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ECONOMICS OF ALTERNATIVE GRAIN LEVELS FOR FEEDING CATTLE

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BY

RAYMOND O. P. FARRISH and JOHN A. MARCHELLO

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ECONOMICS OF ALTERNATIVE GRAIN LEVELS FOR FEEDING CATTLE

by

Raymond O. P. Farrish and John A. Marchello*

INTRODUCTION

This study examines the choice of the optimum type and the economically optimum amount of ration to feed cattle in Arizona. The specific types of rations considered are high grain, intermediate grain, and low grain, high forage. The study covers both heifers and steers of predominatly cross-bred types.

Need for this study was generated by recent changes in the relative prices of grain and other feeds (Figure 1). From the first quarter of 1971 to mid 1975, prices of grain sorghum in Arizona rose 100 percent while alfalfa hay prices rose 50 to 60 percent. With grain prices rising relative to forage prices, and since such feeds are to some degree substitutable in beef production, it appears likely that the least cost ration for producing a given level of beef output may contain relatively greater amounts of forage under current price relations than was previously the case.

The optimum quantity of grain or forage to use in a ration is a function of the relative prices of such inputs, technical input-output relations, and other variables. Over some ranges of prices, it may be desirable to utilize high levels of grain, while over others the optimum may utilize relatively low amounts of grain. This study specifies the ranges of prices over which high, medium or low levels of grain in the ration yield the lowest cost for producing 821 pound heifers or 941 pound steers.

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* Visiting Professor of Agricultural Economics and Professor of Animal Science, respectively.

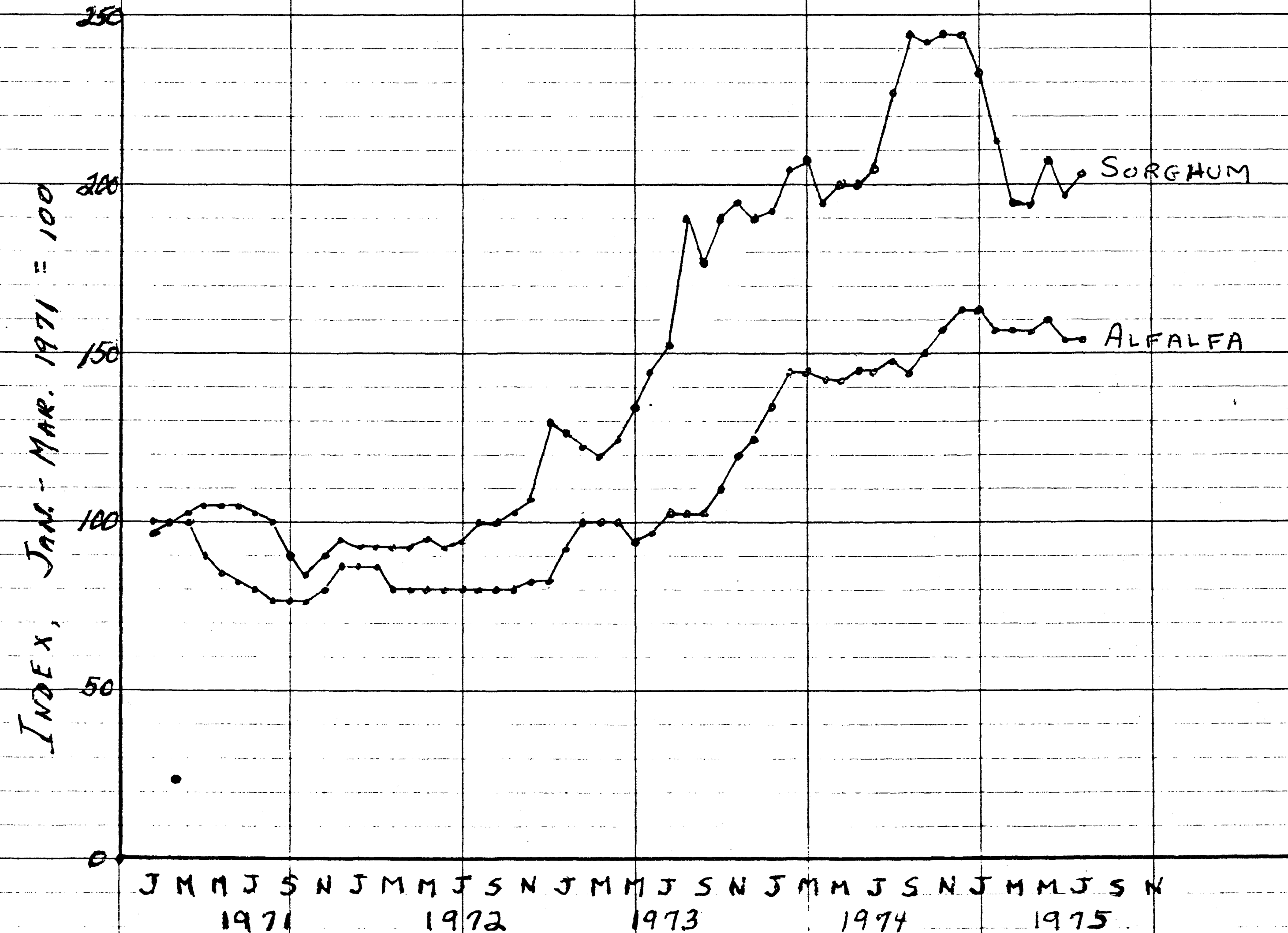

FIGURE 1 INDEX OF PRICES OF GRAIN SORGHUM AND ALFALFA IN ARIZONA, MONTHLY, 1971-75

The optimum quantity of feed and the optimum weight animal to produce depend upon the rate at which the animals convert feed into body weight as well as on the relative prices of feed and fed cattle. Experience in cattle feeding indicates that the optimum weight of animal to produce increases as the relative price of fed cattle increases, the relative price of feed declines, or as the rate at which feed is transformed into meat increases. This study determines the optimum quantity of feed to utilize and the optimum weight animal to produce for steers fed the high and low grain rations. Such optima for heifers or for steers fed the medium grain ration, however, are not determined due to data limitations.

Pronounced changes in cattle rations may, of course, affect many attributes of carcass value in addition to weight: quality grade, yield grade, cutability percentage, tenderness, and other factors may vary with the level of grain and may affect profitability. In order to determine whether such factors need be considered when selecting a particular type of ration, this study also examines various characteristics of carcass quality for the experimental animals.

A few words of caution are in order for those interested in utilizing the results. First, all results are based on data derived from one experiment. Replication of the experiment may yield different results. Such replications are underway at the University of Arizona and will be reported in forthcoming research publications. Second, the results shown in this report about the optimum weight animal to produce, are optimal so long as the objective is to maximize profits from one given lot of cattle. This is not the same as maximizing profits from a succession of lots of cattle during some longer time period. If the latter objective is the goal, the optimum weight of animal to produce would be somewhat less than the weights reported here.

THE EXPERIMENTS

Twenty-one predominantly crossbred heifers were allotted to three groups, with the allotments made by weight and breeding so as to equalize starting weights among the groups and to reduce the influence of breeding on the results. Similarly, twenty-four steers of predominantly crossbred types were allotted to three groups.

The research was planned so that heifers and steers in the high-grain groups (Group I heifers and Group I steers) were fed a starting diet for 14 days and a finishing diet (table 1) until the animals reached target weights of 850 pounds for the heifers and 1,000 pounds for steers. Group I heifers were started on September 18, 1974 at an average weight of 572 pounds and finished December 19, 1974 at an actual average weight of 885 pounds. The Group I steers were started on April 17, 1975 at an average weight of 513 pounds and finished on September 25, 1975 at 979 pounds average.

Group II heifers and Group II steers were fed a medium-grain diet. This consisted of a growing ration (table 2) for 45 days,[1/] the starting ration for 14 days, and the finishing ration until the animals reached their target weights. Group II heifers were started on September 18 at 572 pounds and finished on December 30, 1975 at an average live full weight of 886 pounds. The Group II steers were started April 17, 1975 weighing 522 pounds and finished on September 25, 1975 at an average weight of 1013 pounds.

Both heifers and steers in Group III were fed the high forage, low grain diet, consisting of the growing ration (table 2) throughout the feeding

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1/ Steers were fed the growing ration for 56 days.

period. The heifers were started September 18, 1974 weighing 569 pounds average and finished on January 9, 1975 weighing 842 pounds. The Group III steers were started April 17, 1975 at an average weight of 516 pounds and finished September 25, 1975 at 1015.

Table 1. Composition of Starting and Finishing Diets.

Ingredient	Starting	Finishing
	(%)	(%)
Ground Alfalfa Hay	30.00	15.00
Cottonseed Hulls	10.00	5.00
Steam Processed Milo	51.65	70.95
Molasses	4.00	4.00
Tallow	3.00	3.00
Urea	0.45	0.65
Biofos	0.40	0.40
Salt	0.50	0.50
Ground Limestone	0.00	0.50
TOTAL	100.00	100.00
Vitamin A-10-P, gm.	10.00	10.00
Analysis:		
Protein	11.60	11.40
Calcium	0.55	0.53
Phosphorus	0.30	0.31

Table 2. Composition of Growing Diet.

Ingredient	Proportion of Ration
	%
Creep Feed Pellets[1/]	33.3
Alfalfa Hay	33.3
Cottonseed Hulls	33.3
TOTAL	100.0

[1/] Composed of ground barley, ground sorghum grain, wheat bran, cottonseed meal, can molasses, ground corn, sun cured alfalfa meal, limestone flour, salt, dicalcium phosphate, vitamin A supplement.

Table 3 presents information on the rate of gain in weight for the various groups of experimental animals. Heifers achieved faster rates of weight gain when fed the high or medium grain rather than the low grain ration. Steers, on the other hand, achieved faster rates of gain with the medium or low grain rations.

Table 3. Performance Data for the Three Groups of Experimental Animals

Item	Heifers			Steers		
	Group I	Group II	Group III	Group I	Group II	Group III
Average initial weight, lb.	572	572	569	513	522	516
Average final weight, lb.	855	886	842	979	1013	1015
Average gain per animal,lb.	283	314	273	466	491	499
Days on feed	91	102	112	160	160	160
Average daily gain, lbs. per animal	3.1	3.1	2.4	2.9	3.1	3.1

The experimental heifers were slaughtered in the University of Arizona meats laboratory. The steers were slaughtered in a commercial processing facility in Tucson. Data recorded for both heifers and steers included hot carcass weight, marbling score, conformation grade, fat thickness for the 12th rib, ribeye size in total square inches, percentage of kidney fat, percent cutability and yield grade.

Additional measurements of retail cut yields were made from the right side of heifer carcasses. Also, the 9-10-11th rib cut was removed from the left carcass half and physically separated into fat, lean and bone. The ribeye muscle from this rib section was cut into one inch thick steaks for tenderness evaluation by the Warner-Bratzler shear device.

Table 4 presents carcass data for the various groups of experimental animals. All heifers marbled to about the same degree, and therefore possessed similar quality grades regardless of feeding regime. The same was true for steers. Yield grades and cutability percentages were not materially influenced by type of feed and the averages for each group were similar. Likewise, fat thickness, percent kidney fat and ribeye area all were not significantly affected by type of feed.

Data on the yield of retail cuts from the heifer carcasses are presented in table 5. Based on actual retail cutout, carcasses from the Group I heifers yielded about 2 to 3 percent more saleable cuts than the carcasses from the other two groups. However, the variation within groups is sufficiently large so that no significance can be attached to this result. Likewise, the ribeye muscles from the Group III animals had the lowest shear force values, about 2 pounds less than the other groups, but little significance can be attached to this result. Differences of 3 to 4 pounds would be required before any effect on consumption would be noticeable.

Table 4. Carcass Data for the Three Groups of Experimental Animals

Trait	Heifers			Steers		
	Group I	Group II	Group III	Group I	Group II	Group III
Hot carcass weight, lbs.	494	517	500	593	690	612
Dressing percent	57.9	58.5	59.9			
Marbling score	Slight+	Slight-	Slight+	5-	4+	5
Quality grade	Good+	Good+	Good+	Choice	Choice	Choice
Fat thickness, inch	0.45	0.43	0.40	0.44	0.43	0.51
Kidney fat, percent	3.3	3.6	3.4	2.6	2.4	2.7
Ribeye area, sq.in.	10.3	10.6	10.3	11.5	11.3	11.3
Yield grade	2.9	2.9	2.8	2.7	2.8	3.0
Cutability percent	50.2	50.3	50.5	50.7	50.6	50.0

Table 5. Data on Retail Cuts for Three Groups of Experimental Heifers

Trait	Group I	Group II	Group III
Retail yield of cuts, percent	71.2	69.2	68.0
Shear force value 1/	7.2	7.2	5.8
9-10-11th rib cut data:			
rib weight	7.6	7.9	7.3
percent lean	56.5	54.7	53.8
percent fat	28.8	31.1	32.7
percent bone	14.6	14.3	13.5

1/ Pounds of force required to shear a 0.5 inch diameter core of meat. A lower value indicates more tender meat.

In summary, the composition of the feeding diet did not substantially affect carcass quality for the experimental animals. Further replication of the experiments might, of course, yield different results. But, based on the animals in this study, the carcasses resulting from the three types of feeding regimes may be considered as substantially equal. In turn, this implies that cattle feeders may choose between the three feeding regimes on the basis of the relative cost of producing any given quantity of meat output, with consideration of the effect of the feed on carcass quality disregarded. The key question, then becomes one of determining: (a) the optimum amount of feed to be fed and the optimum weight of animal to produce, and (b) the choice of feeding regime which will minimize the cost of producing a given output. The next two sections examine each of these questions.

GROWTH RATES AND FEED INPUTS

Fellows and Judge, in an economic analysis of broiler production problems, summarize the possible relations between inputs of a production factor and output of a product as follows.

> In production, several general types of input-output relationships can exist when factors are transformed into products. Factors can be transformed into products at a constant rate, at a decreasing rate, and at an increasing rate. Under the constant transformation rate, each additional unit of input gives a constant and equal amount of output. Under a decreasing rate, each additional input unit brings about a smaller increment of output; whereas, under increasing rates a larger increment of output is realized. In any production process, it is possible for each of these rates to exist at some level in the input-output relationship (Figure 2). 2/

The level and shape of any growth response curve for various type of meat animals is, of course, influenced by many factors such as breed, feeding practices, type of housing, temperature, and presence or absence of disease. With most feeding operations, however, a decreasing rate of transformation is generally presumed to exist between the quantity of feed inputs and the resulting meat output, based upon the biological and physiological characteristics of the animals. Indeed, it is only with a decreasing transformation rate that there is any significant economic problem. If feed is being converted into meat at a constant or increasing rate, then if it pays to feed an animal at all, it pays to continue feeding it more.

Nevertheless, because of the influence of extraneous factors such as temperature, the normal decreasing rate of transformation of feed into meat may not be evident with any particular group of animals. The effect of

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2/ Judge, G. C. and Fellows, I. F., Economic Interpretations of Broiler Production Problems, Storrs Agricultural Experiment Station Bulletin 302, Storrs, Connecticut, July 1953, pp. 4-5.

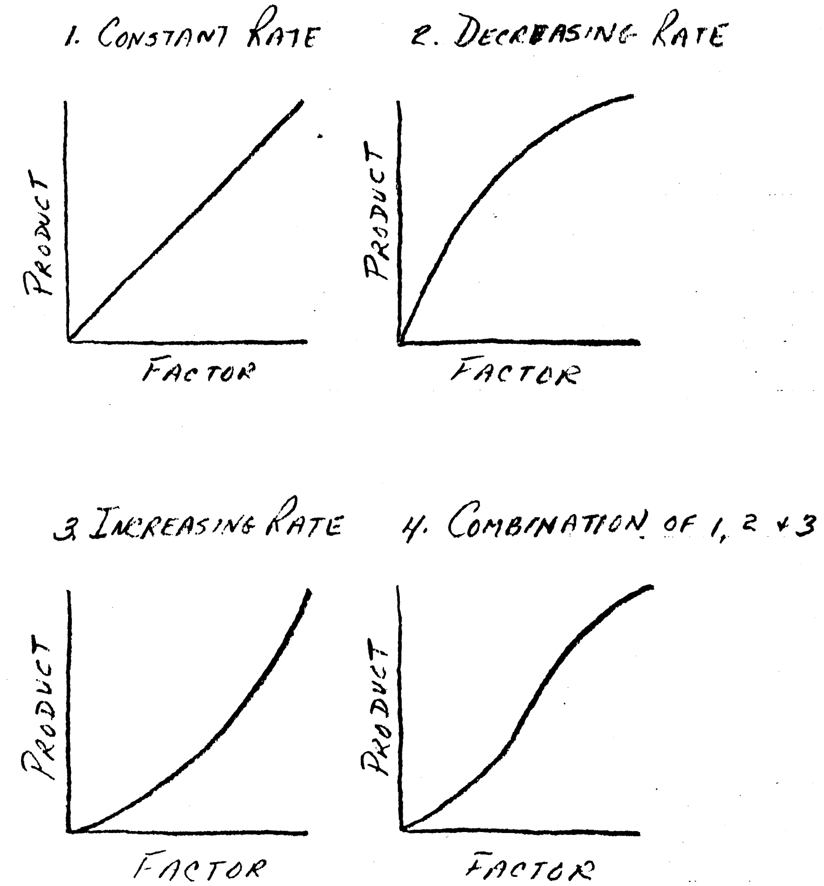

FIGURE 2. General Relationships in transforming a factor into a product.

random, uncontrolled factors may cause the actual input-output relation achieved by any given group of animals to depart substantially from the smooth curves depicted in figure 2. When such departures occur, the problem of determining the optimum quantity of feed is made much more difficult, and perhaps impossible, to solve. The experimental steers exhibited an input-output relation with a decreasing rate of transformation, such as that shown in Figure 2, frame 2. However, the heifers were beset by several uncontrolled factors during the course of the feeding period, in particular unseasonably hot weather during one phase, and the resulting input-output relation did not conform to any of the curves shown in figure 2.

Optimum Feeding Levels for Group I Steers

Figure 3 presents the relation between weight of a steer and the amount of feed consumed, derived from the experimental data for Group I steers. The exact rate of transformation is given by the equation:

$$Y = 5.883 + \underset{(.00029)}{.197901X} - \underset{(.00000028)}{.002223X^2} \qquad (1)$$

$$R^2 = .9972$$

where Y is the estimated weight of the steer in hundred pounds and X is the amount of finishing ration consumed, also expressed in hundred of pounds.[3/]

The relation is derived only from data for the period when the finishing ration, not the starting ration, was consumed.

Beginning with the input-output relation presented in figure 3 and equation (1), the optimum quantity of feed and the optimum weight of steer

3/ Figures in parentheses below the coefficients in the equation are standard errors of the respective coefficient; both coefficients are significantly different from zero at the 99 percent level of probability. See Appendix A for the data from which equation (1) was derived.

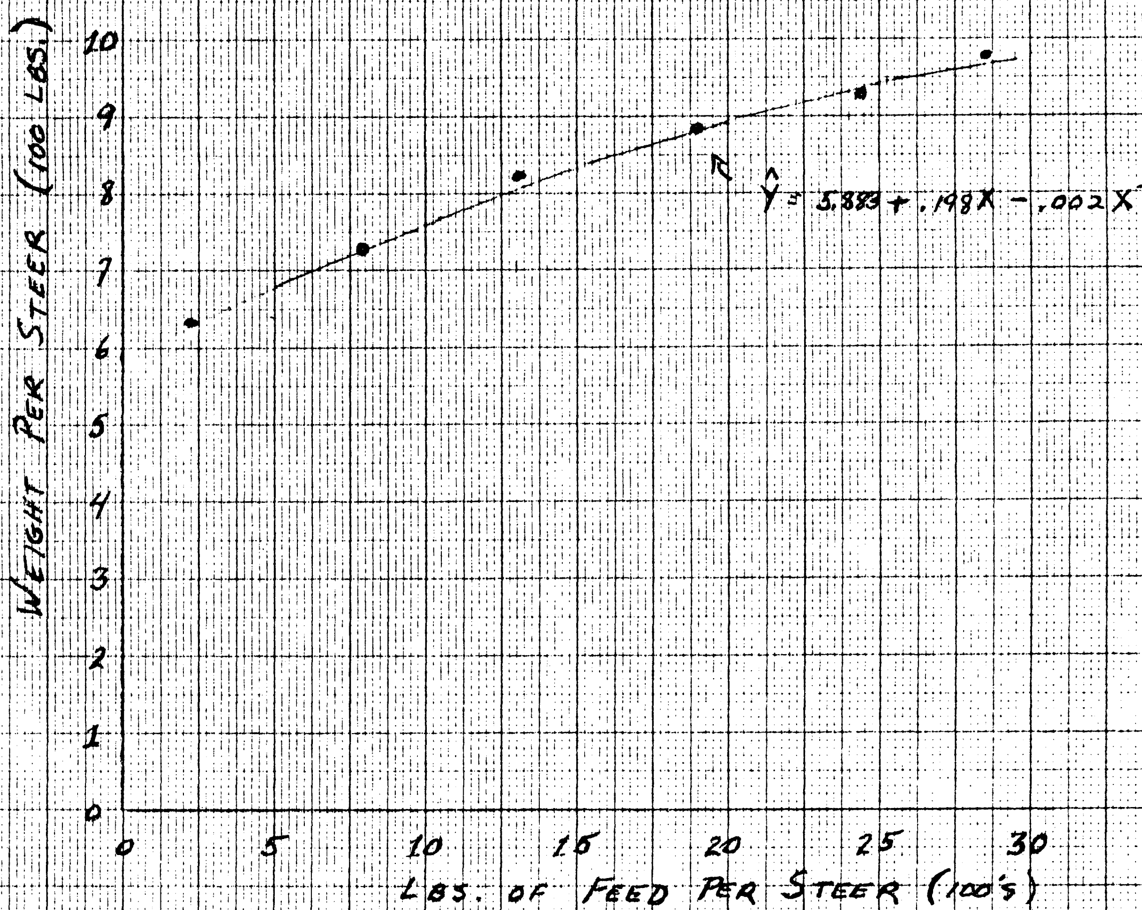

FIGURE 3 RELATION OF WEIGHT PER STEER TO FEED INPUT - RATION I

to produce may be derived in a straightforward manner, as is illustrated in Table 6.[4/] The fifth column of Table 6 shows that the additional meat output resulting from each additional increment of feed declines steadily throughout the range of the data. As a result, the average amount of feed required per pound of gain increases steadily as the cattle are held to heavier weights, as is shown in the sixth column. Thus, the number of pounds of feed per pound of gain is greatly influenced by the decision of how heavy a steer to produce, and as such is subject to a substantial degree of control.

4/ Mathematically, the total returns above feed costs may be expressed as $\pi = P_y Y - P_x X$, where P_y and P_x are the prices of steers and feed, respectively, both expressed in dollars per hundredweight, and π is returns above feed costs. Substituting from (1) yields $\pi = P_y\,5.883 + P_y\,(.197901X) - P_y\,(.002223)X^2 - P_x X$. Differentiating with respect to X, and setting the result equal to zero yields

$$\frac{d\pi}{dx} = .197901\,P_y - .004446\,P_y X - P_x = 0$$

from which $\bar{x} = \dfrac{P_y\,(.197901) - P_x}{P_y\,(.004446)} = 44.51 - 224.92\,\dfrac{P_x}{P_y}$

wherein the optimum quantity of feed, $\bar{x}$, is expressed as a function of the relative prices of steers and feed. Substitution of $\bar{x}$ into (1) yields the optimum weight of steer to produce. Note, however, this result applies only so long as feed is the only variable cost and all other costs are regarded as fixed for the duration of the feeding period.

TABLE 6. GROUP I STEERS: FIXED AND VARIABLE INPUTS AND COSTS AND ASSOCIATED OUTPUTS AND RETURNS PER STEER, ARIZONA 1975, EXAMPLE 1.

Total fixed input	Total variable feed input	Total meat output	Add'l. feed input	Add'l. meat output	Pounds feed per Pound gain	Total fixed costs 2/	Total variable feed costs 3/	Total Costs	Total returns 4/	Added returns	Added costs	Net return
	(lbs.)	(lbs.)	(lbs.)	(lbs.)	-	($)	($)	($)	($)	($)	($)	($)
M.L.C. 1/	0	588.3				225.80	0	225.80	264.74			38.94
			500	93.4						42.03	25.00	
"	500	681.7			5.35	225.80	25.00	250.80	306.77			55.97
			500	82.3						37.03	25.00	
"	1000	764.0			5.69	225.80	50.00	275.80	343.80			68.00
			500	71.1						32.00	25.00	
"	1500	835.1			6.08	225.80	75.00	300.80	375.80			75.00
			500	60.1						27.04	25.00	
"	2000	895.2			6.52	225.80	100.00	325.80	402.84			77.04
			500	48.9						22.01	25.00	
"	2500	944.1			7.03	225.80	125.00	350.80	424.85			74.05
			500	37.8						17.01	25.00	
"	3000	981.9			7.62	225.80	150.00	375.80	441.86			66.06
			500	26.7						12.01	25.00	
"	3500	1008.6			8.33	225.80	175.00	400.80	453.87			53.07
			500	15.6						7.02	25.00	
"	4000	1024.2			9.18	225.80	200.00	425.80	460.89			35.09

1/ Management, labor and capital in the form of feeder calves and feeding facilities. 2/ Calculated at $20.00 per steer for costs of labor, interest, power and fuel, veterinary and medical supplies, administration, maintenance and repairs, depreciation, management, insurance, taxes, interest, and miscellaneous non-feed costs, plus cost of 588 pound steer at $35.00 per cwt 3/ Calculated at $100.00 per ton. 4/ Calcuated at $45.00 per cwt.

The physical data in the left side of Table 6 may be converted to appropriate costs and returns via the application of relevant input and output prices. The column, Total Fixed Costs, in Table 6 includes an estimate of the cost per steer for all non-feed production expenses believed common in many Arizona feedlots. In the example these are presumed to be fixed for the duration of the feeding period. The column, Total Variable Feed Costs is derived by multiplying the variable feed input by an assumed price of 100 dollars per ton. Likewise, the total returns column is derived by multiplying the total meat output by an assumed price of 45 dollars per hundredweight.[5/]

Each increment of 25 dollars per steer expenditure on feed yields an increase in total revenue, but the incremental increase in revenue declines throughout the range of the data. Net returns increase so long as the increment added to total returns exceeds the increment in cost. Profits are maximized at about an expenditure of 100 dollars on feed, with net returns of $77.04 per steer. This corresponds to an input of about one ton of feed and an output of a steer weighing about 895 pounds.[6/] Note that the decision of how long to feed should be made on the basis of maximizing net returns, not total returns. Total returns increase throughout the range of the data, but net returns decrease beyond an expenditure of 100 dollars on feed.

5/ Prices of fed steers, for this example, are assumed constant regardless of the weight of the animal. Variations in the steer price, however, may be incorporated in the analysis through a simple arithmetic computation, as is illustrated later in the text.

6/ A more precise calculation, using the method shown in footnote 4, indicates profits are maximized at an input of 1952 pounds of feed, with a steer weighing 890 pounds.

If the price of fed steers rises relative to feed costs, it will pay the producer to feed the steer to a heavier weight. This is illustrated in Table 7, which reproduces the example of Table 6, except that the price of fed steers is assumed to rise from 45 dollars to 50 dollars per hundredweight, and the price of feed declines from 100 to 90 dollars per ton. Net returns under these assumptions are maximized at $133.75 per steer by producing an animal weighing about 944 pounds. It is interesting that even under the favorable relation of a relatively high fed steer price and relatively low feed prices, at least by current standards, it still does not pay to carry the animals to weights of 1000 pounds or beyond.

Since changing relations between the prices of fed steers and feed prices affect the optimum weight of steer to produce, Tables 8 and 9 are presented to show, respectively, the optimum amount of feed input per animal, and the optimum weight animal to produce under a variety of alternative price relations. Note that the optimum quantities shown in Tables 8 and 9 are true optima only under certain specified conditions, namely that the input-output relation is that shown in figure 3 and equation (1), that all non-feed costs are regarded as fixed for the duration of the feeding period, and the price per pound of fed cattle does not vary with the weight of the cattle produced. Cattle feeders whose conditions approximate these specifications may use the tables as a guide to determining the optimum quantity of feed input in order to maximize returns or minimize losses, as the case may be.

Five comments are in order regarding Tables 8 and 9. First, several of the cells in the tables contain no entries. In such cases, it does not pay the feeder to feed any amount at all under the respective price relations.

TABLE 7. GROUP I STEERS: FIXED AND VARIABLE INPUTS AND COSTS AND ASSOCIATED OUTPUTS AND RETURNS PER STEER, ARIZONA 1975, EXAMPLE 2.

Total fixed input	Total variable feed input	Total meat output	Add'l. feed input	Add'l. meat output	Pounds feed per Pound gain	Total fixed costs 2/	Total variable feed costs 3/	Total costs	Total returns	Added returns	Added Costs	Net return
	(lbs.)	(lbs.)	(lbs.)	(lbs.)	-	($)	($)	($)	($)	($)	($)	($)
M.L.C. 1/	0	588.3				225.80	0	225.80	294.15			68.35
			500	93.4						46.70	22.50	
"	500	681.7			5.35	225.80	22.50	248.30	340.85			92.55
			500	82.3						41.15	22.50	
"	1000	764.0			5.69	225.80	45.00	270.80	382.00			111.20
			500	71.1						35.55	22.50	
"	1500	835.1			6.08	225.80	67.50	293.30	417.55			124.25
			500	60.1						30.05	22.50	
"	2000	895.2			6.52	225.80	90.00	315.80	447.60			131.80
			500	48.9						24.45	22.50	
"	2500	944.1			7.03	225.80	112.50	338.30	472.05			133.75
			500	37.8						18.90	22.50	
"	3000	981.9			7.62	225.80	135.00	360.80	490.95			130.15
			500	26.6						13.35	22.50	
"	3500	1008.6			8.33	225.80	157.50	383.30	504.30			121.00
			500	15.6						7.80	22.50	
"	4000	1024.2			9.18	225.80	180.00	405.80	512.10			106.30

1/ Management, labor and capital in the form of feeder calves and feeding facilities. 2/ Calculated at $20.00 per steer for costs of labor, interest, power and fuel, veterinary and medical supplies, administration, maintenance and repairs, depreciation, management, insurance, taxes, interest, and miscellaneous non-feed costs, plus cost of 588 pound steer at $35.00 per cwt 3/ Calculated at $90.00 per ton. 4/ Calculated at $50.00 per cwt.

Table 8. Optimum quantity of feed input to maximize profits or minimize losses, Group I experimental steers fed a high grain ration, Arizona 1975.

Price of Ration I ($ per ton)	Price of fed steers ($ per cwt.) 25	30	35	40	45	50	55	60
	Optimum pounds of feed input							
70	1302	1827	2202	2483	2702	2877	3020	3139
80	852	1452	1881	2202	2452	2652	2815	2952
90	403	1077	1559	1921	2202	2427	2611	2764
100	-	703	1238	1640	1952	2202	2406	2577
110	-	328	917	1359	1702	1977	2202	2389
120	-	-	595	1077	1452	1752	1998	2202
130	-	-	274	796	1202	1527	1793	2015
140	-	-	-	515	952	1302	1589	1827
150	-	-	-	234	703	1077	1384	1640

Table 9. Optimum weight steer to produce to maximize profits or minimize losses, Group I experimental steers fed a high grain ration, Arizona 1975.

Price of Ration I ($ per ton)	Price of fed steers ($ per cwt.) 25	30	35	40	45	50	55	60
	Optimum weight per steer (pounds)							
70	808	876	916	942	961	973	983	990
80	741	828	881	916	939	957	969	978
90	664	775	843	886	916	937	953	965
100	-	716	799	853	889	916	935	950
110	-	651	750	816	861	892	916	934
120	-	-	698	775	828	867	894	916
130	-	-	640	732	794	838	872	897
140	-	-	-	684	756	808	846	876
150	-	-	-	633	716	775	819	853

Second, the entries in Table 9 indicate that extremely light steers, less than 800 pounds, are often the optimum weight to produce. However, this result holds only if the price per pound of fed steers does not vary with the weight of the animal. In actuality, the light weight animals may be discounted in price relative to heavier steers. If such is the case, then such light weight entries in Table 9 should be reinterpreted. Producers would face a choice of either not feeding at all, feeding to a heavier weight, or selling the lighter animals at a lower price, the decision depending upon which alternative yields maximum net returns. Such a situation is illustrated in Table 10, where the example of Table 6 is reproduced with one change, namely that steers weighing 900 pounds or less now are assumed to sell for 5 dollars per hundredweight less than those weighing more than 900 pounds. The effect is to raise the optimum weight steer to produce from 895 pounds to 944 pounds.

Third, over the entire range of the data, it does not pay the feeder to continue feeding beyond a steer weight of 1000 pounds. In all cases considered, profits are maximized (or losses minimized) by producing animals weighing less than 1000 pounds, even in the extreme case when the fed cattle price is 60 dollars per hundredweight and the price of feed only 70 dollars per ton. This result carries substantial implications for cattle feeders in Arizona. A 1973 study of Arizona's commercial feedlot industry indicated that the average quantity of feed input per animal was 1.49 tons, or 2980 pounds, when the starting weight of the cattle was 500 pounds or more.[7/] However, given the production function in equation (1), it would pay to feed cattle 2980 pounds of feed only when the fed cattle price was 55 dollars

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7/ Menzie, E. L., Hanekamp, W. J., and Phillips, G. W., The Economics of the Cattle Feeding Industry in Arizona, Technical Bulletin 207, Agricultural Experiment Station, University of Arizona, Tucson, Arizona (October 1973) p.72.

TABLE 10. GROUP I STEERS: FIXED AND VARIABLE INPUTS AND COSTS AND ASSOCIATED OUTPUTS AND RETURNS PER STEER, ARIZONA, 1975, EXAMPLE 3

Total fixed input	Total variable feed input	Total meat output	Add'l. feed input	Add'l. meat output	Pounds feed per Pound gain	Total fixed costs[2/]	Total variable feed costs[3/]	Total Costs	Total Returns[4/]	Added Returns	Added Costs	Net Returns
	(lbs)	(lbs)	(lbs)	(lbs)	-	($)	($)	($)	($)	($)	($)	($)
M.L.C.[1/]	0	588.3				225.80	0	225.80	235.32			9.52
			500	93.4						37.36	25.00	
"	500	681.7			5.35	225.80	25.00	250.80	272.68			21.88
			500	82.3						32.92	25.00	
"	1000	764.0			5.69	225.80	50.00	275.80	305.60			29.80
			500	71.1						28.44	25.00	
"	1500	835.1			6.08	225.80	75.00	300.80	334.04			33.24
			500	60.1						24.04	25.00	
"	2000	895.2			6.52	225.80	100.00	325.80	358.08			32.28
"			500	48.9						66.77	25.00	
"	2500	944.1			7.03	225.80	125.00	350.80	424.85			74.05
			500	37.8						17.01	25.00	
"	3000	981.9			7.62	225.80	150.00	375.80	441.86			66.06
			500	26.7						12.01	25.00	
"	3500	1008.6			8.33	225.80	175.00	400.80	453.87			53.07
			500	15.6						7.02	25.00	
"	4000	1024.2			9.18	225.80	200.00	425.80	460.89			35.09

1/ Management, labor and capital in the form of feeder calves and feeding facilities. 2/ Calculated at $20.00 per steer for costs of labor, interest, power and fuel, veterinary and medical supplies, administration, maintenance and repairs, depreciation, management, insurance, taxes, interest, and miscellaneous non-feed costs, plus cost of 588 pound steer at $35.00 per cwt. 3/ Calculated at $100.00 per ton. 4/ Calculated at $40.00 per cwt. for steers weighing 900 pounds or less and $45.00 per cwt. for steers weighing over 900 pounds.

per hundredweight or more and feed prices were 70 dollars per ton or less. The implication is that to the extent that commercial operations have similar input output relations, then feeders well might consider producing lighter weight cattle than has been customary, in order to increase net returns from the feeding operations.[8/]

Fourth, although the entries in Tables 8 and 9 are derived under the assumption that all costs other than feed are fixed, the tables in fact have a more general application. The study cited in footnote 7 indicates that variable costs in commercial cattle feeding operations usually are accounted for on the basis of "per ton of feed fed". This fact permits use of the tables even under those situations where other costs besides feed are considered variable. To do so, simply re-interpret the column labeled "Price of Ration I" to mean "Total Variable Cost per Ton of Feed" and choose the entry corresponding to the appropriate variable cost and price of fed steers. For example, assume that Ration I is selling at 100 dollars per ton, other variable costs are 10 dollars per ton, and fed steers sell for 50 dollars per hundredweight. Feed plus other variable costs amount to 110 dollars per ton, and the tables indicate profits are maximized by feeding 1977 pounds of feed to produce a steer weighing 892 pounds. Changes in the level of fixed

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8/ Relaxation of the assumptions underlying the data in Tables 9 and 10 probably would strengthen, rather than weaken this conclusion. For example, some of the costs regarded as fixed in Table 7 in actuality may be variable, particularly to the custom feeder. If such is the case, the result would be to lower the optimum weight of animal to produce. On the other hand, if commercial feeders were able to achieve a more efficient rate of transformation of feed into meat than was obtained with the experimental animals, then the result might be to increase the optimum weight of animal to produce.

costs, of course, do not affect the optimum amount of feed to utilize.

Fifth, the profit-maximizing rule used in deriving Tables 8 and 9 assumes that profits are to be maximized for one lot of steers. This is not the same as maximizing profits over time from a succession of individual lots of steers. The problem of maximizing profits over time is not considered in this study, since the experimental results were not sufficient to develop a reliable relation between time, feed inputs and meat outputs. However, it can be stated that if time were introduced into the analysis, the result would be that the optimum weight steer to produce would be lighter than that shown in Table 9.

Optimum Feeding Levels for the Group III Steers

The method of analysis of optimum feeding levels for the Group III steers is similar to that for Group I. We start with a production function:

$$Y = 5.880 + \underset{(.000046)}{.114127X} - \underset{(.000000016)}{.000388X^2} \qquad (2)$$
$$R^2 = .9993$$

relating the weight of steers, Y, (in 100 pound units) to the quantity of ration III fed, X, (also in units of 100 pounds).[9/] The production function then may be used to estimate the weight of steer produced at various levels of feed input, the increments of meat output resulting from each increment in feed input, and the average pounds of feed required per pound of gain, as is shown in Table 11. Since equation (2) indicates feed is transformed into meat at a decreasing rate, the additional meat output resulting from each increment of feed input declines steadily throughout the range of the data. Consequently, the average pounds of feed required per pound of gain increases steadily as the animals are fed to heavier weights.

9/ Figures in parentheses below the coefficients are the respective standard errors of the coefficients. Both coefficients differ significantly from zero at the 99 percent level of probability.

TABLE 11. GROUP III STEERS: FIXED AND VARIABLE INPUTS AND COSTS AND ASSOCIATED OUTPUTS AND RETURNS PER STEER, ARIZONA, 1975

Total fixed input	Total variable feed input	Total meat output	Add'l. feed input	Add'l. meat output	Pounds feed per Pound gain	Total fixed costs 2/	Total variable feed costs 3/	Total Costs	Total Returns 4/	Added Returns	Added Costs	Net Returr
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	($)	($)	($)	($)	($)	($)	($)
M.L.C. 1/	0	588.0			--	225.80	0	225.80	264.60			38.80
			500	56.1						25.25	20.00	
"	500	644.1			8.91	225.80	20.00	245.80	289.85			44.05
			500	54.2						24.39	20.00	
"	1000	698.3			9.07	225.80	40.00	265.80	314.24			48.44
			500	52.2						23.49	20.00	
"	1500	750.5			9.23	225.80	60.00	285.80	337.73			51.93
			500	50.2						22.59	20.00	
"	2000	800.7			9.40	225.80	80.00	305.80	360.32			54.52
			500	48.4						21.78	20.00	
"	2500	849.1			9.57	225.80	100.00	325.80	382.10			56.30
			500	46.4						20.88	20.00	
"	3000	895.5			9.76	225.80	120.00	345.80	402.98			57.18
			500	44.4						19.98	20.00	
"	3500	939.9			9.95	225.80	140.00	365.80	422.96			57.16
			500	42.5						19.12	20.00	
"	4000	982.4			10.14	225.80	160.00	385.80	442.08			56.28
			500	40.6						18.27	20.00	
"	4500	1023.0			10.34	225.80	180.00	405.80	460.35			54.55

1/ Management, labor and capital in the form of feeder calves and feeding facilities. 2/ Calculated as in Table 6.
3/ Calculated at $80.00 per ton. 4/ Calculated at $45.00 per cwt.

The physical data in the left side of Table 11 are converted to corresponding cost and returns data through the application of appropriate input and output prices. For this example, fed steers are assumed to be selling at 45 dollars a hundredweight and the low grain ration III is priced at 80 dollars a ton. All non-feed costs are assumed to be fixed for the duration of the feeding period.

Net returns increase as the animal is fed to a heavier weight, so long as the added returns from an increment of feed input exceed the added cost of the increment of feed. Thus in Table 11, net returns are maximized at $57.18 per steer, with total (gross) returns of $402.98 and total costs of $345.80 per steer. This corresponds to producing a steer weighing about 895 pounds, utilizing 3000 pounds of feed.

It is interesting to compare the results of the example in Table 11 (the low-grain ration) with those of Table 6 (the high-grain ration). These two examples differ in only two respects: (a) Table 6 assumes a high grain ration costing 100 dollars a ton while Table 11 assumes a low grain ration costing 80 dollars, and (b) the input-output relation underlying Table 6 is for a high-grain ration while that for Table 11 is for a low-grain ration.[10/] The high-grain ration yields maximum profits of $77.04 per animal while the low-grain ration yields maximum profits of only $57.18, both by producing animals of about 895 pounds in weight. Note, however, that profits do not fluctuate as much with changes in the weight of the animals fed the low grain ration. With low grain, animals fed to weights in excess of 1000 pounds actually

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10/ In both examples, profits are maximized by producing an animal weighing about 895 pounds, but this result is of little significance since the optimum weight animal to produce will vary with changes in the relevant steer and feed prices.

yield higher net returns per animal than those fed the high grain ration. This illustrates that although the high grain ration may yield higher profits at one weight, the low grain ration may yield higher profits at others. This holds even though the relative prices of the two rations do not change, due to the nature of the underlying production functions.

Since the optimum weight of steer to produce and the optimum quantity of ration to feed both vary with changes in relative input and output prices, tables 12 and 13 are presented to show optimum outputs and inputs under a variety of alternative price relations. As in the case of steers fed a high grain ration, the optima in tables 14 and 15 are true optima only under the conditions that: (a) the production function is that specified in (2); (b) either all non-feed costs are considered fixed for the duration of the feeding period, or the column labeled "Price of Ration III" is re-interpreted to read "Total Variable Cost per Ton of Feed"; and (c) the price per pound of fed cattle does not vary with the weight of animal produced.

Comparison of Relative Costs of Rations I and III by Weight of Steer

Comparison of tables 13 and 9 shows that there are many more instances when it pays to feed steers to heavier weights with a low grain rather than a high grain ration. The reason for this lies in the relative shapes of the production functions (1) and (2). Function (1) has a much greater degree of curvature than function (2), which in practical terms means that at higher weights (steers of about 1000 pounds) the high grain ration rapidly becomes a relatively less efficient means of adding weight. This is shown in figure 4, where the two production functions are on the same graph. The production function for the high grain ration I is steeper than the one for the low grain ration at feed inputs of about 2300 pounds per steer or less, but the low grain function is steeper at feed inputs in excess of 2300 pounds.

Table 12. Optimum quantity of feed input to maximize profits or minimize losses, Group III experimental steers fed a low grain ration, Arizona 1975.

Price of Ration III	Price of fed steers ($ per cwt)							
	25	30	35	40	45	50	55	60
($ per ton)	Optimum pounds of feed input							
50	1820	3968	5502	6653	7548	8264	8850	9338
60	-	1820	3661	5042	6116	6975	7678	8264
70	-	-	1820	3431	4684	5686	6507	7190
80	-	-	-	1820	3252	4398	5335	6116
90	-	-	-	210	1820	3109	4164	5042
100	-	-	-	-	389	1820	2992	3968
110	-	-	-	-	-	532	1820	2894
120	-	-	-	-	-	-	649	1820
130	-	-	-	-	-	-	-	747

Table 13. Optimum weight steer to produce to maximize profits or minimize losses, Group III experimental steers fed a low grain ration, Arizona 1975.

Price of Ration III	Price of fed steers ($ per cwt)							
	25	30	35	40	45	50	55	60
($ per ton)	Optimum weight of steer (pounds)							
50	783	980	1098	1176	1228	1266	1294	1315
60	-	783	954	1065	1140	1195	1236	1266
70	-	-	783	934	1038	1112	1166	1208
80	-	-	-	783	918	1015	1087	1140
90	-	-	-	611	783	905	996	1065
100	-	-	-	-	632	783	895	980
110	-	-	-	-	-	648	783	886
120	-	-	-	-	-	-	660	783
130	-	-	-	-	-	-	-	671

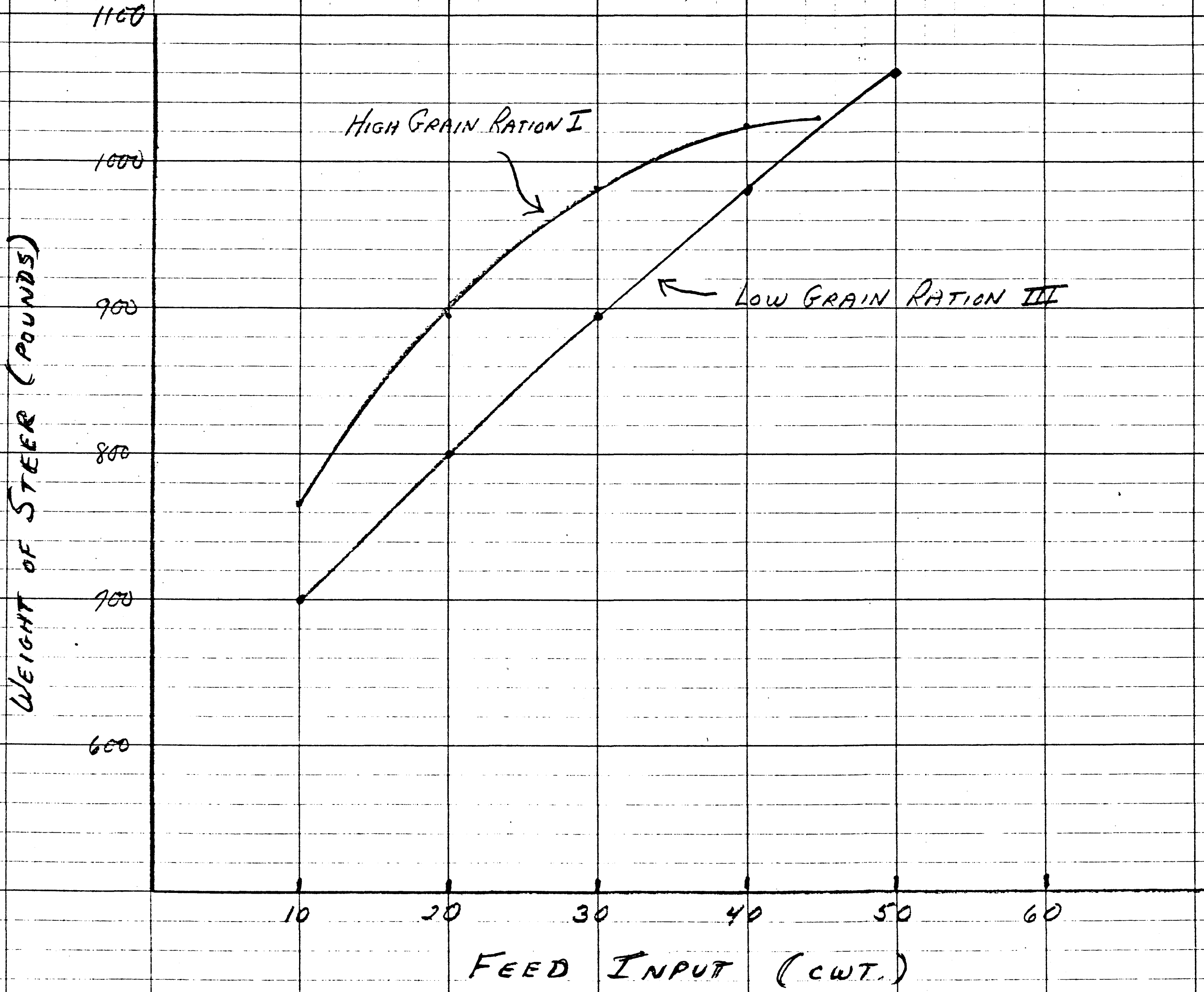

FIGURE 4. COMPARISON OF PRODUCTION FUNCTIONS FOR EXPERIMENTAL STEERS FED HIGH AND LOW GRAIN RATIONS, ARIZONA, 1975

The effect of these production functions on feed costs is illustrated in figure 5, where feed costs are related to the weight of animal produced, with assumed prices of 120 dollars per ton for the high grain ration and 80 dollars per ton for low grain. Under these price relationships, high grain yields lower total feed costs than low grain, so long as the weight of steer produced is 900 pounds or less. But at steer weights in excess of 900 pounds, the low grain ration is less costly.

In other words, in order to choose the least cost ration, cattle feeders must take into account not only the relative prices of the various rations, but also the weight of steer to be produced. Given the same relative prices of low and high grain rations, the low grain ration may be less costly when producing steers of higher weights, while the high grain ration may be less costly for producing lighter weight steers.

Figure 6 presents points at which the high and low grain rations are equally costly for producing steers of various weights. The figure is to be interpreted as follows: for any given weight of steer, say 900 pounds, points above and to the left of the line labeled 900 pounds represent relative prices at which the cost of using ration I, C_1, is greater than the cost of utilizing ration III, C_3. Points below and to the right of the line labeled 900 pounds are price combinations for which C_1 is less than C_3. For example, if the low grain ration is priced at 80 dollars per ton and the high grain ration at 110 dollars per ton, it is cheaper to use the high grain ration if the weight of steer to be produced is 900 pounds. Likewise, if the low grain ration is at 80 dollars and the high grain ration at 120 or more dollars per ton, it is cheaper to use the low grain ration to produce a 900 pound animal.

Figure 6 illustrates how, depending upon the weight of the steer produced, one ration may be either more or less costly than another, even though the

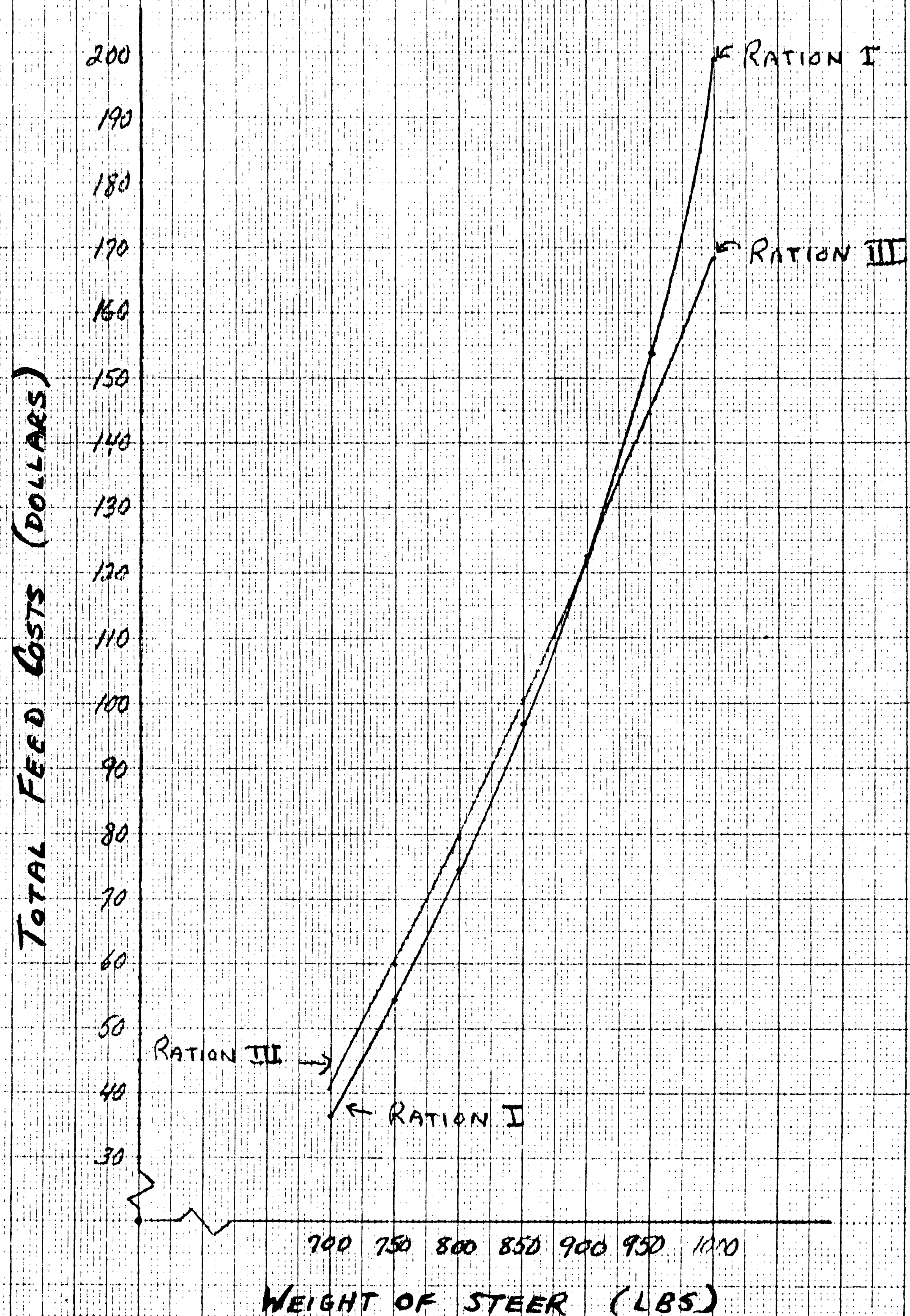

FIGURE 5. TOTAL FEED COSTS OF HIGH (I) AND LOW (III) GRAIN RATIONS RELATED TO WEIGHT OF STEER PRODUCED

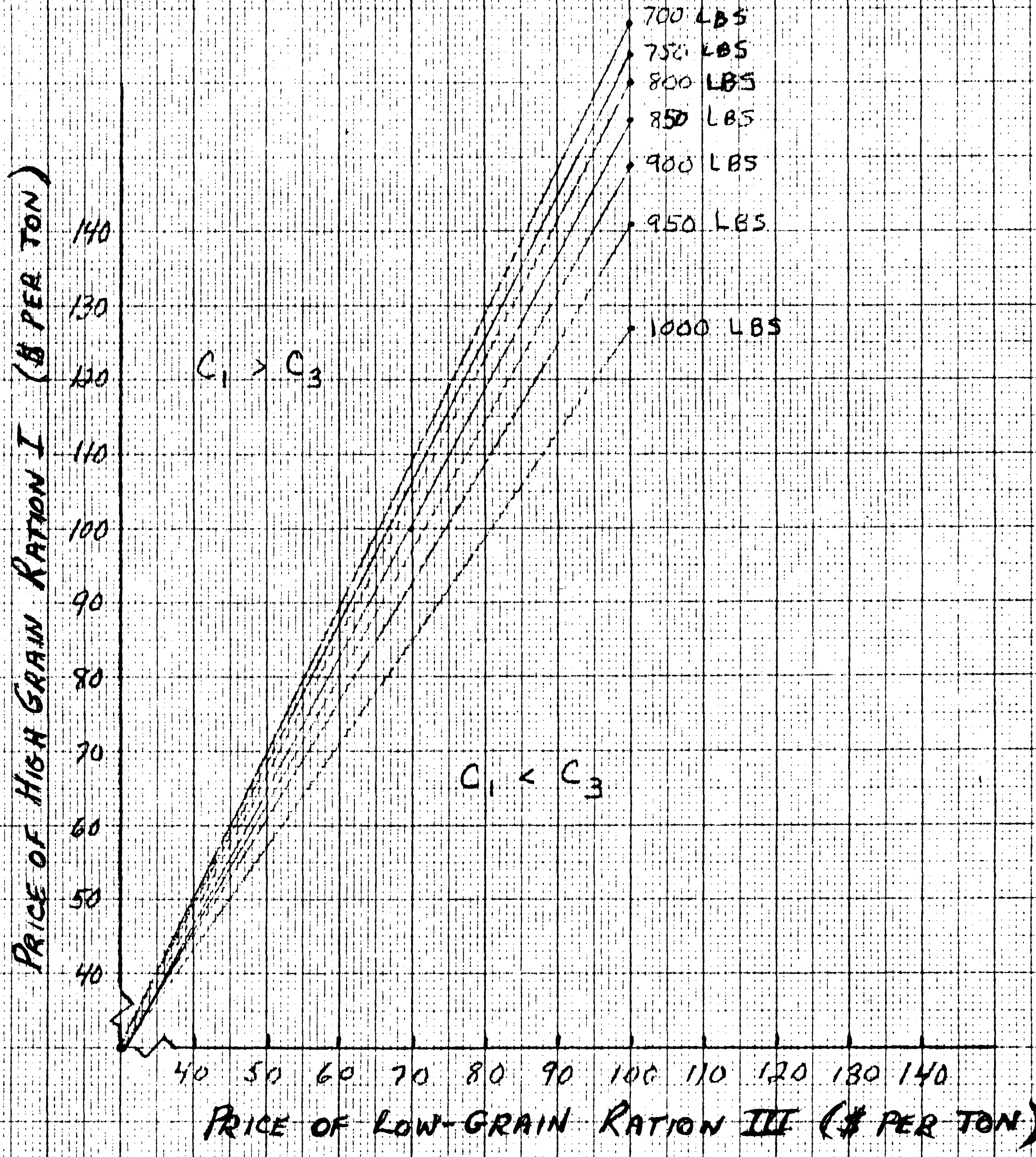

FIGURE 6. BREAKEVEN POINTS FOR CHOOSING BETWEEN HIGH AND LOW GRAIN RATIONS

relative prices of the two rations remain unchanged. For example, suppose the low grain ration is selling at 70 dollars per ton and the high grain ration at 100. If the steers produced weigh 850 pounds or less, it is cheaper to use ration I, the high grain ration. But if the steers weigh 900 pounds or more, then ration III yields lower cost.

The information in figure 6 may be summarized as follows. For all weights considered, namely 700 to 1000 pounds, the high grain ration will yield lower costs if the price of the low grain ration is 79 percent or more of the price of the high grain ration. Conversely, if the price of the low grain ration is 60 percent or less of the price of the high grain ration, then the low grain ration will yield least cost for any weight animal considered. If the price of the low grain ration is between 60 and 79 percent of the price of the high grain ration, the determination of which is least costly depends on the weight of animal produced, with the low grain ration more likely to yield a lower cost as the weight of steers approaches 1000 pounds.

Tables 14 through 20 present data on the relative costs of the high and low grain rations under varying price relations. Each table is for a different weight of steer produced. The stepwise line running diagonally through each table separates the price combinations for which each of the two rations yields least cost. Points below and to the left of the line are combinations for which the low grain ration yields least cost, while those above and to the right show the combinations for which the high grain ration is less costly.

Each of tables 14 through 20 present feed costs for 90 different combinations of relative prices of rations I and III. As would be expected, the relative cost of each ration rises or falls depending upon whether its price rises or falls relative to the other. Comparing tables 14 and 20 illustrates again that the cost of the low grain ration relative to the high

Table 14. Feed costs of high and low grain rations for producing 700 pound steers, by price of ration.

Price of high grain ration	Ration[1/]	Price of low grain ration (dollars per ton)									
		60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	21.21	21.21	21.21	21.21	21.21	21.21	21.21	21.21	21.21	21.21
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
80	I	24.24	24.24	24.24	24.24	24.24	24.24	24.24	24.24	24.24	24.24
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
90	I	27.27	27.27	27.27	27.27	27.27	27.27	27.27	27.27	27.27	27.27
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
100	I	30.30	30.30	30.30	30.30	30.30	30.30	30.30	30.30	30.30	30.30
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
110	I	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33	33.33
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
120	I	36.37	36.37	36.37	36.37	36.37	36.37	36.37	36.37	36.37	36.37
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
130	I	39.39	39.39	39.39	39.39	39.39	39.39	39.39	39.39	39.39	39.39
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
140	I	42.42	42.42	42.42	42.42	42.42	42.42	42.42	42.42	42.42	42.42
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20
150	I	45.45	45.45	45.45	45.45	45.45	45.45	45.45	45.45	45.45	45.45
	III	30.48	35.56	40.64	45.72	50.80	55.88	60.96	66.04	71.12	76.20

[1/] Rations I and III are the high and low grain rations, respectively.

Table 15. Feed costs of high and low grain rations for producing 750 pound steers, by price of ration.

Price of high grain ration	Ration[1/]	Price of low grain ration (dollars per ton) 60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	31.85	31.85	31.85	31.85	31.85	31.85	31.85	31.85	31.85	31.85
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
80	I	36.40	36.40	36.40	36.40	36.40	36.40	36.40	36.40	36.40	36.40
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
90	I	40.95	40.95	40.95	40.95	40.95	40.95	40.95	40.95	40.95	40.95
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
100	I	45.50	45.50	45.50	45.50	45.50	45.50	45.50	45.50	45.50	45.50
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
110	I	50.05	50.05	50.05	50.05	50.05	50.05	50.05	50.05	50.05	50.05
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
120	I	54.60	54.60	54.60	54.60	54.60	54.60	54.60	54.60	54.60	54.60
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
130	I	59.15	59.15	59.15	59.15	59.15	59.15	59.15	59.15	59.15	59.15
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
140	I	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13
150	I	68.25	68.25	68.25	68.25	68.25	68.25	68.25	68.25	68.25	68.25
	III	44.85	52.33	59.80	67.28	74.75	82.23	89.70	97.18	104.65	112.13

[1/] Rations I and III are the high and low grain rations, respectively.

Table 16. Feed costs of high and low grain rations for producing 800 pound steers, by price of ration.

Price of high grain ration	Ration[1/]	Price of low grain ration (dollars per ton) 60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	43.51	43.51	43.51	43.51	43.51	43.51	43.51	43.51	43.51	43.51
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
80	I	49.72	49.72	49.72	49.72	49.72	49.72	49.72	49.72	49.72	49.72
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
90	I	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94
	III	59.76	67.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
100	I	62.15	62.15	62.15	62.15	62.15	62.15	62.15	62.15	62.15	62.15
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
110	I	68.37	68.37	68.37	68.37	68.37	68.37	68.37	68.37	68.37	68.37
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
120	I	74.58	74.58	74.58	74.58	74.58	74.58	74.58	74.58	74.58	74.58
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
130	I	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
140	I	87.01	87.01	87.01	87.01	87.01	87.01	87.01	87.01	87.01	87.01
	III	59.76	69.72	79.68	89.64	99.60	109.56	119.52	129.48	139.44	149.40
150	I	93.23	93.23	93.23	93.23	93.23	93.23	93.23	93.23	93.23	93.23
	III	59.76	69.72	79.68	89.63	99.60	109.56	119.52	129.48	139.44	149.40

[1/] Rations I and III are the high and low grain rations, respectively.

Table 17. Feed costs of high and low grain rations for producing 850 pound steers, by price of ration.

Price of high grain ration	Ration[1/]	Price of low grain ration (dollars per ton)									
		60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	56.56	56.56	56.56	56.56	56.56	56.56	56.56	56.56	56.56	56.56
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
80	I	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
90	I	72.72	72.72	72.72	72.72	72.72	72.72	72.72	72.72	72.72	72.72
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
100	I	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80	80.80
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
110	I	88.88	88.88	88.88	88.88	88.88	88.88	88.88	88.88	88.88	88.88
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
120	I	96.96	96.96	96.96	96.96	96.96	96.96	96.96	96.96	96.96	96.96
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
130	I	105.04	105.04	105.04	105.04	105.04	105.04	105.04	105.04	105.04	105.04
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
140	I	113.12	113.12	113.12	113.12	113.12	113.12	113.12	113.12	113.12	113.12
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25
150	I	121.20	121.20	121.20	121.20	121.20	121.20	121.20	121.20	121.20	121.20
	III	75.30	87.85	100.40	112.95	125.50	138.05	150.60	163.15	175.70	188.25

1/ Rations I and III are the high and low grain rations, respectively.

Table 18. Feed costs of high and low grain rations for producing 900 pound steers, by price of ration.

Price of high grain ration	Ration 1/	Price of low grain ration (dollars per ton)									
		60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	71.58	71.58	71.58	71.58	71.58	71.58	71.58	71.58	71.58	71.58
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
80	I	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
90	I	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03	92.03
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
100	I	102.25	102.25	102.25	102.25	102.25	102.25	102.25	102.25	102.25	102.25
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
110	I	112.48	112.48	112.48	112.48	112.48	112.48	112.48	112.48	112.48	112.48
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
120	I	122.70	122.70	122.70	122.70	122.70	122.70	122.70	122.70	122.70	122.70
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
130	I	132.93	132.93	132.93	132.93	132.93	132.93	132.93	132.93	132.93	132.93
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
140	I	143.15	143.15	143.15	143.15	143.15	143.15	143.15	143.15	143.15	143.15
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75
150	I	153.38	153.38	153.38	153.38	153.38	153.38	153.38	153.38	153.38	153.38
	III	91.50	106.75	122.00	137.25	152.50	167.75	183.00	198.25	213.50	228.75

1/ Rations I and III are the high and low grain rations, respectively.

Table 19. Feed costs of high and low grain rations for producing 950 pound steers, by price of ration.

Price of high grain ration	Ration[1/]	Price of low grain ration (dollars per ton) 60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	89.92	89.92	89.92	89.92	89.92	89.92	89.92	89.92	89.92	89.92
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
80	I	102.76	102.76	102.76	102.76	102.76	102.76	102.76	102.76	102.76	102.76
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
90	I	115.61	115.61	115.61	115.61	115.61	115.61	115.61	115.61	115.61	115.61
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
100	I	128.45	128.45	128.45	128.45	128.45	128.45	128.45	128.45	128.45	128.45
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
110	I	141.30	141.30	141.30	141.30	141.30	141.30	141.30	141.30	141.30	141.30
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
120	I	154.14	154.14	154.14	154.14	154.14	154.14	154.14	154.14	154.14	154.14
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
130	I	166.99	166.99	166.99	166.99	166.99	166.99	166.99	166.99	166.99	166.99
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
140	I	179.83	179.83	179.83	179.83	179.83	179.83	179.83	179.83	179.83	179.83
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20
150	I	192.68	192.68	192.68	192.68	192.68	192.68	192.68	192.68	192.68	192.68
	III	108.48	126.56	144.64	162.72	180.80	198.88	216.96	235.04	253.12	271.20

1/ Rations I and III are the high and low grain rations, respectively.

Table 20. Feed costs of high and low grain rations for producing 1000 pound steers, by price of ration.

Price of high grain ration	Ration 1/	Price of low grain ration (dollars per ton) 60	70	80	90	100	110	120	130	140	150
($ per ton)		Feed cost, dollars per steer									
70	I	115.99	115.99	115.99	115.99	115.99	115.99	115.99	115.99	115.99	115.99
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
80	I	132.56	132.56	132.56	132.56	132.56	132.56	132.56	132.56	132.56	132.56
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
90	I	149.13	149.13	149.13	149.13	149.13	149.13	149.13	149.13	149.13	149.13
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
100	I	165.70	165.70	165.70	165.70	165.70	165.70	165.70	165.70	165.70	165.70
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
110	I	182.27	182.27	182.27	182.27	182.27	182.27	182.27	182.27	182.27	182.27
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
120	I	198.84	198.84	198.84	198.84	198.84	198.84	198.84	198.84	198.84	198.84
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
130	I	215.41	215.41	215.41	215.41	215.41	215.41	215.41	215.41	215.41	215.41
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
140	I	231.98	231.98	231.98	231.98	231.98	231.98	231.98	231.98	231.98	231.98
	III	126.39	147.46	168.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98
150	I	248.55	248.55	248.55	248.55	248.55	248.55	248.55	248.55	248.55	248.55
	III	126.39	147.46	169.52	189.59	210.65	231.72	252.78	273.85	294.91	315.98

1/ Rations I and III are the high and low grain rations, respectively.

grain ration decreases as the weight of steer increases. In table 14, representing 700 pound steers, only 11 of the 90 price combinations yield lower costs for the low grain ration III. In table 20, on the other hand, the low grain ration gives lower costs for 29 of the 90 combinations.

Optimum Feeding Levels for the Experimental Heifers

Although it is a relatively straightforward matter to determine optimum feeding levels when the production function follows a relatively smooth path as in figure 2, it is not so straightforward when the production function is irregular in shape. An irregularly shaped function implies sudden changes in the rate at which feed is transformed into meat, and hence abrupt changes in relative costs and returns.

Data for the experimental heifers did not exhibit any of the relatively smooth input-putput relations shown in figure 2. The data for the heifers fed the low grain ration III plotted in figure 7 illustrate the general situation for all three groups of experimental heifers.

Overall, the group III heifers consumed 3110 pounds of feed per animal and gained 271 pounds, for an average of 11.5 pounds of feed per pound of gain. However, during the first part of the feeding period, they consumed 1029 pounds of feed while gaining 129 pounds, for an average of 8.0 pounds of feed per pound of gain. During the second part of the period, they consumed 1034 pounds while gaining only 45 pounds, for an average of 23.0 pounds of feed per pound of gain. Then during the next two parts of the period, they consumed only 791 pounds of feed while gaining 114 pounds, for an average of only 6.9 pounds of feed per pound of gain. And during the final portion of the feeding period, they consumed 256 pounds of feed but actually lost weight.

The effect of such changes in the rate at which feed is transformed into

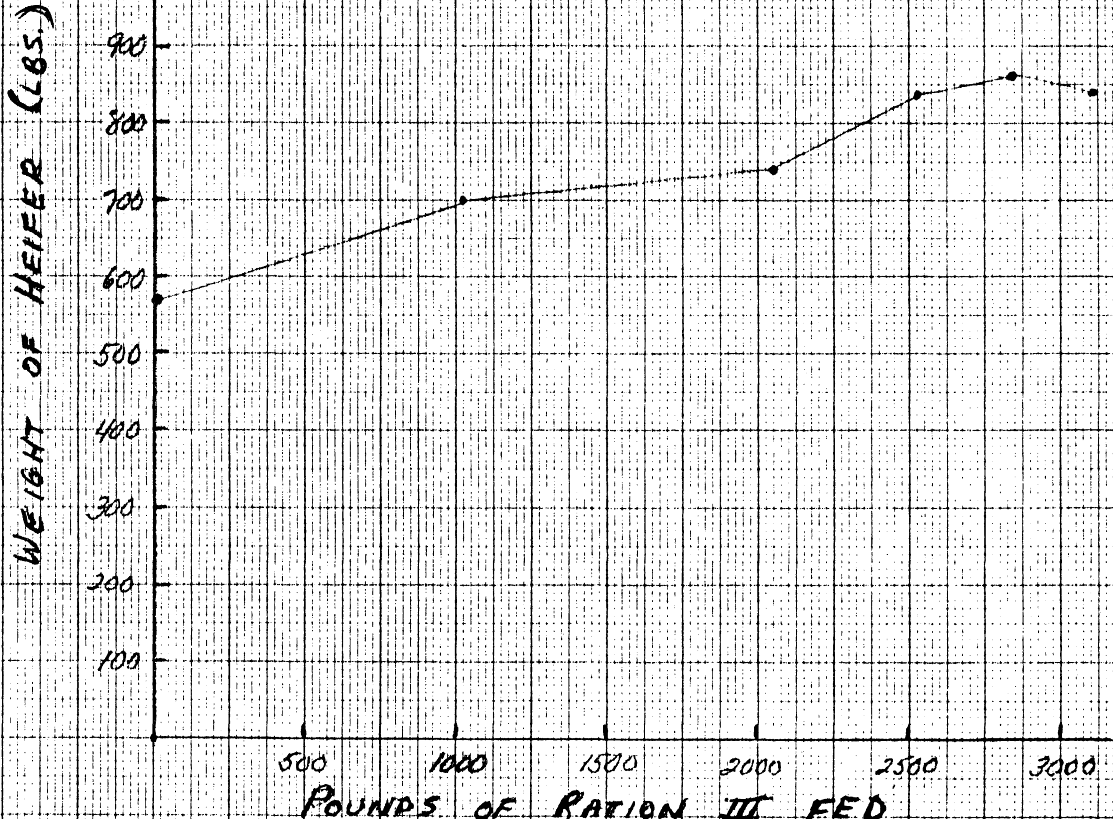

FIGURE 7. RELATION OF FEED INPUT TO WEIGHT OF HEIFER, GROUP III EXPERIMENTAL HEIFERS, ARIZONA 1975

beef on returns above feed costs is shown in Table 21. Returns above feed costs actually decrease as feed inputs increase from 1029 to 2063 pounds, but rise again and reach a peak as feed input is increased to 2539 pounds. Thereafter, returns above feed costs decrease with additional increments of feed inputs.

The cattle feeder confronted with such abrupt and unpredictable changes in the rate of transformation of feed into beef would have a difficult task attempting to determine the optimum quantity of feed to use. Under such circumstances, he is forced into gambling and has little or no control over the cost per pound of gain he will realize. A rational decision as to the optimum quantity of feed input is difficult if not impossible under such circumstances.

As shown in figure 8, all three groups of experimental heifers showed similar patterns of growth during the feeding period. All made substantial gains in weight during the first month, but then gained very little during the following month and a half. Thereafter, all made substantial weight gains during the last half month or so of the feeding period. The cause of these patterns appears to lie in temperature changes, particularly unseasonably hot weather during November. In any event, little can be said about optimum feeding levels for the experimental heifers because of such abrupt changes in the feed to beef transformation rate.

Table 21. Cumulative feed input and meat output and associated costs and returns, group III experimental heifers, Arizona 1975.

Cumulative Feed Input	Meat Output	Total Feed Cost[1/]	Total Returns[2/]	Returns Above Feed Costs	Additional Feed Cost	Additional Returns	Feed Cost per lb. of Gain
(lbs.)	(lbs.)	($)	($)	($)	($)	($)	($)
0	569	0	256.05	-			
					41.16	58.05	.32
1029	698	41.16	314.10	272.94			
					41.36	20.25	.92
2063	743	82.52	334.35	251.83			
					19.04	41.40	.45
2539	835	101.56	375.75	274.19			
					12.60	9.90	.45
2854	857	114.16	385.65	271.49			
					10.24	-6.75	00
3110	842	124.40	378.90	254.50			

1/ Calculated at 80 dollars per ton.

2/ Calculated at 45 dollars per hundredweight.

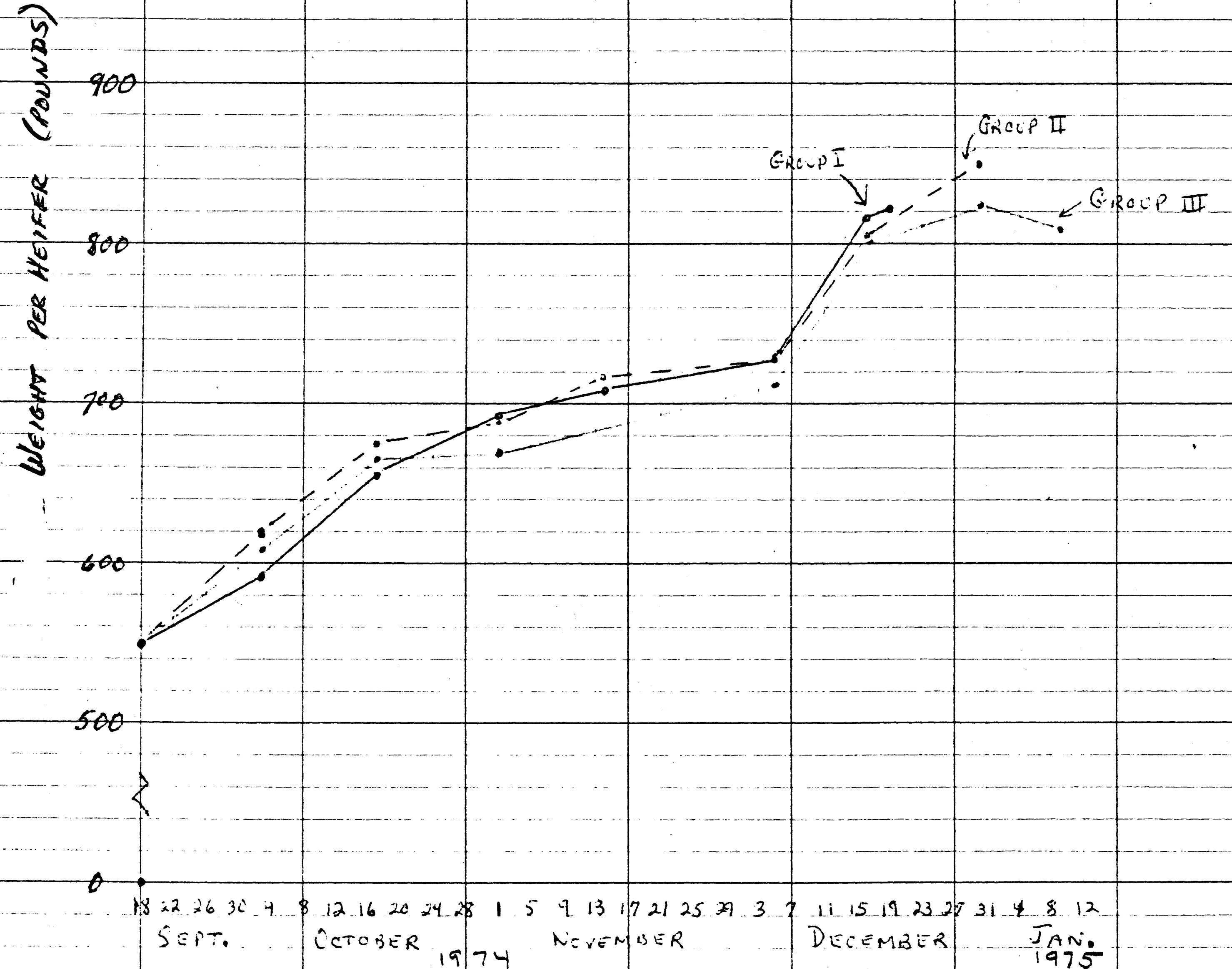

FIGURE 8. WEIGHT GAINS OF EXPERIMENTAL HEIFERS, ARIZONA, 1974-75

OPTIMUM RATIONS UNDER ALTERNATIVE INGREDIENT PRICES

This section determines and compares feeding costs of high, medium and low grain rations for both heifers and steers under alternative prices for the major ingredients in each type of ration, namely milo, alfalfa, cottonseed hulls and creepfeed pellets. These four ingredients comprise 91.65 percent of the weight of the starting ration, 90.95 percent of the finishing ration, and 100 percent of the growing diet (see Tables 1 and 2). Comparisons are made for the production of heifers weighing 821 pounds finish weight and for steers finishing at 941 pounds.

Table 22 presents estimated amounts of each type of ration (starting, finishing and growing) needed to produce 821 pound heifers and 941 pound steers under the three experimental feeding regimes. The estimates are derived directly from the experimental data by the method shown in Appendix B rather than from an estimated production fucntion, because the data did not permit estimation of production functions for any of the three groups of heifers, nor for the group II steers. From the data in Table 22 are derived the entries in Table 23, which shows the quantities of each of the major ingredients used in producing the various groups of experimental animals.

Table 22. Estimated feed inputs for producing 821 pound heifers and 941 pound steers under three experimental feeding regimes, Arizona 1975.

Feeding Regime	Average Starting Weight	Average Finishing Weight	Pounds of feed consumed per animal: Starting Ration	Finishing Ration	Growing Diet
Heifers					
I	572	821	262	1,750	0
II	572	821	280	825	1,158
III	569	821	0	0	2,854
Steers					
I	513	941	223	2,838	0
II	522	941	278	1,473	1,439
III	516	941	0	0	3,840

Table 23. Estimated amounts of major feed ingredients used in producing 821 pound heifers and 941 pound steers under three experimental feeding regimes, Arizona 1975

Feeding Regime	Pounds of ingredients consumed per animal: Alfalfa	Cottonseed Hulls	Creepfeed Pellets	Milo
Heifers				
I	342	114	0	1,377
II	594	455	386	730
III	951	951	951	0
Steers				
I	493	164	0	2,129
II	799	577	475	1,189
III	1,280	1,280	1,280	0

Feeding costs for each of the three feeding regimes may be derived, utilizing the data in Table 23, by means of the following formulas:

Heifers:

$$C_1 = 1377\ P_1 + 342\ P_2 + 114\ P_3 + k_1 \qquad (3)$$

$$C_2 = 730\ P_1 + 594\ P_2 + 455\ P_3 + 386\ P_4 + k_2 \qquad (4)$$

$$C_3 = 951\ P_2 + 951\ P_3 + 951\ P_4 \qquad (5)$$

Steers:

$$C_1 = 2129\ P_1 + 493\ P_2 + 164\ P_3 + k_3 \qquad (6)$$

$$C_2 = 1189\ P_1 + 779\ P_2 + 577\ P_3 + 475\ P_4 + k_4 \qquad (7)$$

$$C_3 = 1280\ P_2 + 1280\ P_3 + 1280\ P_4 \qquad (8)$$

where

C_i = cost of ration i (i = 1, 2, 3,) for producing an 821 pound heifer or 941 pound steer, as the case may be, in dollars.

P_1 = price of milo in dollars per hundredweight.

P_2 = price of alfalfa in dollars per hundredweight.

P_3 = price of cottonseed hulls in dollars per hundredweight.

P_4 = price of creepfeed pellets in dollars per hundredweight.

k_j = cost of minor ingredients in rations 1 and 2 fed to heifers and steers, j = 1, 2, 3, 4.

Formulas 3 through 8 may be used to determine the points at which the various rations are equally costly for producing the given weight heifers or steers, as the case may be. Thus:

Heifers:

$$C_1 - C_2 = 0 \text{ when } P_1 = .389\ P_2 + .527\ P_3 + .597\ P_4 - m_1 \quad (9)$$

$$C_1 - C_3 = 0 \text{ when } P_1 = .442\ P_2 + .608\ P_3 + .691\ P_4 - m_2 \quad (10)$$

$$C_2 - C_3 = 0 \text{ when } P_1 = .489\ P_2 + .699\ P_3 + .774\ P_4 - m_3 \quad (11)$$

Steers:

$$C_1 - C_2 = 0 \text{ when } P_1 = .304\ P_2 + .439\ P_3 + .505\ P_4 - m_4 \quad (12)$$

$$C_1 - C_3 = 0 \text{ when } P_1 = .370\ P_2 + .524\ P_3 + .601\ P_4 - m_5 \quad (13)$$

$$C_2 - C_3 = 0 \text{ when } P_1 = .421\ P_2 + .591\ P_3 + .677\ P_4 - m_6 \quad (14)$$

where

$$m_1 = \frac{k_1 - k_2}{647} \qquad m_2 = \frac{k_1}{1,377} \qquad m_3 = \frac{k_2}{730} \quad (15)$$

$$m_4 = \frac{k_3 - k_4}{940} \qquad m_5 = \frac{k_3}{2,129} \qquad m_6 = \frac{k_4}{1,189}$$

Analysis of the m_i (i = 1, 2, . . . , 6) reveals these to be of a small order of magnitude relative to the other terms in equations (9) through (14), and for simplicity the m_i may safely be deleted from what follows. With this simplification, equations (9) through (14) may be used to determine a relation between the price of milo and the price of alfalfa, given prices of cottonseed hulls and creepfeed pellets, for which the various rations are equally costly. Figures 9 and 10 show such relations for assumed prices of $1.50 per hundredweight of cottonseed hulls and $7.00 per hundredweight of creepfeed pellets.

Figures 9 and 10 may be interpreted in the following manner. Provided that cottonseed hulls and creepfeed pellets are selling at $1.50 and $7.00 per hundredweight, then, if alfalfa is selling at, say, $3.00 per hundredweight:

(a) for heifers, it is less costly to use ration I, the high grain ration so long as milo is selling for about $6.10 per hundredweight or less (figure 9). If the price of milo is over $6.10, it pays feeders to shift to one of the lower grain rations.

(b) for steers, it is less costly to use ration I so long as the price of milo is $5.10 per hundredweight or less. If the price of milo is over $5.10, it pays feeders to utilize one of the lower grain rations.

Comparing figures 9 and 10, there are many more instances when the low grain rations are less costly for steers than for heifers. This is a direct result of the experimental steers performing relatively better than the heifers on the low grain rations (refer to Table 3).

Figures 9 and 10 are provided for illustration purposes only, in order to aid visualizing the relationships involved in determining which of the three rations yields least cost. Since the least cost ration is a function

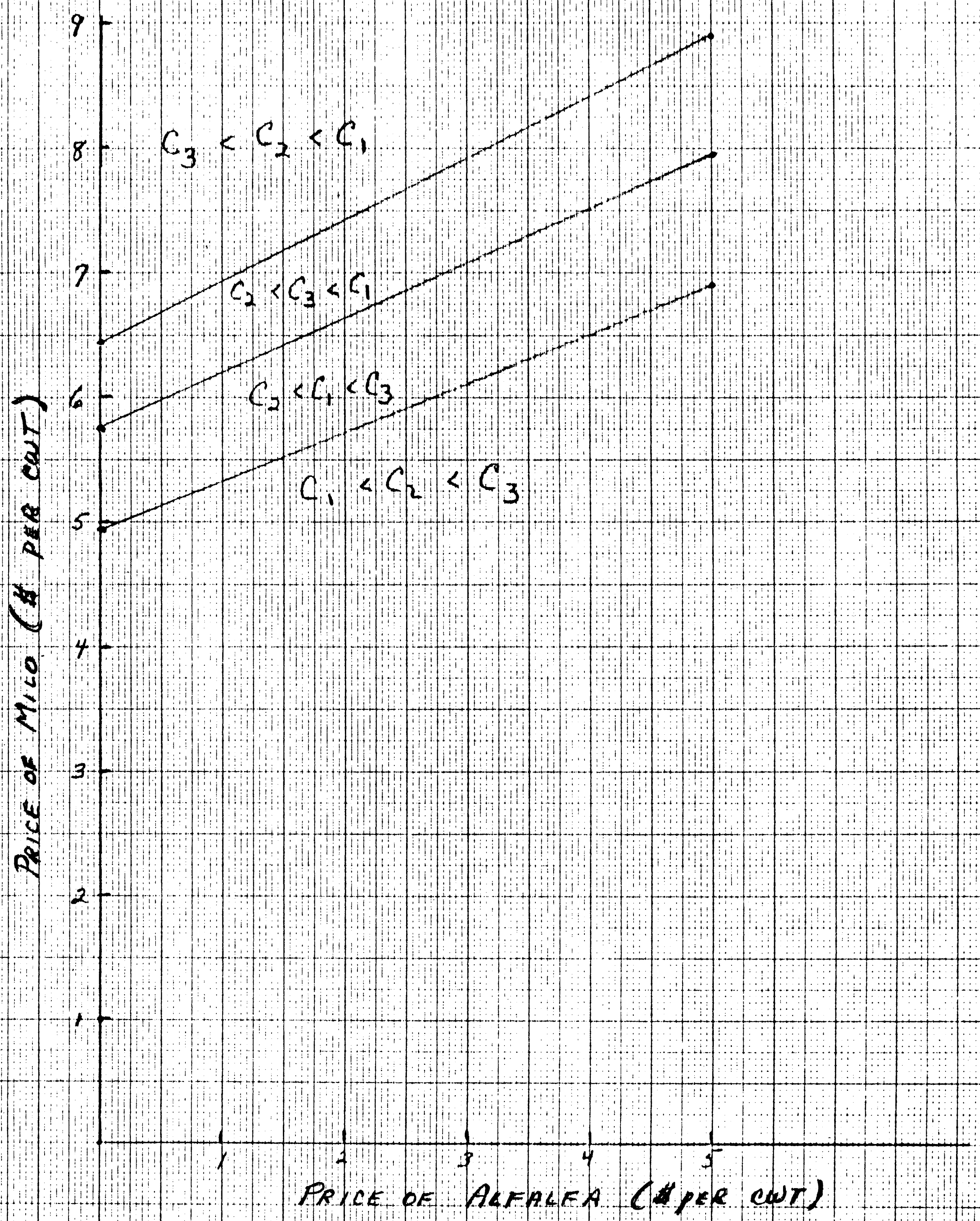

FIGURE 9. PRODUCING 821 LB. HEIFERS: RELATIVE COSTS OF RATIONS I, II AND III, AS FUNCTIONS OF MILO AND ALFALFA PRICES, GIVEN PRICES OF COTTONSEED HULLS AND CREEPFEED PELLETS.

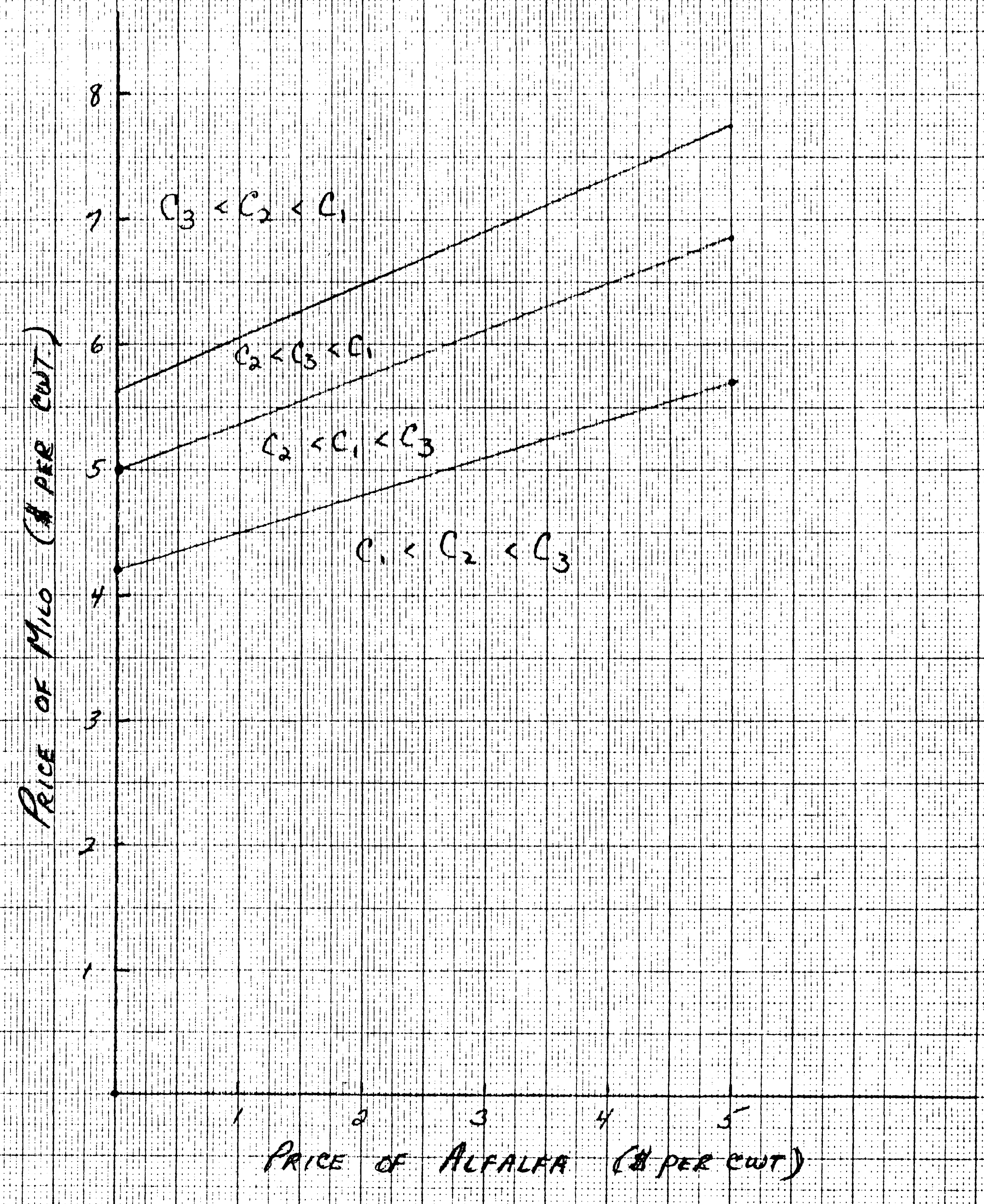

FIGURE 10. Producing 941 lb steers: Relative Costs of rations I, II and III, as functions of milo and alfalfa prices, given prices of cottonseed hulls and creep feed pellets

of the prices of the four major ingredients, Tables 24 and 25 specify which ration is least costly under a range of prices for the four major ingredients.[11/]

The following examples are provided to illustrate the use of Tables 24 and 25.

For heifers (Table 24), if the price of milo is $4.50 per cwt., and the prices of alfalfa, cottonseed hulls and creepfeed pellets are $60, $30 and $140 per ton respectively, then the figure 1 in the corresponding cell indicates ration I, the high grain ration is least costly.

For heifers (Table 24), if the price of milo is $6.50 per cwt., and the prices of alfalfa, cottonseed hulls and creepfeed pellets are $40, $25 and $125 per ton respectively, then the figure 3 in the corresponding cell indicates ration III, the low grain ration is least costly.

For steers (Table 25), if the price of milo is $5.50 per cwt., and the prices of alfalfa, cottonseed hulls and creepfeed pellets are $60, $30 and $140 per ton respectively, then the figure 2 in the corresponding cell indicates ration II, the medium grain ration is least costly.

Similar interpretations hold for the other entries in Tables 24 and 25. In all, each table presents 625 different price combinations of the major feed ingredients. Of these, 391 in Table 24 (heifers) are combinations for which the high grain ration is least costly, while 234 indicate medium or low grain rations yield least costs. For steers, on the other hand, the high grain ration is least costly under only 265 of the combinations, while the medium or low grain rations yield least cost in 360 cases. This illustrates again the relatively better performance of the steers on the low

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11/ The entires in Tables 24 and 25 are derived without regard to the cost of minor ingredients in rations I and II. Inclusion of such costs would not significantly alter any of the results.

Table 24. Least-cost rations for producing 821 lbs. heifers under alternative prices of milo, alfalfa, cottonseed hulls and creepfeed pellets.

Price of Milo*		3.50					4.50					5.50					6.50					7.50				
Price of Alfalfa*		40	50	60	70	80	40	50	60	70	80	40	50	60	70	80	40	50	60	70	80	40	50	60	70	80
Cottonhull Price	Creepfeed Price																									
20	120	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	3	2	2	2	2	3	3	3	3	3
	130	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	3	2
	140	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	2	2	2
	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	3	2	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2
25	120	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	3	2	2	2	2	3	3	3	3	3
	130	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	3	2	2
	140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2
	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2
30	120	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	3	2
	130	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	2	2	2
	140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2
	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2
35	120	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	2	2
	130	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2
	140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2
	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2
40	120	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	3	2	2
	130	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	2	2
	140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2
	150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2

* Milo prices in dollars per hundredweight; alfalfa, cottonseed hull and creepfeed pellet prices in dollars per ton.

Table 25. Least-cost rations for producing 941 lb. steers under alternative prices of milo, alfalfa, cottonseed hulls and creepfeed pellets.

Price of Milo*		3.50					4.50					5.50					6.50					7.50				
Price of Alfalfa*		40	50	60	70	80	40	50	60	70	80	40	50	60	70	80	40	50	60	70	80	40	50	60	70	80
Cottonhull Price	Creepfeed Price																									
	120	1	1	1	1	1	2	2	2	1	1	3	2	2	2	2	3	3	3	3	3	3	3	3	3	3
	130	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	3	2	3	3	3	3	3
20	140	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2	3	3	3	3	3
	150	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3
	160	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2	3	3	3	3	2
	120	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3
	130	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	3	2	2	3	3	3	3	3
25	140	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	2	2	3	3	3	3	3
	150	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2	3	3	3	3	2
	160	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	2	2
	120	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	3	3	2	3	3	3	3	3
	130	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2	3	3	3	3	3
30	140	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	2	2	3	3	3	3	3
	150	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2	3	3	3	3	2
	160	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	2	2	2
	120	1	1	1	1	1	2	1	1	1	1	2	2	2	2	2	3	3	3	2	2	3	3	3	3	3
	130	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2	3	3	3	3	3
35	140	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2	3	3	3	3	3
	150	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2	3	3	3	2	2
	160	1	1	1	1	1	1	1	1	1	1	2	1	;	1	1	2	2	2	2	2	3	2	2	2	2
	120	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	2	2	2	3	3	3	3	3
	130	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	2	2	3	3	3	3	3
40	140	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	2	2	2	2	2	3	3	3	3	2
	150	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	3	3	2	2	2
	160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	2	2

*Milo prices in dollars per hundredweight; alfalfa, cottonseed bull and creepfeed pellet prices in dollars per ton.

grain rations.

Tables 24 and 25 should only be used as a guide in determining which of the three rations is least costly if the weight of animal being produced is 821 pounds per heifer or 941 pounds per steer. At higher or lower weights of animals, the least cost ration is likely to be different from those indicated in the tables.

Recently, there may well have been periods when it would have paid feeders to use rations with lower grain contents. In the fall of 1974, for example, milo approached $6.50 per hundredweight, alfalfa was about $70 per ton, cottonseed hulls were about $35 per ton and creepfeed pellets were about $140. Under such prevailing prices, feeders producing either 821 lb heifers or 941 lb. steers probably would have had lower feed costs with ration II than with ration I.

SUMMARY AND CONCLUSIONS

This study, which examines the choice of the optimum type as well as the economically optimum amount of ration for feeding cattle in Arizona, is based on the results of feeding experiments conducted with three groups of heifers and three groups of steers at the University of Arizona. One group of heifers and one of steers were fed a ration with a high grain content. Another pair of groups were fed a medium grain ration, while the third pair received a low grain ration.

Carcasses from the various groups were evaluated to determine whether the type of diet affected yield grades, tenderness, quality grades, or yield of retail cuts. No significant differences were found.

An analysis of the optimum quantity of feed to use is presented for the groups of steers fed high and low grain rations. The optimum feed input and optimum weight steer to produce, for both high and low grain rations are presented in Tables 8, 9, 12, and 13. The optimum weight steer to produce increases with either increases in the price of fed cattle or decreases in feed prices, for both types of ration. However, for the high grain ration, the optimum weight steer never exceeds 1000 pounds live weight under any of the price conditions examined. This suggests cattle feeders in Arizona well might examine their own operations in order to determine whether they can increase profits and/or reduce losses by feeding steers to lighter weights than is customary. Performance of cattle in commercial feedlots, of course, may not correspond to that of the experimental animals, but the experimental results at the very least indicate the question is worth further investigation.

Overall, steers convert the high grain ration into body weight at a more efficient rate. Which ration is more efficient economically, however, depends upon the relative prices of the rations and the weight of steer produced. Figure 6 and Tables 14 through 20 present information needed to determine which of the two rations is most economical for a range of alternative prices and weights of animal produced. The likelihood that the low grain ration will be more economical increases as the weight of steer produced increases.

For all weights considered, namely 700 to 1000 pounds, the high grain ration will yield lower costs if the price of the low grain ration is 79 percent or more of the price of the high grain ration. Conversely, if the price of the low grain ration is 60 percent or less of the price of the high grain ration, then the low grain ration will yield least cost for any weight animal considered. If the price of the low grain ration is between 60 and 79 percent of the price of the high grain ration, the determination of which is least costly depends upon the weight of animal produced, with the low grain ration more likely to yield a lower cost as the weight of steer increases to 1000 pounds.

The experimental data were not sufficient to permit a determination of the optimum weight animal to produce for the steers fed the medium grain ration, nor for any of the groups of heifers. However, for all six groups, the least cost ration was determined for producing 821 pound heifers and 941 pound steers. Steers performed relatively better on the low grain ration than did heifers.

Tables 24 and 25 on pages 53 and 54 of the text each consider 625 different price combinations of the four major ingredients in each of the rations: milo, alfalfa, cottonseed hulls and creepfeed pellets. For heifers, 391 of the 625 combinations are ones for which the high grain ration is least costly, 195 show the medium grain ration least costly and 39 are ones for which the low grain ration is least costly. For steers, on the other hand, the high grain ration is least costly under only 265 of the 625 combinations, while the medium grain ration is least costly for 220 and the low grain for 140 combinations.

The results indicate that it may well have paid cattle feeders in Arizona to utilize other than high grain rations during recent time periods, such as the fall of 1974. Under prices prevailing at that time, feed costs, for the experimental heifers and steers at least, would have been minimized by utilizing the medium grain ration.

Appendix A

Feeding Data for the Experimental Groups of Heifers and Steers

TABLE A-1. FEEDING DATA FOR THE EXPERIMENTAL GROUPS OF HEIFERS AND STEERS

Period	Group I			Group II			Group III		
	Ration[1]	Cumulative Weight per Animal	Cumulative Variable Feed Input	Ration[1]	Cumulative Weight per Animal	Cumulative Variable Feed Input	Ratio[1]	Cumulative Weight per Animal	Cumulative Variable Feed Input
		(LBS.)	(LBS.)		(LBS.)	(LBS.)		(LBS.)	(LBS.)
					HEIFERS				
9/19-10/3/74	S	616	262	G	646	--[2]	G	634	-
0/4 -11/1/74	F	721	797	G	720	1158	G	698	1029
1/2 -11/14/74	F	736	1067	S	747	1438	G	--	--
1/15-12/5/74	F	758	1574	F	755	1815	G	743	2063
2/5-12/16/74	F	851	1943	F	837	2184	G	835	2539
2/17-12/19/74	F	855	2001	-	-	-	-	-	-
2/17-12/30/74	-	-	-	F	886	2405	-	857	2854
2/31-1/9/75	-	-	-	-	-	-	G	842	3110
					STEERS				
/18-5/2/75	S	573	223	G	-	-	G	-	-
/3-5/16/75	F	634	466	G	655	678	G	668	678
/17-6/13/75	F	732	1027	G	761	1439	G	742	1468
/14-6/27/75	F	-	-	S	782	1717	G	-	
/14-7/11/75	F	822	1565	F[3]	818[3]	1943[3]	G	826	2273
/12-8/8/75	F	884	2137	F	896	2516	G	904	3061
/9-9/5/75	F	931	2681	F	970	3111	G	977	3850
/6-9/25/75	F	979[4]	3082	F	1014[4]	3507	G	1015[4]	4454

/Rations are denoted as: ~~follows~~: S=Starting ~~ration~~, F=Finishing ~~ratio~~n, G=Growing~~. ration.~~ See Tables 2 and 3 of text for ration composition. 2/ Missing entries in cells are periods for which animal and/or feed weights were not recorded. 3/ Data refer to the period 6/28 - 7/11/75. 4/ Average of weights taken on 9/24 and 9/25/75.

Appendix B

Method of Estimation of Quantities of Major Feed Ingredients Used to Produce 821 Pound Heifers and 941 Pound Steers

Method of Estimation of Quantities of Major Feed Ingredients Used to Produce 821 Pound Heifers and 941 Pound Steers

Group I heifers attained an average weight of 855 pounds on December 19, 1974 (see Appendix A, Table A1). Allowing for a 4 percent "pencil shrink", this corresponds to a finish weight of 821 pounds per heifer. This average was the lowest finish weight of any of the three groups of heifers, hence was chosen as the basis for comparisons. For the Group I heifers, the feed inputs consumed through December 19, as shown in Appendix Table A1, were used in further calculations.

The Group II heifers attained average weights of 837 pounds and 886 pounds on December 16 and December 30, respectively. Applying a 4 percent pencil shrink, finish weights are 804 and 851 pounds on the respective dates. By simple interpolation, the Group II heifers are estimated to have reached 821 pounds average on December 21, 1974. Derived from the data in Table A1, Group II heifers consumed 221 pounds of finishing ration during the period December 17 to December 30. By simple interpolation, therefore, they are estimated to have consumed 79 pounds each during the period December 17 to December 21. The estimated 79 pounds per heifer for the December 17 - 21 period, plus the amounts actually consumed during previous periods, were used to compute the feed consumed in producing 821 pound heifers.

Computations for the Group III heifers and the various groups of steers followed the same basic procedure. The date at which each group reached the selected common finish weight was estimated by simple interpolation of the weight data in Appendix Table A1. Then the quantity of feed consumed during the final period was estimated by interpolation of the feed input data in the same table. Details of the calculations are in the following tabulation.

Heifers

	Group I	Group II	Group III
Average Gross Weight, Dec. 16 (lbs.)	851	837	835
Average Finish Weight, Dec. 16 (lbs.)1/	817	804	802
Average Gross Weight, Dec. 19 (lbs.)	855	-	-
Average Finish Weight, Dec. 19 (lbs.)1/	821	-	-
Average Gross Weight, Dec. 30 (lbs.)	-	886	857
Average Finish Weight, Dec. 30 (lbs.)	-	851	822
Estimated Date of Attainment of 821 lb. Finish Weight	Dec. 19	Dec. 21	Dec. 30
Feed Consumption per heifer, 12/17 - 12/30/74 (lbs.)	58 2/	221	315
Estimated Feed Consumption per heifer, 12/17 - attainment of 821 lbs. Finish Weight (lbs.)	58	79	315

Steers

	Group I	Group II	Group III
Average Gross Weight, Sept. 5 (lbs.)	910	970	976
Average Finish Weight, Sept. 5 (lbs.)	873	931	938
Average Gross Weight, Sept. 24 (lbs.)	981	1020	1020
Average Finish Weight, Sept. 24 (lbs.)	941	979	982
Estimated Date of Attainment of 941 lb. Finish Weight	Sept. 24	Sept. 9	Sept. 6
Feed Consumption per Steer, 9/5 - 9/25/75 (lbs.)	401	396	604
Estimated Feed Consumption per Steer, 9/5 - attainment of 941 lbs. Finish Weight	381	79	30

1/ Finish weight equals .96 times gross weight.

2/ 12/17/74 to 12/19/74 for group I heifers.

The estimated amounts of feed consumed were multiplied by the percentages of the major ingredients in each of the rations (growing, starting and finishing) as shown in Tables 1 and 2 of the text in order to derive the quantities of each ingredient shown in Table 23.