Livestock - Feeding

SCHOOL OF AGRICULTURAL ECONOMICS AND EXTENSION EDUCATION

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A Computer Program for Least Cost Livestock Feed Formulation

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Introduction

Commercial feed companies, large livestock feeders and researchers in animal nutrition frequently encounter problems in blending feed ingredients into nutritious, palatable, and most importantly, profitable livestock feed products. Often the blending problem becomes one of choosing among alternative feed ingredients. Based on ingredient prices a least-cost blend is desirable as long as nutritional and palatability standards are maintained.

This paper introduces a computer-aided mechanism for least-cost feed mix calculations. The approach taken is to provide a straightforward feed formulation tool which caters to both nutritional and economic aspects of livestock production.

The computer program described in this paper was originally developed at a Land Grant College of Agriculture in the United States. [1/] Similar tools are available in Ontario from publically supported agencies. The concept and methods discussed in this paper also apply to their use by persons formulating livestock feeds.

The computer program described herein provides a comprehensive tool for least-cost livestock feed formulation to meet various sets of ration (nutritional) specifications. Any livestock feeder, feed company, etc. may obtain the program for their own use. This paper may provide some insights on procedures for incorporating it into an on going management

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[1/] Nelson, T.R., W.L. Brant, and R.E. Just, The Oklahoma Feed Mix Program, Department of Agricultural Economics, Oklahoma State University, Stillwater, 1969.

system. Hopefully, it will also provide background on the data necessary for least-cost feed blending and clear up some common misconceptions about the technique's inherent limitations.

Chapter I

Basic Concepts of Computer Usage for the Feedmix Program

Most every livestock producer has a feed formulation problem. Whenever alternatives exist for feed ingredients, least-cost feed blending can and should be applied. In almost all cases a computer is needed to obtain least-cost answers to a feed blending problem, accurately, in a reasonable time and at reasonable cost. Whether or not the computer is a practical tool for helping to solve feed blending problems depends upon many factors. Each producer, feed company, etc. might first weigh the potential benefits against the cost of computer usage before deciding to proceed. The following discussion is intended to provide some details regarding some of the general technical obstacles to employing the computer for feed blending calculations.

The most widely used method of calculation for least-cost livestock feed formulation is Linear Programming. Therefore a Linear Programming computer program must be readily available. Most computer manufacturers and many independent computer programming companies offer LP packages. These computer programs, unfortunately for livestock feeders, company managers etc., are almost always designed for technicians who understand both the mathematics of Linear Programming and some of the mechanics of running a computer. The first obstacle is, therefore, to obtain a computer program which is designed for practical use outside of a research laboratory environment. The feedmix program described in this paper was designed for the practical user.

The feedmix program obtains the same numerical solution which would be obtained by any linear program. The extended purpose of this program is however, to format input data into convenient form, to provide flexibility through optional calculations, and most importantly, to produce readable output in a form which can be understood by livestock producers, extension workers, animal nutritionists, etc. No professional experience in computer science should be necessary to use the program. Instruction in livestock nutrition and the economics of livestock rations should prepare prospective users. 2/

To be economically feasible, any computer-formulated livestock feed must at least save in feed costs or gain in production enough money to offset the costs of preparing data and processing the problem. As a rule of thumb any cost saving or increased return must be realized during the time period in which conditions pertaining to feed ingredients remain stable enough so as to not require a new computer solution. The magnitude of savings realized with a computer blended feed, as compared to the feed which would have been fed otherwise, or of production gains through the mixing of a better, more productive feed, vary widely with individual situations. If the cost criteria is met, other conditions must be satisfied before the user can benefit from a computer formulated livestock feed. Information must be available on:

1. Nutritional requirements of the animals. One must be able to specify how much protein, energy, fiber, minerals, etc. are required for each class of livestock.

2/ Readers may obtain more information on data requirements and economic concepts for least-cost feed blending from Pfeiffer, W.C., Methods and Guidelines of Least-Cost Feed Formulation.

In many cases a range will be in order, i.e. at least a minimum amount of a nutrient is necessary, but the blend can tolerate some amount in addition to the minimum specification.

2. Alternative feeding ingredients must be identified and priced appropriately. This usually means adjusting prices to compensate for special conditions which exist so that each ingredient is priced fairly at the point that it enters the feedmix. Pricing may take several forms such as:

   a. Delivered cost to the blender for purchased feeds.

   b. Transportation costs might be deducted from the local "market price" for home grown feeds.

   c. Price adjustments for moisture content of feeds used might also be considered.

3. Processing facilities must be reasonably available. Access to a computer is necessary and it should be close to the user's normal place of work. Computer time is often available through local banks, schools and municipal offices. Government agencies are building up computer expertise and some areas are served by government computers for "extension-type" activities such as this. Most medium to large manufacturing companies have access to computers and many are willing to service small volume users on an "after-hours" basis.

The feedmix computer program is written in FORTRAN IV. It is written according to ASA programming standards and, therefore, should be easily adaptable to a wide range of computing machinery. The version described in this paper is running at the University of Guelph on an IBM model 370/155 large scale computer. Memory requirements are 147,000 "bytes" [3] which means that it is relatively compact among the various Linear Programming packages generally available.

Within this amount of computer memory space the feedmix program will accommodate as many as 56 diet restrictions on one problem. Similarly 60 ingredients can be considered in any single feed blending problem. These limits on problem size should be adequate for the most sophisticated feed blending problems likely to be encountered by commercial livestock feeders. Nutrition research may deal with larger blending problems and so may large feed companies. In such cases the feedmix program can be expanded as required with a minimum of difficulty (and hence, minimal expense).

The simplest manner in which to run the feedmix program on an IBM 370 machine requires three sets of punched cards to be entered in the following order:

1) IBM Job Control Language cards,

2) The feedmix FORTRAN source program,

3) Agenda and data cards for the feedmix program.

The job the computer recognizes will entail three steps in the case of IBM equipment. The first two steps are to instruct the machine to 1) compile and 2) edit [4] the program from its FORTRAN form into machine

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[3] A "byte" is a unit of measurement of computer memory on IBM equipment. All computer programs require use of computer memory and are usually more or less expensive to operate depending in part on this measure.

language. The third step is to have the machine execute the "internalized" (machine language) feedmix program on the feed blending problem represented on the agenda and data cards. Job Control Language (JCL) is IBM's scheme whereby this information about the complete job is communicated to the machine. Each IBM computer installation varies slightly in Job Control Language and user's will usually need to consult technicians when running the feedmix program for the first time at a particular location. The following is a suggested set of JCL which should be operable at nearly all IBM 360 or 370 installations.

IBM Card Column #1

```
//FEEDMIX JOB  (accounting information, etc.)
//STEP1  EXEC  FORTGC,REGION.FORT=150K
//FORT.SYSIN   DD DDNAME=PROGRAM
//FORT.SYSLIN  DD UNIT=DISK,SPACE=(80,(2000,100),RLSE),
//             DSNAME=&&LOADSET(FEEDOBJ),DISP=(NEW,PASS)
//STEP2 EXEC   LKED,REGION.LKED=150K
//LKED.SYSLIN  DD UNIT=DISK,DSNAME=&&LOADSET(FEEDOBJ),
//             DISP=(OLD,DELETE)
//LKED.SYSLMOD DD UNIT=DISK,SPACE=(80,(2000,100),RLSE),
//             DSNAME=&&RUNSET(FEEDMIX),DISP=(NEW,PASS)
//STEP3  EXEC  PGM=FEEDMIX,REGION=150K
//STEPLIB      DD UNIT=DISK,DSNAME=&&RUNSET,DISP=(OLD,DELETE)
//FT05F001     DD DDNAME=PROBLEM
//FT06F001     DD SYSOUT=A
```

This seems a bit complicated for a non-computer oriented person. IBM Job Control Language is in fact one of the most complex in the industry.

4/ Actually "linkage-edit" or "link-edit" is the proper IBM ese for this step.

The best advice I can give to the reader is to have their computer installation people work out any special changes to the JCL specified above. There will always be a need to have them establish the complete information on the first card (the "JOB" card) for accounting purposes. In this area almost every computer installation follows its own unique methods. The rest of the JCL should not require more than minimal changes. Once you have a set of JCL cards that works, keep it.

Notice that the suggested JCL cards were broken into 3 steps (they all go into the machine at once, however) according to the steps mentioned above. The events which would occur on the machine can be summarized as follows:

	JCL	Event
1)	//FEEDMIX JOB	See who this job belongs to and start the clock for charging
2)	//STEP1 EXEC FORTGC	Use the built in FORTRAN language compiler to translate a source program into machine language and temporarily put the results on magnetic disk for later use in a file called "LOADSET" under the name "FEEDOBJ"
	//FORT.SYSLIN DD UNIT=DISK	
3)	//STEP2 EXEC LKED	Take a machine language program and prepare it to run in main memory
	//LKED.SYSLIN DD UNIT=DISK	The program is called "FEEDOBJ" and its sitting in disk file "LOADSET"
	//LKED.SYSLMOD DD UNIT=DISK	Take the "ready" version and put it back onto magnetic disk storage for later use in a file called "RUNSET" under the name "FEEDMIX"
4)	//STEP3 EXEC PGM=FEEDMIX	Run the "readied" program called "FEEDMIX" in main memory

//FT06F001 DD SYSOUT=A	Put this program's output in the system's print queue for printing at earliest convenient time

Two other JCL cards in the package were:

JCL	Meaning
(In step 1)	
//FORT.SYSIN DD DDNAME=PROGRAM	The feedmix source program can be found in the card deck under designation "PROGRAM"
(In step 3)	
//FT05F001 DD DDNAME=PROBLEM	The feed blending problem data and control commands for the feedmix program can be found below in this card deck under the designation "PROBLEM"

The complete deck of IBM punched cards containing 1) JCL, 2) Program and 3) Data would be arranged according to the following diagram:

```
                    /*

                 Data Cards

          //STEP3.PROBLEM DD *

              Fortran
          Feedmix Program

     //STEP1.PROGRAM  DD *

   //FEEDMIX JOB (--)
     JCL Cards
```

Figure 1. - Card Deck Arrangement

The task of preparing the basic input card deck may seem arduous and confusing at first. However, once established as a working setup it should not change unless the computer installation makes major equipment changes as well. This task, although necessary and involved, should present few problems. The major portion of the work in computer feed blending will come in understanding how to drive the program through its optional calculations and preparing data from figures on paper. The next chapter deals with the preparation of control (command) cards and data cards for the feedmix program.

Chapter II

Data Preparation for the Feedmix Program

The feedmix program is flexible so that one or many sets of calculations can be made during one computer run. The program recognizes key words (commands) punched on agenda cards to trigger various tasks. Between agenda cards, data cards are read by the program to obtain such things as the feed ingredient's chemical analysis coefficients, feed ingredient prices, diet restrictions and output titling information. The program recognizes 17 different commands which can be stacked (together with data cards) to handle single feed blending problems or many feed blending problems during one computer run (Table 1). The commands, however, cannot be stacked randomly. The feedmix program has certain requirements which force some commands to take precedence. The order in which the program expects to see commands occurring on the agenda generally means that a user must plan each computer run carefully and ensure that the input card deck is stacked appropriately (Figure 2).

The order of commands in the agenda can vary slightly. The agenda concept is similar to the use of procedures in IBM's MPS or other linear programming systems.

Table 1. - Summary of Feedmix Program Commands

	Key Word	Purpose	Previous Command Required	Data Required
1.	HEAD	Set up column headings for "feed nutrient coefficients" on matrix printout.		4 cards for each page
2.	NEW	Enter complete new matrix.	NONE	1 or 2 cards each ingredient
3.	MATRIX	Change coefficients.	NEW	1 or 2 cards each ingredient
4.	RATIO	Establishes allowed ratios of one nutrient to another.	NEW	
5.	CHANGE	Alters the ratios set up originally by the RATIO card.	NEW RATIO	1 card for new ratio
6.	REMOVE	Eliminates ingredient type specifications from matrix.	NEW	None
7.	OUT	Prices out all ingredients at $100/cwt. preparatory to accepting new prices.	NEW	None
8.	SAMPLE	Accepts new set of prices for ingredients, setting price only on those for which a card is entered.	NEW	1 card for each ingredient to be priced
9.	RHSVEC	Reads a set of diet specification values and produces a solution.	NEW HEAD	New set of diet specification values
10.	OLDRHS	Reads in a percentage for each ingredient in a blend now being fed, computes matching RHS and cost and a new solution.	NEW HEAD	1 card for each feed in the present blend

11.	BASIS	Initializes program from optimal basis punched out previously and produces a solution.	NEW HEAD	Basis cards punched by previous computer run.
12.	XBASIS	Designates the right-hand-side (set of diet specifications) to be one previously stored by NEW and produces a solution.	NEW HEAD	None
13.	PCR	Calls for parametric solutions for a specified ingredient within a set price range.	NEW HEAD	1 card for the ingredient on which parametric pricing is wanted.
14.	PLP	Calls for parametric solutions within a requested range in value of a diet specification.	NEW HEAD	1 card per diet specification on which parametric solutions are desired.
15.	PICT	Produces a condensed, data-coded "picture" of the LP matrix, used for technical diagnostic purposes only.	NEW	None
16.	CONV	Uses dry matter contents of ingredients to produce "as fed" feed composition tables.	NEW	1 card for each feed indicating moisture and price.
17.	LAST	Signifies end of data.	NONE	None

Figure 2. - Flowchart For Feedmix Program Command

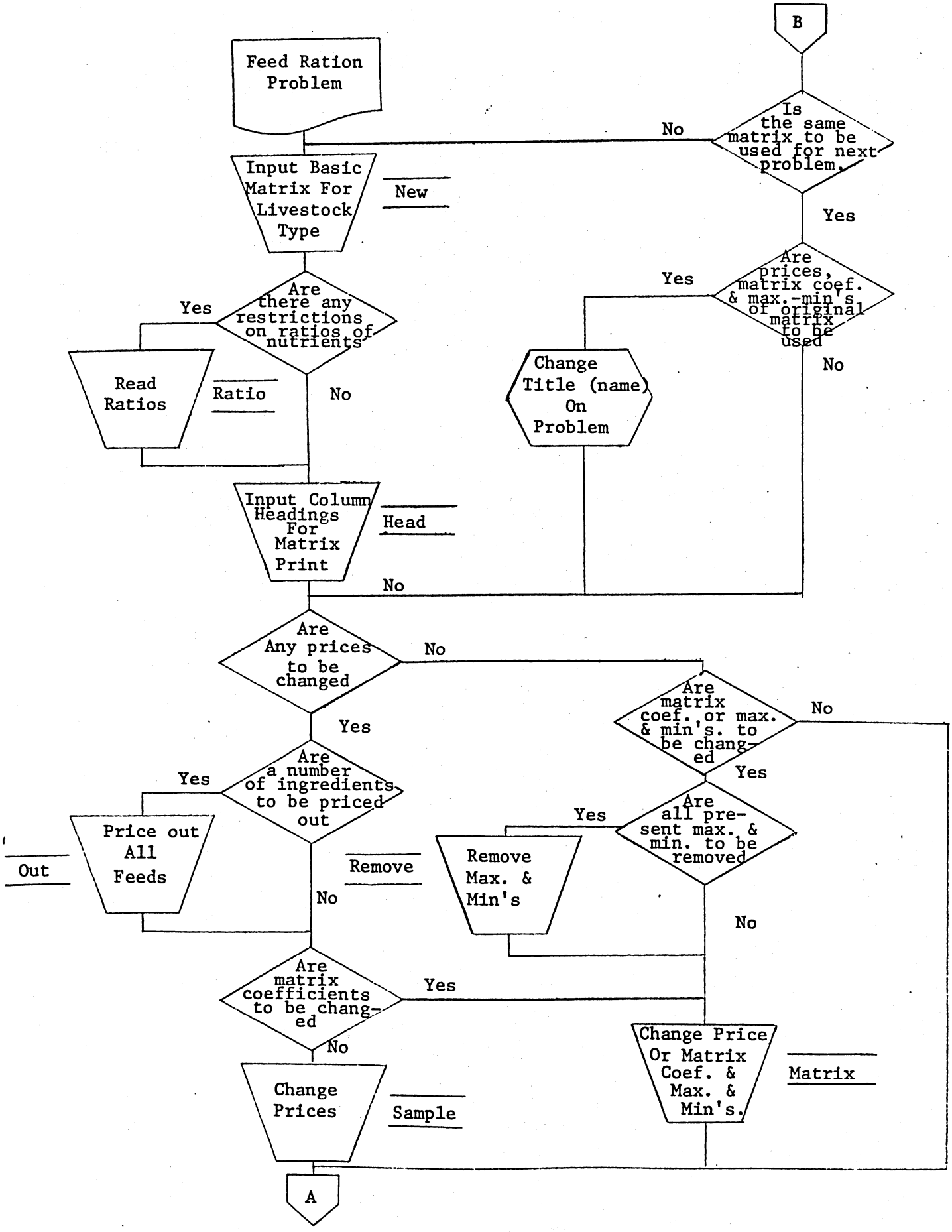
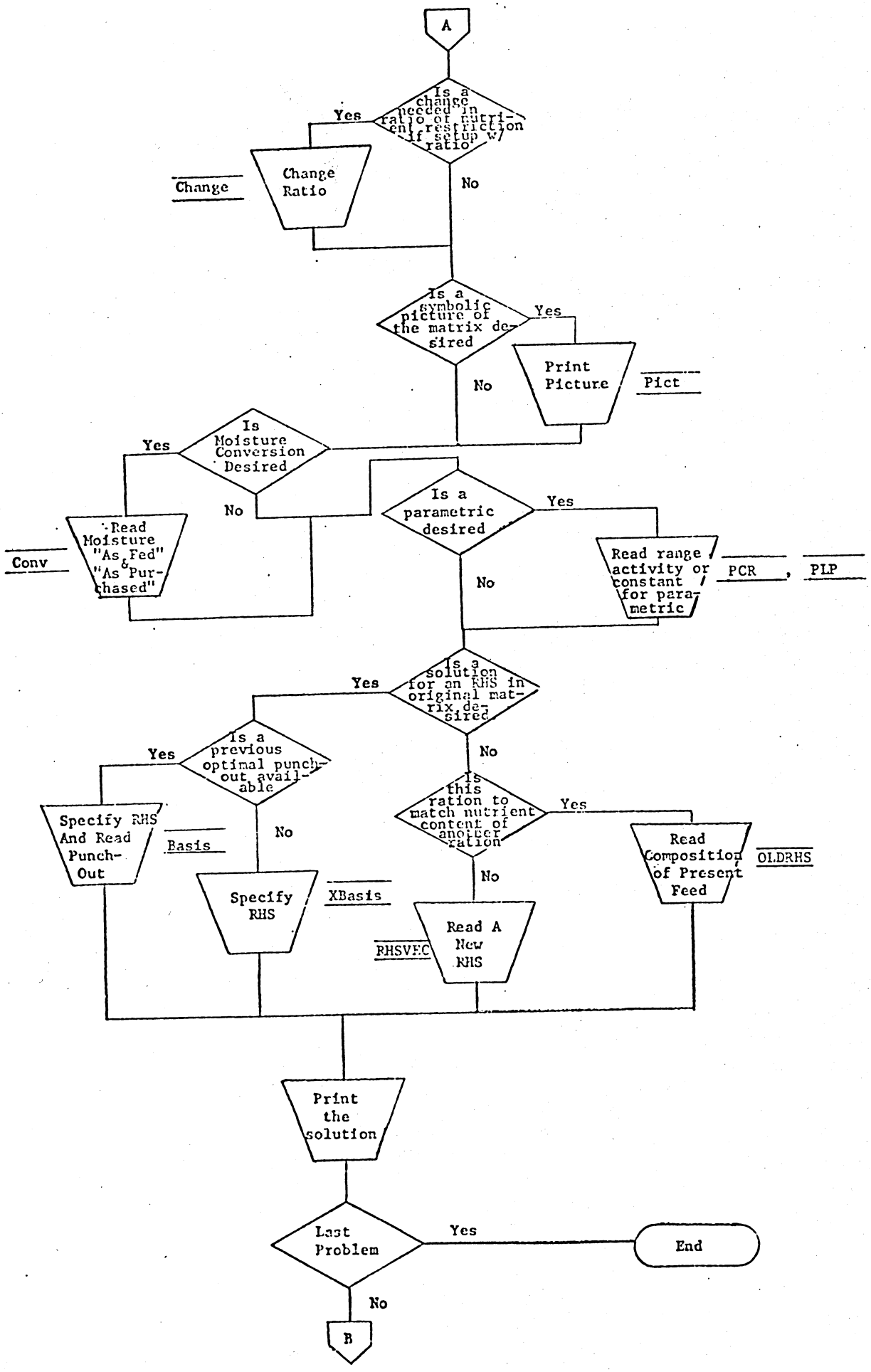


Figure 2. - Flowchart For Feedmix Program Commands (continued)



Preparation of Command and Data Cards

1. The first command (agenda card must contain parameters which define values which control output options, title the printed report and specify the size of the problem to follow. The "HEAD" card is usually the first to be entered. It would be prepared as follows:

Card Columns	Field Content
1 - 4	HEAD
8 - 71	Title. The title is assumed to remain the same through all following agendum cards in which this field is left blank. Any time this field is punched, a print is made of the matrix showing the new title (which also appears on other output pages) and all prices and nutrient coefficients to be used for the following calculations.
72 - 73	The number of diet specifications which are entered as both minimums and maximums. If none, enter 99.
74 - 75	Punch the number 12.
76	1 if a print-out of more than the first 10 nutrients in the problem is desired. Otherwise, 2.
77 - 78	The total number of nutrient coefficients entered with each ingredient plus the number of diet specification entered as both minimums and maximums. This is limited to 50.

All of the parameters possible on agenda cards should be specified on the first agenda card. Thereafter, if any of the columns 74-80 are left blank they are assumed unchanged. (This may be over-ridden in special cases).

The HEAD command causes the program to read cards which contain the headings to be used for the print-out of the ingredient matrix. Four cards for each group of nutrients are read in (nutrients are entered in

groups of 10 or less). Two cards (using only 50 columns of the second) are used to form a line of printed output (each line is 130 spaces hence, the two card/line requirement). Each heading has two printed lines, hence, 4 cards are required in total. Previously required command: None

2. The NEW card:

The new command is used to read in a complete new matrix of nutrient coefficients for ingredients and up to eight different sets of diet specifications (right-hand sides). Punch NEW in columns 1-3.

Format of feed ingredient cards which follow the "NEW" command card.

Card columns	
1-24	Feed ingredient name
25-28	Feed ingredient cost
29-32	First nutrient coefficient
33-36	Second nutrient coefficient
.	.....
65-68	Tenth nutrient coefficient
69-72	Minimum amount of the feed ingredient desired if greater than zero.
73-76	Maximum amount of the feed ingredient allowed in the blend if less than 100 percent.
77	Any non-zero integer corresponding to one in the same column in another ingredient card if more than one ingredient is to enter into the same maximum or minimum specification. Otherwise, blank. When this key entered on a card, no other constraint value can be entered on that card. Individual ingredients can only enter into a single ingredient maximum and/or a single minimum diet specification as a member of a multi-ingredient diet specification.

If there are more than ten nutrient coefficients per feed ingredient, the rest are entered on a second card, four columns each, decimal punched, starting in column one. (i.e. cc. 1-4, 5-8, 9-12, etc.)

NOTE: The last ingredient card is followed by a card with END*** in columns 1-6.

Next names and values for nutrient (diet) specifications are read in the following format:

Card columns	
1	"1" if the specification is a minimum "2" if the specification is a maximum "3" if the specification is an equality

Card columns	
2-25	specification name
26-29	value for right-hand side #1
30-33	value for right-hand side #2
.	.....
54-57	value for right-hand side #8

If both a minimum and maximum is desired for a particular nutrient specification, enter a first card in the above format with a "1" in the first column and the minimum (or set of minimums if many right-hand sides exist). Then, on the second card, enter a "2" in the first column and the maximums desired. Both cards should have the same specification name. Previously required command: None.

The MATRIX card:

The MATRIX command is used to make changes in feed ingredient costs, feed ingredient nutrient coefficients, and/or minimums and maximums for ingredients.

The format for data cards which follow the MATRIX card is the same as in the NEW section described above. However, only the feed ingredient name with the ingredient cost, nutrient coefficients, and minimums and maximums to be changed are entered. Nutrient specification cards (with right-hand side values for diet specifications are not used

in the MATRIX segment. Only the first eight characters of an ingredient name are tested in comparing names, so care should be taken to keep from naming two ingredients identically in the first eight characters.

All costs, nutrient coefficients, and ingredient maximums and minimums that are changed in a MATRIX segment are changed back to the original values specified in the last NEW segment when and only when the title of the problem (which can be specified on the major command cards in columns 8-71) is changed. If the total number of nutrients being considered for each feed ingredient is greater than ten, then each change requires two cards to be entered even if none of the coefficients on the second card are to be changed (i.e. all coefficients must be entered - the unchanged as well as the changed). Previously required command: NEW

NOTE: The last change card is followed by a card with END*** in columns 1-6.

4. The RATIO card:

The RATIO command is used to specify maximum and minimum ratios that two nutrients may be allowed to reach. Format of data cards which follow the RATIO command card:

Card columns	
1-24	Name of first diet nutrient specification.
25-48	Name of second diet nutrient specification.
49-52	Minimum ratio of the first to the second diet nutrient specification.
53-56	Maximum ratio of the first to the second diet nutrient specification.

Ratios may be changed by using the CHANGE command (below). Note that only the last set of ratios will be altered if more than two sets of ratios have previously been specified in a computer run. If a ratio other than one of the ratios in the last set is to be changed, a NEW command must

be used to read in a complete new matrix of coefficients. Previously required command: NEW

5. The CHANGE card:

CHANGE changes the maximum and minimum ratio set up under RATIO. The format for data cards here is the same as for the BASIC card. If this card option is used, only one nutrient ratio may be changed regarding both maximum and minimum ratio constraints (note that only the last set of ratio specifications entered may be modified). Previously required commands: NEW & RATIO

6. The REMOVE card:

The remove command causes the program to remove all feed ingredient restrictions in the matrix so only the current nutrient restrictions apply. The feed ingredient restrictions cannot be reinstated unless a NEW matrix is read in or they are added using the MATRIX command. Previously required command: NEW

7. The OUT card:

OUT automatically sets artificially high prices on all ingredients. This is done prior to SAMPLE (below) which reinstates only selected feed ingredient prices for special runs. For "limited-alternative" runs only the relevant ingredients then need to be priced, using actual market data using the SAMPLE command. The prices are changed back to their original values when a new problem title is encountered on a major command card. Previously required command: NEW

8. The SAMPLE card:

The SAMPLE command causes new market prices to be read. The purpose of SAMPLE is similar to MATRIX except only prices are entered.

Format of data cards:

Card column	
1-8	First 8 characters of feed name
25-28	Feed price (F4.2)

NOTE: The last data card should be followed by a card with END*** in columns 1-6.

If a feed name is not found in the matrix, the price change is ignored. Previously required command: NEW

9. The RHSVEC card:

The RHSVEC command reads in new values for diet nutrient specifications (a new right-hand side) and produces a solution.

Format for data cards to follow the RHSVEC command card:

Card columns	
1-4	Right-hand side value for 1st diet nutrient specification
5-8	Right-hand side value for 2nd diet nutrient specification
77-80	Right-hand side value for 20th diet nutrient specification

If more than 20 diet nutrient specifications are being used, the rest may be entered on a second card starting in column 1, using four columns for each. Previously required command: NEW, HEAD

10. The OLDRHS card:

The OLDRHS command causes the program to read the present feed ingredient composition of a user-specified feed ration. The program will then compute the matching nutrient specifications of ration as well as the cost without making any feed ingredient substitutions. Then a least-cost ration will also be formulated to meet the same nutrient specifications for comparison to the user-specified ration. Format of data cards which

follow the OLDRHS command card:

Card columns

1-24	Ingredient name
25-28	Percentage of feed ingredient being used in an existing feed ration

Only cards which designate percentages of feed ingredients in the present ration must be entered. Also, only the first 8 columns of the name of the ingredient must agree with a name in the matrix.

NOTE: The last ingredient card must be followed by a card with END*** in columns 1-6. Previously required commands: NEW, HEAD

11. The BASIS card:

BASIS reads in a previous least-cost feedmix punch-out and produces a solution (punch a number "n" in column 8 for or selection from the possible 8 sets of diet specifications included in the punch-out).

Discussion:

A previously punched out basis is read in. The "n" should be set to designate the right-hand side for which a solution is desired. $1 \leq n \leq 8$. Previously required commands: NEW, HEAD

12. The XBASIS card:

The XBASIS command produces a solution using a previously read right-hand side (punch a number "n" in column 8 for selection from the possible 8 sets of diet specifications). No other cards are read in. Previously required commands: NEW, HEAD

13. The PCR card:

The PCR command produces parametric operations on the feed ingredient costs, one at a time. Both initial and final costs are read in. A solution is printed for both the initial and final costs as well

as for every decision point within the price range.

Format of data cards which follow the PCR command card:

Card columns	
1-24	Feed ingredient to be used in parametric operations.
25-28	Initial cost value.
29-32	Final cost value (final cost should be greater than initial cost).
33-36	Ingredient number which is to be used in the parametric operations (decimal punched).
37-40	The minimum size of parametric interval to be considered (0.01 is assumed if blank).

If the feed ingredient name is blank or does not match a name in the stored data, the number will be used to locate the ingredient to be used.

The next card should contain either a BASIS, XBASIS, or an RHSVEC command in order to specify which of the diet nutrient specifications are to be used for the parametric operations. Previously required commands: NEW, HEAD

14. The PLP card:

The PLP command produces parametric operations on the diet specifications (right-hand side values); also, one at a time. The initial and final values are read. A solution is printed for both ends of the range, as well as every decision point within.

Format of data card which follows the PLP command card:

Card columns	
1-24	Name of diet nutrient specification to be parameterized.
25-28	Initial value.
29-32	Final value (greater than initial value).
33-36	Number of the restriction on which to perform parametric operations.
37-40	The minimum size of parametric interval to be considered (1% of the initial value is assumed if blank).

As with the PCR command, above, the number will be used only if the name of the diet nutrient specification is blank or does not match one in the data stored in the computer.

The next card should contain either a BASIS, XBASIS, or RHSVEC command in order to specify which of the eight possible sets of diet nutrient specifications are to be used.

NOTE: Parametric operations cannot be performed on equality type specifications. Previously required commands: NEW, HEAD

15. The PICT card:

PICT produces a "picture" of the stored data matrix. This command is used only for technical diagnostic purposes. Previously required command: NEW

16. The CONV card:

The CONV procedure reads dry matter contents of feeds and converts the solution from 90 per cent dry matter feeds to a solution for as fed dry matter feeds. To use this procedure, the matrix entered with the NEW command must contain coefficients for feeds on a 90 per cent dry matter basis.

Format of data cards which follow the CONV command card:

Card columns	
1-8	First 8 characters of feed ingredient name
25-28	Price per cwt. at purchase (F4.2)
29-32	As fed moisture percentage (F4.2)
33-36	Purchase basis moisture percentage (F4.2)
37-40	Inventory factor to account for storage losses, etc. (F4.2)

NOTE: The last data card should be followed by a card with END*** in columns 1-6.

The dry matter and inventory factors need not be entered for all

feeds. The values assumed unless changed are indicated above.

Previously required command: NEW

17. The LAST card:

LAST signifies the end of data for a particular computer run.

APPENDIX I

Dairy Supplement Blending Problem

Table 1. Prices and Nutrient Coefficients for Feed Ingredients

Dairy Supplement Blending Problem Date Processed Nov. 26, 1976

Prices or Coefficients to be Changed Must be Indicated in Red

Ingredients	Cost Per Cwt	Total Energy	Crude Protein	Digestible Protein	(Fat)	Crude Fibre	Ash	Calcium	Phosph-orous	Min %	Max %
Barley	5.25	78.00	10.30	8.90	1.90	5.40	2.80	0.06	0.30		
Corn	4.53	80.00	9.10	7.00	3.90	2.00	1.30	0.02	0.26		40.00
Cane Molasses	0.10	71.30	3.00	0.0	0.0	0.0	8.60	0.66	0.08		10.00
Oats	5.00	72.00	12.00	9.40	4.60	11.00	4.00	0.09	0.33		
Soybean Meal	10.60	80.00	45.70	42.00	1.30	5.80	6.10	0.26	0.63		
Soybean Meal	11.20	80.00	50.40	46.40	1.00	3.20	6.10	0.26	0.63		
Wheat Bran	5.40	67.00	16.40	13.30	4.50	10.00	6.10	0.13	1.29		(8 10.00
Wheat	5.80	80.00	11.00	9.00	2.00	2.60	1.90	0.04	0.39		(8 10.00
Silage	2.50	27.00	3.20	1.90	1.20	9.80	2.40	0.11	0.08		(6 60.00
Alfalfa	3.00	58.00	15.20	10.80	1.80	27.60	7.60	1.20	0.20		(6 60.00
Haylage	1.65	28.00	17.80	5.90	2.00	17.80	5.00	0.88	0.21		(6 60.00
Dical Phosp	5.00	0.0	0.0	0.0	0.0	0.0	78.10	18.00	21.00		
Ground Lime	0.75	0.0	0.0	0.0	0.0	0.0	95.00	38.00	0.0		1.00
Salt	2.00	0.0	0.0	0.0	0.0	0.0	98.00	0.0	0.0	1.00	1.00
Urea	5.00	0.0	281.00	196.00	0.0	0.0	0.0	0.0	0.0		1.00
Bone Meal	6.00	0.0	5.50	4.20	0.40	1.40	85.00	31.30	14.40		

Table 2. The Computed Least-Cost Blend and Cost/Cwt.

Dairy Supplement Blending Problem Date Processed Nov. 26, 1976

Ingredient	Percent In Ration	Cost Per Cwt. Of Ration	Allowed Percentage	Forced Percentage	Restriction Cost Per Unit	Assigned Cost/Cwt.	Incoming Price	Outgoing Price
Barley	18.58	0.98				5.25	4.52	5.36
Corn No. 2	40.00	1.81	40.00		0.0082	4.53	2.71	5.35
Cane Molasses	10.00	0.01	10.00		0.0307	0.10	0.10	3.17
Oats						5.00	4.64	
Soybean Meal						10.60	10.56	
Soybean Meal	14.47	1.62				11.20	6.99	11.25
Wheat Bran			10.00 8)			5.40	5.10	
Wheat			10.00 8)			5.80	5.68	
Silage			60.00 6)			2.50	0.77	
Alfalfa	13.46	0.40	60.00 6)			3.00	1.95	3.80
Haylage			60.00 6)			1.65	0.93	
Dical Phosp	1.50	0.07				5.00	0.67	11.06
Ground Lime			1.00			0.75	0.48	
Salt	1.00	0.02	1.00	1.00	0.0948	2.00	*******	*******
Urea	1.00	0.05	1.00		0.2583	5.00	1.26	30.83
Bone Meal						6.00	1.83	

Total Cost Per Cwt. 4.97

Note All Weights and Percentages Are On An Air Dry Basis.

Corresponding Numbers In Open Parentheses Denote Ingredients Which Enter Under The Same Restrictions.
Numbers Beside Those In Open Parentheses Denote The Actual Values To Which The Groups Of Ingredients Are Restricted.

Table 3. Nutritional Specifications of the Problem and the Nutrient Content of the Least-Cost Blend

Dairy Supplement Blending Problem — Date Processed Nov. 26, 1976

Ingredient	Amount In Ration	Forced Amount	Allowed Amount	Cost of One Unit Change	Valid Range Low	Valid Range High
Total Energy (Megcal)	73.00	73.00		0.1429	72.98	75.58
Crude Protein (%)	18.00	18.00		0.1364	16.29	18.55
Digestible Protein (%)	14.58	13.00				
Ether Extract(Fat) (%)	2.30		6.00			
Crude Fibre (%)	5.98		6.00			
Ash (%)	5.95					
Calcium (%)	0.55	0.40				
Phosphorous (%)	0.60	0.60		0.5944	0.60	1.35

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Number 1 - Poultry
Number 2 - Swine
Number 3 - Dairy Cattle
Number 4 - Beef Cattle
Number 5 - Sheep
Number 6 - Horses
Number 7 - Foxes and Minks
Number 8 - Dogs
Number 9 - Rabbits
Number 10 - Laboratory Animals

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