Maximizing income above feed costs with...

COMPUTER-FORMULATED DAIRY RATIONS

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Feeding trials were conducted to test a computer program designed to formulate rations resulting in maximum income above feed costs from lactating dairy cows. Factors considered by the computer include feed prices, milk prices, milk production response to varying levels of nutrients, maximum voluntary feed intake, and productive ability of the cow. Cows fed the computer-formulated rations returned $15 to $21 more income above feed costs per year than cows fed control rations.

RATIONS AND FEEDING methods for dairy cows have gone through considerable change in recent years. One of the most important is the use of computers to formulate dairy rations. Linear programming techniques are used to test rapidly all combinations of available feed ingredients which fulfill nutrient requirements and select the formula which results in a "least-cost ration".

Another recent change in dairy cattle feeding is the trend toward feeding roughages and concentrates together as a complete ration (all-in-one ration), rather than the more conventional method of feeding concentrates in the milking barn and roughages in a different area. Feeding trials in many states, including California, have shown that at least equal milk production can be obtained from dairy cows fed complete rations, with savings in feeding labor and with less feed wastage compared with conventional feeding methods.

To take full advantage of the two developments discussed above, a computer program was developed to go a step beyond the least-cost ration concept. In addition to feed prices, other variables are included in the program so that a ration is formulated and allotted which maximizes income above feed costs. These additional variables are: the productive ability of the cow (or string of cows), milk prices, milk production response to varying levels of nutrients (energy, protein, calcium, phosphorus, and crude fiber), and maximum voluntary intake of roughages at varying levels of concentrates in the ration. Efficacy of this computer program was tested under controlled experimental conditions in the U.C., Davis dairy herd and under commercial conditions during a field trial using the dairy herd at Deuel Vocational Institution (DVI), Tracy, California. Results of these trials, subsequent modifications in the computer program implemented as a result of the trials, and recommendations for nutrient and other ration constraints for complete-rations are discussed in this report.

Twelve cows were paired according to age, stage of lactation, and previous milk production. One cow from each pair was assigned to the computer-ration treatment at the beginning of the trial while its pair-mate received the control ration. Cows were rotated between treatments at five-week intervals in a double-reversal design so that all cows were on both treatments during the experiment. The first week of each period was used as a change-over interval with data from the last four weeks of each period used in the analysis of the results.

Each group was fed a complete ration outside of the milking parlor, with roughage and concentrate portions of the rations weighed separately but fed together twice each day. Ration components and amounts for both treatments remained constant during the trial. Roughage and concentrate amounts for the control treatment were based on previous management practices in the herd, while the computer specified amounts for the group receiving the computer-formulated ration. Rations for both groups are shown in table 1. Milk from each cow was weighed and sampled twice daily with composite weekly samples analyzed for milk fat content.

The amount and composition of milk from cows in the two treatments are shown in table 2. Production in both treatments was relatively low. However, cows fed the computer-formulated ration produced 0.7 lb more milk with 0.1% higher fat test, resulting in 0.08 lb more milk fat and 1.4 lb more 4% fat-corrected-milk (FCM). The probabilities of the above differences being due to chance alone are listed in the column labelled P, with FCM at less than 8% and milk fat percentage and pounds of milk fat at less than 5% probability. Therefore, (except for the amount of milk,) the chances that the above differences were due to the differences in the feed treatments were very high.

Costs of the two rations are listed in table 1 along with the composition and amounts fed. It should be noted that the computer-formulated ration actually cost more per day, being about 70 cents per cow compared with 69 cents for the control ration. This was because a higher level of concentrate and lower level of roughage was recommended by the computer than was fed to the control group.

The price received for milk with 4% fat during the trial averaged $5.64 per cwt. Therefore, with a difference of 1.4 lb per day of 4% FCM, daily milk returns from the cows fed the computer-formulated ration amounted to almost 8 cents more per cow than the control group. Feed costs were close to 1 cent higher, however, making a net difference of just over 7 cents per cow per day in favor of the computer-formulated ration. On a 305-day lactation basis, this would amount to $21.66 more income above feed cost per cow.

Cows used in the above experiment were relatively low producers and the trial lasted only 15 weeks. Therefore, results should not be extrapolated to higher-producing cows, nor to longer periods of time. However, the trial served the purpose of testing the computer program under actual feeding conditions and indicated that it was worthwhile to test the program further with larger numbers of higher-producing cows under commercial dairying conditions. Therefore, a field trial was set up on a large dairy to test and modify the program as necessary to make it of practical use to the dairy industry.

Davis trial

The DVI herd of 180 milking cows was split into two groups with approximately equivalent previous milk production. One group was fed according to previous management practices at the dairy, with concentrates in the milking parlor and roughages fed separately outside. Alfalfa hay made up part of the ration year-around while corn silage was fed in the winter and spring and oat silage in the summer and fall.

The other group was fed a computer-formulated ration with roughages and concentrates mixed together before feeding. A small amount of concentrates was fed in the milking parlor during part of the trial to encourage cows to come into the parlor more rapidly. New ration formulas were developed as feed prices and availability of feed ingredients varied throughout the trial. An example of the computer ration that was fed during a major part of the trial is shown in table 3.

The trial lasted 13 months. Milk weights were recording twice daily for each cow in the trial — a routine practice in the DVI herd. Milk tests were conducted monthly by the local Dairy Herd Improvement Association (DHIA). DHIA milk fat percentages were multiplied by the total of the daily milk weights to calculate monthly fat and 3.5% FCM production for each cow.

Lactation records

Lactation records (305 days) were calculated for 64 cows in the control group and for 65 cows fed the computer ration. Records from cows which left the herd during the trial were not included in the milk production analysis. When a continuous, full lactation was not completed within the 13-month experimental period, the latter part of the previous lactation completed during the trial period was added to the current incomplete lactation to obtain a 305-day record. This was possible because cows which dried up and left an experimental group were returned to the same group when they freshened again. An attempt was made to balance both groups according to age at the beginning of the trial but this was difficult to maintain because of culling and other management practices during the 13-month period of the trial. Therefore, all production records were converted to a mature-equivalent (ME) basis to remove any bias due to differences in ages of cows in the two groups. Production data from the trial were subjected to an analysis of variance using a completely randomized design.

Milk production and composition (ME basis) are shown in table 4. None of the small differences between groups approached statistical significance, with probabilities of differences being due to chance alone greater than 50% in all cases. Therefore, for all practical purposes, production from the two groups can be considered approximately equal.

Production averages

Average ME milk production of 18,963 and 18,747 lbs, respectively, from the computer-formulated and control rations was excellent, indicating that both rations were nutritionally well balanced. Actual milk production for the 129 cows which completed the trial averaged 17,101 lbs in 305-days.

Fat test in both groups was lower than normal, being 3.18% and 3.28%, respectively. Low fat tests have been a problem in this herd from time to time and may be due partially to the relatively high level of concentrates fed, which result in a low level of fiber in the ration. At one point during the trial, fat test dropped to 2.73% for the group receiving the computer-formulated ration. This was corrected by reformulating the ration with a minimum of 17% crude fiber (90% DM basis) instead of 15%, as originally specified. This resulted in a formula with less concentrates and more silage and a return to a more normal fat test from the group. Subsequently, this minimum level of crude fiber was made a permanent part of the computer-ration program constraints, as discussed here.

Accurate measurement and allotment of feed in a field trial under commercial conditions are always difficult. It is even more difficult in a large herd, such as the DVI herd. Taking into consideration the limitations on the accuracy of the feeding data, the average amounts and costs of the various feeds that were fed during the trial are shown in table 5.

Both groups received the same amount of silage per cow, as the amount recommended for the computer-ration group also was fed to the control group. However, the computer ration contained more concentrates and less hay than the control ration. The amount of hay fed to both groups was calculated from the number of bales fed multiplied by the average bale weight. Cows fed the computer-formulated complete-ration received the same baled hay as the controls but it was shredded and mixed with concentrates and water before feeding.

The amount of concentrate ingredients to mix with the roughage was specified by the computer for the computer ration, one of which is shown in table 3. The concentrate mix fed to the control group was the proprietary brand normally fed at the dairy.

Ration quantities

Cows fed the computer ration received daily an average of 25.88 lbs concentrates, 18.62 lbs shredded alfalfa hay, and 23.4 lbs silage (corn or oats, as available) compared with 21.86 lbs concentrates, 27.94 alfalfa hay and 23.4 lbs silage fed to the control group (table 5). Total daily feed costs were $1.17 and $1.22, respectively, for the computer-ration and control ration, a difference of 5 cents per cow per day in favor of the computer-ration. At 5 cents per day, this amounts to $15.25 per cow per 305-day lactation, or $2745 lower feed cost per year in a 180-cow herd, the approximate size of the DVI herd. Since there was no significant difference in milk production (table 4), the $2745 lower feed cost from feeding the computer-ration would result in an equivalent amount of additional income above feed cost compared with feeding the control ration.

Both the small-scale, well-controlled, double-reversal trial at UCD and the large-scale field trial under commercial conditions at DVI resulted in economic advantages for the cows fed the computer-formulated rations. In the UCD trial, this amounted to $21.66 more income above feed cost per cow per

year, due to increased milk production — even though the computer-ration was slightly more expensive than the control ration. An advantage of at least $15.25 per cow per year for the computer ration in the DVI trail was due to a lower feed cost, with no significant difference in production between the cows fed the computer-formulated and control rations. This was accomplised even though all cows in the computer-ration group were fed the same complete ration regardless of production level or stage of lactation. Subdividing the computer-ration group into strings according to production levels and feeding complete rations with varying roughage-concentrate ratios may have resulted in even greater efficiency of feed utilization from this group.

Minimum constraints

Minimum nutrient constraints (90% DM basis) for the computer-formulated rations used in the trials were 12% crude protein, 15% crude fiber, 0.4% calcium and 0.35% phosphorus, with estimated net energy and digestible protein levels dependent on maintenance and milk production requirements as listed in *Feeds and Feeding* by Morrison, 1956 ed. and the NRC bulletin, *Nutrient Requirements of Dairy Cattle*, 1966 ed. Subsequent to the trials, the 1971 edition of the NRC bulletin was published which contains higher recommendations for protein, calcium and phosphorus than the previous edition. Also, as mentioned earlier, problems were encountered in maintaining a normal milk-fat test during the trial when only 15% crude fiber was required in the ration. This level has been adequate to maintain fat test in some trials, and an even lower minimum level of 13% crude fiber on a dry basis (11.7% at 90% DM) is recommended in the new NRC bulletin. The new NRC minimum appears to be much too low under some conditions because the form as well as the amount of crude fiber in the ration apparently affects fat test. Therefore, to insure proper form and adequate amounts of fiber under most conditions, the minimum constraint on crude fiber was increased to 17% in the computer program, and the minimum roughage level in the ration was specified to be at least 1.5% of the body weight. Adjustments in crude protein, calcium and phosphorus minimum constraints also were made (based on new NRC recommendations) to insure adequate amounts under varying conditions.

The guidelines presently recommended for complete rations and now incorporated into the computer-formulation program are as follows:

Guidelines for Complete-Rations
(90% DM basis)

	%
Crude protein, minimum	
(less than 65 lb milk per day)	13.0
(more than 65 lb milk per day)	14.5
Crude fiber, minimum	17.0
Calcium, minimum	0.6
Calcium, maximum	1.0
Phosphorus, minimum	0.4
Nonprotein nitrogen, maximum	0.45
Roughage (% of body weight), minimum	1.50

In addition to the above guidelines, salt should be included as 0.5% of the concentrate mix. When non-legume roughage predominates in the ration, trace-mineralized salt should replace plain salt. Concentrate percentage of the ration depends on level of milk production, but should not exceed 50 to 60% in order to maintain normal milk-fat test. A range of 30 to 50% concentrates in the ration fulfills energy requirements for most levels of milk production when high-quality forage is fed.

Guidelines

The guidelines may be modified as additional research and experience with complete rations become available. Even with present knowledge, however, the complete ration system makes it possible for dairymen to greatly reduce feeding labor and feed wastage, and obtain at least as high milk production as they do with the more conventional method of feeding roughages and concentrates separately. Furthermore, when the computer program described herein is used to formulate the ration, present results indicate yearly income above feed cost may be increased from $15 to $21 per cow.

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TABLE 1. CONTENT AND COST OF EXPERIMENTAL RATIONS (UCD TRIAL)

	Computer	Control
	lb/day	lb/day
Barley	8.02	7.67
Beet pulp, dried	3.08	1.02
Wheat mixed feed		1.43
Molasses, cane	.99	....
Sodium tripolyphosphate	.12	
Dicalcium phosphate	.12	...
Salt	....	.10
Total concentrate	12.33	10.22
Alfalfa cubes	23.29	25.76
Total ration cost ($/cow/day)	$ .70162	$ .69372

TABLE 2. MILK PRODUCTION AND COMPOSITION (U.C.D. TRIAL)

	Ration		
	Computer	Control	P*
			%
Milk (lb/day)	29.88	29.18	>10
Milk fat (%)	3.30	3.20	< 5
Milk fat (lb/day)	1.00	0.92	< 5
4% FCM (lb/day)	26.94	25.54	< 8

*Probability of difference due to chance alone.

TABLE 3. EXAMPLE OF A COMPUTER RATION (D.V.I. TRIAL)

	lb/day
Corn, Dent No. 2	9.77
Beet pulp, dried	6.01
Wheat mixed feed	6.01
Molasses, cane	1.92
Salt	0.24
Dicalcium phosphate	0.09
Total Concentrate	24.06
Corn silage, 28% DM	21.18
Alfalfa hay, 24% MCF	16.39
Total roughage	23.45 (90% DM)

TABLE 4. MATURE EQUIVALENT MILK PRODUCTION AND COMPOSITION (D.V.I. TRIAL)

	Ration		
	Computer	Control	P*
			%
Milk (lb/305 days)	18,963	18,747	> 50
Milk fat (%)	3.18	3.28	> 50
Milk fat (lb/305 days)	601	611	> 50
3.5% FCM (lb/305 days)	17,941	18,007	> 50

*Probability of difference due to chance alone

TABLE 5. AMOUNTS AND COSTS OF EXPERIMENTAL RATIONS (D.V.I. TRIAL)

	Ration	
	Computer	Control
Concentrate price ($/ton)	55.00	55.00
Concentrate fed (lb/cow/day)	25.88	21.86
Hay price ($/ton)	35.40	35.40
Hay fed (lb/cow/day)	18.62	27.94
Silage price ($/ton)	11.00	11.00
Silage fed (lb/cow/day)	23.40	23.40
Total ration cost ($/cow/day)	1.1700	1.2244