Designing Good Environments and Management for Calves

Anne Marie de Passillé[1], Jeff Rushen[1] and Dan Weary[2]

[1]Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, PO Box 90, 2000 Route 108 East, Lennoxville, Quebec. J1M 1Z3
Email: depassilleam@EM.AGR.CA
[2]Animal Welfare Program, Faculty of Agricultural Sciences, University of British Columbia, 2357 Main Mall Vancouver, BC V6T 1Z4

Take Home Messages

- Calves can be reared successfully in small groups with computerised milk and grain feeders. Calf growth and health is as good as in individual pens.
- Automated calf feeders greatly reduce labour and reduce weaning age.
- Calves do well on high milk intakes: growth, health and feed efficiency is improved. Increasing calves' milk allowance is simplified by the computerised feeding system.
- Group rearing of calves with a computerized feeding system works best when calves have had adequate colostrum, groups sizes are small, cross-sucking is controlled by allowing calves sufficient time to suck, milk allowance is adequate, and grain intake is encouraged by appropriate weaning techniques.
- In all types of housing, young calves must have good ventilation and be protected from drafts and damp and wet bedding.

Introduction

Successful calf rearing requires that we protect the health and welfare of the young calf while profiting from the calves' growth potential.

Calf health is most at risk during the milk feeding period. Surveys report average mortality rates of 6-13% for dairy calves (e.g. Losinger& Heinrichs,1997). This mortality rate is unacceptably high as is the morbidity rate of dairy calves due to respiratory problems and diarrhea. Over the past 10 years these figures have not improved although it is clear that some dairy

producers do achieve much lower calf mortality and morbidity. The first weeks of life don't have to be so difficult for the dairy calf.

There are short and long term benefits to raising healthy and comfortable calves/heifers.

We know more about the short term benefits and we will concentrate on these in this discussion. However, it is also important to recognize possible long term benefits. We have a growing body of literature documenting the many health problems of our high producing dairy cows. Our fast growing, high consuming and high producing cows may need a better start to life to be able to cope with modern production demands.

Computerized calf feeders that allow for efficient rearing of calves are now available but they are underused in North America. This paper looks at how we can satisfy the calf's capacity for fast growth in an environment that ensures its health, satiety, comfort and survival. Specifically, we will focus on how group housing with computerized feeder systems can help you meet those objectives. We will look at the results of an 18-month on-farm study with these feeders and discuss the factors that are involved in the successful use of these feeders.

■ Computerized Milk Feeder System and Group Housing of Calves

European dairy farmers have used computerized calf feeders to feed milk replacer or milk and calf starter for many years. In North America, dairy producers have been worried about the possible negative effects of group housing of calves before weaning. The main fears have been a higher risk of disease transmission and cross-sucking between calves that might lead to milk stealing. This may explain why relatively few computerized feeders are being used on dairy farms even though some dairy producers in Canada and the US are now having good results with these systems.

We have just completed a research project on a commercial farm where milk-fed calves were kept in groups and fed with computerized milk and grain feeders. Our results were very encouraging. We found good growth rates, good calf health and very little cross-sucking. The producer and staff were so happy with the feeders that all heifers are now being raised in this group housing and feeding system.

De Laval calf feeders were installed in a new greenhouse-style barn on a 500-cow dairy in New York State. Half of the barn was set up with individual calf pens and the other half was split into two group pens (one for younger calves and one for calves over 25 days). For 18 months, bucket-fed calves in the

individual pens were compared to those in group pens fed with the calf feeder system. Over 200 calves were examined in the research project that combined nutrition, health and behaviour (de Ondarza, 2002).

The calf feeder system we used in this study was made up of two computerized feeders, one for milk replacer (Figure 1) and one for grain/starter. In this system, calves wear transponders on their necks. When a calf goes into the milk feeder, it is recognized and, if the calf is due to feed at that time, milk replacer powder is mixed with hot water and delivered through a hose and teat. One milk feeder can service two separate pens of calves. The calf starter feeder also recognizes each calf; it delivers the starter to the calf and can measure the amount of starter the calf consumes. A calf starter feeder can service one pen only.

Figure 1. Calf computerized milk feeder with swivel stall gate. When the calf fully enters the stall, the gate swings shut thus preventing other calves from entering the stall. Such a gate helps limit the amount of cross-sucking that occurs.

We compared the performance of the group-housed calves with calves in individual pens that were fed from a bucket. Unfortunately, the calves in this study were fed far less than the recommended levels of milk (see below): calves received only 250 g/day of milk replacer powder during the first half of

the study and 375 g per day during the second half. Bucket-fed calves had their milk split into two feedings per day. Calf starter and water were available in separate buckets ad libitum. At six weeks of age, calves were weaned by diluting the milk replacer over a period of a week.

Calves on the calf feeder system were fed the same type and amount of milk replacer as the calves in the individual pens but in four portions per day. Calves were started on the computerized feeding system at 4 days of age. For the first few feedings of milk replacer, the calves needed to be lead into the stall and made to drink from the nipple. Everyone was amazed at how quickly the calves adapted. Calves were weaned by diluting the milk replacer over 7 days once they had eaten 1 kg (2.2 pounds) of concentrate for 2 days in a row. The minimum weaning age was set at four weeks.

Some producers are concerned that keeping milk-fed calves in groups will allow calves to suck on each other ('cross-sucking'). We were able to minimize such cross-sucking by making a couple of modifications to the milk feeder. The milk feeder stall had a swivel stall gate so that calves were not pushed out or sucked from behind by other calves while they were in the milk feeder. This also allowed calves to stay and suck on the nipple as long as they wanted to after getting their milk replacer. Our research has shown that the calves' motivation to suck is reduced if they can suck for long enough on an artificial teat (de Passillé 2001).

Furthermore, we diluted the milk replacer almost twice the usual amount, which increased the size of the meal and increased the time the calves had to suck to consume their milk. Finally, we stopped the flow of the milk replacer for 16 seconds in between the three half-liter allotments that made up one meal in order to make the meal longer. We did this because we had found from our research that we were able to reduce the amount of non-nutritive sucking the calves did after a meal by increasing the duration of the meal (Haley et al., 1998, Figure 2). These modifications gave calves the opportunity to suck sufficiently on the nipple of the calf feeder, thus minimizing cross-sucking.

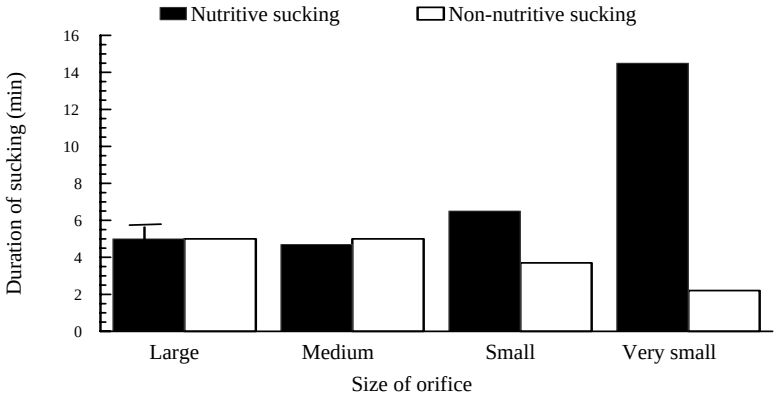

Figure 2. Nutritive sucking is highest and non-nutritive sucking (once all the milk has been drunk) is lowest when milk flow is very slow. The flow by gravity, without a calf sucking on the teat, was 1 l/ min for the large orifice, 700 ml/min for the medium, 450 ml/min for the small and only 200 ml/min for the very small orifice (0.16 cm diameter) (Haley et al. 1998).

Growth and Health of Heifers and Labor Requirements.

The computerized milk feeding system was efficient and gave us similar results to the conventional rearing system. Daily gains from birth to 4-6 weeks of age averaged 0.43 kg on initial low milk diet and 0.50 kg on the later, higher intake diet. During the low intake period, weight gains during the first four weeks were less for the calves fed with the calf feeder than for bucket fed calves. However, once we switched to the higher milk diet, there was no difference between weight gains of calf fed with the computerized system and bucket-fed calves.

One advantage was that the heifers on the computerized feeder were able to be weaned at a younger age (35 days) than the bucketfed heifers (42 days). These economies were possible because weaning could be achieved by diluting the milk and because we had the capacity to measure grain/starter intakes. Overall, calves were fed about 18% less milk replacer when they were weaned according to calf starter intake using the calf feeder system.

Raising heifers with the computerized calf feeder system required only one-third of the labour (1.4 h/calf) than did feeding the calves by bucket (4 h/calf). University of Delaware researchers conducted a study with a similar milk

replacer feeder but without a grain feeder system. They also report important labour savings (de Ondarza, 2002). These lower labour requirements are one of the largest economic advantages with using the computerized feeders.

Calves were healthy on both systems. Coughing was almost non-existent in the barn. In February, there was a BRSV outbreak but there was no relationship between how the calves were housed and fed and the incidence of disease. The incidence of diarrhoea and respiratory disease was very low for most of this study. Researchers at the University of Delaware found that calves fed in a group pen with a calf feeder had fewer days on medication than calves housed in hutches (Kung et al., 1997). Recent epidemiological studies conclude that when group size is small (e.g. 7-10), health problems are similar to those in individual stalls (Losinger and Heinrichs, 1997; Svensson et al., 2003). Keeping groups small is one of the secrets to successful group rearing of milk-fed dairy calves. We have had good results rearing calves in small groups in other experiments (Chua et al. 2002, Hanninen et al 2003), as have other researchers (Hammon et al. 2002, Schiessler et al. 2002), suggesting that group rearing is compatible with good health.

Cross-Sucking During the Milk-Feeding Period and After Weaning

To check for cross-sucking, we put the calves on intensive surveillance. We examined videotapes of heifers in the computerised feeding system for over 135 days, 24 h a day. Once calves were weaned, they were moved into a large pen in another barn. Group and individually reared heifers were mixed in this pen where they were kept for a minimum of 2 months. We also examined 43 days of video from this pen.

Each heifer was observed for over 192 h during the milk-feeding period. Only 31 out of 125 observed heifers were seen to cross-suck at least once, 12 to cross-suck twice, and 6 more than twice. After weaning the rate of cross-sucking was slightly higher, but equal for calves from the two feeding systems. Overall, cross-sucking was rare and of short duration: one out of 10 calves was seen to cross-suck on a given day and events lasted 90 sec on average. There were many days when no cross-sucking events occurred. It is clear that the automated milk feeding system did not stimulate cross-sucking during the milk-feeding period nor lead to an increased motivation to cross-suck during the first weeks following weaning.

Behaviour at the Milk Feeder

Calves visited the milk feeder about 17 times/day although the feeder was programmed such that calves received milk during only 4 of these visits. Calves can spend 2 to 7 min in the feeder sucking at each visit, sucking 3 times longer when they actually received milk. Calves spent a total of 50 min/day in the feeder, and most of this time was spent sucking. Because group size was

small, averaging 8 calves (range of 3 to 16), the milk feeder was unoccupied for over 50% of the time. However, calves were often seen to wait, spending 3% of their day waiting at the milk feeder.

The frequent “unrewarded” visits and the fact that younger calves - who did not yet consume much grain - were visiting the milk feeder more frequently than the older calves suggest strongly that the calves were hungry. Furthermore when feed allocation was increased in the second part of the study, unrewarded visits decreased. We also found that calves spent 40% less time in the milk feeder or waiting to get into the milk feeder, suggesting that they were less hungry. Others have also found that calves will go less often to the feeder when fed higher levels of milk (Hammon et al. 2002; Jensen 2003).

We believe that a higher milk allowance improves the use of the computerized feeder by reducing the number of unrewarded visits that calves make to the feeder. This also improves calf comfort and growth.

■ The Recipe For Successful Group Housing With A Computerized Feeding System

A number of recent reports conclude that raising young calves with computerized feeding systems is successful. Through these different experiments and trials a number of recommendations can be made to maximize the success of group rearing of milk-fed calves.

Colostrum

Increased disease transmission remains a risk in group housing so that it is essential that the calves have adequate immunity. Diarrhea and respiratory illness in the first months are associated with slower growth as well as higher age at first calving and increased risk of dystocia.

Early high-quality colostrum intake, ensuring passive immunity, has been repeatedly demonstrated to be an important factor in protecting the young calf (Davis and Drackley, 1998). Calves that lack adequate passive systemic immunity are more prone to disease and have a higher mortality risk (Svensson et al., 2003). In one study, it was estimated that 31% of calf deaths during the first 3 weeks postpartum could have been prevented if colostrum feeding had been adequate (Wells et al., 1996). Although the need for good colostral intake is well documented, lack of immune protection remains a serious cause of disease and mortality for calves and replacement heifers.

Ensuring rapid and sufficient colostral intake must be a priority for the producer. Colostrum supplements and replacers are being developed and tested to help

ensure early intake of quality immunoglobulins by newborn calves. It is now possible to test for immunoglobulin as well as plasma protein levels in the day-old calf's blood. Inexpensive methods exist and are recommended as a means of assessing, at the farm level, how well calves are protected. Proper management of the passive transfer of immunoglobulin from colostrum can go a long way in improving calf health and welfare (see Davis and Drackley, 1998).

Milk Intake Level

We believe that optimal use of computerized feeders can be achieved by feeding a higher-than-normal level of milk.

Young replacement heifers are, in North America, most often fed 8-10% body weight. This intake covers maintenance costs and a very small weight gain (Drackley, 2003) leading to low feed efficiencies (Diaz et al., 2001). In addition, this intake does not satisfy the calf's appetite. Selection for high-appetite cows has lead to high-appetite calves. Our research shows that calves will consume twice as much milk when fed ad libitum on the dam, by bucket or teat bucket and calves are reported to do this on the computerized milk feeder (Weary, 2001; Schiessler et al. 2002).

There has been some concern about increases in diseases, especially diarrhoea, when feeding more milk to calves. Although some older studies have found such an increase, this is when feeding milk of less than optimal quality. Milk replacer composition, hygiene of milk mixing and delivery equipment as well as deficiencies in water intakes have lead to serious scours when milk feeding level is increased. Another belief is that very early intake of concentrate will ensure better performance after weaning and reduce costs associated with feeding milk.

In contrast, much recent research has shown advantages of feeding calves more milk. When we satisfy the young calves' appetite, we see greater weight gains. But we also get improved feed efficiencies to levels comparable with piglets and lambs and better health (Diaz et al., 2001, Drackley, 2003). Many studies have found that calves will grow better and be healthier if fed to appetite (Weary 2001, Krohn, 2001, Hammon et al., 2002). Indeed, calves can grow as well when fed ad libitum on the computerized milk feeder as they do on the dam (Schiessler et al., 2002).There is also much evidence to support the suggestion that the calf's immune system is also stronger when calves are fed to appetite (Drackley, 2003).

Long-term improvements in production have also been reported with ad libitum feeding in the first 2 months of life, including better milk production in the first lactation (Krohn, 2001). High levels of milk feeding of the young calves do not appear to have the negative impacts that high level of feeding has with older heifers.

In recent experiments we have tested the effects of feeding calves ad libitum by teat (Appleby et al., 2001; Jasper and Weary, 2002). In each experiment we compared weight gain, milk intake, starter intake and number of days with diarrhea for calves fed milk conventionally (i.e. twice daily by bucket at 10% of body weight per day) versus ad libitum from a teat. In the first experiment we found that weight gains during the first 2 weeks of life were less than 0.4 kg/d for the conventionally-fed calves versus 0.85 kg/d for the teat-fed ones. During the next 2 weeks gains were 0.58 and 0.79 kg/d respectively. In a second experiment we again found that the teat-fed calves gained weight more quickly (0.78 versus 0.48 kg/d from birth to weaning at day 37). We also found that calves maintained their advantage in body weight after weaning. In both experiments the differences in weight gain were likely due to teat-fed calves drinking approximately twice as much milk as the calves fed conventionally.

It is commonly thought that calves should be encouraged to increase their consumption of starter at an early age. We found that over the first 5 weeks of life, feeding calves less milk did increase starter consumption but this practice also severely limited weight gains. Moreover, we have found that the ad libitum calves quickly caught up to and indeed surpassed the conventionally-fed calves in their intake of starter after weaning. Thus feeding restricted quantities of milk during the first 4 weeks, as in conventional practice, would seem to have little merit.

One advantage of the computerized feeding systems at weaning is that with no extra labor calf milk intake can be reduced by diluting milk, and starter intake can be monitored automatically so that milk feeding can be stopped as soon as the calf reaches a desired starter intake.

Minimizing Cross-Sucking.

As we have demonstrated, milk-fed calves can be kept in groups without cross-sucking. Our attempts to minimize cross-sucking obviously worked. Since the calves could suck for as long as they wanted after milk ingestion, they did not cross-suck after a milk meal. A door that stops calves from pushing each other out of the feeder permits calves to satisfy their sucking motivation following milk ingestion. The combination of the milk dilution and the slow delivery of milk also helped lengthen sucking duration and thus satisfy the calf. Calves on the computerized milk feeder spent over 45 min/day sucking at the teat of the milk feeder.

In our studies of calf sucking behaviour, we have demonstrated that calves are very motivated to suck and that the taste of milk stimulates sucking. Calves are very motivated to suck for 5-15 minutes after a milk meal and will suck anything available to satisfy this need. When calves are raised in groups, they will suck each other mostly during the 10-20 minutes following milk intake. This cross-sucking can be reduced dramatically by offering the calves a dry rubber teat to

suck after they have finished drinking their milk (Figure 3, de Passillé, 2001). When calves do not have an appropriate object to suck they develop bad habits, such as cross-sucking. This behaviour is considered undesirable as it leads to injuries, urine drinking, and possibly infections and injury in the recipient heifer.

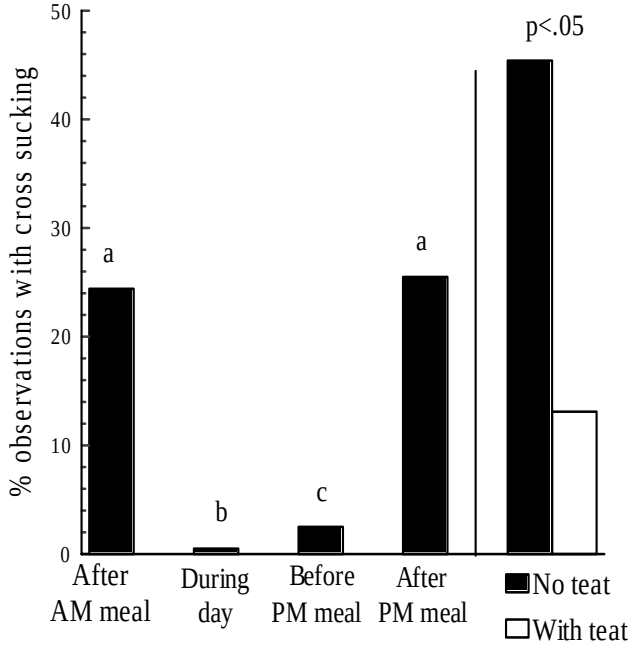

Figure 3 . The amount of cross-sucking that occurred between group housed, milk-fed calves at various times of the day. Some of the calves (white bar) were allowed to suck a dry teat. Cross sucking occurs right after milk meals and is much reduced by letting the calves suck the teat after the milk meal (de Passillé, 2001)

Rather than providing milk from a bucket, a teat allows calves to drink in a more natural manner. We have found that calves fed ad libitum by nipple spend approximately 45 min per day drinking milk (Appleby et al., 2001), compared to just a few minutes per day for bucket-fed calves.

Minimize Group Size and Competition Within Groups.

Group rearing is most successful when group sizes are small. Health problems in small groups (7-10) are no more frequent than with individual housing (Losinger and Heinrichs, 1997; Svensson et al., 2003).

Cross-sucking by group housed calves can be minimized by giving the calves enough opportunity to perform their normal sucking behaviour. In our computerised calf feeding system study we found that there was no aggression at the feeders and that mixing of new calves did not cause problems., but this was likely because the physical structure of the feeder prevented calves from been displaced. In other work, Bruis et al. (2003) have compared calves fed from exposed nipples, with different densities of calves to nipple. When this ratio of nipples: calves declined from 1:1, aggressive competition and displacements increased, resulting in less feeding time for calves (especially subordinates) and less milk intake. Thus producers must either provide adequate access to nipples, or install physical structures that limit aggressive competition.

We have also found that regrouping calves is not necessarily a source of stress if it involves only a simple change of pen and partners (Veissier et al., 2001). However, in large groups with a wide range of calf ages, there can be problems with older and heavier calves disrupting younger calves that are just entering the pen (Hepola, 2003; Jensen, 2003). To reduce aggression and competition within groups, it is an advantage to minimize the variation in age and size within groups. This can be achieved with a pen for younger and a pen for older calves.

Better Weaning Techniques and Controlling Cross-Sucking After Weaning.

Under natural conditions calf weaning is a gradual process. The cow continues to nurse her calf until it is approximately 6-8 months old, but during this time the amount of milk consumed slowly declines as the calf becomes established on solid food. In contrast, calves on a North American dairy farm are typically separated from the cow within 24 h of birth and are fed milk from a bucket for 1-3 months before being weaned to solid food.

To ease the transition to solid food, some producers gradually restrict the milk intake relative to body weight by feeding the same amount of milk despite the calf's increasing body weight with age. Others gradually provide less milk on an absolute basis, by reducing the size of the daily milk ration. However, these methods of weaning may leave the calf hungry.

There is a growing body of evidence that indicates that milk stealing or intersucking (cross-sucking that occurs after weaning off milk) are related to hunger during the weaning process. Intersucking is undesirable because it can lead to milk stealing, udder malformation or injury and infection in the recipient heifer or cow. Heifers that perform intersucking are often underfed at weaning (Kiel et al., 2000, Lidfors and Isberg, 2003). It seems that we need to find ways of weaning dairy heifers that do not cause them to go hungry.

One student in our group (Patterson, 1999), compared the intake (kg/d) of protein from solid foods (starter and hay) and milk by calves fed undiluted milk and calves gradually weaned by feeding increasingly diluted milk starting at 5 weeks of age (see Figure 4). Calves weaned in this way were able to slowly compensate for the drop in milk by increasing intake of solids. However, this same compensation does not occur for very young calves. This shows that it is important to ensure high milk intakes for animals less than 4 weeks of age.

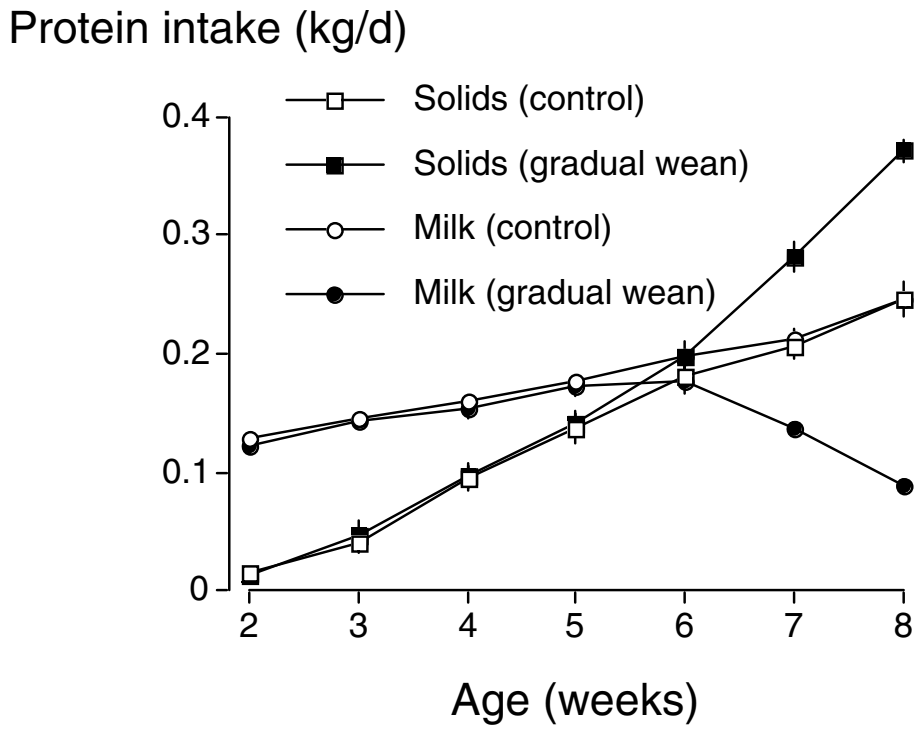

Figure 5. Mean (± s.e.m.) intake (kg/d) of protein from solid foods (starter and hay) and milk by calves fed undiluted milk (control) and those fed increasingly diluted milk over weeks 5 to 8 (gradual wean).

Although more work is required to find the optimal methods of weaning calves, our current results suggest that good results can be achieved by feeding calves to appetite during the first month of life and then gradually weaning by diluting milk over several days. This management can easily be applied when calves are fed by the computerized feeders.

Comfort of Calves

Successful rearing of calves in any system requires that the calf be kept comfortable, but there are few studies on the topic of calf comfort. Calves must be protected from drafts and a wet environment, and poor housing is often the cause of health problems (Davis and Drackley, 1998). Calves will change resting postures when they are cold so that they expose less body surface and improve heat conservation and we have found that calves kept on slatted floors will take these positions more frequently than calves kept on dry straw, suggesting that the slatted floors were too cold. Calves on slatted floors also suffer more frequently from diarrhoea (Hanninen et al., 2003) – clearly slatted floors should not be used for calves.

■ Maximize Advantages of Group Housing

Calves are social animals and keeping dairy calves in groups may provide a number of advantages to both producers and their calves. For example, group rearing allows for early social interactions that are important in the development of normal social behaviour. Group housing provides greater access to space, that together with social contact, facilitates the expression of normal behaviour. Group rearing provides the calves with more space allowing them greater opportunities to exercise. We observed that group housed calves move about for more than double the time shown by individually housed calves.

■ Conclusion

Our studies demonstrate the group housing can be a successful management option for raising young dairy heifers. The success of a group rearing system depends on several factors, including a small group size, good level of passive immunity (via colostral intake), hygiene, keeping animals' dry, good ventilation and protection from drafts and feeding high quantities and high-quality milk ormilk replacer.

The success of a computerized feeding system for dairy calves depends on the same factors as the success of group housing in addition to characteristics of the feeders and of group make up. We have found that using a swivel door on the milk feeder allows the calf to satisfy its sucking motivation so that cross-sucking is at a minimum. The milk feeder can service two groups of 10 calves with no congestion at the milk feeder. Separating animals by age likely helps reduce bullying at the milk feeder.

Acknowledgements

The research described in this article was funded by Agriculture and Agri-Food Canada's MII funds, the Natural Sciences and Engineering Research Council of Canada, De Laval Inc., and Dairy Farmers of Canada. We thank everyone who helped us in this research, especially the following: Mary Beth de Ondarza, George and his team from the Dairy in New York, Lisa Croteau, Marjolaine St-Louis, Wendy King, Steve Methot, Nathalie Caza, Jean-Robert Audet and Derek Haley.

References

Appleby, M.C., D.M. Weary, and B. Chua. 2001. Performance and feeding behaviour of calves on ad libitum milk from artificial teats. Appl. Anim. Behav. Sci. 74, 91-201.

Bøe, K., O. Havrevoll. 1993. Cold housing and computer-controlled milk-feeding for dairy calves: behaviour and performance. Anim. Prod. 57, 183-191.

Chua, B., E. Coenen, J. van Delen, and D.M. Weary. 2002. Effects of pair versus individual housing on the behavior and performance of dairy calves. J. Dairy Sci. 85:360-364.

Davis, C. L., and J. K. Drackley. 1998. *The Development, Nutrition, and Management of the Young Calf.* Iowa State University Press, Ames, IA.

de Passillé, A. M. B. and J. Rushen. 1997. Motivational and physiological analysis of the causes and consequences of non-nutritive sucking by calves. Applied Animal Behaviour Science 53:15-31.

de Passillé, A. M. B. 2001. Sucking motivation and related problems in calves. Appl. Anim. Behav. Sci. 72:175-186

de Ondarza. 2003. Feeding Calves Milk Replacer and Calf Starter with a Computer Feeder Hoard's Dairyman: Feb 24, p143.

Diaz, M. C., M. E. Van Amburgh, J. M. Smith, J. M. Kelsey, and E. L. Hutten. 2001. Composition of growth of Holstein calves fed milk replacer from birth to 105-kilogram body weight. J. Dairy Sci. 84:830-842.

Drackley, J. K. (2003) Nutrition and Health During the Milk Feeding Period in Dairy Calves. Pages 33-46 in Proc. 23rd Annual Feed Ingredients Conference, Prince Agri Procucts, Inc., Rochester, Mn.

Haley, D.; Rushen, J.; Duncan, I.; Widowski, T.; de Passillé, A. M. B. (1998). Effects of resistance to milk flow and provision of hay on nonnutritive sucking by dairy calves. Journal of Dairy Science 81: 2165-2172.

Hanninen, L., H. Hepola, J. Rushen, A. M. de Passillé, P. Pursiainen, V-M Turre, L. Syrjala-Qvist, M. Pyykkonen and H. Soloniemi. 2003. Resting behaviour, growth and diarrhoea incidence rate of young dairy calves housed individually or in groups in warm or cold buildings. Acta. Agri.Scand., SectA, Animal Science 53: 21-28.

Hammon, H. M., G. Schiessler, A. Nussbaum and J.W. Blum. 2002 Feed intake, growth performance, and metabolic and endocrine traits in calves fed unlimited amounts of colostrum and milk by automate, starting in the neonatal period. J. Dairy Science 85: 3352-3362.

Hepola, H. 2003. Milk feeding systems for dairy calves in groups: effects on feed intake, growth and health. Applied animal behaviour science 80:233-243.

Jasper, J., D. M. Weary.2002. Effects of ad libitum milk intake on dairy calves. J. Dairy Sci.85: 3054-3058.

Jensen, M.B. 2003. The effects of feeding method, milk allowance and social factors on milk feeding behaviour and cross-sucking in group housed dairy calves. Applied animal behaviour science 80:191-206.

Keil, N. M., Audigé, L., and Langhans, W. 2000. Factors associated with intersucking in Swiss dairy heifers. Preventive Veterinary Medecine 45, 305-323.

Kung, L., S. Demarco, L. N. Siebenson, E. Joyner, J.F.W. Haenlein and R. M. Morris. 1997. J. Dairy Science:80: 2529-2533.

Lidfors, L. and L. Isberg 2003. Intersucking in dairy cattle: review and questionnaire. Applied animal behaviour science 80:207-231.

Losinger, W.C., A.J. Heinrichs. 1997. Management practices associated with high mortality among preweaned dairy heifers. J. Dairy Res. 64, 1-11.

Quigley, III, J. D., C. J. Kost, and T. A. Wolfe. 2002. Effects of spray-dried animal plasma in milk replacers or additives containing serum and oligosaccharides on growth and health of calves. J. Dairy Sci. 85:413-421.

Schiessler, G., A. Nussbaum, H. M. Hammon and J. Blum. 2002. Calves sucking colostrum and milk from their dams or from an automatic feeding station starting in the neonatal period: metabolic and endocrine traits and growth performance. Animal Science 74:431-444.

Svensson,C.K. Lundborg, U. Emanuelson and S-V Olsson 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. Preventive Veterinary Medicine 1777: 1-19.

Veissier I., Boissy A., de Passillé A.M. , Rushen J., van Reenen C.G., Roussel S. , Andanson S., Pradel, P. (2001) Calves' responses to repeated social regrouping and relocation. Journal of Animal Science 79:2580-2593

Weary, D. 2001. Calf Management: improving calf welfare and production. In: Proceeding of the Western Canadian Dairy Seminar. Red Deer, Alberta, Canada.

Wells, S. J., D.A. Dargatz and S.L. Ott. 1996. Factors associated with mortality to 21 days of life in dairy heifers in the United States. Preventive Veterinary Medicine 29:9-19.