

CASE STUDY: Effect of pen change on daily milk yield of dairy cows

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ABSTRACT

The objective of this experiment was to determine the effect of pen change on daily milk yield by dairy cows over the first 10 day (**d**) after changing pens in a commercial setting. The study was conducted during fall and winter of 2010 to 2011 in 2 Wisconsin dairy herds. In Herd A, 20 % of cows in 2 study pens were randomly assigned to either treatment (**M**) or control (**NM**); half the experimental cows were in M and half were in NM. On d 0, M cows were switched between the 2 study pens. In Herd B, 10 cows were randomly assigned to each M and NM across each of 5 study pens with M cows switching pens on d 0. Daily milk weights for M and NM were analyzed for 10 d prior to and 10 d after d 0 using Proc Mixed of SAS with parity, treatment, d and treatment * d as Fixed effects and cow within treatment as a Random effect. In Herd A, least squares means for average daily milk yield were 32.0 and 32.4 kilograms (**kg**)/d per cow for M and NM, respectively. In Herd B, least squares means for average daily milk yield were 49.3 and 49.4 kg/d per cow for M and NM, respectively. The least squares means for M and NM groups did not differ by the least significant difference for any day within a herd. Moving groups of animals between pens did not have deleterious effects on milk yield.

Keywords

Dairy cow, grouping, milk yield, pens

INTRODUCTION

It has long been a debate of dairy producers and nutritionists whether regrouping cattle is an economically viable decision. An economic advantage may result from cost savings if grouping cows of similar management or nutrition requirements does not cause

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production losses. Furthermore, feeding specific nutrients (i.e. nitrogen and phosphorus) closer to animal requirements across lactation can reduce the excretion of these nutrients and thus the environmental impact of dairy farms. The cluster method of McGilliard (1983) defines how cows may be grouped and fed to maximize income over feed cost (IOFC) using CP and NE_1 requirements as determinants. Expanding upon this model and using August 2011 corn, soybean meal and milk prices, an average dairy farm could see an increase of \$0.10 per day (**d**) per cow in IOFC in moving from a one group to a two group feeding system “V.E. Cabrera (2011, University of Wisconsin-Madison, 279 Animal Sciences 1675 Observatory Drive, Madison, Wisconsin, personal communication)”. It is a practice on some farms to group cows by reproduction status or milking time to save on labor needs, but others are reluctant because they believe that regrouping will have a negative impact on production. Previous dairy cattle behavior research on social interactions was focused on smaller groups of cows, often less than 20 cows, and cows at lower production levels, most less than 25 kilograms (**kg**) per d. Today’s commercial dairy operations commonly have group sizes greater than 80 cows and production levels greater than 34 kg/d. VonKeyserlingk, et al. (2008) studied one focal cow placed into an established group of 11 cows and found that her milk yield decreased 3.7 kg ($P < .05$) on the first d after the move compared to her average of the 3 d prior to the move. However, milk production returned to baseline levels on d 2 after the move. Brackel and Leis (1976) introduced 4 cows into an established group of 20 cows and observed a 0.5 kg per cow trend ($P > 0.12$) for a decrease in FCM for the focal cows the first d after the move compared to the average of 3 d prior to the move. Hasegawa et al. (1997) switched half of the cows between two pens of primiparous cows and observed

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similar milk yield for moved animals the wk following the switch compared to the wk prior, but a 4.7% decrease ($P < .05$) in milk yield during the second wk after the switch compared to the week prior to the switch. Our objective was to compare daily milk yield per cow between cows moved to a new group and cows not moved when all cows were under the same management scheme in a modern, commercial setting.

MATERIALS AND METHODS

Animals

Herd A. A total of 336 Jersey and Jersey x Holstein Crossbred cows were used in this study from Herd A. These cows were housed in a naturally ventilated, sand-bedded free-stall barn on a commercial dairy in Central Wisconsin. Pens used in the study were each comprised of 376 freestalls, 376 headlocks, 233 meters of bunk space and 420 cows. The trial was conducted during fall 2010. Study cows were stratified by parity (multi- or primi-parous) and were 65 to 170 DIM at trial initiation with an average of 146 DIM. There were 139 primiparous and 167 multiparous animals which completed the study. At two different time points, four wk apart, 20% of the cows in each of the two study pens were randomly assigned to either move (**M**) or non-move (**NM**) treatments; equal numbers of cows were assigned to M and NM. Cows were not eligible to be enrolled for the later replication if they had been assigned to M in the first replication. Eighteen cows completed two replications. Cows were milked 3 times a day in a rotary parlor, fed once a day and feed was pushed up every other hour.

Herd B. A total of 280 Holstein cows were used in this study from Herd B. These cows were housed in a cross-ventilated, sand-bedded free-stall barn on a commercial dairy in

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Southern Wisconsin. There were two primiparous pens used for the study; each was comprised of 60 stalls, 63 headlocks, 105 feet of bunk space, and 70 cows. Three multiparous pens were used for the study; each was comprised of 57 stalls, 63 headlocks, 105 feet of bunk space, and 63 cows. Study cows were 60 to 230 DIM at trial initiation with an average of 156 DIM. At three different time points, not within three weeks of each other, 20 cows from each pen were randomly assigned to either M or NM treatments with equal numbers of cows assigned to M and NM. Cows assigned to the M group were ineligible for the M group in the consecutive move. Thirteen cows were enrolled to the study twice and twenty-one were enrolled to the study for all three moves. There were 163 multiparous and 114 primiparous cows that completed the study. Cows were milked three times a day, fed twice a day and feed was pushed up three times per day.

Data Recording

In Herd A, weights from each milking were downloaded from the Boumatic meter system (Daytona Model, 2060 Computer; Boumatic, Madison, Wisconsin) and downloaded to DairyComp 305 (Valley Ag Software, Tulare, California). Missing milking weights were calculated from the weekly average for that cow as calculated in DairyComp 305. In Herd B, milk weights were obtained directly from Afifarm (version 3.04, Afikim Lite Plus parlor system; Afikim, Israel). Missing milking weights were calculated from a 10 d rolling average for that cow as calculated in Afifarm. In both herds, cows were removed from the trial if more than 5 d of milk weights on either side of the move date were missing. A total of 60 cows were removed from the study, 19 for missing milk data and 43 because they left the pen of study for management reasons such as mastitis or culling. Milk weights were recorded for 10 d pre- and 10 d post-move. During the first replication

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in Herd A, the parlor system did not record milk weights for d -4 so those data points were removed from analysis. In Herd B, the parlor system had a malfunction on d 4 during the first replication and those data points were removed from analysis.

Statistical Analysis

Data were analyzed using SAS 9.2 (SAS Institute, 2008) using the MIXED procedure. A repeated measures model was used to analyze the data since the experimental unit was measured repeatedly on a daily basis. To account for auto-correlated errors the first-order autoregressive term, ar(1), was used. Fixed effects were parity, treatment, day, and treatment * d interaction and cow within treatment was the random effect. Farms were analyzed separately. Least significant differences were computed by the PDMIX800 macro (Saxton, 1998).

RESULTS AND DISCUSSION

The results are presented in Tables 1 and 2 and Graphs 1 and 2. There was no difference ($P > 0.10$) in milk yield between treatments. The least squares means for average daily milk yield for the 5 d before and 5 d after regrouping were not different within either herd. There was a reduced milk yield on d 0 for M cows within Herd B, but this did not reach the least significant difference for the day effect. These cows rebounded to the pre-move levels on d 1 post-move. Perhaps this was due to the smaller group size for Herd B compared to Herd A, but this is merely speculative as we have insufficient data to test this hypothesis. As expected, milk yield was greater ($P < 0.05$) for multiparous than primiparous cows in both herds. When analyzed separately, there was no affect of treatment ($P > 0.10$) for either parity group in either herd (data not provided in table or

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figure). While milk yield varied by d ($P < 0.05$), there was no ($P > 0.10$) treatment * d interaction.

Kondo and Hurnik (1990) profiled the social interactions between cows when cow groups are established. Over time, agonistic interactions changes from physical (bunting, pushing, and fighting) to non-physical (threatening and avoiding). Agonistic interactions were greatest immediately after regrouping and decreased more than 60% by d 2. Brakel and Leis (1976) reported that when introducing cows to a new group the newly introduced cows have almost double the agonistic interactions as resident cows. Estevez et al. (2007) stated in a review that farm animals compete for presently available resources and to secure future resources. Estevez et al. (2007) further states that there is a generalized phenomenon of reduced aggression with increasing group size, and dominance relationships are only advantageous if the probability of meeting the same individuals repeatedly over time is high. Otherwise, the cost of establishing the dominance relationships is never recouped. Albright (1978) estimated that cows can only recognize about 100 other animals. In social situations where more than 100 animals are grouped together, there may not be recognition of other animals which could lead to a constant elevation of stress levels. Animals may adapt and choose to eat or lie down in the space provided rather than exhaust energy in establishing a hierarchy which has low likelihood of being beneficial since they would not recognize the animal as a common encounter. Many researchers, Schein and Fohrman (1955), Beilharz et al. (1966), Albright (1978), have failed to find a positive correlation between dominance value (**DV**) and production metrics. However, Blockey (1974) showed weight gain of beef bulls being correlated with DV when pasture was scant, but the same group of bulls had no

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correlation between DV and gain when pasture was abundant. In today's dairy operations, animals with a lower ranking DV have the opportunity to eat to fill during times of lower competition at the feed bunk. This behavior has been reported by Friend and Polan (1974), Friend et al. (1977), and Arave and Albright (1981).

With a greater understanding of the factors involved with social hierarchies and disruption, we speculate that in today's commercial operation there may be enough cows in groups and (or) enough resources (i.e. stalls, bunk space, and feed) for the negative effects of social hierarchy disruption seen in previous research to be minimized. Without adverse effects on milk yield when cows are moved between groups, the feeding of multi-ration groups may become more attractive to dairy producers and their consultants for a means of reducing feed costs and increasing IOFC. Moseley et al. (1976) reported that a 20%-unit change in dietary forage content (DM basis) between groups had minimal impact on solids-corrected milk production. Further, Allen et al. (2009) recently reviewed the hepatic oxidation theory for control of feed intake. This theory states control of intake shifts throughout lactation from a function of rumen fill to a satiety signal sent from the hepatic nerve. If correct, manipulation of dietary carbohydrate sources should be possible to keep intake and productivity higher as the lactation progresses. More research on multi-ration groups with high producing dairy cows is warranted.

IMPLICATIONS

There appears to be no negative impacts of moving mid-lactation dairy cows between pens. If other changes (such as diet) can be incorporated without adversely affecting milk production, dairy producers may be able to manage multiple-ration groups across the

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lactation to take advantage of potential feed cost savings. Furthermore, dairy producers should also be able to incorporate time-saving strategies, such as grouping by reproductive status, without negative effects of cow movement between groups on milk production. With abundant resources (feed, bunkspace, lying space, water) and group sizes similar to the herds used in this study, the cow's cost to establish a social hierarchy may be greater than her benefits. More research should be done examining the effects of pen moves at varying stages of lactation, group sizes and dietary changes.

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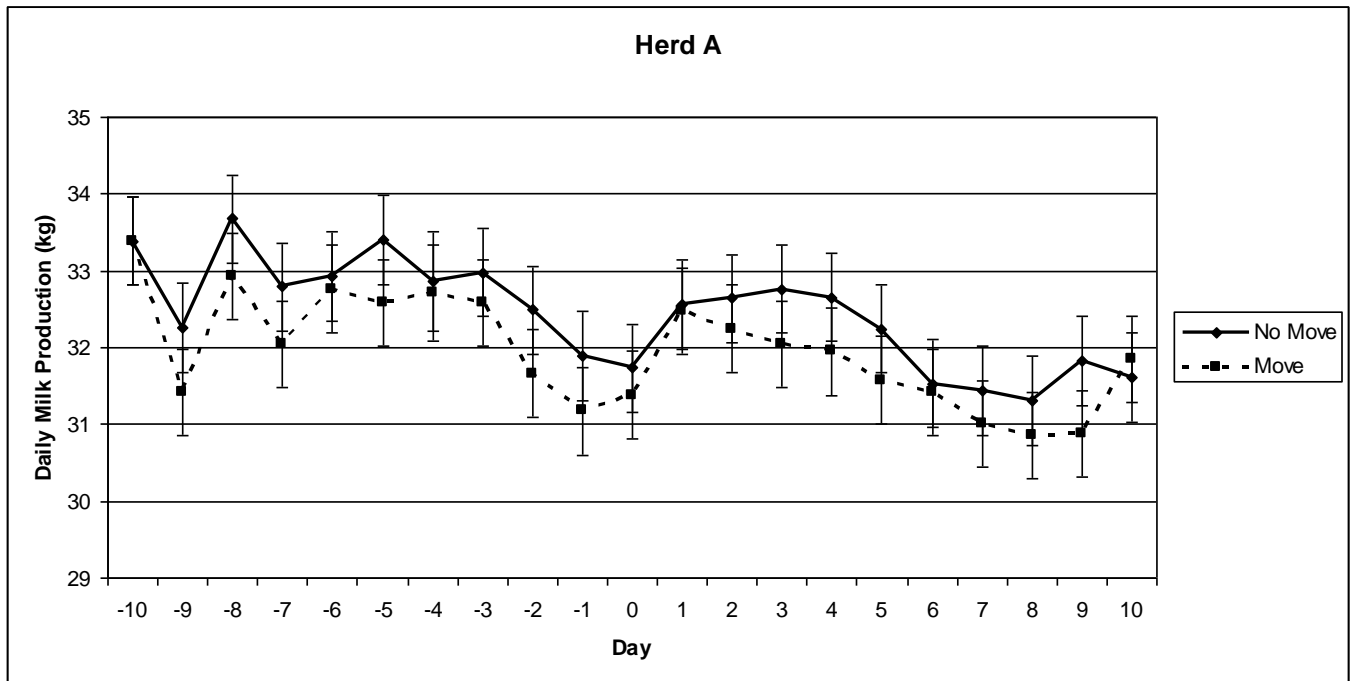
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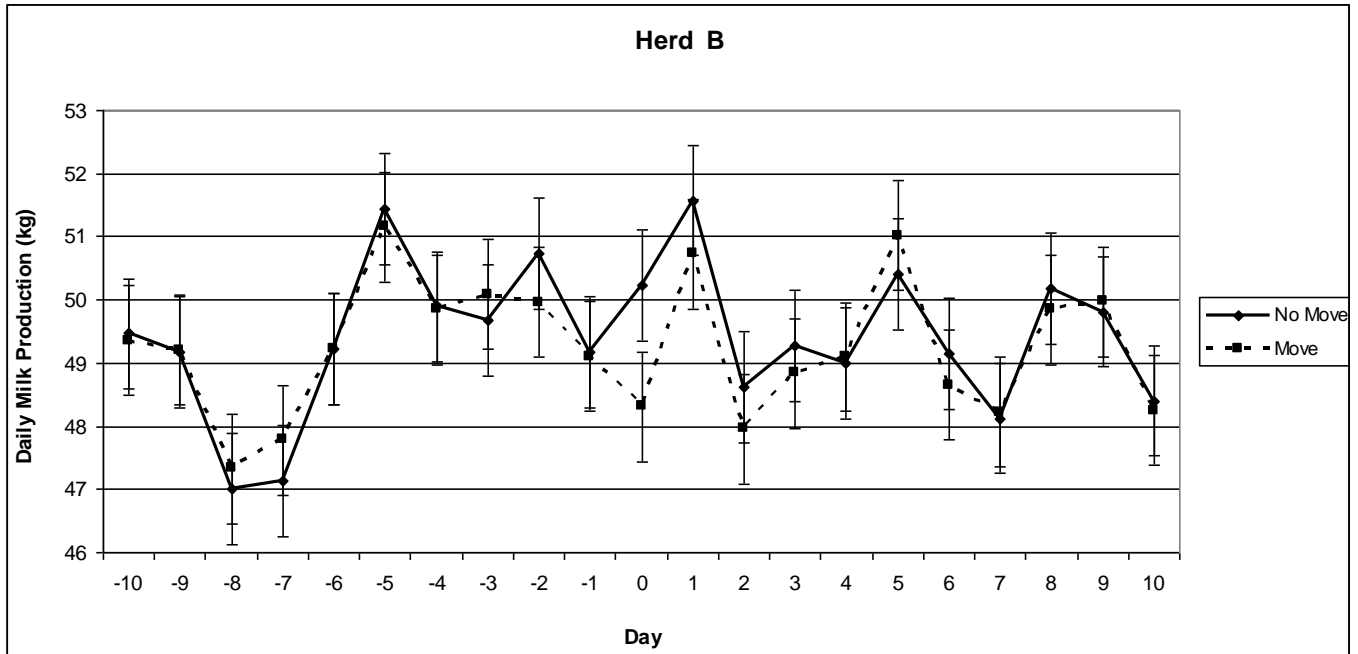
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Graph 1: Herd A daily milk production summarized by treatment



Graph 2: Herd B daily milk production summarized by treatment



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Table 1: Effect of treatment and parity on daily milk production across herds

Milk Production (kilograms/day)	Treatment [^]			Parity [^]			Day [†]	Treatment * Day
	Move	No Move	LSD	Primiparous	Multiparous	LSD	LSD	LSD
Herd A	32.0	32.4	1.4	28.1*	36.3*	1.4	0.5	1.2
Herd B	49.3	49.4	1.8	44.5*	54.2*	1.8	1.0	1.8

[†]Column headings with this symbol reach significance with a p-value <.0001

*Least Squared Means differ p-value <.05

[^] Reported as Least Squared Means

Strategies and concerns in managing multiple groups and diets on dairy farms

A. Zwald

Part 1: Hierarchy Establishment

Part 2: Social Disturbances

Part 3: Effects of Dietary Changes on Milk Production

Part 4: Grouping Strategies

HIERARCHY ESTABLISHMENT

Many factors affect dairy farm profitability. Management strategies are crucial to the survivability of the operation as they are often the distinguishable difference leading to an economic advantage of one business over another. Dairy farms are continually adapting to provide greater care for their animals resulting in increased productivity and profitability. Regrouping of dairy cattle may allow further flexibility in management decisions such as the ability to feed multiple rations across lactation groups, grouping cattle according to milking time, or managing groups according to reproductive status. Therefore, these strategies may result in cost savings, but potential benefits of regrouping hinge on the effect of the social disturbance and potential lost production. Effects of social disturbance have been studied but remain largely unquantified, especially within large group sizes.

Grouping naturally occurs in dairy cattle to reduce the risk of predation. Even though predation is not an issue for confined, domesticated dairy cattle, cows show signs of stress when separated from herd mates (Herskin et al., 2004). Optimal group size remains unknown. Time receiving social grooming (licking beginning at the head or forequarters) from other group members has been observed to positively correlate (0.214, $P < 0.025$) to production (Wood, 1977). Social grooming was observed to be at near negligible levels in animals living in isolation or in a group of 17 (Takeda et al., 2000). Although group sizes of greater than seventeen were not evaluated, Takeda et al. determined group size of 3 to 5 animals would be desirable and allow for the greatest potential production as they saw the greatest amount of social grooming within this

range. Conversely, Albright originally estimated the optimal number of individuals in a group to be near 100 from observations in New Zealand (Albright, 1971). In 1995, Albright observed group sizes up to 260 cows and observed typical behavior patterns for social facilitation and leadership-followership leading to conclusions that facilities were the determining factor for optimal group size (unpublished data cited in Grant and Albright, 2001).

Correlations of agonistic encounters and animal numbers have not led to a clear solution of optimal group numbers. Field experience and research often confounds the effects of group size and space per animal. Calves appear to be unaffected by group size, but there was a negative correlation between space per animal and number of agonistic encounters, $R^2=0.23$ (Kondo et al., 1989). Adult cattle had a correlation of agonistic encounters to decreasing space and increasing group size. The regression equation was $Y_A=0.94+0.78X_1+14544.6/(X_2)^2$ where Y_A is the frequency of agonistic encounters per hour, X_1 is the group size, and X_2 is the space per animal. This equation had an $R^2=0.31$ and the standard partial contributions were 38.7 and 61.3% for X_1 and X_2 , respectively (Kondo et al., 1989). Researchers were unable to simply associate the number in the group to agonistic encounters. It is important to note observations for adult cattle were made in an exercise lot without access to feed and the effect of social dominance and related competition is most easily seen at the feedbunk after animals return from milking or upon feed delivery (Friend and Polan, 1974). Regardless of optimal size according to social interactions, new facilities and scales of efficiency have led to group sizes of greater than 400 cows on dairies today.

Dairy cattle have been known to establish a social hierarchy among group members. Establishment of this hierarchy requires interactions between cows and the establishment of a winner and a loser with the loser yielding space (Schein and Fohrman, 1955). Interactions may be physical (bunting, pushing and fighting) or non-physical (threatening and avoiding). During establishment, there are more physical than non-physical interactions. Over time, presumably as animals learn their place in the hierarchy, most interactions change to a non-physical form (Kondo and Hurnik, 1990). This time-dependant relationship is displayed in Figure 1. The time point which interactions changed from more physical to more non-physical is between 24 and 48 h (Kondo and Hurnik, 1990).

An effort to understand hierarchies requires knowledge of the factors that cause the need for a hierarchy. Competition, and hierarchies established from it, appears to be an effort to secure presently available and future resources (Estevez et al., 2007). Space, especially at the feedbunk, appears to be the main resource desired by dairy cattle (Friend and Polan, 1974). Data indicate less aggression in larger group sizes in poultry, pigs, fowl, fish and other species, and the same principle is believed to happen with dairy cattle, although this has not been quantified. Reduced aggression with increasing group size has been hypothesized to occur because the increase in group size lowers the probability of meeting the same individual over time (Estevez et al., 2007). Albright (1978) states there are estimates that dairy cattle can only recognize approximately 100 animals. This would compound the chance of meeting the same animal as they may have met previously, but be unable to recognize this. If a cow does not meet the same individuals over time, they may not see the benefits from a hierarchy. It has been

hypothesized that very large groups and the desire for a hierarchy would lead to a consistently chaotic state for the animals since they would not be able to recognize those met previously (Albright, 1978). Therefore it would be similar to time zero of Figure 1 at all times and many physical encounters would occur. This recognition estimation has never been tested in a scientific setting and appears invalid as dairymen can have large group sizes, see above average production levels, and do not report an increase in aggression.

The tolerance hypothesis for hierarchy establishment shows greater net benefit in animals spending their time exploiting resources rather than establishing a hierarchy (Estevez et al., 1997). The tolerance hypothesis is believed to exist when groups are large and resources are not limited. Non-overstocked dairy operations, where there is little resource depletion, would follow this hypothesis for hierarchy establishment.

Historically, researchers counted the number of wins and losses and linearly assigned an animal to a place in the hierarchy. This view of a linear hierarchy was challenged, especially in larger groups, as there were triangular and other non-linear patterns observed. Angular dominance value accounts for this and assigns each animal a number based on the number of wins per the number of encounters. Angular dominance value = $\arcsin^{1/2}[(\sum W_i)/N_i]$ where W_i is the rate of wins of i between two heifers, and N_i is the number of heifers encountered. The benefit to the dominant dairy cow appears to be increased feeding time. Interestingly, increases in feeding time have not resulted in increased productivity as subordinate animals obtain their fill during times of lower competition (Friend and Polan, 1974; Friend et al., 1977; and Arave and Albright, 1981). Perhaps this is why many researchers have failed to find a positive correlation between

dominance rank and production (Schein and Fohrman, 1955; Beilharz et al., 1966; Albright, 1978). This behavior and lack of correlation may differ in a resource-limited situation. When feed is limited, dominant animals may have a competitive advantage in increased feed consumption as they may take a greater percentage of the available feed. Research also indicates that the relative amount of feed consumed by dominant animals may change if feed is limited. One study with limited feed available found dominant cows increased consumption from 14% over submissive animals to 23% as competition increased from one to three cows per feeding station (Olofsson, 1999 as cited in Grant and Albright, 2001). A group of beef bulls was reported to have no correlation between average daily gain and dominance rank on abundant pasture but had positive correlation when pasture was scant (Blockey, 1974). Dominance value, as calculated by numerous different measures, has been shown to be positively correlated to weight and age (Arave and Albright, 1981).

SOCIAL DISTURBANCES

Numerous attempts have been made to understand what change in social structure and hierarchy can have on milk production. This is commonly done with regrouping, introducing cows of interest to an already established group, and tracking production. Confounding factors in this area of research are: the number of animals moved, bunkspace available to the animals, and differences in dominance value and stage of lactation in moved animals. Commonly seen is a decrease in feeding the first h after feed

delivery and a decrease in lying time of the newly introduced animals (von Keyserlingk, 2008; Hasegawa et al., 1997). Increased aggression is also observed (Figure 1).

Stress hormones, immunologic measures and metabolites have been used in a limited number of studies to measure animal responses after regrouping. In groups of 12 Holstein steers, with six animals being regrouped at a time, plasma cortisol and non-esterified fatty acid levels were greater ($P < .05$) for the newly introduced animals during the first three h compared with animals which remained in their original pen indicating an increased stress level (Gupta, 2005). There were no significant ($P > .05$) effects on the immunologic assays taken. Since the newly introduced animals comprised half of the group, the remaining animals should experience equal stress of unfamiliar animals. Since differences in stress indicators were seen, questions to environment interactions with new social experiences may be an area of further exploration. There were no differences seen in adrenocorticotrophic hormone, another stress-induced hormone, after the first or any other move. The same animals were moved every two wks, six times in total. Increases seen in plasma cortisol and non-esterified fatty acid levels after the first regrouping did not occur in subsequent regroupings. This would suggest that familiarity of moving may affect consequences of social disturbance.

Although behavior and hormone measurements may give us an indication of the stress of an animal, production is the most easily replicated measure in the field. Collis et al. (1979) found no decrease in production when animals were regrouped. The greatest decrease reported in production loss upon regrouping of dairy cattle was 5% over six d (Schein et al., 1955). Several other studies have described decreased milk production, up to 8.5%, but these decreases lasted for only one d (Brakel and Leis, 1976; von

Keyserlingk et al., 2008). Production returned to baseline levels for all subsequent d. Hasegawa et al. (1997) reported a non-significant decline in production the first wk after regrouping, but significantly decreased production during the second wk following regrouping. More long-term studies to measure lactation persistency with what appears to be the acute stressor of regrouping are warranted.

With conflicting results, some researchers hypothesized a change in dominance value was an indication of actual disturbance to social interactions. Three studies examined this with three different results (Arave and Albright, 1975; Hasegawa et al., 1997; Sowerby and Polan, 1978). Moving one animal had a greater decrease in production than when two animals were moved (Arave and Albright, 1975). In a separate study, Sowerby and Polan (1978) concluded the percent of cows shifted was relatively unimportant. They found no trend in production differences when moving 2-14% of a pen. However, these authors reported observations of one herd owner of more aggressive encounters when moving less than 8 cows. Arave and Albright (1975) found increases and decreases in regrouped cow's production the week after the move compared to the week prior although there were minimal changes in dominance rank. Hasegawa et al. (1997) observed decreases greater than 5 points in angular dominance value resulted in decreased milk production 3.5 and 5.6% during the first and second wk after regrouping animals, respectively. Conversely, production of regrouped animals whose angular dominance value increased more than 5 points also decreased during the second wk after regrouping (Hasegawa et al., 1997). If change in dominance value were a causative effect of lost production, one would expect changes in angular dominance value to have an effect on production whether animals were moved or not and you would not expect

decreased production in animals experiencing an increase in angular dominance value. The same group saw no change in production of unmoved animals when angular dominance value decreased more than 5 points (Hasegawa et al., 1997).

Although not all factors contributing to are known, it is clear that regrouping cattle may have negative effects on animal welfare and production.

EFFECTS OF DIETARY CHANGES ON MILK PRODUCTION

A primary benefit of regrouping cattle throughout their lactation is the ability to group and manage cows of similar needs together. Dairy cows are often grouped by parity, stage of lactation, breeding status or milking time. As nutrient demands change throughout lactation, grouping cattle of similar nutritional needs together allows more precise feeding, thus decreasing nutrient excretion and reducing feed costs (St-Pierre and Thraen, 1999). Knowledge of a dairy cow's nutritional requirements, on-farm ingredient availability and producer hesitation have been limiting factors in the adaptation to multiple diets throughout lactation. Some dairy producers practice multiple-diet strategies and computer models suggest a potential increase of \$0.10 per cow per day in income over feed cost "V.E. Cabrera (2011, University of Wisconsin-Madison, 279 Animal Sciences 1675 Observatory Drive, Madison, Wisconsin, personal communication)" or an increase of up to 3% fat-corrected milk (Pecsok et al., 1992) when moving from feeding one to two diets within the lactating herd. Conversely, substantial changes in diets can account for greater loss of milk production than social changes (Coppock et al., 1981).

Two separate studies have focused on changing nutrient density of diet without introducing confounding social disturbances. Nocek et al. (1985) used group-housed cattle and calan gates to facilitate a change from an original 50% forage diet balanced for 31.8 kg milk production to one of three experimental diets. When production fell and remained between 26.2 and 27.2 kg for 6 consecutive days, cows were randomly assigned to a high, medium, or low allowable milk diet. After 4 wks on their respective trial diet, all cows were switched to the medium diet for an additional 28 d. Changes in dry matter intake and fat-corrected milk production are summarized in Table 1. DMI decreased as percent forage increased and there were decreases in fat-corrected milk production relative to diet. No animals were left on the initial diet to compare persistency of production when a change did or did not happen, but it was noted by the authors that persistency was greatest for those with the smallest change in energy concentration of the diet. Again, more research is needed to compare persistency of lactation with and without diet changes. It was concluded that energy content of a diet should not change more than 15% at a time.

Moseley et al. (1976) made dietary changes to cows individually fed and housed in tie-stalls. Cows of particular interest here were fed a diet consisting of 40% forage and were abruptly switched to a diet containing 60% forage at 81 DIM. After 210 DIM, these animals and animals which had been on a 60% forage diet since parturition were switched to a diet consisting of either 80 or 95% forage. Diet compositions are depicted in Table 3. Intake and milk production data three wks pre- and post-switch are represented in Table 4. Notably, and contrary to popular belief, cows in mid-lactation were able to adapt to a 20% increase in dietary forage with minimal loss of production

when comparing solids-corrected milk. Some of the belief around losing production when regrouping cattle may be from the loss in milk yield, but this yield difference offset by an increased amount of butterfat and protein produced. The metric most easily measured on commercial dairies is yield, not solids or fat corrected milk.

STRATEGIES FOR GROUPING ANIMALS

Dietary changes for cattle after regrouping appear to minimally alter fat- and solids-corrected milk. However, best management practices for regrouping cows is still debated in terms of when regrouping should take place. A common and the most easily calculated on-farm parameter is DIM. Milk production may also be easily measured if the herd has a daily monitoring system or uses professional services, such as DHIA, to capture monthly production information. Professional services may also capture butterfat and protein and thus energy-corrected milk may be calculated for some dairies, but this would take extra effort. Producers may also choose to group cattle according to similar management needs to improve parlor throughput, labor costs associated with reproductive programs or other farm-specific parameters. Since many of these parameters are farm-specific, the focus here is grouping animals according to nutrient requirements.

McGilliard et al. (1983) used computer simulation to compare milk production, fat-corrected milk production, dairy merit (calculated measure using fat-corrected milk and bodyweight) and a cluster method for grouping cattle. The cluster method uses NRC estimates of protein and NE (Mcal) requirements for maintenance and production. This method includes an age-adjustment for animals less than 35 months old accounting for growth needs, which is an improvement upon the earlier, more easily calculated methods.

Correlations within group for each of the grouping strategies are summarized in Table 3. Similarly, in comparison with the cluster method, there were 15% more misgroupings when dairy merit was the grouping method, 22% more with the fat-corrected milk method, and 25% more with the milk production method (McGilliard et al., 1983).

Since this work, knowledge of requirements and metabolism of dairy cattle has increased. This understanding may be a valuable tool to increase dairy cattle productivity while maintaining or decreasing feed costs throughout lactation. One area of advancement in our understanding of metabolism may be the hepatic oxidation theory. The hepatic oxidation theory may account for the control of feed intake in late lactation (Allen et al., 2009). Increased energy requirements of dairy cattle result in lower concentrations of acetyl-CoA in the liver during peak lactation. Throughout this time, gut distension appears to control feed intake (Allen, 1996). As lactation progresses and energy requirements decrease, hepatic oxidation may insert its control of satiety before gut distension occurs. Oxidation of acetyl-CoA in the liver may trigger hepatic glucoreceptors which decrease the firing rate of the hepatic vagal afferent nerve. The decreased frequency of firing is believed to be a satiety signal in the brain. It is understood that large propionate fluxes to the liver when energy demands are low can lead to oxidation of acetyl-CoA. Ruminant starch fermentation increases the amount of volatile fatty acids produced per kg of organic matter consumed. Ruminant starch fermentation also shifts the proportions of volatile fatty acids produced with an increase in propionate compared to acetate. For these reasons, diets with high ruminant starch fermentation have an increased amount of propionate entering the liver. If energy demands are low, this propionate may enter the gluconeogenic pathway in the liver, but a

buildup of TCA cycle intermediates will send acetyl-CoA through the oxidation pathway. This oxidation may slow the firing rate of the hepatic vagal afferent nerve sending messages to the brain, resulting in satiety and a cease of feed consumption (Allen et al., 2009).

The hepatic oxidation theory allows for strategies in ration formulation to allow for maximum glucose uptake throughout lactation by shifting energy sources. Highly fermentable starches should be fed during early to mid-lactation when intake is primarily controlled by gut distention. This would allow for maximum energy intake. Contrarily, during late lactation, when satiety and the resulting decrease in feed intake is believed to be caused by hepatic oxidation of acetyl-CoA, starch sources should be shifted to post-ruminal degradation. This should result in increased meal size and dry matter intake. A decrease in feed intake from 23.75kg/d to 20.7kg/d ($P < .005$) was observed when ground corn was exchanged for barley (a more ruminally fermentable source of starch) without an effect on total tract organic matter digestibility (McCarthy et al., 1989).

Much remains to be learned about the social preferences and metabolism of dairy cows. Management strategies will likely continue to be a major factor in farm profitability and survivability. Increasing feed costs will require dairy owners to continue to adapt feeding strategies to increase animal welfare and productivity. There is accumulating evidence that dairy cattle can be managed and fed in a multiple group system without negative impacts on milk production. Rations balanced to better match metabolism and meet animal requirements without overfeeding should increase herd performance and profitability.

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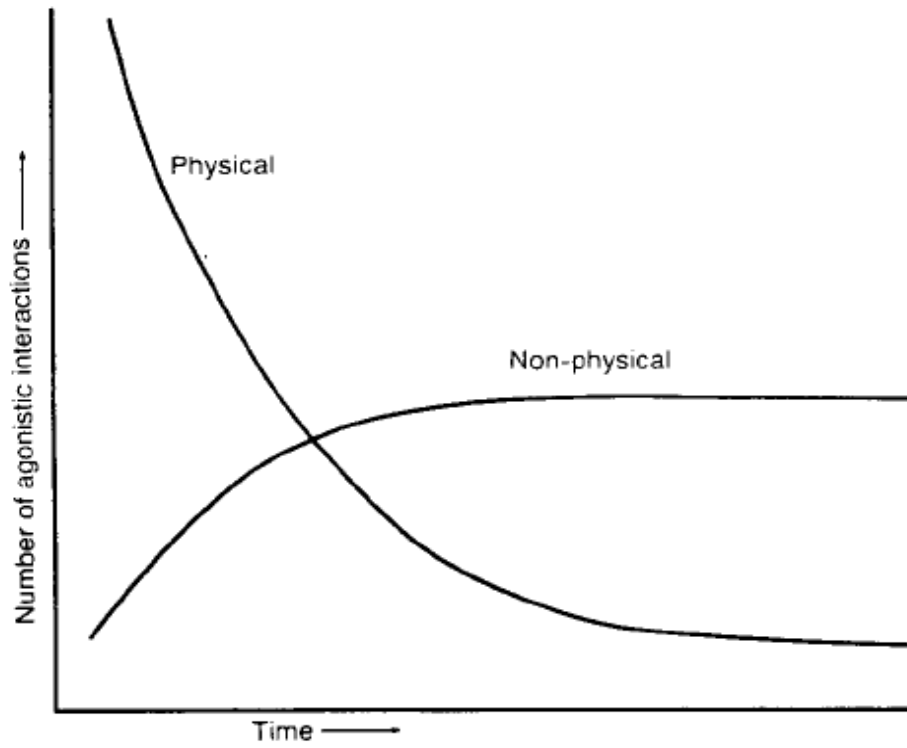
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Figure 1. Time-dependant characteristics of agonistic encounters ¹



¹ Reprinted from Kondo and Hurnik, 1990

Table 1. Performance of cows summarized by trial group ¹

	High ⁵	Medium ⁶	Low ⁷
Average Dry Matter Intake (kg/d)			
Preliminary ²	22.1	22	20.9
Phase 1 ³	21.7 ^a	20.2 ^b	19.4 ^b
Phase 2 ⁴	19.9	20.1	19.3
Average fat-correct milk production (kg/d)			
Preliminary ²	25	24.9	24.8
Phase 1 ³	23.1 ^a	21.4 ^b	21.1 ^b
Phase 2 ⁴	19.6	18.6	18.5

¹ Data from Nocek et al., 1985

² All animals received initial diet (50% forage, 17.6% crude protein, 1.59 Mcal/kg NE_L: balanced for 31.8 kg production)

³ Animals received trail diet (high, medium, or low)

⁴ All animals received medium diet

⁵ Consisted of 57% forage, 16.1% crude protein, 1.57 Mcal/kg NE_L: balanced for 27.2 kg production

⁶ Consisted of 77% forage, 14.9% crude protein, 1.49 Mcal/kg NE_L: balanced for 22.7 kg production

⁷ Consisted of 85% forage, 14.0% crude protein, 1.45 Mcal/kg NE_L: balanced for 18.2 kg production

^{a,b} Means in the same row with different superscripts differ (P<.05)

Table 2. Performance of cows according to diet change ¹

	Phase 1 ⁴	Phase 2 ⁵	
	A to B [*]	B to C [*]	B to D [*]
DMI (kg/d)			
Pre-switch ²	18.9 ^a	16.4 ^a	16.1 ^a
Post-switch ³	17 ^b	14.4 ^b	11.9 ^b
Solids-corrected milk (kg/d)			
Pre-switch ²	24.6	17.8 ^a	18.0 ^a
Post-switch ³	23.6	14.5 ^b	13.0 ^b
Milk Yield (kg/d)			
Pre-switch ²	27.4 ^a	18.5 ^a	19.1 ^a
Post-switch ³	24.9 ^b	15.0 ^b	13.8 ^b

¹ Data from Moseley et al., 1976

² Three week average prior to switching diets

³ Three week average after switching diets

⁴ Switch occurred at 84 days in milk

⁵ Switch occurred at 210 days in milk

^{*} Diets consisted of the following:

A: 40% forage, 16.4% crude protein, 1.91 Mcal/kg NEL

B: 60% forage, 16.4% crude protein, 1.71 Mcal/kg NEL

C: 80% forage, 14.5% crude protein, 1.53 Mcal/kg NEL

D: 95% forage, 14.5% crude protein, 1.39 Mcal/kg NEL

^{a,b} Means in each column within major row heading bearing different superscripts are different (P<.05)

Table 3. Intragroup correlations of nutrient requirements summarized by grouping system¹

	Cluster	Dairy Merit	Fat Corrected Milk	Milk
NE _L (Mcal/kg)	.61	.42	.34	.28
Crude Protein	.66	.61	.54	.49

¹ Data from McGilliard et al., 1983