A FIELD STUDY OF A COMPUTERIZED METHOD OF GROUPING DAIRY CATTLE

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(ABSTRACT)

A computer modeling experiment showed that grouping dairy cattle based on requirements of crude protein and net energy per kilogram expected dry matter intake (Grouper) had unique characteristics relative to other grouping systems. The objective of this study was to adapt the computerized Grouper system for practical use by implementing a field trial in commercial dairy herds to determine its managerial benefits and economic merit. Ten cooperating dairy herds participated in the one year trial. Herds were grouped monthly using test day information obtained from the Dairy Records Processing Center, Raleigh, NC and reports mailed to the cooperators. Feed consumption data and a record of cows not placed according to Grouper recommendations were collected during monthly herd visits or by mail. One set of analyses examined trends in Dairy Herd Improvement (DHI) variables through trial duration while another set compared Grouper to a comparable milk production grouping program with all herd test day information grouped with both systems. No significant changes in DHI variables could be attributed to the Grouper system. Grouper retained younger, smaller cows and those with higher fat test in the high group longer and moved older, larger cows and cows with lower

fat test into the low group sooner than grouping by milk production. Grouper produced higher intraclass correlations among cows in groups for percent Total Digestible Nutrients (0.59 versus 0.41) and percent crude protein (0.65 versus 0.57) than milk production grouping. Economically, Grouper was significantly more expensive when comparing systems based on average feed cost per cow per day. However, this did not consider increased income or decreased costs associated with the system or account for possible benefits such as better health and higher production resulting from feeding more precisely each individual's nutrient requirements. The Grouper program has been automated to be used through either a dairy records processing center or an individual microcomputer and can be considered a practical management tool to help the dairy manager group cows more efficiently and feed more accurately.

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INTRODUCTION

Intense management is needed for dairy producers to realize an adequate return on investment. Economy of size is an influential justification for acquiring more production units to offset the cost of fixed assets. As average herd size increases, management strategies are developed to meet the needs of large dairy operations.

Many large dairy farms feed total mixed rations to cows in groups. Because feed costs constitute the largest expense on most farms, methods which maximize the efficiency and accuracy of feeding and grouping lactating dairy cows are highly desirable.

There are several ways to group and feed large numbers of cows but few research projects have compared these systems. McGilliard et al. (52) have developed a grouping method which groups cows based on requirements of net energy and crude protein per kilogram expected dry matter intake. A computer model of Dairy Herd Improvement records comparing this method to grouping by test day milk and fat-corrected milk showed Grouper to be superior in producing likeness among cows within groups. Although this 'Grouper' system exhibited some unique and potentially beneficial characteristics, a field study was needed to assess benefits of the system in actual herd situations and to adapt the theoretical concept to a practical herd management tool.

This project was undertaken to develop and implement a field study utilizing this grouping procedure to produce a computer program which could be incorporated into the management routine of dairy herds grouping cows and feeding total mixed rations.

REVIEW OF LITERATURE

NUTRIENT REQUIREMENTS OF LACTATING CATTLE

The quality of the feeding program is the single most important factor determining production on most dairy farms (31). In conjunction with this, milk yield per cow and cost of feed have the greatest impact on profitability of milk production (16). It is essential the lactating dairy cow receive a balanced ration to encourage her to maximize production yet prevent the overfeeding of expensive nutrients. Feed costs account for 50% of the cost of production (31) on the average, so every effort must be taken to keep this to a profitable minimum.

Nutrients are chemicals which support the physiological processes of the living body. They can be obtained from ingested foodstuffs which are broken down into a form utilizable by the system. They support the maintenance, growth, pregnancy, and production of the living system. Clark and Davis (16) found that requirements for the lactating dairy cow are a function of milk yield, milk composition, and body weight. They also state that energy and protein appear to be the nutrients most limiting to maximum milk production.

The nutrient needed in the greatest quantity is energy (65). This energy may be expressed as net energy of lactation (NEL), total digestible nutrients (TDN), digestible energy (DE), and metabolizable energy (ME).

Net energy of lactation may be calculated from the latter three as follows (76):

$$NEL = 0.0266 * (TDN\%) -0.12$$

$$NEL = 0.677 * (DE) -0.36$$

$$NEL = 0.703 * (ME) -0.19$$

Energy can be obtained from carbohydrates, fats, and proteins. Usually, the most economical source of energy is roughages but high energy concentrates are often needed in early lactation due to depressed intake and the restrictive effect of the rumen filling with fiber. The dairy producer must strive to ensure maximum food intake to obtain peak milk production yet maintain sufficient fiber percentages for normal rumen function and milk composition. Campbell and Marshall (12) cite factors affecting the energy obtained from feeds as: composition of the ration, physiological function for which it is used, environmental conditions, and size of the animal.

Energy requirements vary according to body size, rate of growth, milk production, and milk composition (65). It is often difficult to balance a ration that meets the animal's needs in early lactation and still maintain an acceptable percentage of fiber in the ration.

Energy and fiber are negatively correlated. As energy in the ration increases, the fiber decreases. This relationship is also evident in forage quality. As forages mature and lignify, energy content decreases.

Too little fiber in a ruminant's ration can lead to rumen acidosis, milk fat depression, off-feed conditions, and an increase in displaced abomasums (16). Etgen and Reaves (31) recommend keeping ration acid detergent fiber above 20%. This percentage can promote maximum intake of energy without leading to metabolic problems. Energy deficiencies are exhibited as rapid weight loss postpartum, low peak milk production, short lactations, and irregular reproductive cycles (31). However, cows can efficiently use body stores to overcome some of the deficiency resulting from depressed intake in early lactation.

Body reserves of protein are limited so the ration must contain enough crude protein for maintenance and lactation. Clark and Davis (16) state that requirements for crude protein can be defined as the minimum amount of protein that will support maximum production. This becomes particularily important to the high producing cow since up to five times normal protein equivalent may be required daily due to large amounts of protein secreted in the milk (12). Protein recommendations as a percent of ration dry matter vary but Clark and Davis (16) observed crude protein percentages greater than 14% of ration dry matter resulted in small but declining rates of increase in milk production. Care must be taken when expressing crude protein requirements as a percent of ration dry matter matter as contrasted to weight of crude protein. Clark and Davis (16) have information which indicates grams of crude protein consumed daily are more closely correlated (.51) with milk yield than percent crude protein (.31) in ration dry matter.

Protein deficiency may be exhibited as emaciation, low milk production, and reduced feed digestion. Etgen and Reaves (31) suggest rations contain 10-18% crude protein as a percent of ration dry matter depending on age and production. However, too much protein can reduce the efficiency of energy utilization (16) and result in digestive upsets, reproductive problems, and be expensive.

FORMULATING RATIONS FOR LACTATING COWS

The National Research Council (58) has developed estimates for determining nutrients required at varying kilograms of milk production and percent butterfat. It also presents averages for a number of commonly used feedstuffs. However, the dairy producer must take regular forage samples to determine what nutrients are available in the feeds unique to that operation. A typical ration can vary from day to day simply by small changes in forage dry matter. Consequently, every effort must be made to formulate the ration with actual feed analysis to limit extraneous sources of variation.

Ideally, specific rations would be formulated for each cow, but with large herds this has become impractical unless computer feeders are installed. A simpler and less expensive way is to feed cows in groups with rations balanced for groups. Formulating rations and feeding dairy cows involves many variables. The goal of the dairy manager must be to meet as many of the individual cow's requirements for nutrients while striving for maximum production at minimum cost.

DRY MATTER INTAKE

Individual dry matter intake is a complex biological phenomenon controlled by both physical and physiological factors (77). Physical factors limit intake to less than metabolic demand in cows which cannot consume enough energy to meet their needs. Physiological factors are the normal homeostatic mechanisms of regulation often controlled by the energy present in the system and needed by the cow. The central nervous system integrates these main factors with variables determining the nutrient needs of the cow to dictate her individual intake.

Variables which can affect intake and nutrient requirements are numerous and often interact to a high degree. Main variables are milk production, stage of lactation, fat production, size of cow, age, body weight, composition of diet, and nutrient balance of the cow (60). Other factors involved in composition of the diet can be quite intangible and difficult to measure, but exhibit a profound effect, i.e. palatability, digestibility and physical form.

Conrad (19) noted that physical and physiological factors regulating intake change in importance as digestibility of the ration changes. At low digestibility, 52-66%, intake was dependent on physical factors like body weight, dry matter digestibility, and undigested residue per unit body weight per day. At high digestibilities, 67-80%, intake was dependent on metabolic size, milk production, and digestibility. He concluded that at low digestibilities, variations in milk yield resulted from variations in intake, but at high digestibilities milk production determined intake.

Dry matter percent and density are also important but rather easily determined. Bull et al. (11) concluded that voluntary intake of mixed diets by lactating cows could be estimated from caloric density. External factors such as temperature extremes or other stressful conditions can also have a marked effect on intake. Bull (10) has noted that reduced intake is the cow's first response to stress.

The typical dry matter intake curve is similar in shape but lags behind the milk production curve. Intake is at its lowest on day of freshening and reaches its maximum two to four months later. It remains high until production is reduced, and declines rapidly at dry off (60). Various researchers (9,15,19,28,39,41,71) have developed prediction equations with moderate success based on the main variables influencing intake. However, Baile (3) states:

> Because of the complexity of the control of feed intake and its interrelationship with energy balance, it is not surprising that prediction equations are only poor guides when applied to a specific situation. Environmental, managerial, and social factors as well as previous feeding experience, physiological conditions (lactation, fat deposition, or growth), the many physical and nutritional qualities of the feed, and various sensory inputs can have a marked effect on feed intake. For a satisfactory prediction of

> feed intake, much more information on the interrelationships of the many factors controlling feeding is required.

Although prediction equations may be accurate on average there are still significant individual differences in intake. Johnson and Trimberger (41) found that individual differences were a very important source of variation in forage dry matter intake. Lahr (46) found that complete diets of less than 60 to 65 percent dry matter may reduce intake by lactating cows. There is also an indication that cows with different sires differ in appetite when fed individually (30), leading to the concept that genetics plays a part in feed consumption independent of milk yield.

PREDICTION EQUATIONS FOR DRY MATTER INTAKE

Although there is skepticism surrounding the ability to predict accurately intake of individual cows, it is an essential aspect of ration formulation. Consequently, various prediction equations have evolved to allow rations to be formulated with a moderate degree of accuracy to ensure the cow receives a ration to meet her nutrient requirements.

Stone (71), in 1960, was the first to predict daily forage dry matter intake. His model contained pounds of daily 4% fat-corrected milk, body weight, and daily weight change with an r-square of .50. He noted that efficiency was highly related to milk production and the more milk produced, the less kilograms TDN required for each additional pound of milk.

Conrad (19) in 1964 reported a correlation coefficient of .811 between digestible dry matter intake and 4% fat-corrected milk using logs of ration digestibility, fecal dry matter per 100 pound body weight, and body weight.

Johnson et al. (41) developed an equation with a correlation coefficient of .59 between forage dry matter intake and 4% fat-corrected milk yield. They felt lactation totals fit the graph best although 50% of the variation was still undetermined. Using backward regression, their equation predicted 308-day total dry matter intake of hay and silage, and contained 308-day fat corrected milk yield, body weight, net gain in body weight, 308-day grain dry matter intake, and age in months at calving. This equation yielded an r-square of .54 and led to the conclusions that intake was affected by stages of lactation and dry period, individual cow differences were the most important sources of variation in forage dry matter intake, and high ambient temperatures could decrease intake and milk yield up to 10 percent.

A statistical analysis of 207 cow balance trials over five years was conducted by Chandler and Walker (15) and used to develop a dry matter intake equation for a least cost ration formulation program. An r-square of .80 was obtained with an equation containing body weight, crude fiber, daily milk production, butterfat percent, and feed type.

Coppock (28) predicted digestible energy intake from stage of lactation, milk yield, and body weight with an r-square of .64. He felt that energy requirements were a function of lactation number, week of lactation, body weight, weight change from previous week, actual milk, solids corrected milk, and days carried calf. He divided the lactation into thirds and noted that the second trimester, the period when the cow is most nearly in energy balance, gave the highest r-square values.

A study of 4135 Holstein records and 704 Jersey records was conducted by Brown et al. (9) and led to prediction models for milk yield and dry matter intake with r-squares of .807 and .741 respectively. They noted that milk yield was the most important variable determining total dry matter intake and for each 100 kg increase in body weight, dry matter intake increased 1.07 kg. The model for predicting the natural log of dry matter intake included stage of lactation, milk production, fat percent, body weight, energy concentration, season, and lactation.

The most recent equation was developed by Holter et al. (39) using 4159 monthly cow trials in one lactation. Significant factors affecting dry matter intake were body weight, fat- corrected milk, days in milk, season, and percents corn and total silage in forage dry matter.

There are a variety of dry matter intake equations which can be used with varying accuracy due to the complexity of mechanisms controlling intake. The question arises as to whether these equations are more accurate for the average individual or for the average of the group. Bines (6) states that simple equations predicting intake from body weight and milk yield are quite accurate in general situations but are of little value in predicting intake of a specific individual.

McGilliard and Conklin (51) discovered a 4.7 percent bias in Brown's (9) prediction equation which is a mathematical consequence of the exponential components of the equation. Thus, prediction for the average cow in the herd was .73 kg greater than average of intake predictions for the herd. Heather et al., (34) compared seven equations available in Great Britain and also concluded that considerable bias still exists in prediction equations and more research is needed to increase accuracy of predicting dry matter intake.

FEEDING COMPLETE RATIONS

Dairying has changed substantially in the last 25 years accompanied by new and more intense management strategies to handle large numbers of animals efficiently and economically.

Complete rations, a mixture of forages, concentrates, supplements, minerals, and vitamins, offer an efficient way to feed groups of cattle. Complete feeds can be utilized as effectively as conventional feeding methods (30,48,49,50,55,66) and have been shown to support high milk production (1,18,20,23,24,30,32,62,66). However, Chandler (14) stated that accurate formulation of the ration is extremely important for complete rations and requires: 1) determination of nutrient concentrations of ration ingredients, 2) proper ration calculation, 3) weighing of feeds, and 4) mixing and blending of these into a uniform feed.

To achieve maximum income above feed cost with complete rations, the rations must be consumed ad libitum (25,35,56,73). The ration must also contain high concentrations of utilizable nutrients, enough fiber to avoid milk fat depression and should be formulated on a least cost basis when choices of feeds are available (73).

There are advantages to feeding complete rations. Coppock (21) cited several including: 1) no preferential feed selection as every bite is nutritionally balanced, 2) parlor feeding can be discontinued, 3) fewer digestive upsets occur in early lactation, 4) unpalatable feeds can be incorporated without substantially affecting intake, 5) the total diet can be formulated quantitatively, 6) additional mineral supplementation may be unnecessary, 7) non-protein nitrogen compounds can be fed for maximum utilization, 8) labor costs of feeding can be reduced, and 9) the cost of purchased feeds can be substantially reduced by bulk purchases.

Complete rations also have several disadvantages. Chandler (14) noted these to be: 1) the investment and maintenance of a mix wagon, 2) disrupted cow flow through the parlor when no grain is offered, 3) magnification of small mistakes in ration balancing, and 4) obsolescence of existing facilities not conducive to feeding a complete feed. Another disadvantage is the inability to determine individual intakes and cows off-feed. Grouping of cows is preferred from an economical and herd health standpoint but there are few experimental data on optimum numbers of cows per group or ration requirements for each group (26) to realize the greatest economy.

PREDICTING INTAKE OF COWS FED IN GROUPS

Do prediction equations reflect the intake of cows fed in groups? Most intake equations are based on cows fed individually to facilitate accurate data collection. However, complete diet feeding incorporates a competive factor since cows eat together at the bunk, causing maximum ad libitum voluntary intake.

Coppock (27) found that cows in groups fed a blended ration of 60% corn silage and 40% concentrate on a dry basis consumed 7.1% more daily dry matter than the same cows fed individually, yet actual milk and 4% fat corrected milk were not significantly different. He fed a blended ration of 60% corn silage and 40% concentrate on a dry basis. The 7.1% extra intake thus resulted in an amount of digestible energy equivalent to 25% of their maintenance requirement. He attributed these findings to increased maintenance from cows moving about freely in the freestall set-up. Coppock's conclusions suggest that all cows in the group consumed 7.1% more dry matter per day, but whether some cows overconsumed substantially and others only slightly is not known. Brown, et al., (9) suggested that cows fed in groups may consume up to 10% more dry matter due to increased maintenance, competition, and wastage. While, nutrient specifications for optimum group rations depend largely on intake of individual cows, the manager neither controls nor is able to determine feed consumption of individuals.

Spahr (73) has given recommendations for group feeding based on the premise that cows usually consume 3.3 to 3.5% of their body weight during peak lactation, with intakes greater than 4% of body weight common in cows producing more than 35 kg milk. He suggested early lactation rations should be formulated so the effect of bulk density on maximum intake is minimized and consumption is controlled primarily by individual physiological factors (73).

Murley and Jones (57) suggested that in a three-group herd, high, medium, and low rations should be formulated for 21, 18, and 15 kg of dry matter intake respectively based on a 600 kg cow. However, regardless of the number of cows per group or the estimated intake, the complete ration should be offered ad libitum for each individual to express her maximum intake potential. Care must also be taken to detect sick cows since daily individual intakes are not known and other means of detection must be developed.

In retrospect, feeding and grouping large numbers of dairy animals is a very important but not well understood practice and more research is needed to determine the system that allows the cow to maximize her output while minimizing input from the dairy producer.

THEORY OF GROUPING

A thorough understanding of the lactation curve clarifies the need for grouping cows when feeding a complete ration. Nutrient requirements vary as a function of body size, milk production, milk composition, and stage of lactation (14). Amount of dry matter a cow can consume affects the concentration of nutrients necessary for a balanced ration.

Cows in early lactation need a concentrated ration to compensate for the demands of peak milk production which occurs 40-50 days before peak intake. Cows are in negative energy balance at these early stages and can lose .45 to 1.3 kg of body weight daily (28). These conditions are conducive to border-line ketosis which results in depressed intake and more weight loss (56). It has been shown that maximum lactation production is dependent on peak milk production (5,44). An additional 200 to 225 pounds of total milk can be expected for each additional pound of peak milk (40). Therefore, high producing cows must be managed to consume large quantities of energy early postcalving (56) to reach high production.

Smith et al. (68) fed three groups of cows either a high (35:47:18), medium (47:35.5:17.5), or low (60:23.5:16.5) forage: high moisture ear corn: concentrate dry matter ration for an entire lactation. They noted that animals fed the medium or low rations were unable to increase their intakes even in the latter stages of lactation to reach energy balances similar to those fed the high ration. Thus, both maximum milk and total milk yield were reduced for that lactation. It was also apparent that feeding lower energy had greater effects on first lactation animals than older animals due to requirements for growth. These results agree with Murley (56) that adequate feeding three weeks prepartum through three to four months of lactation affects profit to a greater extent than adequate feeding at other stages.

Davenport and Rakes (29) claimed that moderate underfeeding during early lactation was not detrimental if midlactation, late lactation, and dry period feeding was adequate for persistent production and regaining lost body weight.

The majority of information favors feeding early lactation cows high energy diets to offset effects of restricted intake and enhance high milk production. Reaching positive energy balance early is also conducive to high conception rates (5) since cows in negative energy balance often do not cycle normally.

The late lactation cow presents the opposite profile. She is in positive energy balance and is more prone to deposit fat rather than maintain high production on a ration of high energy (68). It appears that cows do not regulate intake according to energy needs (22,28,43,62,), especially on corn silage based rations. Mosely et al. (54) noted that dry cows fed 95% and 80% forage rations overconsumed net energy requirements by 18.5% and 30.3% respectively. This type of overconsumption of energy by late lactation and dry cows has led to fat cow syndrome (53), an often fatal metabolic condition where large fat deposits accumulate in the liver and other vital organs. Keys et al. (45) noted there were significant cow deaths when cows were fed a 50:50 forage to concentrate ration throughout lactation and the dry period. Most researchers (4,5,8,13,20,45,53,56,66,67,74) agree that dry cows should be grouped separately from the milking herd. Therefore, all further reference to grouping will include lactating animals only.

GROUPING TO REDUCE VARIATION

In light of the previous discussion, the diverse requirements of a single group of cows make ration formulation difficult. If the herd is maintained as a single group, high producers receive inadequate energy and low producers overconsume energy. Grouping is therefore promoted because it reduces variation among animals in these groups (33).

Grouping implies differences in energy content of rations, most often acccompanied by varying the forage to concentrate ratio (26). The high producing group can receive a very concentrated ration which allows them to produce large quantities of milk while the late lactation cows can receive a lower cost, high forage ration preventing excessive weight gain. Bath (5) feels it important to design a feeding program which allows cows in early lactation to regain lost body weight without promoting fattening during late lactation. Grouping helps achieve these objectives.

Economic consequences of grouping also warrant discussion. Feed cost is usually the largest single expense on most farms and is approximately 50% of the cost of production, so any viable means of reduction should be evaluated (67). Coppock et al. (26) expect greater milk production and more efficient use of feed when cows are fed relative to energy requirements. Cows will therefore peak high but not overconsume expensive feeds later in lactation.

Group rations are often formulated for either average production of the group (5), or average plus one standard deviation (70) such that 83% of the group can meet or exceed their requirements. Thus, up to 50% of a herd fed as one group could be consuming in excess of their requirements.

Several researchers recommend (32,45) feeding at least two rations with different forage to concentrate ratios to early and midlactation cows grouped separately to allow them to reach positive energy balance sooner, produce more milk, consume more dry matter, and lose less body weight (32). Late lactation and overconditioned cows should receive a low concentrate ration since forage intake alone can predominantly meet these cows' requirements (67). Thus grouping can help maximize income received from cows in early lactation while minimizing cost of feeding late lactation animals.

Although the optimum system of grouping has not been determined, most methods consider: 1) efficiency of feed and concentrate allocation, 2) ration specifications for the group, 3) the factors used in obtaining the correct forage to concentrate ratio, 4) labor and housing requirements, and 5) the effect grouping has on milk production (67).

EFFECTS OF GROUPING

Considerable research has been done on the effects of maintaining cows in stratified groups. While many have obtained lower (26,31,54,67,69) or equal (1,29,32,78) production, some have reported greater production (7,17,18,61,67). The discrepency in these results stems from the two main adaptations cows must make as they change from one group to another.

First and foremost they must adapt to a ration change. Secondly, they must also adapt to a social change since cows in a group form a heirarchy (47) and new members must find their niche in the system. Sowerby and Polan (72), in a study of seven herds, noted that shifted cows lost an average of .99 kg milk while unshifted cows lost only .33 kg milk between regular DHI test and a test approximately ten days later and two days after shifting. Milk loss decreased as the study progressed and was predominantly lower in herds which had been grouping before the study. Brakel and Leis (7) also performed an experiment to determine the impact of intergroup transfer on behavior, milk yield, and body weight. They found that milk production decreased 3 percent on the first day following regrouping but after the first day there was no effect on milk yield. Therefore, they concluded cows can be regrouped without significantly affecting milk yield with no ration change. This suggests that cows can adapt to moving between intraherd groups. Therefore, the social effects of grouping probably decrease over time, becoming less consequential as grouping continues.

Effects of the ration change are not as easily offset. Mosely et al. (54) observed that about a 15 day adaptation period was needed when cows received a new ration. Smith et al. (69) reported a 2 kg per cow per day decrease in production the first week after cows switched groups. The magnitude of loss appeared to be related to production at the time they changed groups since cows producing greater than 22 kg milk and first lactation animals producing greater than 19 kg milk lost significantly more production than herdmates producing below these quantities.

Sudden decreases in ration energy seem to have the greatest impact on milk production (1,26,32,54,69) since this can result in decreased energy consumption, lower dry matter intake and ultimately lower milk output. However, results are contradictory since others have found no significant social or ration effects. Clark et al. (17) observed no mean production change between the day before switching and five days after.

Obviously there are some intangible factors involved in successfully managing cows in groups and maintaining high production. To minimize these effects some recommendations can be made. Many researchers (2,4,21,25,33,42,56,57) suggest a minimum of three production groups. This helps reduce variation within groups and among forage to concentrate ratios. Polan and Friend (61) obtained 486 kg more milk in ten months from a three group system versus a one group system. This study took place in a 360-cow commercial herd so all cows were subject to the same environment and forage quality. Researchers have also noted that milk loss during switching lessened as the number of groups increased and severity of the ration changes decreased. Nocek et al. (59) in an experiment examining the effect ration nutrient concentration has on cows moving between groups concluded that nutrient concentration should not decrease more than 15 percent from the previous group ration to maintain milk production at its normal rate of decline.

A successful grouping program also incorporates a regular routine for moving cows and provides adequate bunk space for the number of cows in the group (2). This helps to minimize the stress involved in moving the cows and assimilating them into new groups.

The economic theory of grouping was discussed earlier and data tend to support these ideas but conclusions have been variable. In the study by Polan and Friend (61) of one versus three groups, a return above feed costs of $30.98 per cow was obtained in ten months. The grouped cows actually had higher feed costs of $7.98 more per cow but compensated with 486 kg more milk. Smith, et al., (69) on the other hand, in a study of one versus two groups obtained 88 kg more milk with the single group of cows over a 44 week period. However, the grouped cows had a $30 per cow per year greater income over feed cost due to reduced consumption of concentrate. Everson et al. (32) noted that cows fed a variable forage to concentrate ratio versus a constant forage to concentrate ratio peaked earlier and ate 79 kg more grain. Chandler (13) illustrated hypothetically that $15 to $20 per lactation can be saved by managing cows in a stratified system.

Responses observed in maintaining cows in stratified groups are variable but good management can minimize social and ration effects for grouping to be successful and profitable.

GROUPING CRITERIA AND METHODS

Several factors must be considered when evaluating grouping alternatives. Smith and Coppock (67) feel the main considerations are: 1) herd size, 2) type of feed and facilities, 3) relative feed costs, 4) price of products, 5) physical layout of facilities, 6) labor requirements, 7) herd health, and 8) simplification of the feeding system. These and other criteria have led to the development of various grouping methods. The most common systems are: 1) milk production, 2) stage of lactation, 3) reproduction, 4) age or need for additional growth, 5) body condition, or any combination of these. A survey of 151 randomly chosen Northeast dairymen out of 450 who blended all or most of the ration are summarized in Table 1. One-third of the respondents did not group cows at all. The table represents the remaining two thirds. This survey illustrates the diversity of grouping procedures and incorporation of several methods in one herd as respondents often used more than one criterion to group cows. A more detailed description of some of the main methods will substantiate this point.

Table 1. Criteria for grouping cows as expressed by Northeast dairy producers (60).

Criterion	No. Respondants	Percent
Milk production	109	96
First calf heifers	66	59
Stage of lactation	42	37
Body condition	24	21
Pen size	21	18
Problem cows	11	10
Cows for breeding	5	4
Speed of milking	3	3

Grouping by production is by far the most popular method of grouping. A minimum of three production groups is recommended to minimize ration changes and meet the majority of each group's requirements. This method resembles stage of lactation and reproductive grouping since often the early lactation, high producing cows are open and in the high group. This group will typically average 29 to 32 kg of milk for second lactation and older cows while first lactation animals in this group will average 27 kg of milk per day. The ration will contain a high percentage of concentrate because nutrient demands are high. Intake, however, is often restricted by depressed appetite in early lactation.

The middle group averages 25 kg per day for second lactation and older cows and 20 kg per day for first lactation animals. A medium concentrate ration is fed since intake has usually peaked and maintaining persistency is most important at this stage. Cows should be bred but may not be diagnosed pregnant by the time they enter this group. Therefore, care should be taken to diagnose these cows pregnant as soon as possible after the switch. This is the main disadvantage of this system since it is often necessary to check cows for heat in both the high and middle groups (42).

Finally, the low group will often average 15 to 20 kg milk per day and contain those cows soon to dry off or overconditioned from being in the middle group too long. This ration contains a high percentage of forage which is inexpensive and encourages healthy rumen function. Often late prepartum cows are brought into this group or fed this ration to adapt to the milking herd ration. After freshening they move into the middle group for one to two weeks before they enter the high group. This helps prevent digestive upsets as the ration concentration changes.

Grouping by stage of lactation is similar to production grouping but is based on time periods rather than kilograms of milk. It is most efficient when the range of calving dates in each group is not greater than 30 to 40 days (66). The main advantage to this system is that cows remain in the same group throughout lactation; there is no social change and ration changes can be made gradually as production changes. The main problem with this system is it assumes all cows calving in the same season have the same nutrient requirements and persistency throughout lactation (33). This method places more constraints on reproductive management since the group needs to be observed until all cows are diagnosed pregnant, which may be a long time if difficult breeders are present.

Grouping by reproduction, on the other hand, is compatible with herd health and milking management. Britt (8) has outlined five categories for grouping cows according to reproductive status: 1) early postpartum, prebreeding, 2) breeding group, 3) lactating pregnant cows, 4) nonlactating pregnant cows, and 5) problem cows, open beyond 100 days. This system places its main emphasis on efficient reproductive management but this closely parallels grouping by production and stage of lactation.

Grouping by age or additional growth requirements is based mainly on the physical aspects of the animal. First lactation animals are often smaller and more timid than older cows but need additional nutrients for growth (33) so are grouped separately.

Energy appears to be the most limiting requirement (36,37) for first lactation animals. Roffler and Thacker (63,64) observed that average responses, per percentage unit of added crude protein from 13.5 to 16.5 were 1.2 kg milk for multiparous cows and only .3 kg milk for primiparous cows, suggesting that older cows are more responsive to supplemental protein. However, due to physical size and constraints of intake in early lactation, it is important for young animals to receive a ration concentrated enough to meet their needs while maximizing production.

Jones (42) has outlined a grouping program which incorporates age and need for additional growth. The herd is divided into: 1) first lactation animals, 2) second and older lactation animals with good udders, 3) slow milkers with average udders, and 4) old cows with large udders. This system disregards production and reproductive status, but this can be overcome if herd size is large enough to group first lactation animals separately from older cows. Thus, young animals with good udders can be grouped by production and older animals with varying udder traits can be grouped by production or stage of lactation. This system is flexible depending on herd size and facility constraints.

Grouping by body condition closely parallels stage of lactation, production grouping, and reproductive management since all of these affect body condition. This system is rather subjective and requires close inspection of individual animals. Jones (42) suggests cows less than 200 days in milk form the high group since they are losing and regaining their post-calving body weight at this time. All cows greater than 200 days in milk compose the low group. The main emphasis of this system is to prevent overconditioned cows, but it works best when incorporated into production or stage of lactation grouping.

There is no ideal method for grouping cows as noted from the previous discussion. All methods are rather subjective and do not really conform to the needs of the cow. The most successful systems tend to incorporate several methods while emphasizing production. The majority of cows fall neatly into a designated production group, but there are always problem cows which require judgement decisions. It takes good management to determine where problem cows should be grouped. Clearly a more objective grouping system would be advantageous when deciding how cows should be grouped.

GROUPING BY COMPUTER

McGilliard et al. (52) developed a computer program which simultaneously groups cows based on requirements of crude protein percentage and megacalories net energy per kilogram expected dry matter intake. A computerized simulation study of 110,264 records from 941 herd test days showed this 'Grouper' system placed cows 25, 22, and 15% differently from grouping by test day milk, fat-corrected milk, and dairy merit. The system also had highest intraclass correlations within groups demonstrating that it was superior in placing like cows within the same group.

Grouper utilizes test day milk, test day fat percent, body weight, days in milk, and age to calculate each cow's nutrient requirements. Cows are then ranked in relation to herdmates based on nutrient requirements. Therefore, cows are objectively ranked and grouped according to their nutritional needs rather than by subjective management decisions.

This system contains some unique characteristics not found in other grouping systems. McGilliard et al. (52) suggest cows should have less tendency to become overconditioned in late lactation which may result in fewer health disorders. They recommend implementing the system in actual herds to obtain economic analysis and adapt the program to practical use. This field study was undertaken to examine this system in actual herd situations and obtain further analysis of this grouping system.

MATERIALS AND METHODS

COOPERATOR HERD INFORMATION

Ten cooperator herds were chosen from six Virginia counties with the help of Extension Agent Jerry Swisher in October and November 1983. Herds were selected on the criteria that total mixed rations were being fed to two or more groups of lactating cows, predominant breed was Holstein, and the dairy manager was willing to participate. An outline of responsibilities of VPI and cooperating dairy producers is in Appendix A. A letter of introduction and announcement of visit was sent out November 15, 1983. Table 2 presents the herdcode, location, herd size, group numbers, and primary grouping method of each herd. Herds were visited on November 20, 1983, to obtain herd and management information (Appendix B).

Herd 01 grouped by milk production into two groups. The high and low groups averaged 32 and 20 kg milk respectively. Cows were regrouped soon after test day and fed a corn silage based ration twice a day. Forages were analyzed monthly and rations reformulated when necessary. Group sizes were extremely uneven due to facility constraints. Groups became slightly more even during summer months when shelter was less critical. Dry cows were handled in two separate groups and all cows were taped for body weight postpartum.

Table 2. Cooperator herd characteristics prior to study.

Code	County	Herdsize	Groups	Group sizes	Primary grouping method
01	Rockbridge	157	2	95:30[1]	Milk production
02	Augusta	302	2	126:125	Milk production
05	Albermerle	178	2	145:39	Milk production
21	Hanover	334	5	4(50):100[2]	Milk prod. age
22	Rockbridge	140	1		
30	Augusta	96	2	60:45	Milk production
35	Augusta	138	3	56:28:46	Milk prod. health
47	Pulaski	109	2	64:30	Milk production
56	Montgomery	104	2	50:50	Milk production
96	Augusta	159	2	90:50	Milk production

[1]Group1 : Group2

[2]Two heifer groups size = 50 : two cow groups size = 50 : one late lactation heifer and cow group size = 100

Herd 21 was the largest herd in the study but grouped first lactation animals separately from older animals. Consequently, each parity group was handled as a separate herd. Production and stage of lactation cutoffs for cows were greater than 27 kg milk or less than 100 days in milk, greater than 23 kg milk or 100 to 200 days in milk, and less than 23 kg milk kg milk or greater than 200 days in milk. Heifers were divided at 23 kg milk with late lactation heifers grouped with late lactation cows. Cows switched groups following test day. Total mixed rations were fed three and four times a day to three highest production groups and twice a day to other groups. Rations were corn silage based and reformulated infrequently.

Fewest cows were in herd 30. Group averages were 27 kg milk for high group and 20 kg milk for the low group. Cows were switched following test day if their milk production was below 20 kg milk for two months or if they had gained excessive body condition. A corn silage based ration was fed three times a day in summer and twice a day all other times. Forages were tested semi-yearly and rations reformulated every three months depending on availability of concentrates.

Herd 02 was the largest herd which grouped animals in all lactations together. Groupings were based on milk production but heifers were retained longer in the high group depending on production and body condition. Forages and rations were analyzed and reformulated semi-monthly. Cows were fed corn silage and brewers grain based rations three times a day. Dry cows were handled in two groups.

Herd 96 maintained a high group which averaged 32 kg milk and a low group which included springers. Grouping was based on production and reproductive status although heifers remained in the high group until their production decreased to 20 kg milk. Primary forages were corn silage and alfalfa silage. Rations were fed twice a day and reformulated as necessary.

Herd 47 had two groups of cows with production cutoffs of 23 to 25 kg milk for second lactation and older cows and 20 to 23 kg milk for first lactation animals. Cows were switched following test day and group sizes were flexible. Forages were analyzed every two weeks and rations reformulated as needed. Corn silage based rations were fed twice a day.

Herd 05 maintained two uneven sized groups of cows based primarily on milk production, yet heifers were retained longer in the high group. They were willing to try three milking groups to decrease discrepancy in group sizes. Cows were switched once a month based on milk and stage of lactation. Forages were tested monthly and rations reformulated as needed. The high group was fed twice a day and low group once a day. Main forages were corn silage and alfalfa silage. Herd 05 also participated in the national diversion program and changed management to decrease production to adequate levels.

Herd 56 grouped cows based predominantly on production with a 27 kg milk cutoff for second and later lactation animals and a 25 kg milk cutoff for first lactation animals. Cows were moved following test day and grade cows were switched prior to switching registered cows if possible. Forages were analyzed every two months and rations reformulated on production consistency. Cows received the corn silage based ration twice a day.

Herd 22 was not grouping prior to beginning the study but had altered facilities to begin grouping in January 1984. Forages were analyzed every two weeks and rations reformulated once a month. The ration was based on ammoniated corn silage. Cows were fed a total mixed ration three times a day. Cows producing more than 27 kg milk and heifers producing more than 20 kg milk received varying amounts of a 20% protein concentrate in the parlor. Dry cows were in two groups.

The final cooperating herd, Herd 35, maintained three groups of cows based on milk production and health status. The high group contained cows above 23 kg milk and heifers producing over 20 kg milk. The middle group contained postpartum and mastitic cows, and the low group included the other healthy animals. Cows were fed twice daily and bunks were cleaned once a day. All forages were ammoniated and rations were based on corn silage and free choice hay. Forages were analyzed monthly and rations reformulated as necessary.

DATA COLLECTION

Data for grouping were accessed by microcomputer through the DART (Direct Access to Records by Telephone) program of the Dairy Records Processing

Center (DRPC) in Raleigh, NC. Information obtained for each herd each month included cow identification, test day milk, test day fat percent, body weight, days in milk, age in months, breed code, lactation number, and due date (Appendix C). This information was written to floppy disk and subsequently transferred to the mainframe computer on campus.

Data were also collected from the dairy managers. These included a twice weekly recording of feeds used and amounts fed to each milking group (Appendix D). Cooperators were also asked to record which cows they had in groups different from Grouper recommendations and the reason for this deviation (Appendix E). This information was received by mail or collected during herd visits. Other information obtained during monthly herd visits included feed samples, feed price information, and recommendations or suggestions for improvement of the grouping program. These data were then used to group herds. Necessary adjustments were made and final groupings mailed to cooperators (Appendix F), often within two weeks of test day. All this information was retained in various computer files to be used for subsequent groupings and final analysis.

INITIAL ADJUSTMENTS

Grouper was developed by M. L. McGilliard, J. S. Clay, and R. E. James. The original program was examined in a modeling experiment conducted by Swisher (75) utilizing 110,000 individual test day records. Several changes were needed to adapt the original program for a field study.

The first of these involved calulation of energy requirements. Initially this study sought to group cows and balance rations for these groups according to Grouper recommendations. Grouper calculated group averages and standard deviations for all parameters in each group. Therefore, lead factors could be calculated for NEL and crude protein by adding the standard deviation to the group average, meeting requirements of 85 percent of cows in that group. It was concluded that balancing rations according to Grouper specifications would allow examination of both grouping and feeding aspects of the system. The DAIR4 Ration Balancing program from Virginia Tech was chosen as the best method to use for balancing rations. DAIR4 uses TDN (Total Digestible Nutrients) as an estimation of energy requirements. Therefore, Grouper was modified to calculate TDN requirements in place of NEL.

The second modification involved setting constraints on the five cow parameters used in calculating nutrient requirements. This was to prevent animals with unrealistic data from going through the system unnoticed. The parameters and their limits are in Table 3.

The third modification was to develop a program named Adjust which allowed the user to adjust placement of cows in groups. This was primarily developed to prevent cows from being switched more than once between groups. This program also enabled the user to enter actual average dry matter intake for each group since it was observed these often deviated from

Table 3. Variables and limits used by Grouper to calculate nutrient requirements.

Variable	Minimum	Maximum
Milk (kg)	0	68
Fat (%)	1	9
Body weight (kg)	181	907
Days in milk	1	400
Age at calving (mo)	18	240
Breed code (1-6)	1	6

predicted intake. Each cow's requirements were then adjusted by multiplying by the value obtained from (predicted intake/actual intake).

After creating Adjust, a set of reasons was developed to indicate why cows were in a group different from Grouper recommendation. Reasons, explanations, and the coding system may be found in Appendix G.

FIELD STUDY IMPLEMENTATION

The following discussion for ease of reading and organization was divided into sections by month and gives a chronological discussion of the changes and events. This was to allow the reader to obtain insight into the progression of the field study. The first few months were especially eventful and the bulk of discussion will concern January through July since major changes toward the end of the study were minimal.

JANUARY

December herd test day information was first accessed through DART on January 4, 1984. A cross comparison with DHI sheets showed the last cow to be absent from each record. It was determined this problem originated at the DRPC, so an extra line-feed was added to ensure the last cow was not deleted. Variables for each cow included cow name, test day milk, test day fat percent, body weight, days in milk, age in months, and breed code.

It was noted that files had no identification other than filename. The testdate was incorporated at the beginning of each file. The program could use this testdate in the Grouper report heading so the cooperator could know the testdate of each grouping.

A need for sorting herd 21 files into first lactation or greater animals was solved by adding lactation number to information accessed through DART. These files were then sorted by lactation number on the mainframe computer and two files developed containing separate lactation groups.

Once these initial problems were resolved, herds were grouped for the first time. There immediately seemed to be a problem with the TDN equation since some requirements were unrealistically low. Two other equations were tested with unsatisfactory results. The problem apparently stemmed from attempting to convert NEL requirements to TDN. It was determined that the most accurate method would be to calculate directly TDN requirements for each cow with an equation from NRC (58). Once this was implemented, TDN requirements were accurate.

The first run also highlighted some problems with constraints placed on certain parameters. Several herds had cows greater than 400 days in milk so the maximum value was increased to 1000 days. Another herd had two crossbred cows. It was reasoned that these animals were hybrids of the predominant herd breed. Consequently, for prediction of dry matter intake, these animals received the breed code of the animal immediately preceeding them in the file.

Seven herds were visited on January 14, 1984. December Grouper reports were taken to aid in explanation of the system and to stimulate questions. These reports could not be used for grouping since there was no record of the group cows should have been in previously. Cows could not move between groups more than one time. Therefore, one month's grouping was not sufficient to determine cow placement and fulfill this stipulation.

Forms for recording forage use and additional cow shifting were distributed at this time. A clipboard with a plastic cover was included for ease of use and to encourage cooperators to collect necessary information. The cooperators were enthusiastic and anxious to implement the Grouper system.

January test day information was accessed throughout the month and cows grouped accordingly. Lag time between test day and information availability appeared to be one week to ten days. December and January were regrouped to maintain consistency in the database after program changes had been implemented. Reports for these two months were sent to cooperators. They were advised not to group their cows when it was ascertained that cows were still shifting between groups too frequently to obtain an accurate grouping. One herd of 120 cows had 54 animals in different groups in two consecutive months. It was determined that three months of groupings were necessary before cooperators could be advised to group their animals based on Grouper reports.

At this time a letter describing the field study and Grouper system was sent to extension agents and DHI supervisors of herds on the study. This was to increase awareness of the project and promote cooperation among researchers and those interacting with the cooperators.

FEBRUARY

Several problems became evident by the third month of grouping once the study was underway and trends established. Fat test seemed to have a profound effect on individual cow ranking. This did not seem advantageous since fat test was so variable between individual animals and testing organizations. Some possible solutions included taking an average of each individual's past three tests or setting each cow's fat test at 3.5 percent internally and using a 3.5 percent fat-corrected milk formula. These ideas were supported by the fact that many cows less than 45 days in milk often started lactation in the low group due to depressed fat tests. The idea of forcing cows less than 45 days in milk into the high group could remedy this situation but would not dispell the other effects.

There were also problems with nutrient requirements and ration formulation to meet these requirements. Although requirements remained fairly stable from month to month there was a dilemma between balancing to Grouper requirements after adjusting predicted intakes for actual intake or balancing for a particular level of production. For example, predicted intakes for a high and low group of cows were 18 kg and 15 kg respectively, producing ration requirements of 73% TDN and 16% CP for the high group and 71% TDN and 14% CP for the low group. Actual intakes reported by the cooperator in this situation were 20 kg high group and 19 kg low group. At these actual intakes nutrient concentrations decreased to 66% TDN and 14% CP needed for the high group and 56% TDN and 11% CP needed for the low group. Conceivably, if ration concentrations could be balanced for actual intake with no adverse affects it could be economical but these adjusted ration concentrations were obviously unrealistic.

Another herd had had numerous mastitis and health problems and production was down from normal as a result. This led to low nutrient requirements for each group. The question arose of whether to balance for present requirements or lead cows on to their former production.

In an arbitrary decision for all herds, it was determined that the operator would force cows greater than 305 days in milk out of the high group and animals less than 45 days in milk into the high group. This was done to make room for animals who had to be moved for other reasons. This was justifiable from the fact that these animals were late in lactation and should be close to drying off. February reports were sent out as completed and cooperaters advised to group their herds by the Grouper system.

MARCH

A monthly visit was conducted early in March to seven of ten farms. Herd 05 had started grouping in January and was very pleased with the system.

Herd 22 and herd 35 had not started to group according to Grouper. No contact was made with the managers of herd 01 or herd 02.

The discrepancy between predicted and actual dry matter intake was still evident. Herd 35 had actual dry matter intakes of 25 kg and 20 kg for the high and low groups respectively versus predicted intakes of 17 kg and 16 kg. Consequently the high group required 10.8 percent crude protein and low group 11.2 percent crude protein when using NRC requirements with actual intakes. Thus, low group animals actually required a higher protein concentration than high group animals due to differences in intake. These intakes were adjusted to 21 kg and 17 kg for ration balancing purposes.

One major reason for increased lag time between test day and mailing of Grouper reports was the cooperators' delay in sending feeding and cow switching information back to the University. To speed up this process, a self-addressed stamped envelope was enclosed with Grouper reports mailed to the cooperator.

A telephone conversation with the manager of herd 30 revealed that production was still down. They wanted to increase the ration concentrations to increase production. The low group increased from 66 percent TDN to 69 percent TDN although Grouper recommended 57 percent TDN. High group protein was set at a minimum of 16 percent.

Herd 01 expressed satisfaction with the system in another telephone conversation but was not content with the ration formulations. They felt cows were eating more and needing more than rations reflected. Grouper recommended feeding 13 percent protein to the high group but they were actually feeding a 17 percent protein ration. They also wondered why some cows with high production were in the low group. These animals exceeded the maximum 305 days in milk for the high group. It was decided that only lowest ranked cows exceeding the limit would be moved down to make room in the high group.

At this point in the study, cows and rations seemed to become more settled with less drastic cow movement taking place and rations remaining similar month to month. Some cooperators had expressed concern about heifers with excessive condition remaining in the high group. Since body weights generally are adjusted at time of calving, many animals which had calved at 40 kg were heavier in late lactation, and unless the cooperator updated body weights in DHI records, the program often left these animals in the high group. Therefore, the cooperators were encouraged to update body weights periodically.

A lower limit of 2.5% of body weight was placed on dry matter intake since individuals with extremely long lactation periods or low production would exceed the normal range for dry matter intake prediction equations. Normal predictions resulted in low estimated intake and unreasonable requirements for protein and energy, i.e. 109% TDN and 19% crude protein. The incorporation of this 2.5% lower limit alleviated the problem.

APRIL

A program utilizing a 3.5 percent fat-corrected milk formula was developed to aid in minimizing the affect fat test appeared to have on individual cow ranking.

A telephone conversation with herd 01 to obtain feed information revealed that they would prefer to feed their own rations since the cows were producing well. They still were not comfortable with Grouper formulated rations. This conversation led to further evaluation of the system. Some groups averaged 1.8 kg to 2.3 kg less milk this month and requirements were slightly lower. Questions arose again whether rations should be balanced to recommendations or remain unchanged with the hope production would increase to its previous level. There seemed to be potential for creating a downward spiral with this method of adjusting rations for actual intake rather than setting feeding goals. Even incorporating a lead factor did not remedy the situation since the decrepancy between actual and predicted dry matter intake created unrealistic group requirements. A letter was sent out April 25, 1984, explaining the current situation regarding ration balancing and giving cooperators incentive to send in data needed to group their herds.

Herd 05 stopped grouping during summer months while cows were out to pasture. Test day information continued to be accessed and Grouper reports generated during these months to maintain the database.

MAY

A monthly herd visit was conducted in early May. Herd 22 was still experiencing the effects of initiating a grouping system. The managers were noticing that younger cows seemed to adapt to switching groups better than older cows. Therefore, their adherance to Grouper recommendations was moderate. Herd 01 was becoming more satisfied with the system and what it offered but still was not convinced about the ration formulations. Herd 30 and herd 96 were very cooperative and returned information promptly. Herd 35 and herd 02 returned information less frequently.

To resolve the discrepancy between predicted and actual dry matter intakes, a new set of equations developed by Holter (38) was examined. The major differences between these equations and Brown's (9) equations were as follows:

1) Season affect was replaced by Julian date.
2) There was a separate equation for first lactation animals.
3) Four percent fat-corrected milk was used rather than actual milk.
4) Percent forage from corn silage and percent forage dry matter from any silage was used instead of crude fiber percent (which had been held constant at 16.6%).

Since Holter's equations were from a more recent study, it was determined that these equations would be used to predict more closely actual intake.

At this point, project objectives were reevaluated and it was ascertained that the main goal was to test a grouping method rather than a total grouping and feeding system. Consequently, ration balancing continued only in two herds where the cooperator requested it.

Holter's (38) dry matter intake prediction equations were incorporated into a new program known as FCGroup. The original program and the program using 3.5 percent fat-corrected milk formula were discarded. The age adjustment factor was modified to include two lactations rather than one by increasing maintenance requirements from 20% down to zero from 25 to 45 months of age. Formulas and discussion for determining nutrient requirements and dry matter intake may be found in Appendix H.

The number of cows changing groups seemed to be excessive this month but this was probably a result of incorporating the new equations. There were still considerable problems trying to get cooperators to return sheets promptly.

JUNE

June was an uneventful month except further discussion with herd 35 disclosed they were not grouping their cows by the Grouper system. Their record keeping system was highly computerized and not well suited to using the printed Grouper reports because the owner would have to enter group numbers for individual cows into his database. A system allowing them to access Grouper reports through computer was developed to meet their needs and encourage participation.

JULY

Five herds were visited early in July. Many cooperators were pleased with the grouping system but did not like the feeding aspects or rations being formulated. Herd 96 suggested there should be some method of distinguishing those cows soon to dry off so they could be placed in the low group for ease of drying off. Herd 05 began grouping again with two milking groups.

In light of the past visit, ration balancing was discontinued. There appeared to be too much discrepancy between predicted and actual intakes to balance rations with accuracy. The debate whether cows were simply eating more, needing more nutrients, or both was unresolved.

The suggestion by herd 96 was further examined. Files from DART were expanded to include projected calving date. The program was modified to calculate dry date from this and automatically force cows within 45 days of dry period into the bottom of the low group. The farmer had the option of specifying a particular length dry period. This modified program was used to group July herds. Cows greater than 305 days in milk were no longer forced out of the high group.

AUGUST

A visit to herd 21 revealed they were very pleased with the system. The only animals not adhering to Grouper were open cows which were required by the manager to be in the high group. Two herds required no manual cow adjustments this month. It appeared that inclusion of dry dates and new prediction equations had alleviated earlier manual adjustments. Herd 30 dropped off the study since grouping was discontinued and computerized feeders were installed. Testday information for herd 30 continued to be accessed and Grouper reports generated but not mailed.

SEPTEMBER

Monthly herd visits showed the study to be running smoothly as a result of fine tuning the program and terminating ration balancing. Overconditioned heifers were still creating some discrepancy since initial body weights were leaving them continuously in the high group if they had been small at calving. Increasing body weights automatically to account for growth was discussed but not incorporated.

OCTOBER

Little activity took place this month. The program was modified to automatically place cows less than 45 days in milk in the high group. This resulted in fewer manual adjustments.

NOVEMBER

A quadratic equation was developed to automatically increase heifer body weights 91 kg throughout first lactation. The 91 kg increase was an estimate obtained in discussions with cooperators. This was entered as an option in the program.

DECEMBER

Cooperators received two Grouper reports this month. One included adjusted heifer body weights. They were asked to compare these weights to their estimation of heifers' actual weights.

The constraint on fat percent was also modified to automatically acquire a value of 3.5% if the fat% constraint was outside the range 1.0% to 9.9%. This was included since cows frequently had a fat percent of 0.0 if there were problems with sampling or estimating records.

FIELD STUDY CONCLUSION

Herds were grouped through December 1984. A herd visit was scheduled in February to obtain closing remarks and general evaluation of the system by cooperators. A letter was sent out listing some of the more important aspects to be considered in the closing visit.

The final visit was the culmination of the field portion of the project. At this point eight cooperators were still grouping their herds. Survey questions are in Appendix I. A synopsis of answers to questions are in the conclusion. Those not discussed were not addressed by cooperators or they noted no change.

A letter was sent in early March announcing the termination of the project and explaining what analysis would be done. In early May, another letter containing some questions on a postcard was sent to cooperators. This was intended to determine whether they still preferred to be on Grouper once they had time to redevelop their own systems.

The program underwent some slight modifications during this time. Some of the opening questions were rearranged for ease of use. A change was also made to the body weight adjustment formula. Analysis of data available at the University revealed heifers gained an average of 62 kg between the beginning of their first and second lactation. Postcalving bodyweight was regained after seven weeks and continued to increase linearly throughout lactation. The equation:

$$\text{growth (kg)} = 0.27*(\text{ Days in milk} - 85 \text{ })$$

with a minimum increase of 0 kg and a maximum of 60 kg was developed to reflect this increase based on days in milk.

ANALYSIS OF DATA

Three major areas were analyzed. The first examined changes in herd year information by evaluating differences in average DHI variables from January 1984 to January 1985, good and fair cooperators, and project and non-project herds of represented counties. Secondly, to examine differences in cow movement and group characteristics relative to a conventional grouping method, Grouper was compared to a milk-only grouping system utilizing the same computer program. Lastly, these two systems were evaluated on the basis of economic and practical merit.

Data for the first analysis were obtained from DHI records. January 1984 and January 1985 project herd variables were compared with the model:

$$Yijk = \mu + Hi + Tj + Eijk$$

Yijk = DHI variable effect

μ = project herd mean

Hi = effect of Ith herd

Tj = effect of Jth year

Eijk = random error

Dependent variables are in Table 7. A contrast was also made of variable means to estimate changes from 1984 to 1985. The purpose of this analysis was to see if differences existed between year average values from beginning to end of study between herds and years. Herd 30 was deleted from this analysis since it did not complete the study.

This same dataset was used to compare good and fair cooperators as determined by their level of adherence to Grouper recommendations. The model $Yij = \mu + Ci + Eij$ was used where:

Yij = DHI variable effect

μ = project herd mean

Ci = effect of Ith cooperator category (good or fair)

Eij = random error

Dependent variables (Yij) were change from January 1984 to January 1985 in year average milk, year average fat percent, persistency, first lactation peak milk, second and older lactation peak milk, average body weight, and average days open for each herd.

Project and non-project herds in counties represented were compared to see if similar or dissimilar trends existed. DHI files from November 1983 and November and December 1984 were used with the model $Yij = \mu + Pi + Eij$ where:

Yij = DHI variable effect

μ = herd mean

Pi = effect of Ith herd designation (project or non-project)

Eij = random error

Dependent variables (Yij) were the change from 1983 to 1984 year average milk, year average fat percent, persistency, first lactation peak milk, second and older lactation peak milk, first lactation mature equivalent milk, and second and older lactation mature equivalent milk for each herd. Least squares means were obtained for all previously mentioned analyses.

The second area of analysis contained several parts. The database for these analyses was created by grouping all herd months with the completed Grouper program and a milk-only grouping program. The milk-only program was adapted from Grouper and ranked cows by milk production but included all constraints on individual cow information and cow movement. Eight different files were generated containing data on each herd month grouping. For example, one file contained original Grouper DART files. Another had only herd and group average values on all variables for both systems. All herd months containing more than two cow groups were deleted from these analyses to create a dataset uniform in number of groups. Only test day information between January 1, 1984 and January 5, 1985 was used to confine data to twelve monthly test days per herd and cover all seasons.

The first analysis determined variables affecting individual cow and ration values. The model was $Yijklm = \mu + Hi + Mj + Sk + Gl + (SG)kl + Eijklm$ where:

Yijklm = DHI variable effect

μ = herd mean

Hi = effect of Ith herd

Mj = effect of Jth month

Sk = effect of Kth system (Grouper or milk-only)

Gl = effect of Lth group (1 or 2)

(SG)kl = interaction effect of Lth group and Kth system

Eijklm = random error

This analysis used group average values (Yijklm) of individual cow and ration variables for each herd month group to detect differences and examine effects of each independent variable. Of primary interest in this model was the group by system interaction which was useful for determining whether the groups within one system differed more than groups in the other system. If significant, further analysis would be warranted to examine how these groups and systems differed. Identical datasets were used to compare systems so it was assumed that the system effect would be insignificant but was included to permit interaction of group and system in the model.

The second analysis looked at individuals fitting into one of four categories derived from the Grouper group number and milk-only group number for each herd month, i.e. high Grouper and high milk-only = category 11. The model was Yijkl = μ + Hi + Mj + Ck + (HC)ik + Eijkl where:

Yijkl = herd variable

μ = overall herd-month mean

H_i = effect of Ith herd

M_j = effect of Jth month

C_k = effect of Kth category (11,12,21,22)

$(HC)_{ik}$ = interaction effect of Kth category and Ith herd

E_{ijkl} = random error

Least squares means from this analysis presented a profile of the cows placed in similar groups by each system and animals which Grouper placed in the high group but milk-only placed in the low group and vice versa. Interaction of category and herd was used to test category effect.

Another analysis obtained average days in milk for each grouping system when cows switched from high to low groups. Variables of parity groups, defined as first lactation animals or second and older lactation animals, were also examined. Along this same vein, lactation was divided into four stages based on days in milk. These were 0 to 45 days, 46 to 105 days, 106 to 255 days, and over 255 days. Cows were again divided into parity groups and percent cows from each parity group in each stage of lactation was determined and compared across grouping systems.

Homogeniety of cows within groups was an important statistic since Grouper had previously been shown to be superior in placing like cows within the same group (52). Variance components of group and residual were estimated for TDN%, TDN kilograms, CP%, CP kilograms, dry matter intake kilograms, milk kilograms, and fat-corrected milk kilograms. The intraclass correlation, or repeatability, among cows in the same group, herd, and month was estimated from variance components. The model was $Yijkl = \mu + Hi + M(i)j + Gk + Eijkl$ where:

$Yijkl$ = variable effect

μ = herd mean

Hi = effect of Ith herd

$M(i)j$ = effect of Jth month in Ith herd

Gk = effect of Kth group (1 or 2)

$Eijkl$ = random error

Expected mean squares for group and residual were

$$EMSgroup = \sigma^2 e + N\sigma^2 g$$

$$EMSerror = \sigma^2 e$$

where:

$\sigma^2 e = MSe$

$\sigma^2 g = (MSg - MSe)/N$

N = number of cows per group in balanced data

The formula $\sigma^2 g/(\sigma^2 g + \sigma^2 e)$ was used to obtain the intraclass correlation among cows in a group. The denominator of this formula represents total variation composed of between group and within group variation and the numerator containing only between group variation. As the correlation approaches 1.0, within group variation becomes very small indicating that animals in that group are very similar but animals between groups are very dissimilar. The opposite condition exists when the correlation is near 0.0. Variance components obtained in this analysis were used to obtain correlations for Grouper and milk-only to see which system produced higher correlations within groups and greatest variance between groups for nutrient concentrations.

Another analysis in this set looked at changes in group averages before and after cows were forced to move by the Adjust program. This determined if Adjust was altering group averages significantly. Adjust did not move cows forced by Grouper in either group due to days in milk or dry date, but upheld the rule that cows needed to be recommended twice before moving to another group provided there was room in the group.

The last major area of interest examined economic consequences of formulating rations for each group of cows by obtaining an average feed cost per cow per day based on average requirements for TDN and CP at predicted dry matter intake and a total average monthly feed cost obtained by multiplying this figure by number of cows per group for each month group. These values were compared across systems to see if Grouper produced a more economical basis for feeding cows in groups due to the characteristics of animals placed in each group. To facilitate ration balancing for groups in this analysis, a range of four values each of TDN% and CP% were obtained for high and low groups based on group averages across herds. Eight ration combinations were obtained for each group to ensure that a full spectrum of CP% and TDN% was represented. One CP% was coupled with two TDN% since TDN exhibits a wider range than crude protein. Rations were formulated for each nutrient combination using Virginia average feed values and current prices for five commonly used feeds. These were corn silage, alfalfa hay, corn grain, 44% soybean meal, and an all-purpose mineral mix. Nutrient analysis and prices of these feeds may be found in Table 4. Average estimated dry matter intake for high and low groups was used in formulating standard rations. A lower limit of 19% ADF was set to ensure adequate fiber. TDN was also restricted to a minimum of 66% and maximum of 73% due to limits imposed by the inability to balance a ration outside of these values because of the ingredients chosen. A cost per kilogram dry matter was obtained for each of the nutrient combinations after rations were formulated. Table 5 presents the nutrient combinations and actual and predicted cost per kilogram dry matter. The predicted cost was obtained using the model $Yijk = \mu + Ci + Tj + Ci^2 + Tj^2 + (CT)ij + Eijk$

$Yijk$ = cost effect

μ = ration cost mean

Ci = effect of Ith crude protein percent

Tj = effect of Jth TDN percent

Ci^2 = effect of Ith crude protein percent squared

Tj^2 = effect of Jth TDN percent squared

$(CT)ij$ = interaction effect of Ith crude protein percent and Jth TDN percent

$Eijk$ = random error

Table 4. Nutrient analysis[1] and cost per ton of feeds used for ration formulation.

Feed	DM%	CP%	TDN%	ADF%	$/ton
Corn silage	39	7.6	66	29	28
Alfalfa hay	86	17.3	57	42	110
Corn grain	86	10.1	88	3	170
Soybean meal	90	48.7	85	10	185
Mineral mix	95	0	0	0	340

[1]Averages Va Tech Forage Testing lab and NRC, 1978.

Table 5. Nutrient concentrations and actual and predicted cost per kilogram dry matter intake for high and low groups.

Group	CP%	TDN%	Dollars per kilogram Actual[1]	Predicted[2]
High	17	73	0.152	0.152
High	17	71	0.138	0.138
High	16	73	0.152	0.152
High	16	69	0.126	0.126
High	15	73	0.150	0.151
High	15	71	0.139	0.139
High	14	73	0.149	0.149
High	14	69	0.127	0.127
Low	15	71	0.134	0.134
Low	15	67	0.112	0.113
Low	14	69	0.121	0.119
Low	14	66	0.109	0.107
Low	13	71	0.129	0.130
Low	13	67	0.104	0.107
Low	12	69	0.116	0.115
Low	12	66	0.101	0.101

[1]Calculated from formulated rations.
[2]Calculated from regression equations.

Regression coefficients for two equations were obtained with this same model which could be used to calculate an average feed cost per cow per day for each group in each herd, month, and system. These regression coefficients are in Table 6. The equations predicted cost per kilogram per day for the concentrations of nutrients in the group average. Their accuracy for the eight ration combinations can be seen in Table 5. Total cost per cow per day was obtained by multiplying cost per kilogram by average predicted kilograms of intake for cows in the group. These costs were analyzed with the model

$$Yijklm = \mu + Hi + Mj + Sk + Gl + Eijklm$$

where

Yijklm = cost/cow/day mean

μ = herd mean cost

Hi = effect of Ith herd

Mj = effect of Jth month

Sk = effect of Kth system

Gl = effect of Lth group

Eijklm = random error

and costs were compared across groups and systems to see if one system produced more economical ration combinations than the other. Obtaining total monthly feed costs helped to show impact of differences in system costs.

Table 6. Regression coefficients for determining cost per kilogram dry matter for a high and low group of cows.

Variable	High group	Low group
Intercept	0.052182	1.559238
CP%	-0.024245	0.016665
TDN%	0.001543	-0.051069
$CP\%^2$	-0.000379	0.000220
$TDN\%^2$	-0.000023	0.000439
CP%*TDN%	0.000507	-0.000293
r^2	0.99	0.98

RESULTS AND DISCUSSION

THE PROGRAM

Changes from the field study resulted in a substantially automated Grouper program, requiring a minimum of user input. The user is prompted to enter herd identification, date, number of groups, size of groups except last, and desired length of dry period. In addition, the program optionally updates heifer body weights, automatically forces cows less than 45 days in milk into the high group, cows within 45 days of dry off into the low group, and sets percent of forage dry matter from corn silage and any silage both at 60% of ration dry matter. Once Grouper has run, the user is prompted to enter number of reports desired and whether to run Adjust or quit. Adjust is a program designed to compliment the Grouper program. It automatically checks the previous month's grouping and makes necessary cow movements resulting from cows needing to change groups if recommended twice, or return to a previous group if not recommended twice. The program also maintains the group sizes entered in Grouper. The user must enter identification and name of the file from the previous month. After the program executes, the user is prompted to enter the number of printed reports desired. The scheme of computerized data flow for both programs is presented in Appendices J and K.

There are several items which were set to default for ease of producing a database and to automate the program for a DRPC. Should a dairy manager desire, these items could be included to add more control and flexibility to the grouping system since there are still situations where management overrides will be needed. For example, a cow's production may be extremely low one month so Grouper places her in the lower end of the bottom group. Although this may be the first recommendation to move her to this group, she does not return to her previous group because it became full of other cows with a higher ranking needing to move to that group. The dairy manager may desire to keep open cows in high groups longer or move overconditioned animals into low groups sooner. It may also be desirable to place cull cows in certain groups. Adjust allows for this type of manipulation since it can be programmed to print to screen every cow switching groups and force certain individuals into specific groups. Grouper can also be changed to prompt the dairy manager for actual percents of forage dry matter from corn silage and any silage for a more precise dry matter intake prediction, to leave heifer body weights unadjusted for growth, or not to force cows less than 45 days in milk into the high group. There is also a milk production grouping system available containing all the options and constraints of Grouper but ranking cows on milk production rather than nutrient requirements. This was developed for analysis purposes.

TRENDS IN HERD PARAMETERS

There were no control groups, i.e. conventionally grouped cows, to compare against experimental groups in this study. Consequently, measures of Grouper influence had to be obtained by examining changes in DHI herd variables prior to and at the end of the study. Caution must be exercised when drawing conclusions from these results since there are an infinite number of variables affecting these parameters on a day to day basis over which any grouping system would have little effect. Furthermore, the program experienced major modifications through the first seven months of the study and cooperators did not adhere strictly to Grouper recommendations so the effects of the system are masked by these conditions.

Table 7 presents least squares means and differences for herd variables taken from January 1984 and January 1985 DHI summary sheets. Persistency and average age of second and older lactation animals were significantly different ($p<.05$) from 1984 to 1985 with persistency increasing and average age decreasing. However, there were enough variables tested for significance that these two are likely significant by chance alone. Persistancy may have a relationship to the grouping system since the system should promote more accurate grouping and feeding therefore increasing persistency of milk production. It should be also noted that this persistency measures only a one month change in expected test day milk yield. Average age of second and older lactation animals is probably unrelated to the grouping system. Although statistically nonsignificant, production tended to decrease for all measures of milk yield except M.E. milk for cows which increased. These production trends are probably related to extreme decreases in production experienced by two cooperators, one on the national diversion program and the other with problems unrelated to the study.

Table 7. Least squares means and resulting difference of project herd variables from January 1984 to January 1985.

Variables	1984	1985	1985 minus 1984
Total cows	176	184	7.89
Test day milk (kg)	21	21	-0.34
Test day fat (%)	3.68	3.39	-0.22
Year avg. milk (kg)	7610	7503	-107
Year avg. fat (kg)	260	262	1.81
Percent in milk	86	88	1.22
Persistency (%)	99	104	5.00*
Days in milk	158	160	1.22
M.E. milk heifers (kg)	8241	8124	-117
M.E. fat heifers (kg)	285	278	-7.41
Peak milk heifers (kg)	28	27	-0.45
Avg. age heifers (mo)	29	29	0.0
M.E. milk cows (kg)	8396	8427	30.6
M.E. fat cows (kg)	285	282	-2.32
Peak milk cows (kg)	36	36	-0.20
Avg. age cows (mo)	60	59	-1.11*
Avg. body weight (kg)	580	577	-2.52
Avg. days open	118	117	-1.33
Avg. days dry	66	69	3.33
Calving interval (mo)	13	13	-0.05
Avg. days 1st breed	80	81	0.67
% breedings serviced	58	59	1.11
% successful	45	45	0.33

* significant ($p<.05$)

M.E. designates mature equivalent.

To determine if differences existed between the degree of participation of cooperators, they were divided into good and fair categories based on adherance to Grouper recommendations as witnessed by the researchers. There were six classified good and three classified fair. Table 8 has least squares means for each category and the difference from 1984 to 1985 in selected herd variables. Table 9 follows with actual differences between 1984 and 1985 values presented by herd and category. Decrease in days open was significantly larger for good cooperators and probably related to the degree of management existing on each farm. However, comments elicited during the final interview indicate that dairy managers tended to spend more time grouping and paid more attention to their animals during the field trial which could have reduced average days open by increasing heat detection practices. Persistency clearly increased for both categories of cooperators but production decreased for all measures of milk yield for good cooperators. This is contradictory to increased persistency although peak milk loss probably affected production enough to offset effects of increased persistency. As noted previously, two good cooperator herds lost substantial amounts of total average milk. One of these herds participated in the national milk diversion program and purposely decreased production by lowering nutrient content of rations and drying off all animals at 18 kg milk. The other producer encountered numerous nutrition and dry matter intake problems from adapting new feeds and feeding practices unrelated to the study.

The third analysis in this set examined how these same variables including M.E. milk and fat for both parity groups compared with non-project herds

Table 8. Least squares means and the difference in herd variables from January 1984 to 1985.

Variable	Good herds	Fair herds	Good minus Fair
Total avg. milk (kg)	-210	98	-308
Total avg. fat (%)	0.12	-0.05	0.17
Persistency (%)	6.8	1.3	5.5
Heifer peak milk (kg)	-0.98	0.60	-1.58
Older peak milk (kg)	-0.68	0.76	-1.44
Avg. body weight (kg)	0.00	-7.57	7.57
Days open	-7.00	10.00	-17.00

*Project herds did not differ significantly ($p<.05$) between good and fair cooperators.

Table 9. Individual good and fair cooperator variable differences from January 1984 to 1985.

Class	Total milk (kg)	Fat (%)	Persistency (%)	Hpeak[1] (kg)	Cpeak[2] (kg)	Bwt[3] (kg)	Dopen[4]
Good	332	-0.11	-2	0	0.4	-41	-26
Good	-609	0.06	12	0.9	0	41	9
Good	-1334	0.31	13	-4.5	-6.8	-4	-15
Good	475	0.19	4	1.8	1.8	-14	6
Good	-408	0.14	10	-3.6	-0.4	-4	-12
Good	282	0.15	4	-0.4	0.9	23	-4
Fair	-103	0.17	1	0.4	0.4	-18	5
Fair	25	-0.08	-4	0.9	0.4	4	6
Fair	372	-0.24	7	0.4	1.4	-9	19

[1]Heifer peak milk
[2]Older peak milk
[3]Body weight
[4]Average days open

in the same counties. All variables were statistically nonsignificant indicating that project herds changes did not differ from other herds in these counties during the study. Table 10 has least squares means of variables tested. Noted that many changes observed in project herds are large compared to non-project herds but standard errors for the project herds are large. However, some of the same trends observed in previous analyses are exhibited. Persistency increased in all herds but more in project herds. Total milk decreased only in project herds but peak milk and M. E. milk for heifers and cows decreased in all herds. Because of small numbers of project herds, these analyses are inconclusive.

GROUPER VERSUS MILK-ONLY

This group of analyses sought to compare Grouper to a conventional grouping system based on milk production. The dataset was created from actual project herd records and utilized test dates and group sizes which were obtained during the field project corresponding to each herd and month. However, individual cow groupings were generated strictly by computer using the present programs of Grouper and milk-only. Each herd and month was grouped using both systems which allowed for a month to month comparison of the two grouping systems in each herd.

The first analysis was used to compare group average between systems. Group averages per cow for milk production, fat percent, body weight, days in milk, age, crude protein percent, TDN percent, and dry matter intake were obtained for each herd and month. These variables along with kilo-

Table 10. Changes in least squares means of project and non-project herd variables from November 1984 to November 1985.

Variable	Project herds(9)	Non-project herds(133)
Total milk (kg)	-98	3.6
Total avg. fat (%)	0.08	0.04
Persistency	2.75	1.39
Heifer peak milk (kg)	-0.45	-0.14
Cow peak milk (kg)	-0.39	-0.15
Avg. body weight (kg)	-6.23	2.34
Avg. days open	1.25	1.62
M.E. milk-heifers (kg)	-122	-6.7
M.E. milk-cows (kg)	-77	-41

M.E. designates mature equivalent.

grams crude protein and TDN were compared by groups between systems to see what variables differed between high groups and low groups across systems. Table 11 presents least squares means, standard errors, and Grouper minus milk-only values for each group. Crude protein percent was the only nonsignificant variable among like groups across systems. All other variables including kilograms of crude protein required were significantly different when compared across systems within groups. From Table 11, Grouper placed younger, smaller, lower producing animals with higher butterfat test in the high group resulting in higher nutrient percentages but lower nutrient kilograms than milk-only due to lower kilograms dry matter intake required. On the other hand, Grouper placed older, larger, higher producing animals in the low group resulting in lower nutrient percentages but higher nutrient kilograms and higher dry matter intake than milk-only. This supports the Grouper theory that younger smaller cows need a more nutritionally concentrated ration so should stay in the high group longer while older, larger animals which can consume larger amounts of dry matter would move to low groups sooner, creating groups which are more alike in nutritional requirements.

Analysis of variance of these data revealed herd, month, group, and the interaction of group by system to contribute significant variation to all variables except crude protein percent. There was no interaction implying groups within one system did not differ more than the other system in crude protein percent. System effect was significant only for average age although systems should not differ since they contained identical cow

Table 11. Least squares means of individual cow data and nutrient requirements, standard errors, and Grouper minus milk-only by group and system.

System/group	CP%	TDN%	CPkg	TDNkg	DMIkg	Milkkg	Fat%	FCMkg	BWTkg	DIM	Age
Grouper/ 1	15.4	71.2	2.75	12.70	17.82	27.70	3.46	25.43	572	123	46
Milkonly/ 1	15.3	70.3	2.81	12.91	18.35	28.61	3.38	25.95	588	114	53
Grouper/ 2	12.5	61.9	2.05	10.15	16.35	18.47	3.67	17.55	605	237	56
Milkonly/ 2	12.6	63.1	1.97	9.87	15.63	17.23	3.77	16.64	583	249	47
Standard error	0.05	0.18	0.01	0.05	0.04	0.17	0.02	0.14	1.2	1.8	0.3
G-M, group 1	0.14	0.93*	-0.06*	-0.20*	-0.53*	-0.91*	0.07*	-0.51*	-16*	9*	-6*
G-M, group 2	-0.09	-1.13*	0.08*	0.27*	0.72*	1.24*	-0.10*	0.91*	22*	-13*	9*
Standard error	0.08	0.26	0.02	0.06	0.06	0.24	0.03	0.20	1.6	2.6	0.4

* significant ($p<.01$)

information. This phenomenon must be attributed to differences in group sizes between herds and few sums of squares for system.

The next analysis placed cows into one of four categories based on group number in both systems. By examining at least squares means of cows placed in the same group by both systems and those placed in opposite groups in the two systems, a profile of differences in grouping systems was developed. Table 12 presents categories, percent of cows per category, and least squares means for each category.

Category 11 (high group both systems) contained the greatest percentage of cows since high groups usually contained the majority of animals. Categories 11 and 22 contained 80% of the animals which demonstrates that the two grouping systems placed cows in different groups 20% of the time. An examination of least squares means presents the same pattern as observed in the previous analysis. Grouper placed cows with lower milk production, higher fat test, smaller body weight, younger age, and more days in milk in the high group while milk-only placed animals with these characteristics in the low group. The opposite situation existed in category 21 which is low Grouper and high milk-only. Thus Grouper favored those animals which were smaller and younger but required more concentrated rations. An examination of nutrients required in category 12 revealed Grouper placed those animals needing fewer kilograms of nutrients in the high group and those animals needing more kilograms of nutrients in the low group as opposed to milk-only in category 21. This situation is a function of expected dry matter intake and the nutrient concen-

Table 12. Least squares means of cow variables categorized by cows in the same group and different groups in each system.

CAT[1]	Grouper	Milk-only	% of cows	Milkkg	Fat%	Bwtkg	DIM	Age	TDN%	CP%	TDNkg	CPkg	DMIkg
11	High	High	49	29	3.4	581	105	50	72	16	13	2.9	18
12	High	Low	10	20	3.7	529	207	30	71	14	11	2.2	15
21	Low	High	10	26	3.3	621	156	65	65	14	12	2.5	18
22	Low	Low	31	16	3.8	601	264	53	61	12	10	1.9	16

[1]Category based on group number in each system, i.e. CAT 11= high Grouper,high milk-only.

trations required at different amounts of intake. This supports Grouper theory since older, larger animals would move to low groups sooner than in milk production grouping systems since their intake consumption would allow them to meet requirements from the low group ration.

Days in milk when cows switched groups were examined to determine how these differed between systems. Cows were divided into two parity groups with first lactation animals separate from older animals. Swisher (75) had found substantial differences in this variable, but it was hypothesized that the most recent Grouper and milk-only programs had enough constraints on cow movement to diminish these differences. Table 13 has average days in milk when animals switched groups and the range of days in milk in each system. As a whole, systems did not differ. However, some differences are clearly evident when parity groups were considered. Grouper kept first lactation animals in the high group 95 days longer than milk-only. On the other hand, Grouper moved older animals 39 days sooner on the average. Again, it can be observed that Grouper favored younger, smaller animals due to restricted dry matter intake and high energy demands. Grouper also tended to leave animals in the high group longer as evidenced by the higher maximum values when cows switched groups. This is probably related to the influence fat percent exerts on nutrient requirements and inability to accurately predict intake at these extreme stages. This represents trends found in previous analysis (52) where cows classified as incorrectly grouped by the Grouper system, i.e. cows in high milk group who should have been in the low group, were 70 kg larger, 16

Table 13. Average days in milk and range when cows switched groups by system and parity group.

Parity group	Grouper	Max	Min	Milk-only	Max	Min
First lactation	253	625	47	168	530	46
Older	177	694	46	216	649	46
All animals	199	694	46	200	649	46

months older, and in milk 48 days longer than cows accurately grouped in the high group.

Along this same premise, lactation was divided into four stages based on days in milk. These stages were obtained from work done by Swisher (75) except stage one includes animals less than 45 days in milk instead of 46 to be consistent with grouping constraints in this project. Percent of cows in the high group was determined at each stage for each parity group and system. This analysis helped determine when the greatest shift occurred between groups, how systems differed, and how this compared to previous findings. Table 14 presents results from this analysis.

Grouper kept first lactation animals in the high group much longer since almost half were still there during stage 4 compared to 15% for milk-only. Milk-only shifted approximately the same percent after stage 2 and stage 3 while Grouper made the greatest shift after stage 3. Since all animals less than 45 days in milk are forced into the high group, stage 1 is expected to contain 100% of animals grouped. It should be noted that in all other stages in this parity group, Grouper exceeds the percentage of cows in the milk-only groups by an obvious margin. The nutrient requirements and restricted intake of these animals warrant their placement in the high group until growth and production declines allow them to consume adequate nutrients in the low group.

Grouper did not place older animals as favorably relative to the high group. Milk-only percentages exceeded Grouper percentages in both stage

Table 14. Percentage of cows in high group by system and parity group at four stages of lactation.

Stage	Days in milk	Grouper %	Milk-only %
		----- First lactation -----	
1	<45	100	100
2	46-105	94	72
3	106-255	81	44
4	>255	44	15
		-- Second and older lactation --	
1	<45	100	100
2	46-105	77	93
3	106-255	40	21
4	>255	17	20

2 and 4 although Grouper had a considerably larger percentage in stage 3. It should be noted that stage 2 contained almost the reverse values from those for first lactation animals. Both systems shifted the most animals after stage 2 but milk-only had a dramatic shift at this stage which is the result of cows decreasing production after reaching peak milk and becoming pregnant. This large shift was not evident in first lactation animals since they tend to exhibit greater persistency throughout lactation. Grouper obviously considers more aspects of the animal as witnessed by the gradual decline in percentages rather than one major shift as observed in milk-only. The systems do obtain similar percentages in stage 4. These trends are similar to those observed by Swisher (75). However, constraints placed on cow movement in this current study eliminated any differences in stage 1, and restricted animals from moving more than once. Also, cows within 45 days of dry date were forced into the low group which may have affected some results.

An important aspect of analysis was to determine if Grouper was superior to milk-only in producing large intragroup correlations and small inter-group correlations as had been found previously (52). Variance components between and within groups were estimated and used to compute ratios and correlations for dependent variables. These can be found in Table 15. As noted from Table 15, results are similar for percentages of TDN and CP but dissimilar when compared to kilograms TDN and CP. Grouper produced higher intraclass correlations and ratios than milk-only when considering percentages of TDN and CP. However, milk-only yielded similar trends when

Table 15. Correlations and variance components for Total Digestible Nutrients (TDN), Crude Protein (CP), Dry Matter Intake (DMI), and milk within and between groups by systems.

Functions of variances	Grouper	Milk-only	Grouper	Milk-only	Grouper	Milk-only
	TDN%		CP%		Milk (kg)	
Between groups[1]	48.27	29.16	4.78	3.99	45.83	67.64
Within groups[2]	33.33	42.35	2.58	2.95	37.86	27.55
Ratio[3]	1.45	0.69	1.85	1.35	1.21	2.46
Correlation[4]	0.59	0.41	0.65	0.57	0.55	0.71
	TDN (kg)		CP (kg)		DMI (kg)	
Between groups[1]	3.57	4.82	0.27	0.37	1.25	3.82
Within groups[2]	3.14	2.55	0.23	0.18	5.37	4.16
Ratio[3]	1.14	1.89	1.17	2.05	0.23	0.92
Correlation[4]	0.53	0.65	0.54	0.67	0.19	0.48

[1] $\sigma^2 g$
[2] $\sigma^2 e$
[3] $\sigma^2 g / \sigma^2 e$
[4] $\sigma^2 g / (\sigma^2 g + \sigma^2 e)$, likeness of cows within a group

kilograms of TDN and CP were examined. This can be explained by the effect dry matter intake has when considering percentages of nutrients required in a ration. Milk-only is superior in placing cows with similar dry matter intakes into the same group as indicated by greater intragroup correlations and less within group variances. This results in cows with similar requirements for kilograms of nutrients being placed together. However, Grouper tends to place cows with dissimilar dry matter intakes together ($r = 0.19$) since cows are grouped by percentages required in a ration. Percentages of nutrients are a function of dry matter intake so cows with dissimilar dry matter intakes may be placed together based on concentrations of nutrients required as a result of predicted intake.

Grouper is based on the premise that some animals with high intake predictions and high requirements for kilograms of nutrients can consume enough of a low group ration to meet requirements. Therefore, it is not necessarily desirable to have high intragroup correlations for dry matter intake.

It is also of interest to note that the difference in correlations for Grouper versus milk-only is greater for TDN% (.18) than for CP% (.08) indicating that Grouper has a greater effect on TDN%. Thus there is a greater chance of misgrouping cows on energy requirements than protein requirements when using the milk-only system.

McGilliard et al. (52) obtained correlations of .61 for net energy ratio and .66 for crude protein percent. So although several constraints were imposed on the system during its modification for field use, the homogeneity of cows within groups did not differ greatly from the original program.

The last analysis in this set examined whether group averages of variables changed significantly after the Adjust program was executed to make necessary forced movements of cows to uphold restrictions on when cows could switch groups. This was to determine if forced movements were altering groupings enough to affect original group requirements for TDN% and CP%. All results were insignificant ($p>.05$) indicating that Adjust had no effect on averages for variables in each group.

The information contained in these analyses comparing Grouper to milk-only presented evidence consistent with the basic principles of the Grouper system. Even with constraints imposed on cow movement, increasing heifer body weights for growth, and forcing cows into groups because of calving or dry-off, the analysis was similar to previous findings (75). Grouper, more than the milk grouping system creates groups with cows more closely correlated in nutrient concentrations required in the ration. This results in a high group composed of more heifers, animals with more restricted intake due to smaller body weight, and those that produce more butterfat. The low group contains not only low producers but older, bigger animals which can consume sufficient nutrients from a low group ration due to the ability to ingest large amounts of dry matter. The next section will examine whether this is an economically feasible method of grouping dairy cattle.

ECONOMIC ANALYSIS

Determining the economic consequences of grouping cows with Grouper versus milk-only was difficult since there was no method to account for differences in income or to determine the costs associated with each system except on a theoretical basis. Although actual feeding data were available for some herds it was incomplete, reflected conditions in a drought year, and actual intakes were different than predicted in high groups for most herds. Consequently, standard feed analyses, common feeds, and predicted dry matter intake values were used to estimate the cost of feeding animals based on the average nutrient concentration required for each group in each herd, test day, and system.

Table 16 depicts average feed cost per cow per day for each group and each system. These are averages of costs calculated from average CP% and TDN% for each herd month group in conjunction with prediction equations earlier described. High groups were not significantly different between systems. Daily feed cost for the average cow in the high group differed less than one cent between systems. As noted from Table 16, Grouper was significantly ($p<.05$) more expensive when low group cost per cow per day and herd cost per cow per day were compared between systems.

To investigate further the causes of these differences, an average monthly feed cost per herd was obtained and is presented in Table 17. It costs approximately $122 more per month to feed cows on the Grouper system which accumulates to $1464 in a year. There is considerable variability in

Table 16. Least squares means of average feed cost per cow per day by group and system.

Group	System ($/cow/day) Grouper	Milk-only
High	2.48	2.47
Low*	1.68	1.62
System average*	2.08	2.05

*Grouper cost significantly (p<.05) more than milk-only when comparing low groups and systems overall.

Table 17. Average monthly feed cost ($/mo) for each herd each system and the value of Grouper cost minus milk-only cost for each.

Herdcode	No. of cows	Grouper ($/mo)	Milk-only ($/mo)	Grouper minus Milk-only ($/mo)
01	161	9211	9120	91
02	305	14670	14426	244
05	175	10065	9943	122
22	135	8388	8235	153
30	97	4575	4484	91
35	149	6680	6527	153
47	107	6954	6954	0
56	111	5886	5795	91
96	156	9333	9180	153
Average		8418	8296	122

costs of the systems but in no herd was Grouper less expensive than milk-only.

These results are not consistent with the idea that feed costs should decrease in the Grouper system since each cow should be consuming more nearly her specific requirements. It was hypothesized that more of the inexpensive low group ration should be consumed by large cows who can meet their requirements eating this ration rather than the expensive high group ration. Conversely, it was thought the cows moved to the high group by Grouper would eat less feed and save money. However, it appears that when the high group becomes more homogeneous, the energy concentration required for that group increases due to requirements of cows in that group. Therefore, the effect of less feed consumed is offset by higher cost per kilogram. The Grouper low group required a lower concentration of nutrients than the milk-only low group, but this lower cost per kilogram is offset by higher dry matter intake resulting from the size of cows in this group. This makes Grouper the more expensive system theoretically, especially in the low group. Table 18 illustrates this by examining four months of an individual herd's feed cost per cow per day for each group and system.

There are some other points to be considered when drawing conclusions from this analysis. Although Grouper was theorized to be more economical, the high cost ingredients, i.e. soybean meal and corn grain, made up a small percentage of the low group ration. The ration composition in this group is usually changed by increasing or decreasing type or amount of forage

Table 18. Comparison of four months of Grouper and milk-only rations by groups for an individual herd.

Month	Jan	Apr	Jul	Oct
Grouper Group 1				
No. cows	50	63	54	52
CP%	15.5	16.8	16.4	16.2
TDN%	71	73	73	73
DMI (kg)	20.2	19.3	19.0	19.4
$/kg	.14	.15	.15	.15
$/cow	2.81	2.93	2.89	2.94
Total $/mo.	4286.91	5629.50	4754.25	4662.75
Milk-only Group 1				
No. cows	50	63	54	52
CP%	15.3	16.6	16.3	16.1
TDN%	69	73	73	72
DMI (kg)	21.0	19.6	19.4	20.3
$/kg	.13	.15	.15	.15
$/cow	2.66	2.97	2.95	2.95
Total $/mo.	4057.03	5707.80	4855.02	4683.32
Grouper Group 2				
No. cows	37	44	33	43
CP%	12.6	13.8	13.3	13.3
TDN%	66	67	66	66
DMI (kg)	17.5	17.0	16.7	17.6
$/kg	.10	.11	.10	.10
$/cow	1.79	1.87	1.75	1.84
Total $/mo.	2023.21	2504.04	1760.28	2418.02
Milk-only Group 2				
No. cows	37	44	33	43
CP%	12.7	14	13.4	13.4
TDN%	66	68	66	66
DMI (kg)	16.5	16.6	16.1	16.5
$/kg	.10	.11	.10	.10
$/cow	1.70	1.90	1.69	1.73
Total $/mo.	1913.22	2549.75	1698.63	2269.48

fed. This has less impact on price than changing composition of the high group ration by changing amounts of these high cost ingredients. If a producer fed the same rations as required in a milk-only system, money would be saved in the Grouper system.

Another consideration is that although rations could not be formulated for more than 73% TDN, the majority of cows in the high group required a higher concentration, especially in the Grouper system. Conceivably, many cows in the high group would consume to capacity to meet their energy needs. This consumption could result in higher dry matter intake and more cost associated with the high group. This would also be a possibility in the milk-only system although the energy concentration in this group was not as high due to higher intake predictions.

It should also be mentioned that in considering these systems, there is no measure of increased health associated with more accurate feeding practices, effects of heifers receiving adequate nutrients for growth and production, losses in production associated with moving cows between groups at differing amounts of production, or influence of feed availability and cost on differences between the two systems. It is also possible that if lead factors were used in ration formulation, the system costs may be similar since Grouper produced smaller lead factors. The price ratio of milk to feed can have a marked effect on the way dairy managers design feeding programs and this could shift the benefits of one grouping system over another. Another consideration is the common practice of switching first lactation animals at lower production than older animals in a milk production grouping system. This could result in even less difference between systems since the theory of Grouper is to ensure that these smaller, younger animals receive adequate nutrients for production and growth. However, Grouper was designed to account for more than an individual's production since fat test and body weight exert considerable influence on nutrient needs and intake predictions. Therefore, Grouper places animals in groups automatically and more accurately than relying only on milk production to determine all of an animal's needs.

Though the Grouper system theoretically costs more to feed, analyses have demonstrated that cows have available a diet which more nearly matches most of their needs. If this does not result in higher production and healthier cows then the concept behind balancing rations has dubious economic validity. In this study, there is no measure of these benefits or of the production loss or increase realized by holding heifers longer in the high group while shifting older cows sooner to the low group.

CONCLUSIONS

The Grouper program resulting from this field study is sufficiently automated and practical to be used on microcomputers or available as a DHI option. Mechanics of operator intervention would vary with the computerization. Conclusions to be drawn from this study indicate that Grouper is a successful method for grouping dairy cows. Comments made by cooperators during the final survey were positive, such as:

1) All cooperators liked the system and felt it had definite merit.

2) Seven of 8 would pay a nominal fee for the service.

3) Each cooperator used information provided on the reports differently to accomplish specific goals.

4) Many felt they spent more time grouping their cows but considered this advantageous since they paid more attention to individual cows.

5) Cooperators still on the project did not want it discontinued.

6) Seven of 8 felt the information was unique.

Only eight cooperators were interviewed since two had dropped the study before completion. An additional questionaire sent to cooperators four months after completion of the project revealed that of the five responding, all would prefer to be on the Grouper system even after readjusting to their own system.

From a practical management standpoint, Grouper offers the dairy manager an opportunity to see how each cow relates to the rest of the herd based on nutritional requirements and an objective approach to grouping the herd. Group averages and standard deviations produced by the program can be used as a guide for lead factors and ration balancing either based on milk production or actual requirements for CP% and TDN%.

Evidence indicates the Grouper system may produce higher feed costs than the milk-only system when rations are formulated to system recommendations. However, this study was designed to evaluate a grouping system in actual herd conditions while the economic analyses were derived under conservative theoretical conditions. As a grouping system, Grouper feeds cows most accurately, ensuring that several characteristics of the animal are considered when placing her in a group receiving a particular ration. Before Grouper can be considered both a grouping and feeding system, researchers must have a better understanding of: a) intake of cows fed in groups with various ration formulations, b) effect of genetic differences on nutritional requirements, c) long-term effects of adequately feeding first lactation animals, d) production changes associated with moving cows between intraherd groups at various amounts of production, e) and long-term effects of preventing overconditioning of cows in late lactation.

Grouper appears to be an effective management tool to aid the dairy producer in grouping cows more accurately. Further research would be helpful to determine long-term economic aspects of one system versus another under identical environmental conditions.

SUMMARY

A field study was developed and conducted to evaluate the Grouper system of assigning cows to groups based on requirements of crude protein and TDN per kilogram expected dry matter intake. Specific objectives sought to measure and evaluate economic and practical merits relative to conventional grouping methods, identify managerial benefits, and assess the practicality and convenience of the system as rated by participating dairy managers.

The Grouper system was implemented in ten cooperating dairy herds for one year. Individual cow data were accessed from the Dairy Records Processing Center at Raleigh and included cow identification, test day milk production, test day fat percent, body weight, days in milk, age, breed, and lactation number. Cows were grouped using the Grouper program. Feed consumption data and a record of cows not assigned according to Grouper recommendations was kept by the cooperator and collected at monthly herd visits or by mail. The program was modified several times as the field study progressed: 1) TDN% replaced NEL, 2) constraints were placed on all cow variables, 3) Adjust program was developed temporarily for manual cow movement, 4) dry matter intake prediction equations were updated, 5) restrictions were set regarding cow placement after calving and when a cow could switch groups, 6) due date was used to force cows into the low group shortly before drying off, 7) heifer body weights could be adjusted

automatically for growth, and 8) milk production could replace nutrient requirements as the primary grouping criterion.

Analytical procedures examined changes in DHI herd management variables from beginning to end of the study. The Grouper program and the milk production grouping program were compared on the basis of homogenity of groups, cow placement, profiles of groups, and economics. Data for the latter analyses were obtained by grouping cows each herd test day using both programs with identical contraints on cow movement.

Analysis of DHI variables revealed no significant changes in herd information which could be attributed to the Grouper system given the wide range of conditions affecting these variables.

Although the program was revised to work more practically in actual herds, it still placed younger (46 versus 52 months), smaller (572 versus 588 kg) cows in the high group and older (56 versus 47 months), larger (605 versus 583 kg) cows in the low group compared to the milk-only system. This was consistent with previous research (52). The younger, smaller animals need the higher concentration of nutrients typical of a high group ration while the older, larger animals can consume enough nutrients to meet their requirements on a low group ration. Twenty percent of animals were grouped differently between systems indicating that systems group cows differently. Grouper also placed a higher percentage of first lactation animals in the high group through lactation, with 44% still in the high group at 256 days in milk compared to 15% for the milk system.

Milk-only kept more older lactation animals in the high group except during mid lactation. Grouper produced more homogeneous groups with higher intragroup correlations for crude protein percent (.65 versus .57) and TDN percent (.59 versus .41) resulting from greater variance between groups than the milk-only system.

A theoretical analysis of anticipated feed cost per cow per day showed Grouper at $2.08 to be more expensive than milk-only at $2.05 per cow per day when average feed costs were predicted for each herd month group. Increased energy concentrations in high groups and higher dry matter intake in low groups served to offset expected savings from feeding more of the lower cost low group ration and less of the higher cost high group ration. This economic analysis, however, did not consider potential benefits of the Grouper system, such as increased production and healthier cows.

This study has shown the Grouper system to be a viable method for determining how cows in large herds should be placed in groups. The computer program has been modified to work in commercial herd situations but has retained the characteristics that make it unique. Because economic comparisons are of ultimate importance, more complete examination of actual costs and returns of Grouper compared to other systems must be pursued before final conclusions can be drawn regarding its usefulness as a feeding system. However, as a grouping system it is superior to the milk-only system.

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APPENDIX A. FIELD STUDY RESPONSIBILITIES

RESPONSIBILITIES OF VPI:

Data collection
- herd visits - beginning of trial and semi-monthly
- collect forage samples
- feed consumption data
- cows not adhering to Grouper recommendations
- significant health changes
- problems encountered

Ration balancing
- rations balanced initially, then as warranted by forage changes
- balanced according to group averages plus one standard deviation

RESPONSIBILITIES OF COOPERATORS:

- adhere to Grouper for one year beginning January 1984
- complete forage use sheets weekly
- submit price information on purchased feeds
- note cows calving and body weight at calving
- note health changes
- record cows not adhering to Grouper recommendations and reason.
- allow VPI to obtain copy of DHI herd sheets directly from Raleigh.
- complete surveys
- present detailed personal testimony regarding Grouper system

APPENDIX B. INITIAL SURVEY OF PROJECT HERDS.

INFORMATION SOLICITED ON PRESENT GROUPING SYSTEM:

Criteria for grouping
- size of groups
- determinants of groups
- ration formulation program
- treatment of first lactation animals
- treatment of sick animals
- reproductive problem cows
- prepartum and postpartum cows
- switching procedure

Miscellaneous
- dry cow management
- bunk maintenance
- forage use
- feeding system
- flexibility of group numbers
- opinion of present system

APPENDIX C. DART FILE ACCESSED FOR GROUPING

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841110
000002,051.0,3.8,1400,106,082,3,5,0000
000011,039.3,3.6,1400,289,064,3,4,0000
000015,028.6,3.7,1400,334,065,3,4,0206
000055,082.3,2.7,1400,079,067,3,4,0000
000056,075.0,3.4,1300,110,065,3,4,0720
000062,070.0,3.1,1300,079,134,3,9,0000
000098,079.5,4.3,1400,098,056,3,2,0000
000169,085.0,3.7,1500,143,082,3,6,0719
000177,091.5,3.9,1400,052,049,3,3,0000
000178,082.5,3.8,1300,030,050,3,3,0000
000180,070.5,2.3,1200,071,048,3,3,0810
000181,089.5,0.0,1400,012,050,3,3,0000
000185,082.5,4.3,1500,024,050,3,3,0000
000186,108.0,3.9,1300,322,037,3,2,1012
000271,062.5,3.8,1100,107,026,3,1,0705
000272,073.5,3.4,1200,099,026,3,1,0716
000273,074.5,3.4,1200,036,027,3,1,0000
000275,054.5,2.7,1200,100,025,3,1,0000
```

Year Month Day
Cow, milk (lb), fat%, body weight (lb), days in milk, age (mo), breed, lactation number, due date

APPENDIX D. FORAGE USE SHEET.

GROUPER 1984

Group #:

Week	Corn sil.	Haylage	Hmc	Conc			No. of Cows

Group #:

Week	Corn sil.	Haylage	Hmc	Conc			No. of Cows

APPENDIX E. RECORD OF COWS NOT ADHERING TO GROUPER RECOMMENDATIONS.

GROUPER 1984

Additional cow shifting or cows not adhering to recommendations

Date	cow	from gr	to gr	reason

APPENDIX F. SAMPLE GROUPER REPORT

HERD: TEST
DATE: 19 OCTOBER , 1984
NO. OF COWS: 19
NO. OF GROUPS: 2
GROUP 1: 10
GROUP 2: 9

GROUPER **
DAIRY SCIENCE DEPARTMENT
VIRGINIA TECH
BLACKSBURG 24061

GROUP 1

COW	RANK	MILK	FAT	BWT	DIM	AGE. LACT	BRD	DRY DATE	TDN%	CPROT%	DM
000022	1	79.0	3.5	1300.	11.*	78.5	3	0/ 0	85.	19.2	39.2
000008	2	54.0	3.1	1117.@	114.	31.1	3	3/25	71.	15.1	35.1
000007	3	50.0	2.9	1010.@	102.	27.1	3	4/10	70.	14.8	32.7
000023	4	60.0	3.3	1400.	38.*	46.2	3	5/22	67.	14.4	41.1
000012	5	65.0	3.1	1400.	154.	116.8	3	4/28	66.	14.4	42.8
000001	6	68.5	3.0	1400.	90.	46.2	3	5/22	66.	14.4	44.4
000019	7	48.0	3.2	1300.	246.	54.2	3	2/ 9	65.	13.6	35.6
000017	8	52.0	3.0	1300.	49.	37.2	3	0/ 0	65.	13.6	37.9
000011	9	35.0	3.4	1010.@	102.	28.1	3	5/ 1	66.	13.2	29.4
000006	10	36.0	3.8	1194.@	243.	40.1	3	4/29	65.	13.1	31.4
AVERAGE		54.8	3.2	1243.	115.	51.			69.	14.7	37.0
S. DEV.		13.9	0.3	153.	80.	28.			6.	1.8	5.0

GROUP 2

COW	RANK	MILK	FAT	BWT	DIM	AGE. LACT	BRD	DRY DATE	TDN%	CPROT%	DM
000015	11	50.5	2.7	1400.	194.	69.4	3	3/ 9	63.	13.1	37.0
000025	12	35.5	3.4	1100.	194.	44.2	3	4/22	62.	12.7	30.3
000020	13	50.0	2.8	1300.	89.	42.2	3	4/13	61.	12.8	37.8
000018	14	40.0	3.5	1300.	209.	63.4	3	12/28	62.	12.6	34.5
000016	15	30.5	3.6	1500.	270.	56.3	3	4/ 1	53.	9.9	37.5
000021	16	32.0	4.9	1400.	316.	66.4	3	11/26	61.	12.0	35.0
000014	17	10.0	4.0	1500.	254.	80.5	3	11/12	36.	5.4	37.5
000004	18	40.0	3.5	1215.@	278.	24.1	3	11/ 8	71.	14.1	32.0
000013	19	21.0	4.0	1400.	437.	59.3	3	11/18	47.	8.4	35.0
AVERAGE		34.4	3.6	1346.	249.	56.			57.	11.1	35.2
S. DEV.		13.0	0.7	131.	96.	17.			10.	2.8	2.6

- COW MUST BE IN LOW GROUP (WITHIN 45 DAYS OF DRY DATE)
@ - COW'S WEIGHT HAS BEEN ADJUSTED FOR GROWTH
* - COW MUST BE IN HIGH GROUP (LESS THAN 45 DAYS IN MILK)

COW	RANK	GROUP	COW	RANK	GROUP	COW	RANK	GROUP	COW	RANK	GROUP
000001	6	1	000011	9	1	000016	15	2	000021	16	2
000004	18	2	000012	5	1	000017	8	1	000022	1	1
000006	10	2	000013	19	3	000018	14	2	000023	4	1
000007	3	1	000014	17	2	000019	7	1	000025	12	2
000008	2	1	000015	11	2	000020	13	2			

APPENDIX G. ADJUST REASON CODES.

Reasons (restricted to ten):

1. Grouper recommendation.
2. Special cases (group size constraints, etc.).
3. Less than 45 days in milk.
4. Not recommended for two months to switch groups.
5. Recommended for two months to switch groups.
6. Greater than 305 days in milk (moved from high group to allow room for others.
7. Into group since cows may not move more than one group in two month period.
8. Moved due to group constraints and recommended at least once.
9. In group from previous month.

APPENDIX H. EQUATIONS FOR CALCULATING NUTRIENT REQUIREMENTS AND PREDICTING DRY MATTER

Nutrient requirements for TDN and crude protein were calculated separately for each cow each test day based on the sum of requirements for maintenance and production as designated by NRC (58). Lactating cows have approximately 10-15% greater requirements for maintenance than dry non-pregnant cows. These requirements also provide enough energy for normal activity of cows fed in freestall systems. Energy and protein for maintenance is a function of body weight and age of the animal. Animals in first and second lactation need 20% and 10% respectively more energy and protein for growth above that required for maintenance. Additional amounts of these nutrients are also needed for both milk and butterfat production. The following formulas were used to determine the nutrient needs for maintenance and production for each cow each test day in the grouping system.

Maintenance:

$$\text{TDN (kg)} = (0.0093 + 0.0351 * (\text{body weight kg})^{75}) * (1.2 - 0.01 * (\text{Age mo.} - 25))$$

$$\text{CP (g)} = 104.78 + 0.73 * (\text{body weight kg}) - 0.00015432 * (\text{body weight kg})^{2} * (1.2 - 0.01 * (\text{Age mo.} - 25))$$

$$\text{Age mo.} = 25 \text{ minimum, } 45 \text{ maximum}$$

Production:

$$\text{TDN (kg)} = \text{milk kg} * (0.155 + 0.0423 * \text{fat\%})$$

$$\text{CP (g)} = \text{milk kg} * (4586 + 1036 * \text{fat\%})/100$$

Each sum of maintenance and production for kilograms TDN and grams CP was converted to percentage of dry matter intake by the following formulas.

$$\text{TDN \%} = (\text{TDNkg} * 100)/ \text{DMIkg}$$

$$\text{CP \%} = (\text{CPg} / \text{DMIkg}) * 0.1$$

DMI = predicted dry matter intake

Prediction equations for dry matter intake were initially those of Brown (9).

$$\text{DMIkg} = e$$

$$\text{DML} = 0.519776 + 0.04177 \quad \text{(for Oct,Nov,Dec,Jan,Feb,Mar)}$$

- 0.004122 (for Apr,May,Jun)
- 0.037648 (for Jul,Aug,Sep)
- 0.000827 * (days in milk)
- 0.148073 * (natural log days in milk)
+ 0.33922 * (natural log kg milk per day)
+ 0.099266 * (kg fat per day)
+ 0.000675 * (body weight kg)
+ 0.018001 * (16.66% crude fiber)
- 0.000557 * (16.66% crude fiber)^2

where DML = natural log dry matter intake

Prediction equations were changed to those developed by Holter (38) during the sixth month of the study.

Dry matter intake (kg) prediction for first lactation animals.

DMI(kg) = -36.3608
- 0.2166 * (days in milk)
+ 2.0404 ^{5}* (days in milk)^2
+ 1.96782 * (natural log days in milk)
- 0.00848 * (Julian day)
+ 2.392 ^{5}* (Julian day)^2
+ 4.61768 * (natural log body weight kg)
+ 5.5925 * (natural log 4% fat-corrected milk kg)
- 6.1311 ^{5}* (% corn silage in forage dry matter)^2

Dry matter intake (kg) prediction for second and older lactation animals.

DMI(kg) = -91.773
- 0.05362 * (days in milk)
+ 6.5993 ^{5}* (days in milk)^2
+ 3.696708 * (natural log days in milk)
- 0.00935 * (Julian day)
+ 2.6666 ^{5}* (Julian day)^2
- 9.0645 ^{6}* (body weight kg)^2
+13.2217 * (natural log body weight kg)
+ 0.00346 * (4% fat-corrected milk kg)^2
+ 3.637 * (natural log 4% fat-corrected milk)
+ 0.1277 * (% corn silage in forage dry matter)
- 9.5055 ^{4} (% corn silage in forage dry matter)^2
- 6.193 ^{5} (% silage in forage dry matter)^2

Both corn silage percent and silage percent in forage dry matter were set to default at 60% since these values tended to maximize predicted intake.

Holter (38) also included a breed adjustment factor for intake.
DMI = DMI * (1.107) for Ayshire, Guernsey, and Jersey.

APPENDIX I. FINAL SURVEY QUESTIONNAIRE.

1. What influence has Grouper had on your grouping system? What have the benefits been?

2. Have you made any major management changes since the Grouper program program started and would these changes continue without continuing on the Grouper system?

3. Did you notice any economic value to the Grouper system? Was there any effect on the feeding program?

4. Does Grouper offer unique or valuable information not available elsewhere or in a more convenient format?

5. Was the unnecessary information on the Grouper sheets?

6. Did you spend more or less time grouping your herd?

7. Did you notice any significant changes in peak milk, persistency, or herd health while on the Grouper system?

8. Were there any repeat mistakes or problems that consistently showed up on the reports?

9. What was your most frequent reason for disagreeing with Grouper placings and what percent of your herd did you feel should be grouped differently?

10. What type of dairy producer do you feel would benefit most from Grouper?

11. Did you use the TDN% and CP% as a guide for ration balancing?

12. If Grouper were available through DHI, would you pay for the service?

13. Do you have any suggestions or changes to the Grouper program that you would like to see?

14. Do you feel that Grouper had any effect on the trends in your rolling herd average?

APPENDIX J. APPENDIX J. FLOW OF GROUPER PROGRAM.

1. Operator enters:
   a. Herd name
   b. Date
   c. Length of dry period desired
   d. Cows less than 45 days in milk in Group 1? Y/N
   e. Heifer body weights increased for growth? Y/N

2. Computer reads DART herd file.

3. Checks validity of each cow record.
   a. Invalid -- cow not ranked, listed at report bottom
   b. Valid -- calculates dry matter intake, TDN, crude protein requirements, and percentages

4. Operator enters
   a. Number of groups
   b. Size of each group except last

5. Calculates means and standard deviations of TDN% and CP%

6. Standardizes TDN% and CP% with (y-x) / std. deviation

7. Marks cows to be forced into a particular group

8. Checks size of group 1 after forced moves
   a. If too large -- check with operator to increase capacity

9. Ranks all cows not forced (Grouper algorithm)

10. Add forced cows to group 1 and fill with ranked cows

11. Rerank group 1

12. Create other groups similarly

13. Force remaining cows and cows to dry off into last group

14. Recalculate group averages and standard deviations

15. Run Adjust program (optional) to check where cows were last month

16. Create index by cow identification for report bottom.

17. Print report

APPENDIX K. FLOW OF ADJUST PROGRAM

(After first grouping, adjusts cows for where they were last month.)

1. Computer reads current grouping.

2. Computer reads grouping information from previous month.

3. Computer reads group sizes from current grouping.

4. Operator chooses Automatic adjustments? Y/N
   If yes:
      a. Computer counts cows to be moved back to previous group.
      b. Highest ranked cows are moved first to group 1.
      c. Lowest ranked cows are moved first out of group 1.

5. Operator can manually adjust cows.
   a. Add cows
   b. Delete cows
   c. Force cows into particular groups.

6. Computer rechecks group sizes.

7. Calculates group averages, standard deviations, and cow index.

8. Prints report.

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