70	2.70	0.40
Tryptophane	%	0.07	0.25	0.57	0.64	0.12
Xanthophyll	mg/kg	15.432				
Vitamin B_{12}	mg/kg			0.110		

Table 2. (Continued).

Nutrients	St. Bone Meal (X_{36})	Limestone (X_{37})	L.M.A.P. (X_{38})	Mav-12-A (X_{39})	L.M.A.C. (X_{39})	White sorg (X_{40})	Barley (X_{41})
Metabolizable energy			1767.0	1501.0	2125.0	3307.0	2337.0
Fat			10.39	4.51	4.20	1.50	1.75
Protein			23.33	30.66	38.36	8.30	8.50
Lysine			1.11	1.81	2.32	0.21	0.19
Methionine			0.26	0.49	0.53	0.13	0.13
Methionine plus Cystine			0.56	0.83	1.07	0.28	0.34
Calcium	24.0	38.0	12.490	13.400	5.740	0.240	0.048
Phosphorus (Available)	12.0		3.540	2.120	1.900	0.078	0.103
Vitamin A			92.124	120.000	39.683	0.245	-
Riboflavin			54.610	24.000	25.900	1.102	1.102
Pantothenic acid			84.440		44.050	9.921	5.512
Niacin			290.810	98.000	135.050	35.274	44.092
Choline			1026.0	1301.0	1993.4	441.0	882.0
Crude fiber			4.56	5.50	4.43	2.50	5.90
Arginine			1.40			0.28	0.42
Glycine						0.30	0.20
Tryptophane						0.09	0.12
Xanthophyll							
Vitamin B_{12}							

Table 3. Nutrient and ingredient specifications for rations L-1.1 to L-1.10, produced by the firm during 1967.

Specifications	Unit	Min. or Max.	L-1.1	L-1.2	L-1.3	L-1.4	L-1.5
Metabolizable energy	Cal/kg	Min.	2535.0	2535.0	2535.0	2535.0	2535.0
Fat	%	Min.	3.0	3.0	3.0	3.0	3.0
Protein	%	Min.	17.0	17.0	17.0	17.0	17.0
Lysine	%	Min.	0.70	0.70	0.70	0.70	0.70
Methionine	%	Min.	0.26	0.26	0.26	0.27	0.27
Methionine plus cystine	%	Min.	0.53	0.52	0.52	0.53	0.54
Calcium	%	Min.	3.0	3.0	3.0	3.0	3.12
Phosphorus (Available)	%	Min.	0.45	0.45	0.45	0.42	0.42
Vitamin A	1000 IU	Min.	10.02	10.02	10.02	10.02	10.02
Riboflavin	mg/kg	Min.	4.41	4.41	4.41	4.41	4.41
Pantothenic acid	mg/kg	Min.	12.12	12.12	12.12	12.12	12.12
Niacin	mg/kg	Min.	46.30	46.30	46.30	46.30	46.30
Choline	mg/kg	Min.	926.0	926.0	926.0	926.0	926.0
L.M.A.P.	%	Min.	12.0	12.0	12.0	6.0	6.0
Mav-12-A	%	Min.	100.0(Max)	100.0(Max)	100.0(Max)	5.0 (Min)	5.0 (Min)
Crude fiber	%	Max.	5.30	5.30	5.30	5.30	5.30
Metabolizable energy	Cal/kg	Max.	2579.0	2588.0	2582.0	2579.0	2615.0
Methionine	%	Max.	0.30	0.30	0.30	0.30	0.30
Methionine plus cystine	%	Max.	0.60	0.60	0.60	0.60	0.60
Calcium	%	Max.	3.10	3.46	3.48	3.27	3.30
Phosphorus (Available)	%	Max.	0.80	0.80	0.80	0.80	0.80
Wheat bran	%	Max.	15.0	15.0	15.0	15.0	15.0
Feather meal	%	Max.	5.0	5.0	5.0	5.0	5.0
Oats	%	Max.	25.0	25.0	25.0	25.0	25.0
Arginine	%	Max.	100.0	100.0	100.0	100.0	100.0
Glycine	%	Max.	100.0	100.0	100.0	100.0	100.0
Tryptophane	%	Max.	100.0	100.0	100.0	100.0	100.0
Xanthophyll	mg/kg	Min.	5.0	5.0	5.0	5.0	5.0
Vitamin B_{12}	mg/kg	Max.	100.0	100.0	100.0	100.0	100.0
Weight	kg	Equal	1.0	1.0	1.0	1.0	1.0

Table 3. (Continued).

Specifications	L-1.6	L-1.7	L-1.8	L-1.9	L-1.10
Metabolizable energy	2535.0	2535.0	2690.0	2535.0	2535.0
Fat	3.0	3.0	3.0	3.0	3.0
Protein	17.0	16.92	16.0	16.0	16.0
Lysine	0.70	0.70	0.70	0.70	0.70
Methionine	0.27	0.26	0.26	0.26	0.25
Methionine plus cystine	0.54	0.52	0.51	0.52	0.50
Calcium	3.0	3.0	3.0	3.0	3.0
Phosphorus (Available)	0.43	0.45	0.45	0.45	0.45
Vitamin A	10.02	10.02	10.02	10.02	10.02
Riboflavin	4.41	4.41	4.41	4.41	4.41
Pantothenic acid	12.12	12.12	12.12	12.12	12.12
Niacin	46.30	46.30	46.30	46.30	46.30
Choline	926.0	926.0	918.98	926.0	926.0
L.M.A.P.	6.0	11.50	11.50	11.50	11.50
Mav-12-A	5.0 (Min)	100.0 (Max)	100.0 (Max)	100.0 (Max)	100.0 (Max)
Crude fiber	5.42	5.39	5.30	5.30	5.30
Metabolizable energy	2579.0	2579.0	2718.0	2721.00	2740.0
Methionine	0.30	0.30	0.30	0.30	0.30
Methionine plus cystine	0.60	0.60	0.60	0.60	0.60
Calcium	3.12	3.10	3.10	3.10	3.10
Phosphorus (Available)	0.80	0.80	0.80	0.80	0.80
Wheat bran	15.0	15.0	15.0	15.0	15.0
Feather meal	5.0	5.0	5.0	5.0	5.0
Oats	25.0	25.0	25.0	25.0	27.0
Arginine	100.0	100.0	100.0	100.0	100.0
Glycine	100.0	100.0	100.0	100.0	100.0
Tryptophane	100.0	100.0	100.0	100.0	100.0
Xanthophyll	5.0	5.0	5.0	5.0	5.0
Vitamin B_{12}	100.0	100.0	100.0	100.0	100.0
Weight	1.0	1.0	1.0	1.0	1.0

rows 14 and 15. The first 16 minimum restrictions require 16 slack variables with -1 coefficients and 16 artificial variables with +1 coefficients. The 16 artificial variables are in col 1 (X_1) to col 15 (X_{15}) and col 28 (X_{28}) and the 16 slack variables are in col 42 (X_{42}) to col 57 (X_{57}). Only three rations, L-1.4, L-1.5 and L-1.6, have two minimum ingredient restrictions; the rest have only one minimum ingredient restriction. In order to convert the row 15 minimum restriction into a maximum restriction for the seven rations, the coefficient of slack variable in col 56 (X_{56}) was changed from -1 to +1 and the price of that ingredient was changed to 10,000 L.P./kg to prevent it from coming into the solution. The minimum restriction in row 28 has an artificial variable with a +1 coefficient in col 28 (X_{28}) and a slack variable with a -1 coefficient in col 57 (X_{57}). The weight control restriction in row 30 has an artificial variable with a +1 coefficient in col 30 (X_{30}). The 13 maximum restrictions require 13 slack variables with +1 coefficients. These are in col 16 (X_{16}) to col 27 (X_{27}) and col 29 (X_{29}). Thus there are a total of 30 rows and 57 columns in this model. In the objective function, the slack variables are given zero coefficients and the artificial variables, coefficients of 10,000. This is because slack variables do not add any cost to the formula and the artificial variables are not desired in the final solution. The model, thus developed is shown in Appendix B.

2) L-2: A similar linear programming model was developed for L-2 rations. However, certain changes were made due to changes in ingredient restrictions. Table 4 shows the specifications for L-2.1 to L-2.10 rations. It also shows that L-2.1 and L-2.2 rations have a

Table 4. Nutrient and ingredient specifications for rations L-2.1 to L-2.10, produced by the firm during 1967.

Specifications	Unit	Min. or Max.	L-2.1	L-2.2.	L-2.3	L-2.4	L-2.5
Metabolizable energy	Cal/kg	Min.	2626.0	2513.0	2513.0	2513.0	2513.0
Fat	%	Min.	3.0	3.0	3.0	3.0	3.0
Protein	%	Min.	15.50	16.32	16.13	16.13	16.19
Lysine	%	Min.	0.65	0.65	0.65	0.65	0.65
Methionine	%	Min.	0.24	0.25	0.24	0.25	0.25
Methionine plus cystine	%	Min.	0.49	0.49	0.49	0.50	0.50
Calcium	%	Min.	2.82	3.20	3.20	3.20	3.20
Phosphorus (Available)	%	Min.	0.45	0.47	0.47	0.41	0.40
Vitamin A	1000 IU	Min.	9.32	10.02	10.02	10.02	10.02
Riboflavin	mg/kg	Min.	4.41	4.41	4.41	4.41	4.41
Pantothenic acid	mg/kg	Min.	12.12	12.12	12.12	12.12	12.12
Niacin	mg/kg	Min.	46.30	46.30	46.30	46.30	46.30
Choline	mg/kg	Min.	851.00	882.00	882.0	882.0	882.0
L.M.A.P.	%	Min.	100.00(Max)	100.00(Max)	11.00	5.50	5.50
Mav-12-A/L.M.A.C.	%	Min.	22.00	24.00	100.00(Max)	5.00	5.00
Crude fiber	%	Max.	6.00	6.00	6.00	6.00	6.00
Metabolizable energy	Cal/kg	Max.	2657.00	2607.00	2614.00	2557.00	2597.00
Methionine	%	Max.	0.30	0.30	0.30	0.30	0.30
Methionine plus cystine	%	Max.	0.60	0.60	0.60	0.60	0.60
Calcium	%	Max.	3.10	3.50	3.50	3.50	3.50
Phosphorus (Available)	%	Max.	0.80	0.80	0.80	0.80	0.80
Wheat bran	%	Max.	15.00	15.00	15.00	15.00	15.00
Feather meal	%	Max.	5.00	5.00	5.00	5.00	5.00
Oafs	%	Max.	25.00	25.00	25.00	25.00	25.00
Arginine	%	Max.	100.0	100.0	100.0	100.0	100.0
Glycine	%	Max.	100.0	100.0	100.0	100.0	100.0
Tryptophane	%	Max.	100.0	100.0	100.0	100.0	100.0
Xanthophyll	mg/kg	Min.	5.00	5.00	5.00	5.00	5.00
Vitamin B_{12}	mg/kg	Max.	100.0	100.0	100.0	100.0	100.0
Weight	kg	Equal	1.00	1.00	1.00	1.00	1.00

Table 4. (Continued).

Specifications	L-2.6	L-2.7	L-2.8	L-2.9	L-2.10
Metabolizable energy	2474.00	2518.00	2634.00	2634.00	2634.00
Fat	3.00	3.00	3.00	3.00	3.00
Protein	15.50	15.50	15.13	15.49	15.50
Lysine	0.65	0.65	0.65	0.65	0.65
Methionine	0.25	0.23	0.23	0.24	0.23
Methionine plus cystine	0.50	0.48	0.46	0.48	0.46
Calcium	3.00	3.00	2.98	3.00	2.96
Phosphorus (Available)	0.41	0.45	0.48	0.45	0.47
Vitamin A	10.02	10.02	10.02	10.02	10.02
Riboflavin	4.41	4.41	4.41	4.41	4.41
Pantothenic acid	12.12	12.12	12.12	12.12	12.12
Niacin	46.30	46.30	46.30	46.30	46.30
Choline	882.00	882.00	844.27	862.48	882.00
L.M.A.P.	5.50	11.0	11.0	11.0	11.0
Mav-12-A	5.00	100.0 (Max)	100.0 (Max)	100.0 (Max)	100.0 (Max)
Crude fiber	6.00	6.00	6.00	6.00	6.05
Metabolizable energy	2657.00	2657.00	2695.00	2665.00	2700.00
Methionine	0.30	0.30	0.30	0.30	0.30
Methionine plus cystine	0.60	0.60	0.60	0.60	0.60
Calcium	3.10	3.10	3.10	3.10	3.10
Phosphorus (Available)	0.80	0.80	0.80	0.80	0.80
Wheat bran	15.00	15.00	15.00	15.00	15.00
Feather meal	5.00	5.00	5.00	5.00	5.00
Oats	25.00	25.00	17.00	25.00	37.00
Arginine	100.0	100.0	100.0	100.0	100.0
Glycine	100.0	100.0	100.0	100.0	100.0
Tryptophane	100.0	100.0	100.0	100.0	100.0
Xanthophyll	5.00	5.00	5.00	5.00	5.00
Vitamin B_{12}	100.0	100.0	100.0	100.0	100.0
Weight	1.00	1.00	1.00	1.00	1.00

minimum restriction for a new kind of ingredient, a concentrate. Since the computer cannot handle more than 31 rows, one of the concentrates, Mav-12-A in row 15 with a minimum restriction in the previous model, was replaced by the new concentrate, L.M.A.C. for L-2.1 and L-2.2 rations in row 15 and col 39 (X_{39}). For the rations L-2.3 to L-2.10, L.M.A.C. was removed from row 15, col 39 and Mav-12-A was replaced, since the new concentrate was no more used in any one of the subsequent rations, while Mav-12-A was used in the later rations. The nutrient composition of L.M.A.C. was also removed from col 39 and that of Mav-12-A was replaced in its original column.

The solutions for both L-1 and L-2 rations were obtained on the IBM 1620 Computer at the AUB Computer Center.

Setting up the Reprogramming Schedule

The reprogramming schedule was developed to represent an appropriate sequence of ration reformulations. The schedule reflects each point of time throughout the year where changed market and/or specification conditions dictated that a new feed formula be computed. The following changes were considered while developing the reprogramming schedule for the layer rations:

1) Changes in speicifcations: Every time the specifications changed, a new feed formula was developed using linear programming, subject to the condition that the amounts of nutrients present in the last formula did not meet the changed nutrient specifications. This was done to insure the validity of cost comparison which requires that formulae to be compared should have used the same basic data for computations.

2) Changes in prices of ingredients: Just because the prices of some ingredients changed, did not necessarily imply that a new formula be computed. The prices of included ingredients can change within a certain range, without requiring reformulation of a ration. Also, excluded ingredients will stay out of a ration as long as their market prices exceed the corresponding highest feasible prices in the previous solution. Accordingly, a new formula was developed as a result of changes in prices of ingredients when the new prices of included ingredients were outside the lower and upper limits of prices as given in the previous solution or the new prices of excluded ingredients were lowered below the highest feasible level indicated in the previous solution.

3) Changes in the kinds of ingredients available: If a new ingredient became available at a certain point of time and was a possible substitute for another ingredient, the ration was reformulated.

Reprogramming schedules were developed for both L-1 and L-2 rations. These reprogramming schedules for L-1 and L-2 are shown in Tables 5 and 6. Since the restrictions for all the ten rations in both L-1 and L-2 were different from each other, each was programmed.

The first column in Tables 5 and 6 shows the ration number and the month. The second column shows the month and the third column shows the changes in prices of ingredients in the month shown in col 2. The last column shows whether a new formula was developed or the same formula remained valid and only the cost of the formula was computed according to the price in the month shown in col 3. If only the cost of the formula was computed in a certain month, then the formula was valid for that month. The solid lines separate the formulae from each other which have different specifications.

Table 5. Reprogramming schedule for L-1 rations.

Ration Number	Month	Changes in prices (L.P./kg)	Remarks
L-1.1 Jan.	Jan.	-	New formula L-1.1 Jan. developed.
L-1.1 Jan.	Feb.	L.M.A.P. at 50.04	Only cost recomputed for L-1.1 Jan.
L-1.1 Jan.	Mar.	1) L.M.A.P. at 49.90 2) Barley at 24.30	Only cost recomputed for L-1.1 Jan.
L-1.1 Jan.	Apr.	1) Soymeal at 47.80 2) L.M.A.P. at 48.97 3) Barley at 25.70	New formula L-1.1 Apr. developed.
L-1.1 Apr.	May	1) L.M.A.P. at 48.69 2) Barley at 24.40	Only cost recomputed for L-1.1 Apr.
L-1.1 Apr.	June	No changes	-
L-1.2 June	June		New formula developed
L-1.2 June	July	1) Soymeal at 40.70 2) Barley at 28.20	Only cost recomputed for L-1.2 June.
L-1.2 June	Aug.	1) L.M.A.P. at 49.54 2) White sorghum at 22.00	New formula L-1.1 Aug. developed.
L-1.3 Aug.	Aug.	-	New formula L-1.3 developed Aug.
L-1.4 Sept.	Sept.	-	New formula L-1.4 Sept. developed.
L-1.5 Sept.	Sept.	-	New formula L-1.5 developed.
L-1.5 Sept.	Oct.	1) Yellow corn at 23.00 2) Wheat bran at 15.50 3) Soymeal at 39.10 4) Oats at 17.10 5) L.M.A.P. at 47.83 6) White sorghum n.a. 7) Barley at 24.70	New formula L-1.5 Oct. developed.

Table 5. (Continued)

Ration Number	Month	Changes in prices (L.P./kg)	Remarks
L-1.6 Oct.	Oct.	-	New formula L-1.6 Oct. developed.
L-1.7 Oct.	Oct.	-	New formula L-1.7 Oct. developed.
L-1.7 Oct.	Nov.	1) Wheat bran at 14.50 2) L.M.A.P. at 47.26 3) Barley n.a.	New formula L-1.7 Nov. developed.
L-1.8 Nov.	Nov.	-	New formula L-1.8 Nov. developed.
L-1.9 Nov.			New formula L-1.9 Nov. developed.
L-1.9 Nov.	Dec.	No changes	-
L-1.10 Dec.	Dec.	-	New formula L-1.10 Dec. developed.

Table 6. Reprogramming schedule for L-2 rations.

Ration Number	Month	Changes in prices (L.P./kg)	Remarks
L-2.1 Jan	Jan.	-	New formula L-2.1 Jan. developed.
L-2.1 Jan.	Feb.	No changes	Only cost recomputed for L-2.1 Jan.
L-2.1 Jan.	Mar.	Barley at 24.30	Both cost and formula L-2.1 Jan. applies.
L-2.1 Jan.	Apr.	1) Soymeal at 47.80	New formula L-2.1 Apr. developed.
L-2.1 Apr.	May	Barley at 24.40	Both cost and formula L-2.1 Apr. applies.
L-2.1 Apr.	June	No changes	-
L-2.2 June	June	-	New formula L-2.2 June developed.
L-2.2 June	July	1) Soymeal at 40.70 2) Barley at 28.20	Only cost recomputed for L-2.2.June.
L-2.2 June	Aug.	1) White sorghum at 22.00	New formula L-2.2 Aug. developed.
L-2.3 Aug.	Aug.	-	New formula L-2.3 Aug. developed.
L-2.4 Sept.	Sept.	-	New formula L-2.4 Sept. developed.
L-2.5 Sept.	Sept.	-	New formula L-2.5 Sept. developed.
L-2.6 Sept.	Sept.	-	New formula L-2.6 Sept. developed.
L-2.6 Sept.	Oct.	1) Yellow corn at 23.00 2) Wheat bran at 14.50 3) Soymeal at 39.10 4) Oats at 17.00 5) White sorghum n.a. 6) Barley at 24.70	New formula L-2.6 Oct. developed.

Table 6. (Continued).

Ration Number	Month	Changes in prices (L.P./kg)	Remarks
L-2.6 Oct.	Nov.	1) Wheat bran at 14.50 2) Barley n.a.	Only cost recomputed for formula L-2.6 Oct.
L-2.7 Nov.	Nov.	-	New formula L-2.7 Nov. developed.
L-2.8 Nov.	Nov.	-	New formula L-2.8 Nov. developed.
L-2.9 Nov.	Nov.	-	New formula L-2.9 Nov. developed.
. . .	. . .	. . .	. . .
L-2.9 Nov.	Dec.	No changes	-
L-2.10 Dec.	Dec.	-	New formula L-2.10 Dec. developed.

IV. RESULTS AND DISCUSSION

The linear programming model developed in chapter III was used to formulate least-cost L-1 and L-2 rations. The least-cost rations formulated by the linear programming method and rations formulated by the firm through its conventional method are shown in Tables 7 and 8. These tables also compare the costs under the two systems and show the savings which the firm could have realized during 1967 if it had used linear programming in formulating its rations.

Conventional Versus Linear Programming Formulae

Table 7 shows the conventional and the linear programming formulae with their costs (L.P./kg) for L-1 rations. Two kinds of differences which occur between the conventional and the linear programming formulae are: differences in the amounts of the ingredients common to both formulae and the addition of new ingredients in some of the linear programming formulae which were not used in the conventional formulae. Yellow corn was generally used at higher levels in conventional compared to linear programming formulae except in formulae L-1.6 October, L-1.7 November, and L-1.10 December. The higher levels of yellow corn in the conventional formulae were usually compensated for by lower levels of wheat bran, soymeal and/or oats. In all cases, the costs of the linear programmed formulae were lower than those of the conventional formulae. However, the savings from the linear programmed

Table 7. Conventional versus linear programming formulae for L-1 rations.

	L-1.1 Jan-Mar		L-1.1 Apr-May		L-1.2 June		L-1.2 Aug		L-1.3 Aug	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	54.00	45.39	54.00	47.99	48.00	44.64	48.00	32.40	38.00	32.40
Wheat Bran (Loc)	15.00	13.26	15.00	15.00	10.00	11.90	10.00	10.57	10.00	10.86
Feather Meal (Loc)	-	3.17	-	0.22	-	-	-	-	-	-
Soymeal (50% US)	15.00	12.34	15.00	14.09	15.00	15.17	15.00	16.18	15.00	15.39
Oats (US)	-	9.81	-	6.66	10.00	11.30	10.00	13.64	10.00	13.30
St. Bone Meal (Egypt)	-	-	-	-	-	-	-	-	-	-
Limestone (Loc)	4.00	4.03	4.00	4.04	5.00	4.99	5.00	4.92	5.00	4.98
L.M.A.P.	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Mav-12-A	-	-	-	-	-	-	-	-	-	-
White Sorghum (US)	-	-	-	-	-	-	-	10.29	10.00	11.07
Barley (Loc)	-	-	-	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	31.356	30.450	28.829	28.249	30.778	28.262	27.535	27.150	27.238	26.981
Savings (L.P./kg)	0.9056		0.5799		0.2361		0.3848		0.2548	

Table 7. (Continued)

	L-1.4 Sept		L-1.5 Sept		L-1.5 Oct		L-1.6 Oct		L-1.7 Oct	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	39.35	32.40	49.70	32.40	49.70	46.71	45.70	46.56	46.40	46.30
Wheat Bran (Loc)	11.00	12.14	10.00	11.41	10.00	12.97	12.00	13.75	12.00	12.14
Feather Meal (Loc)	-	-	-	-	-	-	-	-	-	-
Soymeal (50% US)	15.00	15.48	15.00	16.37	15.00	15.20	15.00	14.85	14.00	14.02
Oats (US)	9.50	11.10	10.00	12.09	10.00	9.35	12.00	9.54	12.00	11.84
St. Bone Meal (Egypt)	-	-	-	-	-	-	-	-	-	-
Limestone (Loc)	4.65	4.62	4.30	4.69	4.30	4.77	4.30	4.30	4.10	4.20
L.M.A.P.	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	11.50	11.50
Mav-12-A	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-	-
White Sorghum (US)	9.50	13.26	-	12.04	-	-	-	-	-	-
Barley (Loc)	-	-	-	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	27.402	27.156	27.840	27.333	26.403	26.156	26.133	26.126	26.657	25.638
Savings (L.P./kg)	0.2469		0.5070		0.2484		0.0074		0.0187	

Table 7. (Continued)

	L-1.7 Nov		L-1.8 Nov		L-1.9 Nov		L-1.10 Dec	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	46.46	47.59	52.00	42.37	51.50	47.67	43.50	47.97
Wheat Bran (Loc)	2.00	15.00	5.50	2.27	5.00	15.00	-	11.65
Feather Meal (Loc)	-	0.21	-	-	-	-	-	-
Soymeal (50% US)	4.00	13.64	14.00	14.95	15.00	14.87	14.00	13.15
Oats (US)	2.00	7.86	13.00	24.70	13.00	6.76	27.00	11.51
St. Bone Meal (Egypt)	-	-	-	-	-	-	-	-
Limestone (Loc)	4.10	4.20	4.00	4.21	4.00	4.20	4.00	4.22
L.M.A.P.	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50
Mav-12-A	-	-	-	-	-	-	-	-
White Sorghum (US)	-	-	-	-	-	-	-	-
Barley (Loc)	-	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	25.472	25.424	25.984	25.666	26.188	25.651	25.612	25.371
Savings (L.P./kg)	0.0476		0.3185		0.5366		0.2409	

formulae as compared to the conventional formulae varied from a maximum of 0.9056 L.P./kg for ration L-1.1 January to a minimum of 0.0074 L.P./kg from ration L-1.6 October.

Table 8 shows the conventional and linear programming formulae with their costs (L.P./kg) for L-2 rations. The same two kinds of differences were observed in this table as were explained in the case of Table 7. The linear programming formulae were characterized by lower levels of yellow corn, somewhat smaller reductions in wheat bran, small positive changes in soymeal, and more of oats and white sorghum, whenever available, except for formula L-2.10 December where the patterns were reversed. In all cases, the costs of the linear programmed formulae were lower than those of the conventional formulae with the savings varying from 0.5745 L.P./kg for formula L-2.5 September to 0.0026 L.P./kg for formula L-2.1 January.

Gross Savings for L-1 and L-2 Rations during 1967

Tables 9 and 10 show the number of equivalent working days each formula was used for L-1 and L-2 rations. The number of equivalent working days was computed, assuming 25 working days in a month. These figures were used for computing gross savings in 1967 for each formula as shown in Tables 11 and 12. The term "gross" is affixed to savings to indicate that the costs of computing the linear programmed rations have not been deducted from the "savings". The first column in the tables, shows the ration number and the month in which it was used. The second column gives the savings (L.P./kg) resulting from the use of

Table 8. Conventional versus linear programming formulae for L-2 rations.

	L-2.1 Jan-Mar		L-2.1 Apr-May		L-2.2 June		L-2.2 Aug		L-2.3 Aug	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	59.00	40.72	59.00	41.14	51.00	38.39	51.00	32.40	41.00	32.00
Wheat Bran (Loc)	15.00	5.66	15.00	5.04	10.00	9.25	10.00	8.59	10.00	9.31
Feather Meal (Loc)	-	2.27	-	-	-	-	-	-	-	-
Soymeal (50% US)	-	-	-	1.72	-	0.93	-	1.34	13.00	13.78
Oats (US)	-	25.00	-	25.00	10.00	21.72	10.00	22.84	10.00	23.95
St. Bone Meal (Egypt)	-	-	-	-	-	-	-	-	-	-
Limestone (Loc)	4.00	3.90	4.00	4.66	5.00	5.42	5.00	5.38	5.00	5.38
L.M.A.P.	-	-	-	-	-	-	-	-	11.00	11.00
Mav-12-A/L.M.A.C.*	22.00	22.45	22.00	22.44	24.00	24.29	24.00	24.41	-	-
White Sorghum (US)	-	-	-	-	-	-	-	5.04	10.00	4.18
Barley (Loc)	-	-	-	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	28.829	28.826	28.829	28.747	29.104	28.678	29.104	28.574	26.675	26.124
Savings (L.P./kg)	0.0026		0.0818		0.4250		0.5302		0.5516	

* L.M.A.C. was used for L-2.1 and L-2.2 only.

Table 8. (Continued)

	L-2.4 Sept		L-2.5 Sept		L-2.6 Sept		L-2.6 Oct		L-2.7 Nov	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	39.80	32.40	49.80	32.40	41.00	32.40	41.00	40.33	44.00	42.95
Wheat Bran (Loc)	13.00	9.46	11.00	9.07	15.80	14.25	15.80	15.12	15.00	14.18
Feather Meal (Loc)	-	-	-	-	-	-	-	0.01	-	0.01
Soymeal (50% US)	12.00	12.89	12.00	13.60	11.50	12.27	11.50	11.61	10.80	10.95
Oats (US)	10.00	23.37	12.00	23.87	17.00	19.55	17.00	18.02	15.00	16.56
St. Bone Meal (Egypt)	-	0.03	-	-	-	0.01	-	0.01	-	-
Limestone (Loc)	4.70	5.40	4.70	5.42	4.20	4.35	4.20	4.39	4.20	4.36
L.M.A.P.	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	11.00	11.00
Mav-12-A	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	-	-
White Sorghum (US)	10.00	5.95	-	5.14	-	6.67	-	-	-	-
Barley (Loc)	-	-	-	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	26.542	26.215	26.923	26.357	26.161	26.059	24.881	24.852	24.380	24.360
Savings (L.P./kg)	0.3268		0.5745		0.1018		0.0293		0.0208	

Table 8. (Continued)

	L-2.8 Nov		L-2.9 Nov-Dec		L-2.10 Dec	
	Conv.	L.P.	Conv.	L.P.	Conv.	L.P.
Yellow Corn (US)	51.00	42.54	51.80	41.77	37.00	38.57
Wheat Bran (Loc)	6.90	6.34	9.00	5.89	-	4.45
Feather Meal (Loc)	-	-	-	-	-	-
Soymeal (50% US)	10.00	10.74	11.00	11.97	11.00	10.75
Oats (US)	17.00	25.00	13.00	25.00	37.00	30.86
St. Bone Meal (Egypt)	-	-	-	-	-	-
Limestone (Loc)	4.10	4.38	4.20	4.37	4.00	4.37
L.M.A.P.	11.00	11.00	11.00	11.00	11.00	11.00
Mav-12-A	-	- -	-	-	-	-
White Sorghum (US)	-	-	-	-	-	-
Barley (Loc)	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00
Cost (L.P./kg)	24.840	24.470	25.042	24.706	24.408	24.281
Savings (L.P./kg)	0.3693		0.3360		0.1269	

Table 9. Formula dates for L-1 rations and the number of equivalent working days for which each formula was used by the firm during 1967.

Formula Number	Starting Date	Finishing Date	Equivalent working Days
L-1.1	1.1	26.6	146.67
L-1.2	27.6	17.8	42.02
L-1.3	18.8	31.8	11.37
L-1.4	1.9	5.9	4.17
L-1.5	6.9	11.10	29.69
L-1.6	12.10	17.10	4.83
L-1.7	18.10	21.11	28.77
L-1.8	22.11	22.11	0.83
L-1.9	23.11	27.12	28.43
L-1.10	28.12	31.12	3.22
		Total	300.00

Table 10. Formula dates for L-2 rations and the number of equivalent working days for which each formula was used by the firm during 1967.

Formula Number	Starting Date	Finishing Date	Equivalent working Days
L-2.1	1.1	26.6	146.67
L-2.2	27.6	17.8	42.02
L-2.3	18.8	31.8	11.37
L-2.4	1.9	5.9	4.17
L-2.5	6.9	17.9	9.67
L-2.6	18.9	12.11	45.90
L-2.7	13.11	21.11	7.72
L-2.8	22.11	22.11	0.83
L-2.9	23.11	27.12	28.43
L-2.10	28.12	31.12	3.22
		Total	300.00

Table 11. Gross savings for L-1 rations during 1967.

Formula Number	Savings (L.P./kg)	Volume (tons)	Gross savings (LL.)
L-1.1 Jan-Mar	0.9056	1725.00	15621.60
L-1.1 Apr-May	0.5799	1150.00	6668.85
L-1.1 June	0.5799	498.28	2889.55
L-1.2 June	0.2361	76.66	181.00
L-1.2 July	0.2486	575.00	1429.25
L-1.2 Aug	0.3848	314.76	1211.18
L-1.3 Aug	0.2548	259.21	660.47
L-1.4 Sept	0.2469	95.83	236.61
L-1.5 Sept	0.5070	479.16	2429.37
L-1.5 Oct	0.2484	203.66	505.90
L-1.6 Oct	0.0074	111.09	8.22
L-1.7 Oct	0.0187	259.21	48.47
L-1.7 Nov	0.0476	402.49	191.59
L-1.8 Nov	0.3185	19.16	61.04
L-1.9 Nov-Dec	0.5366	653.23	3505.27
L-1.10 Dec	0.2409	74.06	178.41
	Total	6896.80	35826.98
		Average savings/ton	LL. 5.19

Table 12. Gross savings for L-2 rations during 1967.

Formula Number		Savings (L.P./kg)	Volume (tons)	Gross savings (LL.)
L-2.1	Jan-Mar	0.0026	1500.00	39.00
L-2.1	Apr-June	0.0818	1433.00	1172.19
L-2.2	June	0.4250	67.00	284.75
L-2.2	July	0.4907	500.00	2453.50
L-2.2	Aug	0.5302	289.80	1536.52
L-2.3	Aug	0.5516	210.20	1159.46
L-2.4	Sept	0.3268	80.64	263.53
L-2.5	Sept	0.5745	193.55	1111.94
L-2.6	Sept	0.1018	209.68	213.45
L-2.6	Oct	0.0293	500.00	146.50
L-2.6	Nov	0.0225	199.99	44.99
L-2.7	Nov	0.0208	149.99	31.19
L-2.8	Nov	0.3693	16.67	61.56
L-2.9	Nov-Dec	0.3360	568.81	1911.19
L-2.10	Dec	0.1269	64.52	81.87
		Total	5983.85	10511.64
			Average savings/ton	LL.1.76

linear programming. Some of these figures were taken from the last rows of Tables 7 and 8. The third column shows the volume of feed produced for each ration formula. These figures were computed by multiplying equivalent working days each formula was used, by the volume of feed produced by the firm each day. The daily feed productions were 23.33 and 20.00 tons for L-1 and L-2 rations, respectively. The last column is the product of columns 2 and 3 and gives the gross savings that could have been realized if linear programming rather than conventional method were used by the firm. These gross savings amounted to LL. 35,826.98 for L-1 rations and LL. 10,511.64 for L-2 rations or a total of LL 46,338.62.[1] This total gross savings was for two-thirds of the firm's volume of business. The average gross saving per ton was LL. 5.19 for L-1 rations and LL. 1.76 for L-2 rations.

Supplementary Information
Supplied by Linear Programming

The linear programming method supplies supplementary information other than just the least-cost formula and cost, such as: analysis of least-cost ration, price stability ranges and shadow prices. This information can assist management in making various decisions concerning ingredient procurement and inventory control. The supplementary information for least-cost L-1.1 January ration is shown in Appendices C, D, E, F, and H. Selected items, along with examples of practical interpretations are described below.

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1. The costs of computation are well under ten percent of this figure.

Nutrient Analysis for Least-Cost Ration

Appendix D shows the analysis of the least-cost L-1.1 January ration. The first column shows the names of the formula specifications and the second column shows the values for these specifications. The third column shows the amounts of specified nutrients present in the least-cost solution. The last column indicates the differences between columns 2 and 3. The positive figures reflect surpluses of nutrients and feedstuffs, relative to the specification levels, while negative figures indicate deficits. The zero values indicate those specifications exactly met in the final solution. The number of zeros in the last column is equal to the number of ingredients in the least-cost solutions. This follows from the linear nature of the problem in that it takes seven ingredients to fulfill seven specifications, exactly. These seven specifications which were exactly met are critical in that changes in the levels of these specifications would affect the cost of the least-cost solution. The other 23 specifications which are either in surplus (of the minimum restriction) or deficit (of maximum restriction) do not affect the cost of the least-cost ration.

The values shown in the last column of Appendix D can also be read from columns 1 and 2 of Appendix C. The first value in col 2 of Appendix C is 2.003, and it can be identified as the surplus for xanthophyll by col 57 as shown in row 1, col 1 of Appendix C. The specifications with zero values in Appendix D do not appear at all in col 2 of Appendix C. The other values in col 2 of Appendix C can be interpreted with the help of the key to the variables used in the linear programming model as given in Appendix A.

The practical use of such an analysis is obvious in that one can see at a glance the amounts of different nutrients and feedstuffs present in the least-cost ration. Another advantage is that solutions obtained through linear programming are quality controlled. This is because the various specifications are for sure met (apart from deviations in the composition of feedstuffs) in the linear programming solutions. No such guarantee exists for ration formulae obtained through the "systematic" trial and error method.

Price Stability Ranges

Price stability ranges indicate the limits over which the prices of included ingredients could fluctuate, one at a time, without necessitating changes in the least-cost feed formula. They also indicate which variables would be introduced and which would be eliminated from the solution if the prices were to fall outside the limits indicated.

Appendix E shows the price stability ranges for included ingredients in the least-cost solution for L-1.1 January. The market price for soymeal (X_{34}) was 62.70 L.P./kg and the lower and upper price limits for soymeal are 52.39 and 93.24 L.P./kg. If the price of soymeal were to go below 52.93 L.P./kg, the quantity of soymeal in the ration would increase. A surplus of choline (X_{54}) would result and wheat bran would no longer be in deficit, i.e. X_{22} would go out of the solution. On the other hand, if the price of soymeal were to go above 93.24 L.P./kg, less of soymeal would be used. A surplus of methionine (X_{46}) would occur and methionine and cystine would no longer be in deficit, i.e. X_{19} would go out of the solution.

The lower and upper limits for L.M.A.P. are 25.23 and 51.40

L.P./kg as compared to its market price of 51.40 L.P./kg. If the price of L.M.A.P. were to go below 25.23 L.P./kg, more of L.M.A.P. would come into the solution, thereby resulting in a surplus of L.M.A.P. over its minimum restriction as indicated by the introduction of variable X_{55}, the surplus variable for L.M.A.P. At the same time limestone (X_{37}) would be eliminated from the solution. On the other hand a price of L.M.A.P. above 51.40 L.P./kg, would not affect the amount of L.M.A.P. in the ration since it already is at its minimum restricted level.

The practical use of price stability ranges is in deciding when a ration must be reformulated. If the price of any one of the included ingredients falls outside its respective lower or upper limit, a new least-cost ration formula has to be computed with the changed prices of the ingredient. Thus, the price stability ranges can be used as guidelines for reprogramming. Reprogramming schedules based on this principle were developed in chapter III and are shown in Tables 5 and 6 for L-1 and L-2 rations.

Appendix E shows that some ingredients have narrow price stability ranges while others have wide ranges. A practical implication of this information is on purchasing decisions. It appears reasonable to suggest that narrow price ranged ingredients need to be studied more carefully than wide price ranged ingredients when purchasing and inventory decisions are made.

<u>Shadow Prices of Excluded Ingredients</u>

The shadow price of an excluded ingredient shows the amount by which its price would have to drop before it could be profitably included in the least-cost ration formula. The shadow price of steamed bone meal for L-1.1 January ration is shown as -25.88 L.P./kg in row 31, column 36 of Appendix C. The shadow prices of excluded ingredients for L-1 and L-2 rations are shown in Appendices F and G.

The price of steamed bone meal would have to drop by 25.88 L.P./kg before it could be profitably included in the least-cost ration. Another interpretation of shadow price is in terms of penalty cost of using an excluded ingredient. If steamed bone meal is used at one percent level in the solution at its present market price of 30.00 L.P./Kg, the cost of the ration would increase by 0.26 L.P./kg.

The practical implication of shadow prices for excluded ingredients is that these prices can be used as guidelines for purchasing ingredients. A feed mixing firm should not purchase steamed bone meal unless its price drops to 4.12 L.P./kg (30.00 - 25.88). At any higher price the firm would incur a higher cost ration if it includes steamed bone meal in its ration formula. If an excluded ingredient is on inventory, its shadow price would indicate the penalty cost of using up its stock.

Shadow Prices of Exactly Met Specifications

The shadow price of an exactly met specification indicates the amount by which the cost of the formula would change if the specification were changed by one unit. The cost of the formula would increase if the minimum restriction were increased and would decrease if it were lowered. The reverse pattern of changes in the cost of the formula applies for changes in maximum restrictions.

The shadow prices of exactly met restrictions are shown in the last row and their respective column of Appendix C. Appendices H and I show the shadow prices of exactly met nutrient specifications for L-1 and L-2 rations.

Three minimum and two maximum nutrient specifications were exactly met in ration L-1.1.January which are shown in the third column of Appendix H. The shadow prices for these five nutrient specifications vary from a lowest value of 0.002 L.P./unit change in metabolizable energy to the highest value of 38.77 L.P./unit change in methionine. The shadow price of methionine indicates that if its specification were increased by 0.01 % from its present level, the cost of the formula would increase by 0.387 L.P./kg. Similarly, if the maximum specification of crude fiber were decreased by 1 % from its present level, the cost of the formula would increase by 0.061 L.P./kg.

The shadow prices shown in Appendices H and I vary from nutrient to nutrient. In order to compare the values for the different nutrients on an equivalent basis, the shadow price for each nutrient was multiplied by one percent of the specification level for the nutrient and the average values were obtained. These values, shown parenthetically below, indicate that the same four nutrients: methionine, metabolizable energy, crude fiber and calcium were the most critical for both the L-1 and L-2 rations. For L-1 rations, methionine (0.0772), crude fiber (0.0225) and calcium (0.0092) were critical in all 14 rations while metabolizable energy (0.0654) was critical in nine rations only. For L-2 rations, methionine (0.0825) and metabolizable energy (0.0689) were critical in all 13 rations while calcium (0.0005) was critical in 12 rations and crude fiber (0.0014) was critical in nine rations.

The practical implication of the shadow prices of exactly met nutrient specifications are three fold: one is to explore by nutritional research, the possibility of changing the levels of the nutrient specifications to favor maximum economical performance; these levels might differ from the more commonly used levels that favor maximum physiological performance. The other is the possibility of reducing the levels of critical nutrient specifications with a combination of non-critical or less critical nutrients. The level of methionine may be reduced by a combination of certain levels of pyrodixine giving similar performance results as the higher level of methionine alone.

Still another possibility is that of meeting the critical nutrient specifications through synthetic sources rather than through natural sources. The shadow price of methionine for L-1.1 January ration indicates that the cost of one kg of methionine by the included ingredients in the least-cost ration is LL.38.78. The 1967 equivalent price of pure synthetic methionine in Lebanon was about LL.11.25/kg. This suggests the possibility of a substantial economic advantage from supplementing layer rations with synthetic methionine.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This case study of a feed mixing firm in Lebanon compared the costs of the layer rations actually developed and sold by the firm in 1967 with those that would have been incurred if linear programming had been used in its ration formulations. Three basic kinds of information needed for formulating rations were collected from the firm: prices of the ingredients available in the inventory of the firm during 1967, the nutrient composition of the ingredients, and the nutrient specifications for its rations. In addition, data on the costs of the actual formulae and the volume produced under each formula were collected.

A linear programming model was developed with 30 restrictions and 57 variables(including real, slack, and artificial variables). The solutions were obtained on the IBM 1620 Computer at the AUB Computer Center. The costs of the linear programmed formulae were compared with those of the conventional formulae and the savings/kg. were multiplied by the respective volumes of feed produced. The sum of these products yielded the gross savings which the firm would have realized during 1967. The gross savings were L.L. 46,338.62 for the firm studied.

Additional information such as: nutrient analysis of least-cost ration, price ranges of the included ingredients, shadow prices of excluded ingredients and of exactly met specifications were computed and their practical uses were explained.

Conclusions

These conclusions were derived from the case study in 1967 of layer rations in one feed mixing firm in Lebanon. The inability to evaluate the representativeness, from a statistical standpoint, of the feed firm and the feed formulation conditions it experienced in 1967, precludes any necessary general validity in Lebanon of the substantive conclusions below. The first conclusion, however, almost assuredly has general validity since the management in the case firm studied is in all likelihood above average for Lebanon. With these reservations in mind, the following conclusions are drawn from the results of this study as discussed in the last chapter.

Savings

Substantial savings are possible in Lebanon through the use of linear programming in formulating poultry rations.

Competitive Positions of Ingredients

The ingredients with the strongest competitive position for use in layer rations were yellow corn, white sorghum (when available), wheat bran, oats, and limestone. They were a part of all the least-cost rations. On the other hand, barley was included in none of the least-cost rations; this indicates its weak competitive position.

Shifts in Ingredients Combinations

In general, the levels of yellow corn in the linear program formulae were less than those in the conventional formulae. To compensate for this, higher levels of wheat bran, soymeal and/or oats were usually used in the least-cost rations.

Nutrient Substitution

The high shadow price of some nutrient specifications points to the possibility of these nutrients being provided from synthetic, rather than natural, sources. Methionine is one such example.

Non-critical Nutrient Specifications

Six nutrients were always in surplus in the least-cost rations: fat, protein, lysine, riboflavin, pantothenic acid, and niacin. The requirements controlling the levels of these nutrients, therefore, were not critical in determining the specific ingredient combinations of least possible cost.

Recommendations

This part of the chapter is subdivided into two parts: recommendations for poultry feed mixers in Lebanon and recommendations for further research.

Recommendations for Poultry Feed Mixers in Lebanon

It is recommended that poultry feed mixing firms in Lebanon adopt linear programming in formulating their rations. Substantial direct savings would thereby result. Furthermore, use of supplementary information generated by linear programming would permit more economical feedstuff procurement and inventory control decisions.

Recommendations for Further Research

The model used in this study was restricted to its present size as this is the first such study made under Lebanese market conditions. Another reason is the limitations of the present capacity of the computer to handle a matrix of larger size. The present model could be expanded to take into consideration additional restrictions of practical importance to feed mixing firms. Some of these aspects are suggested below:

The model used in this study does not take account of possible limits on the quantities of ingredients on inventory of feed firms nor of possible limits on the minimum amounts of feedstuffs that can be purchased in single lots. Both limitations often are of practical concern. They can be built into a linear programming model through the introduction, where appropriate, of maximum and minimum ingredient availability restrictions. These restrictions may in turn create the problem of over- or under-utilization of the capacity of the feed mixer. Such capacity problems can again be handled by imposing appropriate maximum and/or minimum restrictions. However, one should be careful when making restrictions on ingredient use and plant size to avoid inconsistencies which might creep into the model.

Firms producing poultry feed, generally produce more than one product. Bishop(1963) found that the costs of least-cost solutions by linear programming could be reduced if multiple product restrictions were included in the model rather than computing least-cost rations for each product individually. The linear programming model can be expanded to include multiple product restrictions for the firms producing more than one product.

The specification ranges within which a formula does not change can be found by solving the dual of the problem. This would indicate the lower and the upper limits over which the exactly met specification levels could vary without the shadow prices for the specifications losing their validity. Such information would be of a particular use to a feed mixer, who because of the season of the year, needs to modify the levels of certain of his ration specifications.

LITERATURE CITED

Bishop, R.B. 1962. Some observations on linear programming as a method of formulating better broiler diets. Feedstuffs. 34:28-34.

Bishop, R.B. 1963. Least-cost formulas must reflect least-cost feed manufacturing. Feedstuffs. 35:18-19.

Cortas, A. and A. Sattar. 1968. Agricultural Statistics, 1954-66. A. Ec. No. 10, Ministry of Agriculture, Republic of Lebanon, Beirut.

Dantzig, G.B. 1951. Maximization of a linear function of variables subject to linear inequalities in Activity Analysis of Production and Allocation, edited by T.C. Koopmans. John Wiley & Sons, Inc., New York.

Dorfman, R. *et al*. 1958. Linear Programming and Economic Analysis. McGraw Hill Book Company, Inc., New York.

Ferguson, R.O. and L.F. Sargent. 1958. Linear Programming: Fundamentals and Applications. McGraw Hill Book Company, Inc., New York.

Heady, E.O. and W. Candler. 1958. Linear Programming Methods. The Iowa State College Press, Ames.

Hubbell, C.H. 1965. Analysis table for feed ingredients. Feedstuffs. 37:25-26.

Hutton, R.F. *et al*. 1958. A least-cost broiler feed formula: Method of derivation. Production Research Report No. 20. Agricultural Research Service, USDA. Washington, D.C.

Katzman, I. 1956. Solving feed problems through linear programming. Journal of Farm Economics. 38:420-429.

Maddy, K.H. *et al*. 1963. The application of linear programming to feed formulation. Feedstuffs. 35:28-30, 70-71.

Seagraves, J.A. 1963. Reducing feed cost through use of linear programming. A.E. Information Series No. 104. Department of Agricultural Economics. University of North Carolina. Raleigh.

Stafford, J.H. and L.E. Ott. 1965. Managerial aspects of least-cost feed formulation with linear programming. Marketing Research Report No. 729. Economic Research Service. USDA. Washington, D.C.

Stigler, G.J. 1945. The cost of subsistence. Journal of Farm Economics. 27:303-314.

Swanson, E.R. 1955. Solving minimum-cost feed mix problems. Journal of Farm Economics. 37:135-139.

Taylor, D.C. and N.J. Daghir. 1968. Determining least-cost poultry rations in Lebanon.(in press) Publication No. 32. Faculty of Agricultural Sciences, American University of Beirut and Bureau of Agricultural Economics, Ministry of Agriculture, Republic of Lebanon, Beirut.

Ward, G.H. and J.S. Fuleihan. 1962. Economic analysis of poultry production in Lebanon. Publication No. 18. Faculty of Agricultural Sciences. American University of Beirut and Agricultural Research Service, Ministry of Agriculture, Republic of Lebanon, Beirut.

Waugh, F.V. 1951. The minimum-cost dairy feed. Journal of Farm Economics. 33:299-310.

APPENDIX A

Key to the variables in the linear programming model used in this study

Artificial variables for

X_1	Metabolizable energy
X_2	Fat
X_3	Protein
X_4	Lysine
X_5	Methionine
X_6	Methionine plus Cystine
X_7	Calcium
X_8	Phosphorus(Available)
X_9	Vitamin A
X_{10}	Riboflavin
X_{11}	Pantothenic Acid
X_{12}	Niacin
X_{13}	Choline
X_{14}	L.M.A.P.
X_{15}	Mav-12-A or L.M.A.C.
X_{28}	Xanthophyll
X_{30}	Weight

Slack(deficit) variables for

X_{16}	Crude fiber
X_{17}	Metabolizable energy
X_{18}	Methionine
X_{19}	Methionine plus Cystine
X_{20}	Calcium
X_{21}	Phosphorus(Available)
X_{22}	Wheat bran(Local)
X_{23}	Feather meal(Local)
X_{24}	Oats(U.S.)
X_{25}	Arginine
X_{26}	Glycine
X_{27}	Tryptophane
X_{29}	Vitamin B_{12}

APPENDIX A(Continued)

Real variables for

X_{31}	Yellow Corn(U.S.A.)
X_{32}	Wheat Bran(Local)
X_{33}	Feather meal(Local)
X_{34}	Soymeal(50%, U.S.A.)
X_{35}	Oats(U.S.A.)
X_{36}	St. bone meal(Local)
X_{37}	Limestone(Local)
X_{38}	L.M.A.P.
X_{39}	Mav-12-A or L.M.A.C.
X_{40}	White sorghum(Local)
X_{41}	Barley(Local)

Slack(surplus) variables for

X_{42}	Metabolizable energy
X_{43}	Fat
X_{44}	Protein
X_{45}	Lysine
X_{46}	Methionine
X_{47}	Methionine plus Cystine
X_{48}	Calcium
X_{49}	Phosphorus(Available)
X_{50}	Vitamin A
X_{51}	Riboflavin
X_{52}	Pantothenic Acid
X_{53}	Niacin
X_{54}	Choline
X_{55}	L.M.A.P.
X_{56}	Mav-12-A or L.M.A.C.
X_{57}	Xanthophyll

Appendix B. Input matrix for L-1.1 January ration

1.000	2535.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	3.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.000	17.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.000	.700	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
5.000	.260	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
6.000	.530	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
7.000	3.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
8.000	.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
9.000	10.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
10.000	4.410	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
11.000	12.120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.000	46.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.000	926.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14.000	12.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.000	5.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17.000	2579.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18.000	.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.000	.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.000	3.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21.000	1.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.000	15.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23.000	5.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24.000	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28.000	5.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ER F8	.36767900E+08										
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}

X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}	X_{31}	X_{32}	X_{33}	X_{34}
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3373.000	1124.000	2227.000	2535.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.500	4.000	1.100	.500
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.800	13.800	85.000	50.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.210	.550	1.800	3.200
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.180	.160	.570	.770
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.340	.400	3.370	1.510
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.010	.180	.250	.200
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.075	.274	.250	.195
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.992	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.102	2.205	1.764	2.646
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.850	26.455	7.716	13.228
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19.841	143.299	17.637	20.944
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	441.000	1014.000	882.000	2866.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.900	14.600	1.000	3.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3373.000	1124.000	2227.000	2535.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.180	.160	.570	.770
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.340	.400	3.370	1.510
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.010	.180	.250	.200
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.075	.274	.250	.195
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000	0.000
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000
0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	.400	.690	5.100	3.800
0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	3.500	.690	5.700	2.700
0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	.070	.250	.570	.640
0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	15.432	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	.110	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000

ER F8 .38703295E+08
ER F8 .23303216E+08
ER F8 .32294529E+08
ER F8 .54951868E+08

X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

2645.000	0.000	0.000	1767.000	1501.000	3307.000	2337.000	-1.000	0.000	0.000	0.000	0.000
6.300	0.000	0.000	10.390	4.510	1.500	1.750	0.000	-1.000	0.000	0.000	0.000
12.500	0.000	0.000	23.330	30.660	8.300	8.500	0.000	0.000	-1.000	0.000	0.000
.380	0.000	0.000	1.110	1.810	.210	.190	0.000	0.000	0.000	-1.000	0.000
.130	0.000	0.000	.260	.490	.130	.130	0.000	0.000	0.000	0.000	-1.000
.290	0.000	0.000	.560	.830	.280	.340	0.000	0.000	0.000	0.000	0.000
.100	24.000	38.000	12.490	13.400	.240	.048	0.000	0.000	0.000	0.000	0.000
.099	12.000	0.000	3.540	2.120	.078	.103	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	92.124	120.000	.245	0.000	0.000	0.000	0.000	0.000	0.000
1.102	0.000	0.000	54.610	24.000	1.102	1.102	0.000	0.000	0.000	0.000	0.000
12.125	0.000	0.000	84.440	0.000	9.921	5.512	0.000	0.000	0.000	0.000	0.000
14.330	0.000	0.000	290.810	98.000	35.274	44.092	0.000	0.000	0.000	0.000	0.000
882.000	0.000	0.000	1026.000	1301.000	441.000	882.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11.200	0.000	0.000	4.560	5.500	2.500	5.900	0.000	0.000	0.000	0.000	0.000
2645.000	0.000	0.000	1767.000	1501.000	3307.000	2337.000	0.000	0.000	0.000	0.000	0.000
.130	0.000	0.000	.260	.490	.130	.130	0.000	0.000	0.000	0.000	0.000
.290	0.000	0.000	.560	.830	.280	.340	0.000	0.000	0.000	0.000	0.000
.100	24.000	38.000	12.490	13.400	.240	.048	0.000	0.000	0.000	0.000	0.000
.099	12.000	0.000	3.540	2.120	.078	.103	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
.600	0.000	0.000	1.400	0.000	.280	.420	0.000	0.000	0.000	0.000	0.000
.400	0.000	0.000	0.000	0.000	.300	.200	0.000	0.000	0.000	0.000	0.000
.120	0.000	0.000	0.000	0.000	.090	.120	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000

ER F8 .35753541E+08
ER F8 .34676589E+08
ER F8 .31978200E+08
ER F8 .38052800E+08
ER F8 .32807670E+08

	369970.000	389997.300					-10000.000	-10000.000	-10000.000	-10000.000	-10000.000
X_{35}	X_{36}	X_{37}	X_{38}	X_{39}	X_{40}	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}	X_{46}

x_{47}	x_{48}	x_{49}	x_{50}	x_{51}	x_{52}	x_{53}	x_{54}	x_{55}	x_{56}	x_{57}
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	-1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	-1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	-1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-10000.000	-10000.000	-10000.000	-10000.000	-10000.000	-10000.000	-10000.000	-10000.000	-10000.000	10000.000	-10000.000

Appendix C. Output matrix for ration L-1.1 January

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
57.000	2.003	-.010	0.000	0.000	0.000	-109.036	0.000	0.000	0.000	0.000	0.000
44.000	1.719	.017	0.000	-1.000	0.000	352.253	0.000	0.000	0.000	0.000	0.000
35.000	.098	.001	0.000	0.000	0.000	7.811	0.000	0.000	0.000	0.000	0.000
34.000	.123	0.000	0.000	0.000	0.000	-1.269	0.000	0.000	0.000	0.000	0.000
45.000	.090	0.000	0.000	0.000	-1.000	4.266	0.000	0.000	0.000	0.000	0.000
43.000	1.080	.003	-1.000	0.000	0.000	10.858	0.000	0.000	0.000	0.000	0.000
19.000	.003	0.000	0.000	0.000	0.000	-13.711	0.000	0.000	0.000	0.000	0.000
37.000	.040	0.000	0.000	0.000	0.000	-.024	0.000	0.000	0.000	0.000	0.000
51.000	3.426	-.001	0.000	0.000	0.000	-3.637	0.000	0.000	0.000	0.000	-1.000
38.000	.119	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
52.000	6.788	-.011	0.000	0.000	0.000	-39.939	0.000	0.000	0.000	0.000	0.000
33.000	.031	0.000	0.000	0.000	0.000	5.234	0.000	0.000	0.000	0.000	0.000
49.000	.086	0.000	0.000	0.000	0.000	.020	0.000	0.000	-1.000	0.000	0.000
53.000	21.154	-.138	0.000	0.000	0.000	-634.075	0.000	0.000	0.000	0.000	0.000
56.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32.000	.132	-.001	0.000	0.000	0.000	-4.686	0.000	0.000	0.000	0.000	0.000
17.000	43.999	-1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18.000	.039	0.000	0.000	0.000	0.000	-.999	0.000	0.000	0.000	0.000	0.000
47.000	.066	0.000	0.000	0.000	0.000	13.711	-1.000	0.000	0.000	0.000	0.000
48.000	.100	0.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000	0.000
21.000	1.263	0.000	0.000	0.000	0.000	-.020	0.000	0.000	0.000	0.000	0.000
22.000	1.740	.104	0.000	0.000	0.000	468.639	0.000	0.000	0.000	0.000	0.000
23.000	1.825	-.026	0.000	0.000	0.000	-523.458	0.000	0.000	0.000	0.000	0.000
50.000	1.485	0.000	0.000	0.000	0.000	-7.009	0.000	0.000	0.000	-1.000	0.000
25.000	98.869	0.000	0.000	0.000	0.000	-20.499	0.000	0.000	0.000	0.000	0.000
26.000	97.766	.001	0.000	0.000	0.000	-1.570	0.000	0.000	0.000	0.000	0.000
27.000	99.826	0.000	0.000	0.000	0.000	-1.442	0.000	0.000	0.000	0.000	0.000
31.000	.453	0.000	0.000	0.000	0.000	-7.065	0.000	0.000	0.000	0.000	0.000
29.000	99.996	0.000	0.000	0.000	0.000	-.575	0.000	0.000	0.000	0.000	0.000
24.000	15.190	-.153	0.000	0.000	0.000	-781.122	0.000	0.000	0.000	0.000	0.000
	30.450	-9999.998	-10000.000	-10000.000	-10000.000	-9961.227	-10000.000	-10000.000	-10000.000	-10000.000	-10000.000

X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}
0.000	0.000	.016	-.014	0.000	-4.305	0.000	0.000	0.000	-1.979	0.000	0.000
0.000	0.000	-.063	.038	0.000	7.418	0.000	0.000	0.000	2.808	0.000	0.000
0.000	0.000	-.001	-.002	0.000	.374	0.000	0.000	0.000	.185	0.000	0.000
0.000	0.000	0.000	-.002	0.000	-.051	0.000	0.000	0.000	-.009	0.000	0.000
0.000	0.000	0.000	.001	0.000	.041	0.000	0.000	0.000	.028	0.000	0.000
0.000	0.000	-.002	.080	0.000	.843	0.000	0.000	0.000	.292	0.000	0.000
0.000	0.000	.002	0.000	0.000	-.267	0.000	0.000	0.000	-.095	0.000	0.000
0.000	0.000	0.000	-.003	0.000	0.000	0.000	0.000	1.000	.026	0.000	0.000
0.000	0.000	.001	.534	0.000	-.178	0.000	0.000	0.000	-.144	0.000	0.000
0.000	0.000	0.000	.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-1.000	0.000	.009	.764	0.000	-.844	0.000	0.000	0.000	-1.280	0.000	0.000
0.000	0.000	-.001	0.000	0.000	.117	0.000	0.000	0.000	.043	0.000	0.000
0.000	0.000	0.000	.034	0.000	-.008	0.000	0.000	0.000	-.014	0.000	0.000
0.000	-1.000	.109	2.752	0.000	-22.243	0.000	0.000	0.000	-16.247	0.000	0.000
0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	-.160	0.000	0.000	0.000	-.118	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
0.000	0.000	-.002	0.000	0.000	.267	0.000	0.000	0.000	.095	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
0.000	0.000	0.000	-.034	0.000	.008	0.000	0.000	0.000	.014	1.000	0.000
0.000	0.000	-.079	.028	0.000	16.098	0.000	0.000	0.000	11.823	0.000	1.000
0.000	0.000	.119	.034	0.000	-11.754	0.000	0.000	0.000	-4.348	0.000	0.000
0.000	0.000	.001	.920	0.000	-.276	0.000	0.000	0.000	-.127	0.000	0.000
0.000	0.000	.003	0.000	0.000	-.405	0.000	0.000	0.000	-.166	0.000	0.000
0.000	0.000	.001	.012	0.000	.407	0.000	0.000	0.000	.232	0.000	0.000
0.000	0.000	0.000	.002	0.000	-.019	0.000	0.000	0.000	-.002	0.000	0.000
0.000	0.000	.001	0.000	0.000	-.279	0.000	0.000	0.000	-.128	0.000	0.000
0.000	0.000	0.000	0.000	0.000	-.012	0.000	0.000	0.000	-.004	0.000	0.000
0.000	0.000	.139	.279	0.000	-37.471	0.000	0.000	0.000	-18.588	0.000	0.000
-10000.000	-10000.000	-9999.993	-9999.739	-10000.000	-.607	0.000	0.000	0.000	-.101	0.000	0.000

X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}	X_{31}	X_{32}	X_{33}	X_{34}
0.000	0.000	0.000	0.000	0.000	-1.000	0.000	75.237	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-106.723	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-7.063	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.342	0.000	0.000	0.000	1.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.067	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-11.110	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.645	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.005	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.487	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	48.643	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.652	0.000	0.000	1.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.551	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	617.388	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.493	0.000	1.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-3.645	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.551	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-449.303	0.000	0.000	0.000	0.000
1.000	0.000	0.000	0.000	0.000	0.000	0.000	165.247	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.836	0.000	0.000	0.000	0.000
0.000	0.000	1.000	0.000	0.000	0.000	0.000	6.313	0.000	0.000	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	-8.844	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	1.000	0.000	0.000	.105	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.875	1.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.000	.181	0.000	0.000	0.000	0.000
0.000	1.000	0.000	0.000	0.000	0.000	0.000	706.358	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	-10000.000	0.000	-9993.438	0.000	0.000	0.000	0.000

x_{35}	x_{36}	x_{37}	x_{38}	x_{39}	x_{40}	x_{41}	x_{42}	x_{43}	x_{44}	x_{45}	x_{46}
0.000	27.719	0.000	0.000	-22.049	22.838	26.131	.010	0.000	0.000	0.000	109.036
0.000	-39.318	0.000	0.000	57.388	-20.578	-40.802	-.017	0.000	1.000	0.000	-352.253
1.000	-2.602	0.000	0.000	1.803	-.599	-1.469	-.001	0.000	0.000	0.000	-7.811
0.000	.126	0.000	0.000	.100	.087	.298	0.000	0.000	0.000	0.000	1.269
0.000	-.393	0.000	0.000	.235	-.229	-.059	0.000	0.000	0.000	1.000	-4.266
0.000	-4.093	0.000	0.000	-.255	.963	-.980	-.003	1.000	0.000	0.000	-10.858
0.000	1.342	0.000	0.000	-2.374	.748	1.648	0.000	0.000	0.000	0.000	13.711
0.000	.633	1.000	0.000	.345	.007	.002	0.000	0.000	0.000	0.000	.024
0.000	2.021	0.000	0.000	-23.361	.292	1.294	.001	0.000	0.000	0.000	3.637
0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	17.921	0.000	0.000	2.450	-2.281	14.650	.011	0.000	0.000	0.000	39.939
0.000	-.608	0.000	0.000	.990	-.316	-.706	0.000	0.000	0.000	0.000	-5.234
0.000	-11.796	0.000	0.000	-2.003	.004	.083	0.000	0.000	0.000	0.000	-.020
0.000	227.457	0.000	0.000	-197.189	30.566	131.603	.138	0.000	0.000	0.000	634.075
0.000	0.000	0.000	0.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	1.655	0.000	0.000	-.811	.340	1.181	.001	0.000	0.000	0.000	4.686
0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.999
0.000	-1.342	0.000	0.000	2.374	-.748	-1.648	0.000	0.000	0.000	0.000	-13.711
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	11.796	0.000	0.000	2.003	-.004	-.083	0.000	0.000	0.000	0.000	.020
0.000	-165.532	0.000	0.000	81.140	-34.062	-118.188	-.104	0.000	0.000	0.000	-468.639
0.000	60.880	0.000	0.000	-99.093	31.623	70.687	.026	0.000	0.000	0.000	523.458
0.000	1.781	0.000	0.000	-121.417	1.223	1.679	0.000	0.000	0.000	0.000	7.009
0.000	2.326	0.000	0.000	-5.388	1.093	2.278	0.000	0.000	0.000	0.000	20.499
0.000	-3.258	0.000	0.000	-1.081	-3.308	-2.731	-.001	0.000	0.000	0.000	1.570
0.000	.038	0.000	0.000	-.542	.097	.094	0.000	0.000	0.000	0.000	1.442
0.000	1.796	0.000	0.000	-1.428	1.479	1.693	0.000	0.000	0.000	0.000	7.065
0.000	.066	0.000	0.000	-.109	.034	.077	0.000	0.000	0.000	0.000	.575
0.000	260.236	0.000	0.000	-180.322	59.917	146.923	.153	0.000	0.000	0.000	781.122
0.000	-25.876	0.000	0.000	-9965.333	-9976.916	-9978.691	-.002	0.000	0.000	0.000	-38.773

X_{47}	X_{48}	X_{49}	X_{50}	X_{51}	X_{52}	X_{53}	X_{54}	X_{55}	X_{56}	X_{57}
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.016	.014	0.000	1.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.063	-.038	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	.002	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.001	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	-.080	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.002	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.003	0.000	0.000
0.000	0.000	0.000	0.000	1.000	0.000	0.000	-.001	-.534	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.009	0.000	0.000
0.000	0.000	0.000	0.000	0.000	1.000	0.000	-.009	-.764	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000
0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	-.034	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	1.000	-.109	-2.752	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000	0.000
0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.034	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	.079	-.028	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.119	-.034	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	-.001	-.920	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.003	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.001	-.012	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.002	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.001	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.139	-.279	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-.007	-.261	0.000	0.000

APPENDIX D. Nutrient analysis for L-1.1 January ration

L-1.1 JANUARY

YELLOW CORN (USA)	X(31)	COST=	25.00	PERCENT=	45.38598500
WHEAT BRAN (LOC)	X(32)	COST=	14.50	PERCENT=	13.25982300
FEATHER MEAL (LAC)	X(33)	COST=	41.00	PERCENT=	3.17450700
SOY MEAL	X(34)	COST=	62.70	PERCENT=	12.34323300
OATS (USA)	X(35)	COST=	19.00	PERCENT=	9.80919200
LIMESTONE (LOC)	X(37)	COST=	2.70	PERCENT=	4.02727000
L.M. (A) P	X(38)	COST=	51.40	PERCENT=	11.99999900

TOTAL PERCENT= 100.00000900 COST= 30.45040780

METABOLIC ENERGY	RESTRICTION=	2535.000000	COMPUTED=	2535.00002274	DIFFERENCE=	.00002274
FAT	RESTRICTION=	3.000000	COMPUTED=	4.08031712	DIFFERENCE=	1.08031712
PROTEIN	RESTRICTION=	17.000000	COMPUTED=	18.71951847	DIFFERENCE=	1.71951847
LYSINE	RESTRICTION=	.700000	COMPUTED=	.79083909	DIFFERENCE=	.09083909
METH.	RESTRICTION=	.260000	COMPUTED=	.26000002	DIFFERENCE=	.00000002
METH+CYS.	RESTRICTION=	.530000	COMPUTED=	.59636199	DIFFERENCE=	.06636199
CALCIUM	RESTRICTION=	3.000000	COMPUTED=	3.10000068	DIFFERENCE=	.10000068
PHOSPHATE (AVAIL)	RESTRICTION=	.450000	COMPUTED=	.53688804	DIFFERENCE=	.08688804
VITAMIN A	RESTRICTION=	10.020000	COMPUTED=	11.50510804	DIFFERENCE=	1.48510804
RIBOFLAVIN	RESTRICTION=	4.410000	COMPUTED=	7.83642965	DIFFERENCE=	3.42642965
P. ACID	RESTRICTION=	12.120000	COMPUTED=	18.90897795	DIFFERENCE=	6.78897795
NIACIN	RESTRICTION=	46.300000	COMPUTED=	67.45413586	DIFFERENCE=	21.15413586
CHOLINE	RESTRICTION=	926.000000	COMPUTED=	926.00007177	DIFFERENCE=	.00007177
L.M. (A) P.	RESTRICTION=	12.000000	COMPUTED=	11.99999900	DIFFERENCE=	-.00000100
MAV-12 (A) (MAX)	RESTRICTION=	100.000000	COMPUTED=	0.00000000	DIFFERENCE=	-100.00000000
CRUDE FIBER (MAX)	RESTRICTION=	5.300000	COMPUTED=	5.29999924	DIFFERENCE=	-.00000075
MET ENER (MAXIMUM)	RESTRICTION=	2579.000000	COMPUTED=	2535.00002274	DIFFERENCE=	-43.99997726
METH. (MAXIMUM)	RESTRICTION=	.300000	COMPUTED=	.26000002	DIFFERENCE=	-.03999997
METH+CYS. (MAX)	RESTRICTION=	.600000	COMPUTED=	.59636199	DIFFERENCE=	-.00363800
CALCIUM (MAXIMUM)	RESTRICTION=	3.100000	COMPUTED=	3.10000068	DIFFERENCE=	.00000068
PHOS (MAXIMUM)	RESTRICTION=	1.800000	COMPUTED=	.53688804	DIFFERENCE=	-1.26311195
WHEAT BRAN (MAX)	RESTRICTION=	15.000000	COMPUTED=	13.25982300	DIFFERENCE=	-1.74017700
FEATHER ML. (MAX)	RESTRICTION=	5.000000	COMPUTED=	3.17450700	DIFFERENCE=	-1.82549300
OATS (MAXIMUM)	RESTRICTION=	25.000000	COMPUTED=	9.80919200	DIFFERENCE=	-15.19080800
ARGININE (MAX)	RESTRICTION=	100.000000	COMPUTED=	1.13083456	DIFFERENCE=	-98.86916543
GLYCINE (MAX)	RESTRICTION=	100.000000	COMPUTED=	2.23345321	DIFFERENCE=	-97.76654678
TRYP. (MAXIMUM)	RESTRICTION=	100.000000	COMPUTED=	.17378215	DIFFERENCE=	-99.82621784
XANTH.	RESTRICTION=	5.000000	COMPUTED=	7.00396520	DIFFERENCE=	2.00396520
VIT. B12 (MAXIMUM)	RESTRICTION=	100.000000	COMPUTED=	.00349195	DIFFERENCE=	-99.99650804
WEIGHT	RESTRICTION=	1.000000	COMPUTED=	1.00000009	DIFFERENCE=	.00000009

A P P E N D I X

APPENDIX E

Price stability ranges for included ingredients for L-1.1 January ration

Limits of X_{35}	17.060	19.546	X_{42}- X_{19}	X_{20}- X_{48}
Limits of X_{34}	52.393	93.241	X_{54}- X_{22}	X_{46}- X_{19}
Limits of X_{37}	-930.042	6.582	X_{16} -X_{22}	X_{20}- X_{48}
Limits of X_{38}	25.233	51.400	X_{55}- X_{37}	X_{38}- X_{38}
Limits of X_{33}	33.592	43.337	X_{46}- X_{19}	X_{20}- X_{48}
Limits of X_{32}	13.640	17.347	X_{20}- X_{48}	X_{42}- X_{19}
Limits of X_{31}	24.207	29.418	X_{20}- X_{48}	X_{42}- X_{19}

APPENDIX F

Shadow prices of excluded ingredients
for L-1 rations produced
during 1967

Ration Number	Feather meal (X_{33})	St. bone meal (X_{36})	Barley (X_{41})
L-1.1 Jan	-	25.88	-
L-1.1 Apr	-	21.14	4.11
L-1.2 June	2.69	26.12	5.64
L-1.2 Aug	7.87	25.87	9.79
L-1.3 Aug	7.87	25.87	9.79
L-1.4 Sept	7.87	20.87	6.29
L-1.5 Sept	7.87	20.87	6.29
L-1.5 Oct	6.60	16.57	5.04
L-1.6 Oct	6.60	16.57	5.04
L-1.7 Oct	-	15.79	4.66
L-1.7 Nov	-	15.78	4.68
L-1.8 Nov	7.27	22.82	-
L-1.9 Nov	6.32	21.05	-
L-1.10 Dec	11.90	19.99	-

APPENDIX G

Shadow prices of excluded ingredients
for L-2 rations produced
during 1967

Ration Number	Feather meal (X_{33})	Soymeal (X_{34})	St. bone meal (X_{36})	Barley (X_{41})
L-2.1 Jan	-	9.70	27.79	-
L-2.1 Apr	3.49	-	27.30	7.63
L-2.2 June	7.98	-	26.69	6.12
L-2.2 Aug	7.87	-	26.01	9.91
L-2.3 Sept	7.87	-	25.87	9.79
L-2.4 Sept	7.87	-	-	6.43
L-2.5 Sept	7.87	-	20.87	6.29
L-2.6 Sept	7.87	-	-	6.43
L-2.6 Oct	-	-	-	4.99
L-2.7 Nov	-	-	17.92	-
L-2.8 Nov	9.43	-	21.29	-
L-2.9 Nov	9.43	-	21.29	-
L-2.10 Dec	7.26	-	17.82	-

APPENDIX H

Shadow prices(L.P./kg) of critical nutrients
for L-1 rations

Nutrients	Unit	L-1.1 Jan	L-1.1 Apr	L-1.2 June	L-1.2 Aug	L-1.3 Aug	L-1.4 Sept	L-1.5 Sept
Metabolizable energy(Min)	Cal/kg	0.002	-	0.003	0.003	0.003	0.003	0.003
Protein(Min)	%	-	-	-	-	-	-	-
Methionine(Min)	%	38.773	38.843	43.623	33.4040	33.404	33.404	33.404
Methionine plus Cystine(Min)	%	-	0.012	-	- -	-	-	-
Choline(Min)	mg/kg	0.007	-	-	-	-	-	-
Xanthophyll(Min)	mg/kg	-	-	-	0.072	0.072	0.072	0.072
Crude fiber(Max)	%	0.607	0.484	0.154	0.086	0.086	0.086	0.518
Calcium(Max)	%	0.101	0.439	0.084	0.102	0.102	0.102	0.102

APPENDIX H(Continued)

Nutrients	L-1.5 Oct	L-1.6 Oct	L-1.7 Oct	L-1.7 Nov	L-1.8 Nov	L-1.9 Nov	L-1.10 Dec
Metabolizable energy(Min)	0.001	0.001	-	-	0.001	-	-
Protein(Min)	-	-	-	0.112	0.124	-	-
Methionine(Min)	28.017	28.017	19.143	18.832	29.210	27.525	4.931
Methionine plus Cystine(Min)	-	-	0.273	-	-	-	-
Choline(Min)	-	-	-	-	-	-	0.005
Xanthophyll(Min)	-	-	-	-	-	-	-
Crude fiber(Max)	0.518	0.651	0.660	0.435	0.435	0.552	0.980
Calcium(Max)	0.409	0.409	0.464	0.466	0.320	0.446	0.521

APPENDIX I

Shadow prices(L.P./kg) of critical nutrients
for L-2 rations

Nutrients	Unit	L-2.1 Jan	L-2.1 Apr	L-2.2 June	L-2.2 Aug	L-2.3 Aug	L-2.4 Sept	L-2.5 Sept
Metabolizable energy(Min)	Cal/kg	0.004	0.004	0.003	0.003	0.003	0.003	0.003
Methionine(Min)	%	53.796	45.191	44.657	33.673	33.404	33.355	33.404
Methionine plus Cystine	%	-	-	-	-	-	-	-
Calcium(Min)	%	0.035	-	-	-	-	-	-
Phosphorus(Min)	%	-	-	-	-	-	1.768	-
Vitamin A(Min)	1000 IU	0.377	0.461	0.463	0.580	-	-	-
Xanthophyll(Min)	mg/kg	-	-	-	0.042	0.072	0.071	0.072
Crude fiber(Max)	%	-	-	0.076	0.065	0.086	0.072	0.086
Calcium(Max)	%	-	-	0.043	0.091	0.102	0.077	0.102

APPENDIX I (Continued)

Nutrients	L-2.6 Sept	L-2.6 Oct	L-2.7 Nov	L-2.8 Nov	L-2.9 Nov	L-2.10 Dec
Metabolizable energy (Min)	0.003	-[1]	0.001	0.003	0.003	0.001
Methionine (Min)	33.355	22.282	23.152	32.264	32.264	29.210
Methionine plus Cystine	2.935	3.206	-	-	-	-
Calcium (Min)	-	-	-	-	-	-
Phosphorus (Min)	1.768	1.410	-	-	-	-
Vitamin A (Min)	-	-	-	-	-	-
Xanthophyll (Min)	0.071	-	-	-	-	-
Crude Fiber (Max)	0.072	0.515	0.444	-	-	0.435
Calcium (Max)	0.077	0.383	0.312	0.071	0.071	0.320

1. The figure was less than 0.001

APPENDIX J

List of abbreviations

American University of Beirut	AUB
Calorie	Cal
Column	Col
International Business Machine	IBM
International Unit(for Vitamins)	IU
Kilogram	kg
Lebanese Pound	LL
Lebanese piaster	L.P.
Maximum	Max.
Milligram	mg
Minimum	Min.