MANAGMENT FACTORS AFFECTING CALF GROWTH AND HEALTH.

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ABSTRACT

Two calf feeding trends are emerging in the dairy industry in the United States. Large herds often find it economical to feed pasteurized waste milk; while smaller herds are embracing technological advancements by utilizing automated calf milk feeders. Housing of calves varies depending on feeding mechanism. Calves fed using autofeeders are grouped together but large herds often find it more labor efficient to house calves individually in elevated wooden crates or polyethylene hutches. Two studies were conducted. The objective of the first field study was to evaluate the influence of diet and housing type on growth and morbidity in 84 Holstein heifer calves in a 2 by 2 factorial experimental design. Calves were housed in either polyethylene hutches or elevated wooden crates with slatted floors. Diets consisted of pasteurized waste milk or the same waste milk supplemented to provide approximately 454 g of milk replacer solids containing 25% protein and 10% fat (LOL Balancer). Calves were randomly placed in 1 of 4 treatment groups 48 h after birth and monitored until weaning (~60 d of age). Body weights and hip heights were measured at time of enrollment and weaning. Milk samples of pasteurized waste milk were obtained five times weekly to measure standard bacteriological plate count, fat, protein and total solids content. All calves were fed 3.3 L of liquid diet via bottle at 0730 and 1530 h. Calves were monitored daily for respiratory and digestive illness and treated according to established protocols. Pasteurized waste milk contained 332,171 ± 733,487 cfu/ mL, 3.51 ± 0.59% fat, 3.13 ± 0.30% protein, and 11.64 ± 1.05% total solids. Housing ($P = 0.02$) and diet ($P = 0.01$) affected weight gain, but there was no interaction. Least squares average daily gain for crate and hutches were 0.52 ± 0.024 and 0.59 ± 0.024 kg/d. Least squares average daily gain for waste milk and balancer diets were 0.52 ± 0.024 and 0.60 ± 0.024 kg/d, respectively. Housing or diet did not affect hip height growth/d (0.196 ± 0.007 cm). Health of the calves was not affected by diet or housing. Supplementing waste milk with balancer or housing calves in hutches resulted in higher weight gain. The objective of the second study was to evaluate management, and sanitation and consistency of liquid delivered to calves via automated feeders. Ten herds in Virginia and North Carolina with sophisticated (Förster-Technik, Germany) and basic (Biotic Industries Inc., TN, USA) machines completed a 60-question survey concerning calf and autofeeder management. Duplicate milk replacer samples were obtained to measure sanitation, dry matter, and temperature of milk in the autofeeder at the time of the survey. Six dairies from the original 10 were visited monthly for 3 mo for continued evaluation of sanitation, dry matter, and temperature of milk replacer from the autofeeder. Seven herds utilizing basic machines had a mean SPC of 6,925,000 ± 7,371,000 cfu/ml. The mean dry matter and temperature readings were 12.0 ± 2.1 Brix and 38.8 ± 6.7 °C, respectively. Three dairies that used sophisticated autofeeders had a mean SPC of 1,339,000 ± 2,203,000 cfu/ml. Mean dry matter and temperature readings were 10.37 ± 1.68 Brix and 38.6 ± 6.76°C, respectively. Dairies were also categorized based on management strategies. Producers that purchased autofeeders to manipulate feeding rates, refocus labor to sanitation, and care and well-being of calves, or for technological advancements were successful at rearing calves via autofeeders. Dairy producers who purchased an autofeeder to explore feeding options were not as successful because proper time and management was not dedicated to care of calves or to maintenance of the autofeeder.

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INTRODUCTION

The primary heifer rearing goals of most dairy producers are to raise calves efficiently and economically. Until heifers give birth and enter the lactating herd, they are an investment. Because money is not being generated by young animals it can be difficult for producers to justify spending money and time, especially, on neonatal calves.

When operating a calf program there are many options to decide how to house and group calves and what to feed calves. This thesis is focused on the performance of calves fed relevant liquid feed diets and housed in common housing types; as well as the management and sanitation of automated milk feeders utilized in the calf industry.

Chapter 1

LITERATURE REVIEW

The evaluation of neonatal programs is typically measured by mortality rates. Morbidity rates and growth performance are also measures used to evaluate calf rearing programs although these methods are not as common as mortality rates. A recent survey, released from National Animal Health and Monitoring Systems, reported 8.1% of calves were stillborn, with an additional 7.8% mortality rate for preweaned dairy calves in the United States, in 2006 (NAHMS, 2007). Digestive illnesses were the primary cause of death (56.5%) with respiratory following at 22.5% (NAHMS, 2007). The average mortality rate for calves in the U.S. (7.8%) was above the benchmark goal of less than 5%. There are several factors that can affect calf performance, well-being, and ultimately mortality. Colostrum management, calf health, housing environment and nutrition, play important roles in the well-being and survivability of neonatal dairy calves (Godden et al., 2005).

Colostrum management

At birth, the newborn calf is immunologically naïve. Neonatal calves depend on passive immunity, via colostrum immunoglobulin, from their dam. Ingestion of colostrum provides immediate immunologic protection for 2 to 4 wk after birth; while essential immune components begin to function and develop (Bush et al., 1971).

Calves that do not consume adequate amounts of immunoglobulins are described as having failure of passive transfer (FPT). According to NAHMS (2007) 19.2% of dairy calves in the United States had failure of passive transfer of immunity, which is defined as serum immunoglobulin G (IgG) concentration being less than 10 mg/ml (Godden, 2008) or less than 1.0 g/dl of gamma globulin in total serum protein. Calves with FPT cause economic losses to the dairy farm and dairy industry because of increased morbidity and mortality rates (Poulsen et al., 2010). Failure of passive transfer is dependent on amount of colostrum consumed, time fed, and colostrum quality - which includes quantity of IgG and concentration of bacteria in colostrum.

There are many factors that contribute to variation in immunoglobulin levels of colostrum. Nutrition of the dam, environment, and management explain some variation in colostrum IgG but lactation number, breed, and time of colostrum collection relative to calving may have a larger impact on IgG concentration in colostrum (Table 1.1) (Devery-Pocius and Larson, 1983, Moore et al., 2005, Morin et al., 1997, Muller and Ellinger, 1981, Poulsen et al., 2010). Moore et al. (2005) found that delayed harvest of colostrum after calving resulted in 17%, 27%, and 33% decrease in IgG concentrations at 6 h, 10 h, and 14 h, respectively.

Amount of bacteria in colostrum can negatively affect absorption of antibodies (James et al., 1981, Johnson et al., 2007). Bacteria can be from infected mammary glands or post-harvest during storage and handling. After harvest, bacteria can exponentially increase from unsanitary milking equipment or lack of cooling. Industry recommends bacteria levels below 100,000 cfu/mL for colostrum (Johnson et al., 2007).

Table 1.1 Immunoglobulin concentrations (mg/ml) of colostrum and milk

Item	Milking number (Colostrum)			Milk
	1	2	3	
IgG, mg/ml	48.0	25.0	15.0	0.6

Adapted from (Foley et al., 1978).

Johnson et al. (2007) found pasteurized colostrum had lower bacteria counts without decreasing IgG concentrations. Total plate counts of heat-treated colostrum was 1.15 ± 0.26 $\log_{10}$ cfu/mL compared to raw colostrum, 3.95 ± 0.2 $\log_{10}$ cfu/mL. Calves fed heat-treated colostrum had significantly higher serum concentrations of total proteins (6.3 ± 0.1 g/dL) and IgG's (22.3 ± 0.9 mg/mL) at 24 h after birth than calves fed raw colostrum (5.9 ± 0.1 g/dL and 18.1±1.2 mg/mL), respectively. Apparent efficiency of absorption (AEA) was greater in calves fed pasteurized colostrum compared to calves fed raw colostrum, 35.6 ± 0.02% and 26.1 ± 0.02%, respectively. Apparent efficiency of absorption is an estimate of the proportion of total IgG fed that is absorbed and circulating in the calf. James et al. (1981) found that calves challenged with bacteria had a reduced uptake of gamma globulin. This suggests that bacteria have an inhibitory relationship with IgG absorption. The specific mechanism of inhibition is unknown but can be hypothesized that antibodies bind to bacteria. Therefore the antibodies are not freely circulating and available to the calf. With fewer bacteria in the colostrum it is proposed that calves are able to absorb more IgG (Johnson et al., 2007).

Having sufficient amounts of clean, good-quality colostrum readily available can be difficult to achieve on many dairies. For dairies that encounter this issue, colostrum replacers (CR) and colostrum supplements (CS) are available. Colostrum replacers typically provide ≥100 g IgG per dose; whereas, colostrum supplements are used to enhance IgG levels in maternal colostrum and have lower levels of IgG (<50 g/dose). These products provide alternatives to feeding colostrum to neonatal calves. Poulsen et al. (2010), found that calves fed maternal colostrum had higher serum total proteins (sTP) (5.59 ± 0.67 g/dl) and IgG (1,868 ± 853 mg/dl) 1 to 7 days after birth compared to calves fed CR at the first feeding and CS during the second feeding (sTP, 5.27 ± 0.54 g/dl; IgG, 1,348 ± 693 mg/dl). Although there were differences between treatment groups, the CR-CS group absorbed adequate amounts of immunoglobulin (≥ 1,000 mg/dl) to have passive transfer of immunity. These results indicate that while feeding colostrum is the best choice, if clean, high-quality colostrum is not available 125g IgG of CR within 2 hours after birth followed by a feeding of 45g IgG of CS 2 -12 after birth is an acceptable alternative to achieve passive transfer of immunity. However, Jones et al. (1987) found no difference in plasma IgG levels at 24 h when 250 grams of IgG were fed from wither maternal colostrum or serum-derived colostrum replacer.

Effective colostrum management depends on several vital practices.

- Milk the fresh cow as soon as possible. The longer a cow waits to be milked the more diluted IgG concentration will be. At 6 h, 10 h, and 14 h after calving IgG concentrations decreased 17%, 27% and 33% (Moore et al., 2005).
- Colostrum should be handled as carefully as milk sold for human consumption. Keep it clean by storing in clean containers and/or feeding it within one hour of milking; bacteria grow rapidly and interfere with antibody absorption. Standard plate count should be less than 100,000 cfu/ml (Johnson et al., 2007).
- If the colostrum cannot be fed immediately cool it quickly by submerging clean plastic bottles of frozen water into the colostrum. Relying on a refrigerator will delay cooling by hours.
- Measure quality by using a Brix refractometer which estimates total solids level with reasonable accuracy. A reading of 23 Brix or higher indicates desirable Ig content of at least 50g of IgG/L(Bielmann, 2010).
- Pre-cooled good-quality colostrum can be refrigerated or frozen. Refrigerated colostrum should not be stored longer than 4 d; frozen colostrum can be stored for a maximum of 1 yr. Determine which method is best depending on the number of fresh cows.
- To thaw or warm colostrum, place in hot water bath of no more than 120°F. Use a thermometer to determine temperature. Place bottle(s) in water bath. Occasionally place thermometer in air hole of nipple to monitor temperature. Feed colostrum at 100-105°F. Feeding colostrum too hot is not palatable for calves; colder temperatures will cold stress calves.

Nutrition

It is customary in the dairy industry for the neonatal calf to consume a liquid milk diet during the first months of life. Producers have several liquid feed options. Until the mid-1950s whole milk was primarily utilized (Otterby, 1981). Whole milk from the bulk tank contains approximately 25% protein and 27% fat on a fry matter basis but is usually the most expensive liquid feed (Davis and Drackley, 1998). Approximately 70% of preweaned dairy calves in the U.S. in 2006 were fed milk replacer (MR) (NAHMS, 2007). Of that 12.7% is medicated. Salable whole milk was fed to calves on 29.4% of all U.S. herds, but 30% of those herds have fewer than 100 cows (NAHMS, 2007). Thirty percent of all U.S. herds feed raw waste milk to calves and 2.8% feed pasteurized waste milk (PWM). Of the 2.8% of producers that fed pasteurized waste milk, 28.7% of those herds are deemed large herds (500 or more cows) (NAHMS, 2007). Because salable whole milk is not an economically feasible liquid diet on modern dairy farms, the focus of this section will be on waste milk and milk replacer.

Milk Replacer. Milk replacers were originally developed in the early 1950s. Feeding milk replacer was less expensive than feeding whole milk and producers were able to market more saleable milk, rather than feed it to calves (Davis and Drackley, 1998). Quality and variety of milk replacers have significantly improved over the decades. Initially milk replacers were used to extend milk and fed as ‘gruels’ (Otterby, 1981). The goals of feeding milk replacer were focused on low cost and early weaning, not on meeting animal requirements for maintenance and growth. The methodology of feeding preweaned calves has shifted from the former to the latter since the 1950s. Today’s milk replacers consist of varying amounts of protein to fat ratios - anywhere from an 18:20

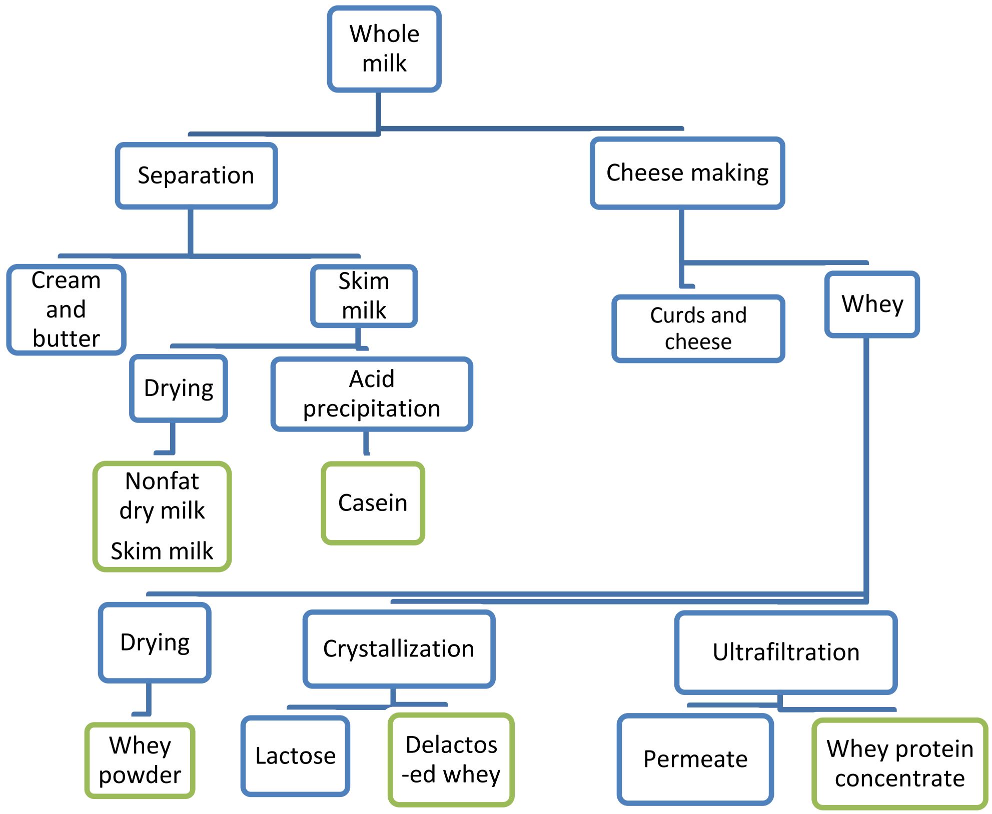

Figure 1.1 Steps in milk processing and the associated by-products used in manufacture of milk replacers (Adapted from Tomkins and Jaster, 1991; cited from Davis and Drackley, 1998)

(protein: fat) to 28:20, with 20:20 being the most commonly used. In addition to level of protein, byproducts of cheese production, processed soy and wheat proteins, serum protein and spray dried whole egg have been utilized with varying degrees of success.

Byproducts of cheese are the most popular protein ingredients in high-quality milk replacer. They are dried whey or whey powder, whey protein concentrate, delactosed whey, dried skim milk, and casein (Figure 1.1). The advantage of using milk-derived proteins are that they have more desirable amino acid content and are easily digested by the calf, as compared to non-milk proteins. However, milk-derived proteins are the most expensive ingredient in milk replacers and are in demand by the human food industry. Alternative non-milk protein sources such as soy protein concentrate, modified soy flour, wheat gluten, animal plasma, and spray dried whole egg. These non-milk protein sources are less expensive and less digestible particularly for the calf less than 3 wk of age. After three weeks a portion of milk protein may be replaced with some vegetable proteins with satisfactory results (Davis and Drackley, 1998).

Waste Milk. Utilization of waste milk (discarded or nonsalable milk) is increasing in popularity among large herds (500 or more cows). This is because waste milk is readily available and if adequately preserved an excellent source of digestible nutrients (Jamaluddin et al., 1996). Waste milk includes milk from transitions cows, cows with mastitis and cows treated with antibiotics. It is estimated that the average cow produces 62 kg of nonsalable milk per lactation (Blosser, 1979).

Feeding neonatal calves raw waste milk increases risk of transmission of bacteria, such as *Mycobacterium paratuberculosis, Salmonella* spp, *Mycoplasma* spp, *Listeria monocytogenes, Campylobacter* spp, *Mycobacterium bovis,* and *Escherichia coli*

(Godden et al., 2005, Jorgensen et al., 2006). To decrease concentrations of bacteria, on-farm pasteurizers are utilized. The literature reports that properly operating pasteurizers destroy *Mycoplasma* spp (Butler et al., 2000, Stabel et al., 2004), *Salmonella* spp (Stabel et al., 2004), *E. coli*, *L. monocytogenes,* and *Staphylococcus aureus* (Godden et al., 2005). It is debated if *M. paratuberculosis* is completely killed after pasteurization. Some studies reported total destruction after pasteurization (Keswani and Frank, 1998, Stabel et al., 2004) while others have reported isolation of *M. paratuberculosis* organism after pasteurization (Gao et al., 2002, Sung and Collins, 1998). Regardless, the proper use of pasteurizers decreases the risk of transmitting infectious disease to the young calf. Two widespread pasteurization systems available to dairy producers are batch pasteurizers and continuous flow high-temperature short-time (HTST) pasteurizers. Batch pasteurizers require heating milk to 68.2°C (145°F) for 30 minutes; while HTST heats milk for 15 seconds at 71.7°C (161°F) (Butler et al., 2000).

There has been an increased use of on farm pasteurizers. Few studies have reported the monitoring of on-farm pasteurizers. Jorgensen et al. (2006) obtained 31 waste milk samples before and after pasteurization, in the upper Midwest region of the U. S. Mean standard plate counts before pasteurization were 8,822,000 cfu/mL with a range of 6,000 - 72,000,000 cfu/ mL. Post-pasteurization levels averaged 35,000 cfu/mL with a range of 0 - 420,000 cfu/mL. Scott (2006) reported pre-pasteurization levels of waste milk from 3 North Carolina (NC) and 10 California (CA) herds. The NC herds averaged 17 million cfu/mL and CA herds averaged 1.6 million cfu/mL pre-pasteurization. Post pasteurization SPC levels on NC herds averaged 430,000 cfu/mL and 13,000 cfu/mL on CA herds. These studies show extremely high bacteria levels prior to pasteurization. Although, there was a decrease in bacteria post pasteurization, the mean bacteria levels for the NC herds were well above the recommended benchmark of <20,000 cfu/mL for pasteurized waste milk (Godden et al., 2005); which is the same standard as grade A milk for human consumption.

A further concern of feeding pasteurized waste milk is the calves' consumption of antibiotics. Most waste milk contains milk from cows treated with antibiotics. While pasteurization kills bacteria, it does not alter the antibiotic residue in the milk. A Wisconsin study found waste milk samples tested positive for B-lactam drug residues pre- and post-pasteurization (Jorgensen, 2006). Without knowing levels of antibiotic residues it is unclear what implications antibiotic residues have on calf health.

Another apprehension in feeding waste milk or PWM is the inconsistency in nutrient content and available volume. Total solids of whole milk are approximately 12.5%. A 2009 study on a California calf ranch that obtained waste milk pooled from 12 dairies found total solids averaged 11% (Moore, 2009). Samples from individual farms ranged from a low of 5.1% to 13.5% total solids. Another study of pasteurized waste milk, conducted in the upper Midwest percentage of fat and protein averaged 3.90 and 3.51 (Jorgensen, 2006). That fat and protein levels were higher than whole milk likely due to inclusion of transition milk which contains higher fat and protein levels than whole milk.

A study conducted in California evaluated performance of 300 male and female calves fed PWM versus non-pasteurized waste milk. Both groups received the same rate of intake, 4 L of milk twice daily for the first month, followed by 4 L once daily until weaning at 10 to 12 weeks. Weights were determined weekly by a heart-girth tape.

Calves fed PWM had increased weight gains, and decreased incidences of morbidity as compared to those fed raw waste milk (Jamaluddin et al., 1996).

Godden et al. (2005), measured calf performance (growth rates, morbidity, and mortality) of calves fed 3.8 L of PWM versus 20:20 at a rate of 0.45 kg in 3.8 L of water per d in two equal feedings. Four hundred thirty-eight dairy calves were enrolled over a 6 month period in 2002. Volumes were adjusted according to ambient temperature. Volumes of each milk diet at feedings were 1.9, 2.4, and 2.8 L when mean temperatures were > -4.4°C (24°F), -15.0 °C to -4.4°C (5°F to 24°F), and <-15.0°C (5°F), respectively. Average daily gain (ADG) was greater from calves fed PWM (0.47 kg/d) compared to MR (0.35 kg/d). Morbidity risk was evaluated by first treatment event. Thirty-two percent of calves fed MR received treatment while only 12.1% of calves fed PWM received treatment. Calves fed PWM also had significantly lower mortality rates (2.2%) than calves fed MR (11.6%) as shown in Table 4. It is suggested that calves fed PWM were healthier and had increased growth rates for several reasons. There was a nutrient difference in the diets. On a dry matter basis MR was 20% protein and 20% fat. While the nutrient content was not described for waste milk, it was expected to contain approximately 25.6% protein and 29.6% fat on a solids basis (Davis and Drackley, 1998). Using these assumptions calves fed PWM consumed more Mcal (2.97)/d than calves fed MR (2.47 Mcal) (NRC, 2001). On a liquid analysis, calves fed 20:20 received 2.36% protein and 2.36% fat per L; while calves on waste milk obtained 3.50% protein and 4% fat/L. Therefore calves fed waste milk had higher gains and body reserves.

Table 1.2 Preweaning morbidity and mortality rates for dairy calves fed pasteurized waste milk (treatment group, n=223) or commercial milk replacer (control group, n=215) from day 1 of age until weaning

Variable	Control group[1] (No. affected/ No. of calves [%])	Treatment group[2] (No. affected/ No. of calves [%])	Odds ratio (95% CL)	*P* value
Morbidity events				
All months*	69/215 (32.1)	27/223 (12.1)	3.99 (2.34-6.79)	<0.001
Winter†	55/105 (52.4)	22/108 (20.4)	4.23 (2.29-7.79)	<0.001
Summer†	14/110 (12.7)	5/115 (4.4)	3.26 (1.12-9.48)	0.021
Mortality events				
All months*	25/215 (11.6)	5/223 (2.2)	10.37 (3.03-35.54)	<0.001
Winter†	22/105 (21.0)	3/108 (2.8)	29.81 (3.91-227.47)	<0.001
Summer†	3/110 (2.7)	2/115 (1.7)	1.40 (0.17-11.25)	0.75

[1] Calves fed 20:20 milk replacer
[2] Calves fed pasteurized waste milk
* Model controlled for herd of origin, sex, season of birth, and serum total protein concentration. †Model controlled for herd of origin, sex, and serum total protein concentration.
CL= Confidence limits
For analysis of morbidity events, only the first preweaning treatment event was considered.
(Godden et al., 2005)

When feeding pasteurized waste milk, the total solids vary on a daily basis. An option to increase metabolizable energy to a consistent quantity is to fortify the milk. Currently no field studies have been published demonstrating the value of supplementing pasteurized waste milk with more solids.

Housing environment

In today's dairy industry several systems are used to house preweaned dairy calves. These systems include, individual housing such as hutches, elevated pens, or individual pens in barns or greenhouses. While calves can be housed in groups, approximately 74% of calves in the United States are housed individually (NAHMS, 2007).

Calves in the U. S. are commonly housed individually in 'calf hutches' (Stull and Reynolds, 2008). Hutches are typically built with polyethylene, fiberglass, or wood. Calves in hutches are either tethered to the hutch or have a perimeter fence, which allows calves to choose whether to be inside or outside the hutch. Proper management of hutches requires adequate dry bedding. Keeping a clean, dry environment inside the hutch can be labor intensive.

Elevated individual pens with expanded wire or wooden slatted floors are commonly used in California. Occasionally, these pens are located above a flush system to remove animal waste. The disadvantage of elevated pens is a lack of bedding which increases chances of calves experiencing more leg and joint problems; as well as, increased energy requirements from cold stress due to exposure to drafts and cold air (Stull and Reynolds, 2008). Lack of bedding in this housing system makes it less labor intensive.

The recommended space for calves (birth to 2 months) housed individually is 32 sq. ft/animal and a minimum of 28 sq. ft/animal for group-housed calves (Stull and Reynolds, 2008). While housing calves individually can be beneficial to laborers, not allowing calves to interact with each other could lead to failure to develop social and herd behaviors (Jensen and Kyhn, 2000, Stull and Reynolds, 2008), which are necessary behaviors needed to survive in a lactating herd.

Performance has been evaluated in calves housed individually in previous studies (Higginbotham, 1997, Macaulay et al., 1995, Van Horn, 1975). In California, Higginbotham and Stull (1997) monitored the growth of 30 calves in three housing types (10 calves/treatment) from birth to 6 weeks of age. The calf houses were as follows; 1) conventional enclosed wooden hutches (2.0 x 1.0 x 1.0 m high) with an aluminum roof which covered 60% of the floor area, 2) thermomolded opaque polymer hutches (2.0 x 1.0 x 1.3 m high) with ridge-top ventilation systems and an outdoor pen (1.4 x 1.8 m), and 3) molded opaque polyethylene hutch (2.0 x 1.4 x 1.3 m high) with ridge-top ventilation systems and an outdoor pen (1.7 x 1.5 m). All hutches were bedded with straw and maintained according to management protocols. Weekly body weights resulted in no differences among housing types for average daily gain (ADG). Weight gain and health was not superior in a particular individual housing type.

Van Horn et al. (1975) examined the effects of housing on calf growth of 119 calves from July 1973- January 1974 in Florida. Housing consisted of; 1) a closed barn with 1.22 x 1.83 m pens on a concrete floor which required daily bedding, 2) portable outdoor 1.22 x 3.05 m pens made from 1.9 cm pipe covered with woven fence wire for the retaining sides, 1/3 of pens were covered with a roof of galvanized tin, and 3) .61 x 1.22 m flush pens with slatted floors made from 2.5 x 5.1 cm cypress slats or expanded metal. Calves in housing treatment 3 were located in a pole-type shed which was open on three sides and closed on the north. Weekly body weights were obtained from each calf.

The authors reported no differences in growth and suggested choice of housing systems is dependent on economics.

Another trial, which occurred during the fall months in Utah, randomly assigned 30 calves to 1 of 3 housing groups (10 calves/ housing group) (Macaulay et al., 1995). The groups were as follows; 1) conventional wooden hutches (1.2 x 2.4 x 1.2 m high) with an outdoor pen (1.2 x 1.8 m), 2) enclosed molded polyethylene domes (2.2 diameter x 1.5 m high), and 3) thermomolded opaque polymer hutches (1.4 x 2.2 x 1.3 m high) with ridge-top ventilation systems and an outdoor pen (1.2 x 1.8 m). Calves were weighed weekly from birth to weaning (8 wk). The results of this study concluded no differences in growth of calves. Based on these previous studies (Higginbotham, 1997, Macaulay et al., 1995, Van Horn, 1976) differences in individual housing arrangements appear to have little impact on growth rate.

Group housing calves has not been well received by dairy producers due to concern for transmission of disease among young preweaned calves. Comingling calves is thought to facilitate more rapid spread of enteric and respiratory disease (Stull and Reynolds, 2008). These systems are based on the fact that calves are herd animals, which allows development of social behavior and interaction (Stull and Reynolds, 2008). A study conducted in Denmark concluded that calves housed in groups provided the opportunity to express play behavior, which stimulated motor and social skills crucial for normal behavioral development (Jensen and Kyhn, 2000). Another study showed pair-housed calves vocalized less, spent more time at the concentrate feeder, ingested more concentrate, and gained (numerically) more weight than individually-housed calves (De Paula Vieira et al., 2010). Few studies (Warnick, 1977) have compared health of calves housed individually versus paired or grouped (Warnick, 1977) (Table 1.4). This is interesting since morbidity and disease mortality are typically cited as the major incentive to house calves individually.

Table 1.3 Summary of disease problems in calves reared in two housing systems

Treatment	No. of calves	No. of calves requiring medication	No. of medication treatments given
Group	12	5	8
Individual	12	2	2

(Warnick, 1977)

Automatic calf feeders

Automated calf milk feeders have been well received in the European Union and have been gaining popularity in the United States over the last few years. This form of milk feeding requires calves to be housed in groups. Calves are fitted with a radio frequency identification (RFID) tag or similar identifying device which allows the computer to recognize each calf in the group. Several recommendations are commonly cited regarding rearing calves on autofeeders that are not supported by research; 1) house calves individually for 1-2 wk prior to being fed via automated feeder, and 2) no more than 25 calves/ nipple. The majority of the research involved with computerized milk feeders concerns behavioral development and manipulating liquid diet intake.

Several features of automated feeders can be viewed as nutritional advantages. Traditionally, individually housed calves are fed twice a day at varying intervals between feedings. With a computerized feeder, calves feeding habits can mimic a more natural, cow-calf scenario, which provides daily milk allotment in more feedings per day with smaller amounts consumed per meal. A programmed amount of meals/d is set for each calf; for example, consumption of 4-6 meals/d rather than 2 meals/d. When calves receive more meals/d they don't consume as much volume/meal; therefore regulating their metabolism, decreasing stress, and keeping a cow-calf approach to milk intake. Sophisticated automated feeders such as the equipment made by Förster-Technik (Germany) allow programming of different meals/d and volume size/meal depending on age, concentration (dry matter) of milk, and supply an abundant amount of data/animal. This allows for an intensified feeding program to be easily implemented.

The most common automated feeders used in the U. S. are Förster-Technik and Biotic systems (Bell Buckle, TN), which require feeding milk replacer. The powder is dry-stored in a hopper and when a calf's RFID tag is read in the stall the milk replacer is mixed, with temperature regulated water, and is available for the calf to consume.

Published studies that utilized automated calf feeders evaluated social behavior, milk portions (volume/meal), milk allowance (meal/d), and calf health (Jensen 2004, 2006, 2009, Vieira et al., 2008). In 2004, Jensen found that calves housed in groups of 24 displayed more signs of competition to access the autofeeder than in groups of 12 calves. The number of calves per feeder, up to 24, had no effect on milk intake. Calves fed 4 meals per d spent less time at the autofeeder compared to calves fed 8 meals/d. Although number of meals did not have an effect on the duration of ingesting milk. Feeding fewer meals with fewer calves per nipple reduces competition and disturbances at the autofeeder. Another study conducted in Denmark found that limit fed calves which developed a disease had significantly reduced unrewarded visits and a tendency of reduction in rewarded visits to the autofeeder (Jensen, 2009).

It is assumed that automated feeders mix milk more consistently than humans and are sanitary, but research indicating the function of these feeders under field conditions does not exist.

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Chapter 2

EFFECTS OF HUTCHES AND FORTIFIED WASTE MILK ON GROWTH AND HEALTH IN PREWEANED HOLSTEIN DAIRY CALVES.

ABSTRACT

Large California dairies often find it economical to feed pasteurized waste milk and house calves in elevated wooden crates. The objective of this field study was to evaluate the influence of diet and housing type on growth and morbidity in 84 Holstein heifer calves in a 2 by 2 factorial experiment. Calves were housed in either polyethylene hutches or elevated wooden crates with slatted floors. Diets consisted of pasteurized waste milk or the same waste milk supplemented to provide approximately 454 g of additional milk replacer solids containing 25% protein and 10% fat. Calves were randomly placed in 1 of 4 treatment groups 48 h after birth and were monitored until weaning (~60 d of age). Body weights and hip heights were measured at time of enrollment and weaning. Milk samples of pasteurized waste milk were obtained five times per wk to measure standard plate count 332,171 ± 733,487 cfu/ mL, percent of fat 3.51 ± 0.59, protein 3.13 ± 0.30, and total solids 11.64 ± 1.05. All calves were fed 3.12 L via bottle at 0730 and 1530 h. Calves were monitored daily for respiratory and digestive illness and treated according to protocols. Housing ($P = 0.02$) and diet ($P = 0.01$) affected weight gain, but there was no interaction. Least squares weight gain means for crate and hutches were 0.52 ± 0.024 and 0.59 ± 0.024 kg/d, respectively. Least squares weight gain means for waste milk and balancer diets were 0.52 ± 0.024 and 0.60 ± 0.024 kg/d, respectively. Calves housed in crates fed balancer had similar gain to calves housed in hutches fed waste milk. Housing or diet did not affect hip height growth/d (0.196 ± 0.007 cm). Health was not affected by diet, housing, or their interaction. Supplementing waste milk with balancer or housing calves in hutches resulted in improved weight gain. The importance of this advantage warrants economic evaluation.

(Keywords: calves, diet, housing)

INTRODUCTION

Feeding calves pasteurized waste milk (PWM) is a viable diet option commonly utilized on large dairy herds. It has been documented that bacteria levels in PWM can vary between and within herds. High bacteria levels (>20,000 cfu/ml) post pasteurization can be attributed to poor pasteurizer function and/or levels exceeding several million cfu/ml of waste milk prior to pasteurization (Elizondo-Salazar et al., 2010, Scott, 2006). Other challenges when feeding PWM under field conditions are the daily fluctuation of supply and nutrient content. Studies documenting efforts to minimize variation of nutrient components by fortifying PWM have not been published.

Calf housing is a concern as evidenced by legal actions taken by some animal welfare groups regarding calf housing practices on California calf ranches (Animal Legal Defense Fund, 2012). Many large dairies and calf ranches in California rear calves in elevated wooden crates. It is suspected that in the future this housing type will no longer be a legal option. Previous studies comparing calf growth in several different housing environments found no significant differences in weight gain or health (Van Horn et al., 1975, Higginbotham and Stull, 1997).

The objectives of this study were to determine variation of bacteria levels and nutrient components (percentage of total solids, protein, and fat) of waste milk on a daily basis, evaluate performance and health of calves housed in polyethylene hutches versus elevated wooden crates, and compare performance and health of calves fed pasteurized waste milk versus pasteurized waste milk fortified with a 25% protein, 10% fat all-milk-solids powder supplement.

MATERIALS AND METHODS

A field trial was conducted between June and August, 2010 on a dairy located in the central valley of California. Calves originated from two dairies under the same ownership, but were housed at one dairy. Eighty-four calves were enrolled in the study over a three week period.

Newborn care and handling

Neonatal calves received three feedings of colostrum and navels were dipped with iodine. All feedings of colostrum measured 23 Brix or higher with a refractometer (Walco International Inc., CA, USA). Each calf received 3.8 L of colostrum within 4 h of birth, an additional 2 L at 12 h, and 2 L between 12 and 24 h of birth via bottle or esophageal feeder. After the third colostrum feeding, calves at Dairy 1 were transported 40 km to Dairy 2 by an in-house driver. Thirty-two calves were born at Dairy 1 while the remaining were born at Dairy 2. Calves, blocked by dairy of origin, were randomly assigned to treatment and placed in individual housing within 48 h of birth according to a predetermined randomized chart.

Treatments, feeding, and housing

In this 2 by 2 factorial experiment, the major treatment classifications were housing type and diet as shown in Table 2.1. Calves were housed in either polyethylene hutches (Agri-Plastics Inc., Cortland, NY) or elevated wooden crates with slatted floors. The hutch was approximately 1.1 m wide x 1.8 m long with the fenced area approximately 1.1 m wide x 1.8 m long. Hutches were bedded with wood chips which were replenished as needed. Elevated wooden crates housed three calves individually per unit. Each individual stall was 0.7 m wide x 1.5 m long.

Diets consisted of PWM or the same waste milk supplemented with Balancer (Bal) (Land O' Lakes Animal Milk Products Co., Black River Falls, WI) to provide approximately 454 g of additional milk replacer solids containing 25% protein and 10% fat on a dry matter basis.

Waste milk was obtained once daily at 12:00 p.m. from two dairies under the same ownership where it was mixed and placed in a 3028 L holding tank. Milk was pasteurized using a high temperature short time (HTST) pasteurizer (Goodnature Terminator T-900, Orchard Park, NY) at 72°C for 15 seconds. Pasteurization occurred prior to each feeding and bottled, or mixed with Bal and then bottled. The original intention of the study was to standardize solids to 15% in the supplemented diet. However, this proved not to be feasible due to daily fluctuation in waste milk solids and expertise of calf feeding labor. Based on previous evaluation, waste milk was assumed to be 10% solids to which additional water and 454 g of milk replacer solids were added to achieve an estimated solids level of 15%. Liquid diets were fed twice daily in 3.3 L bottles at 0700 and 1500 h. At 53 d calves received one bottle daily and then were weaned at 60 d if eating approximately 1 kg of starter grain. Samples of PWM and Bal were obtained prior to the morning feeding approximately 5 d/wk. Samples of PWM were sent daily to Hilmar Cheese Company (Hilmar, CA) to determine percentage of total solids, fat and protein (FOSS FT1 Hillerod, Denamrk). An additional PWM sample was sent to Silliker Lab (Salida, CA) for measurement of standard plate count (SPC). A corresponding Bal sample was frozen and shipped to Land O' Lakes, Inc. lab (Fort Dodge, IA) at the end of the trial for measurement of percentage of total solids, fat and protein. Balancer samples were tested separately from PWM samples because lab equipment at Silliker Lab was unable to process samples with Bal powder.

Starter grain containing 22% CP (A.L. Gilbert, Oakdale, CA) was provided fresh daily. Starter grain intake was not reliably measured due to labor constraints. Water buckets were rinsed and refilled each morning and additional water added in the afternoon.

Data collection

At the time of enrollment each calf was weighed and hip height measured. Blood samples were obtained using a 21G vacutainer system from jugular vein within 7 d of birth to measure serum gamma globulin content. Samples were frozen and shipped monthly to Land O' Lakes, Inc. lab, with percentage of gamma globulin from serum determined by Zinc Sulfate Turbidity Test (McEwan et al., 1970). Scale weight and hip height were measured a second time, near the time of weaning at 60 d. Calves were measured in one day during the week that they turned 60 d, due to challenges weighing calves housed in crates.

Calf health was monitored daily. After the morning feeding calves were monitored for appetite, fecal consistency, and symptoms of respiratory illness and depression using calf health scoring chart (2009). Calves with a fecal score ≥3 were considered to have a scour event and received electrolytes (Land O' Lakes Animal Milk Products Co., Electrolyte Base and Add Pack, Black River Falls, WI) once daily for 3 d. Calves were monitored for nasal discharge, cough, ear position, and rectal temperature. If 2 or more parameters were abnormal, calves received antibiotic treatment and a respiratory event was recorded.

The experimental protocol and procedures were approved by the Institutional Animal Care and Use Committee at Virginia Polytechnic Institute and State University (10-068).

Statistical analysis

Data analysis was conducted using standard software (version 9.2, SAS Institute, Cary, NC) and values of $P \leq 0.05$ were considered statistically significant when comparing means or other parameter estimates.

Performance. Average calf weight and hip height at arrival and weaning, and average daily weight gain and hip height growth were analyzed by housing, diet, and their interaction. An analysis of variance (Glimmix) included fixed effects of housing, diet, their interaction, and farm. Because there were only 2 dairies, farm was precluded from being specified as random. Farm of origin had no influence and was ultimately omitted from the model.

Health. The frequency of scour scores and respiratory occurrences by housing, diet, and their interaction were compared. A new morbidity event was classified after 3 d, however only the first occurrences of scour score and respiratory events were evaluated. Chi square was used to test differences in health event distributions between treatments. The simplicity of this analysis best suited the comparison of housing, diet, and their interaction when evaluating morbidity incidences.

Single and multiple occurrences of respiratory and scour scores were evaluated by diet, housing, and their interaction to detect the probability of calves having a morbidity event or not, or if calves had none, one, or ≥2 morbidity events. Binomial and multinomial distribution models did not show significant differences in probability of health events between housing types or between diets.

Scour score and respiratory event data were also evaluated as a non-normal distribution. A nonparametric model (NPar1Way, Wilcoxon) analyzed ranked scour scores and respiratory observations but found no differences among treatments.

Multiple occurrences of scour scores were considered in a mixed model (Glimmix) that included treatment and date as fixed effects with calf as a random effect.

Milk quality. Averages for percentage of total solids, protein, and fat were determined for Bal and PWM. Standard plate count averages were also determined for PWM. Correlations of percentage of total solids, protein, and fat were measured between Bal and PWM using paired samples by date.

Effects of milk solids or SPC on scour scores or respiratory events were evaluated by diet, housing, and their interaction. A mixed model (Glimmix) tested PWM solids, Bal solids, or bacteria levels on scour scores and respiratory events.

RESULTS AND DISCUSSION

A total of 84 Holstein heifer calves were born and enrolled in this study between June 1st and 23rd, 2010. One heifer died at 5 d of age from navel ill and was omitted.

Serum concentrations of immunoglobulins measured during the first week of life to evaluate passive transfer of immunity were not different between housing or diet. Only two calves had failure of passive transfer as indicated by values of 0.76 and 1.0 g/dl gamma globulin of serum. These two calves were housed in hutches; one was fed Bal, and the other received PWM. The current study had only 2% failure of passive transfer while NAHMS (2007) reported 19% of calves having failure of passive transfer in the United States.

***Nutritional and bacterial content of diets*.** Waste milk components as a percentage of total solids, protein, and fat varied on a daily basis as shown in Figure 2.1. As expected, percentages of protein and overall solids percentages in waste milk was increased in the Bal treatment (Figure 2.2 and 2.3, and Table 2.2). Mean total solids for PWM was 11.6% ± 1.1%. Balancer total solids averaged 13.6% ± 1.2%. Mean protein was increased in the Balancer diet (3.9% ± 0.4%) compared to PWM (3.2% ± 0.3%). Variation in waste milk components and bacteria has been documented (Elizondo-Salazar et al., 2010, Jorgensen, 2006, Moore, 2009, Scott, 2006). Moore reported total solids from 12 dairies and calf ranches in California that ranged from 5.1 to 13.5%. The maximum is similar to the maximum percentage of total solids found in this study. The low solids (5.1%) found by Moore is likely from addition of flush line water, which would dilute the total milk solids. Jorgensen et al. (2006) found the mean protein (3.51%) and fat (3.90%) percentage of waste milk samples from 31 dairies or calf ranches. It is likely that this study gathered milk from several Jersey herds (breed was not specified) or contained milk from a greater proportion of cows within days of calving because of the high average percentage of protein and fat.

Correlations between PWM and Bal for percentage of total solids, protein, and fat were 0.51, 0.53, and 0.79, respectively when paired by day. The correlation in components between Bal and PWM was expected. Because addition of the balancer supplement increased the protein percentage far more than the fat percentage, the correlation between the two treatments was much closer to 1.00 for the fat percentage.

The majority of published studies evaluating efficacy of on-farm pasteurizers utilized a single date sample. However, one published study measured performance of pasteurizers under repeated daily observations (Elizondo-Salazar et al., 2010), similar to the current study. In the current study standard plate counts in PWM varied on a daily basis as expected (Figure 2.4). Means for SPC were 332,171 ± 733,487 cfu/ml, with a range of 14,000 to 4,000,000,000 cfu/ml. A majority of the samples was 100,000 cfu/ml or less. However, these results are still substantially over the goal of 20,000 cfu/ml which indicates successful pasteurization (Godden et al., 2005). Evaluation of SPC of PWM indicated that equipment used in this trial was rarely successful in achieving desired reductions in SPC and/or bacteria concentration prior to pasteurization.

Scott (2006) reported SPC of PWM from 10 dairies in California and 3 dairies in North Carolina. California (CA) PWM had fewer colony forming units (13,000 cfu/ml) in waste milk than North Carolina (NC) herds (430,000 cfu/ml).

Pasteurizers were evaluated in NC biweekly over a 7 mo period and CA herds twice during a 6 month period. A recent study (Elizondo-Salazar et al., 2010) evaluating 6 dairies in Pennsylvania reported an average of 5,877 ± 28, 481 cfu/ml in waste milk post-pasteurization, with a range of 0 to 250,000 cfu/ml. Samples were collected twice daily for 15 d from herds ranging from 500 to 2,000 cows. Jorgensen (2006) found low mean bacteria levels of 9,000 ± 23 cfu/ml post pasteurization in 27 herds, with a range of 0 to 80,000 cfu/ml. However, Jorgensen (2006) reported fewer SPC (9,000 ± 23 cfu/ml) than total coliform species (305,000 ± 1,116 cfu/ml). The findings in the current study are larger possibly due to pasteurizer not functioning properly and/or the lack of adequate refrigeration prior to pasteurization.

Performance. Weight and height of calves at enrollment was not different between treatments, as desired. It was hypothesized that calves fed Bal and housed in hutches would have the greatest growth. Differences in average daily gain (ADG) were observed by housing and diet, but not by interaction as shown in Table 2.3. Calves housed in hutches had greater ADG (0.59 ± 0.02 kg/d) than calves housed in crates, (0.52 ± 0.02 kg/d) (P=0.02). Calves fed Bal had greater ADG (0.60 ± 0.02 kg/d) than calves fed PWM, (0.52 ± 0.02 kg/d) (P=0.01). These results corresponded with NRC energy allowable ADG requirements for a 60 kg calf at 27°C. The NRC predicted a calf fed Bal and PWM would gain 0.62 kg/d and 0.53 kg/d, respectively. Bal fed calves consumed 4.18 Mcal of metabolizable energy daily. In comparison, PWM fed calves consumed 3.87 Mcal of metabolizable energy. There was no difference in average daily hip height growth by housing or diet. However, Bal fed calves had increased body weight (P= 0.01) and hip height (P=0.01) at weaning.

The results of this study suggest that diet and housing affected weight gain. Calves fed Bal received more metabolizable energy than calves fed PWM. It is likely that calves housed in hutches had greater gains because their maintenance requirements were lower as there is less protection from drafts and cool temperatures in elevated crates and no bedding for calves to nest. Although this study was conducted during the summer months, the average low temperature during the month of June, 2010 at this location was 14°C. Calves less than 14 d of age are considered to be cold stressed when temperatures are less than 15°C. Data in the current study do not agree with previous studies that found no differences in weight gain in calves housed individually in hutches versus crates (Higginbotham, 1997, Macaulay et al., 1995, Van Horn, 1976). The previous studies had limited animal numbers per treatment group (10 calves/treatment) (Higginbotham, 1997, Macaulay et al., 1995). Also, environment plays an important role in measuring housing differences. It is probable the differences in temperature, humidity, and nighttime cooling did not impose sufficient environmental stresses on calves to have an impact on maintenance requirements.

Hip height growth differences among housing and diet were not different. This would indicate that calves fed Bal likely had more body condition, as stature was not different.

Health. Differences in morbidity by diet, housing, or their interaction were not significant. Frequency of calf scour and respiratory events were not different due to diet ($p = 0.59$, $p=0.70$), housing ($p=0.57$, $p=0.27$), or their interaction ($p=0.55$, $p=0.47$), respectively, as shown in Tables 2.4-2.9. In the current study diet, housing, or their interaction had no impact on calf morbidity. Godden et al. (2005) evaluated morbidity of 215 calves fed equal volumes of a 20% protein: 20% fat MR and 223 calves fed PWM. They found morbidity of 32.1% for calves fed MR as compared to only 12.1% of calves consuming PWM. The lack of differences in morbidity in the current study is likely due to differences in nutrient intake. Calves in the current study consumed 4.18 Mcal (Bal) or 3.87 Mcal (PWM). Whereas, the calves in Godden et al. (2005) received approximately

2.97 Mcal (PWM) or 2.47 Mcal (20:20 MR). In the current study, calves were fed increased solids and volume compared to traditionally fed calves. Therefore, since both diets, in the current study, received more nutrients, morbidity differences were not apparent. Differences in morbidity between the current study and Godden et al. (2005) could also be due to factors found in milk and transition milk. Waste milk contained milk from fresh cows, among milk from other cows. Both diets in the current study contained waste milk. It can be speculated that calves in the current study had higher concentrations of immunoglobulins and nonspecific immune factors (i.e. leukocytes, cytokines, hormones, and lactoferrin) found in transition milk (Le Jan, 1996), as compared to calves fed MR by Godden et al (2005).

There was no relationship between health events and PWM solids, Bal solids, or bacterial levels. It was hypothesized that calves fed milk containing high concentrations of bacteria would be more prone to scours or respiratory illness. This study demonstrated that feeding higher levels of milk solids (Bal) did not contribute to an increased incidence of scours. There was no effect of milk solids or SPC on morbidity ($P = 0.45$). The knowledge of SPC was not a useful tool to predict calf morbidity.

CONCLUSIONS

Pasteurized waste milk is utilized on many large dairies. It was documented that PWM varied in bacteria concentrations and nutrient contents daily. This study illustrated the need to monitor pasteurizers and nutrient content of waste milk to ensure delivery of consistently adequate nutrient concentrations. Supplementing PWM is a viable way to increase solids while still utilizing waste milk. With more protein and solids in the diet, maintenance requirements were satisfied and more nutrients were partitioned for growth.

Housing calves in hutches rather than crates also allowed calves to allocate more nutrients to growth. Differences in health were not observed likely due to the fact that calves receiving both diets were fed better than traditional calf feeding programs which limit solids intake to 400 to 500g of solids daily. Balancer and hutches are more expensive than PWM and crates but calves with increased growth during the prewean period, if transitioned to grain well, will reach maturity earlier and enter the lactating herd at an earlier age, and therefore produce money for the producer at an earlier age (Raeth-Knight et al., 2009).

Table 2.1 Treatment groups by diet and housing in a 2 by 2 factorial design

Treatments			
Pasteurized waste milk (PWM)		Balancer (Bal)	
Wooden crate n=21	Plastic hutch n=21	Wooden crate n=20	Plastic hutch n=21

PWM fortified with Balancer = Bal
n=Number of calves within treatment group

Table 2.2 Least squares means of pasteurized waste milk (PWM) and balancer (Bal) components as a percentage on a liquid basis

Milk parameter	Least squares means	SE	Minimum	Maximum
PWM solids (%)	11.6	1.1	9.0	13.2
PWM protein (%)	3.1	0.3	2.3	3.6
PWM fat (%)	3.5	0.6	1.9	4.7
Bal solids (%)	13.6	1.2	10.2	15.1
Bal protein (%)	3.9	0.4	2.9	5.1
Bal fat (%)	2.9	0.4	2.2	3.7

Table 2.3 Least squares means of weight, hip height at birth and weaning, and daily gain of calves housed in crates or hutches and fed pasteurized waste milk (PWM) or pasteurized waste milk supplemented with balancer (Bal)

Growth variable	PWM + crate	Bal + crate	PWM + hutch	Bal + hutch	SE	**P-values**		
						Housing	Diet	HxD
Initial (3 d)								
BW (kg)	38.6	38.5	37.5	37.8	1.2	0.46	0.95	0.90
Hip height (cm)	78.8	79.1	78.0	79.4	0.8	0.70	0.28	0.50
At weaning (60 d)								
BW (kg)	68.4	70.3	68.5	75.2	1.8	0.18	0.02	0.19
Hip height (cm)	89.8	90.5	89.1	92.0	0.7	0.60	0.01	0.12
ADG (kg/d)	0.50	0.54	0.53	0.65	0.03	0.02	0.01	0.26

Table 2.4 Percentage of calves having none, one, or multiple respiratory events by treatment (P=0.46)

Treatment		Respiratory occurrences		
		0	1	2
PWM + Crate	N	11	5	5
	Percent	52.4	23.8	23.8
Bal + Crate	N	7	8	5
	Percent	35.0	40.0	25.0
PWM + Hutch	N	5	6	10
	Percent	23.8	28.6	47.6
Bal + Hutch	N	8	6	7
	Percent	38.1	28.6	33.3
Total	N	31	25	27
	Percent	37.4	30.1	32.5

Table 2.5 Percentage of calves having none, one, or multiple scour events by treatment (P=0.55)

Treatment		Scour score occurrences		
		0	1	2
PWM + Crate	N	8	10	3
	Percent	38.1	47.6	14.3
Bal + Crate	N	6	10	4
	Percent	30.0	50.0	20.0
PWM + Hutch	N	8	9	4
	Percent	38.1	42.9	19.0
Bal + Hutch	N	9	12	0
	Percent	42.9	57.1	0.00
Total	N	31	41	11
	Percent	37.35	49.40	13.25

Table 2.6 Percentage of calves having none, one, or multiple respiratory events by housing type (P=0.26)

Housing type		Respiratory occurrences		
		0	1	2
Crate	N	18	13	10
	Percent	43.9	31.7	24.3
Hutch	N	13	12	17
	Percent	30.9	28.6	40.5
Total	N	31	25	27
	Percent	37.35	30.12	32.53

Table 2.7 Percentage of calves having none, one, or multiple scour events by housing type (P=0.57)

Housing type		Scour occurrences		
		0	1	2
Crate	N	14	20	7
	Percent	34.1	48.8	17.1
Hutch	N	17	21	4
	Percent	40.5	50.0	9.5
Total	N	31	41	11
	Percent	37.35	49.40	13.25

Table 2.8 Percentage of calves having none, one, or multiple respiratory events by diet (P=0.69)

Diet		Respiratory occurrences		
		0	1	2
Bal	N	15	14	12
	Percent	36.6	34.1	29.3
PWM	N	16	11	15
	Percent	38.1	26.2	35.7
Total	N	31	25	27
	Percent	37.35	30.12	32.53

Table 2.9 Percentage of calves having none, one, or multiple scour events by diet (P=0.58)

Diet		Scour occurrences		
		0	1	2
Bal	N	15	22	4
	Percent	36.6	53.7	9.8
	N	16	19	7
PWM	Percent	38.1	45.2	16.7
	N	31	41	11
Total	Percent	37.35	49.40	13.25

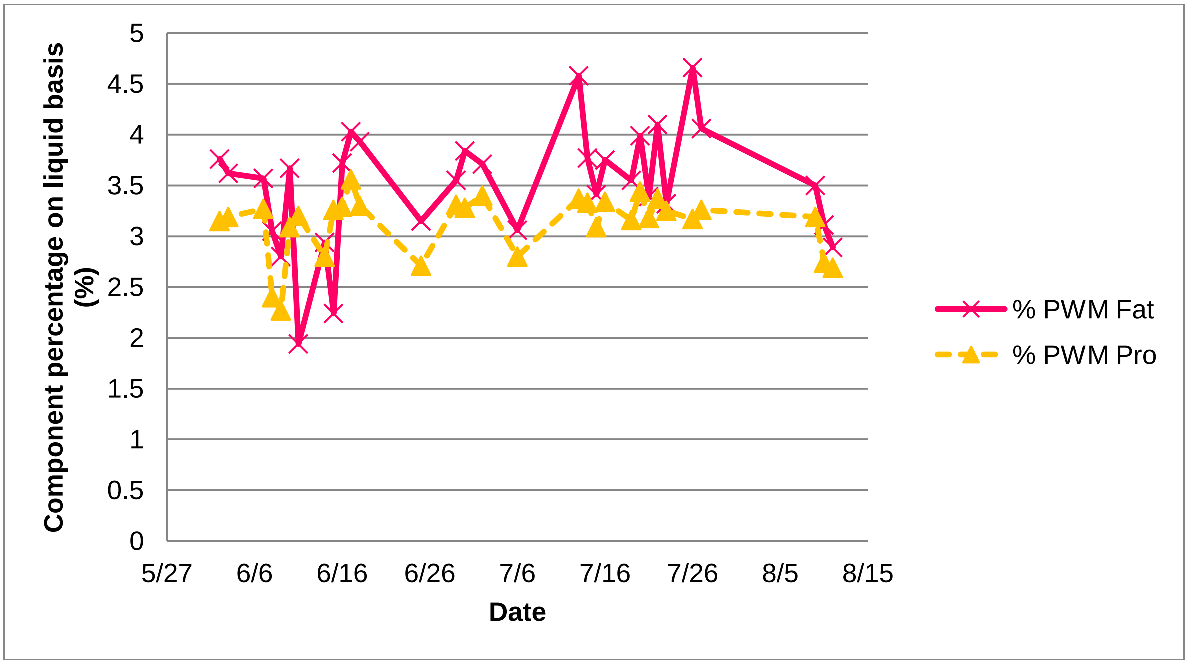

Figure 2.1 Percent of protein and fat in pasteurized waste milk (PWM) by date

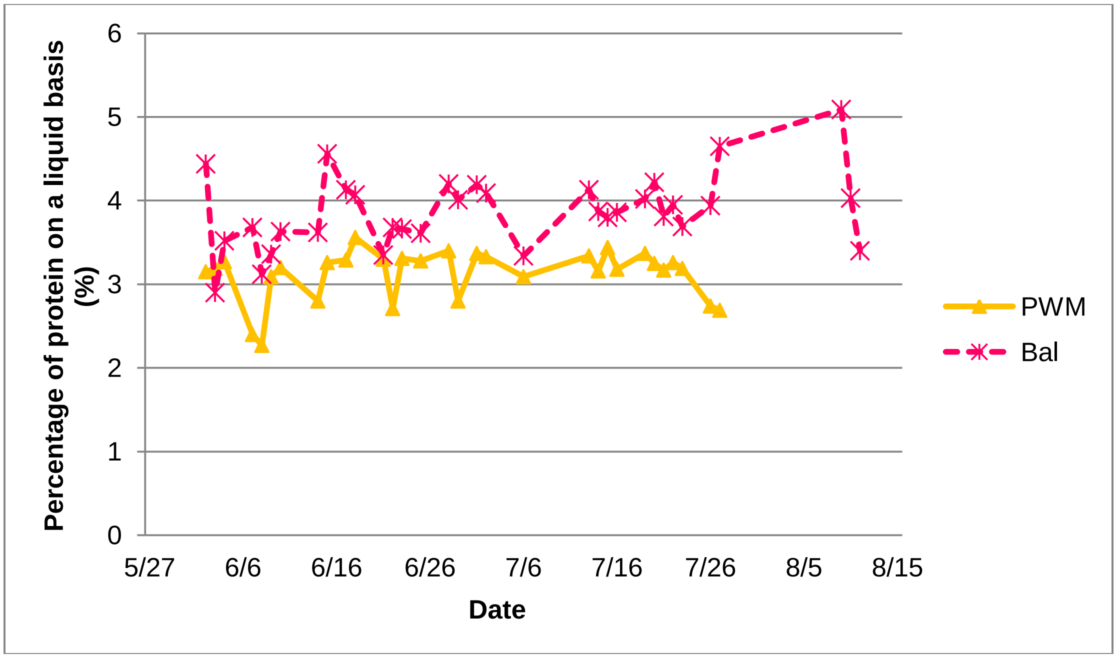

Figure 2.2 Pasteurized waste milk (PWM) and Balancer (Bal) protein as a percentage on a liquid basis

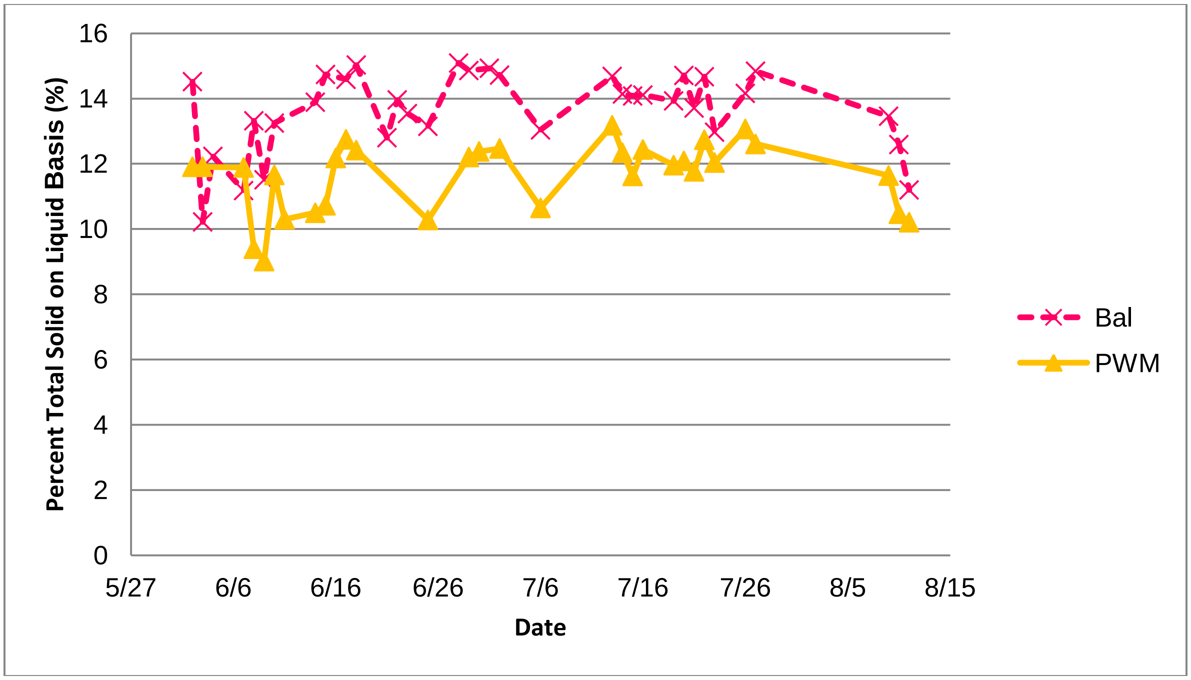

Figure 2.3 Total solids of Balancer (Bal) and pasteurized waste milk (PWM)

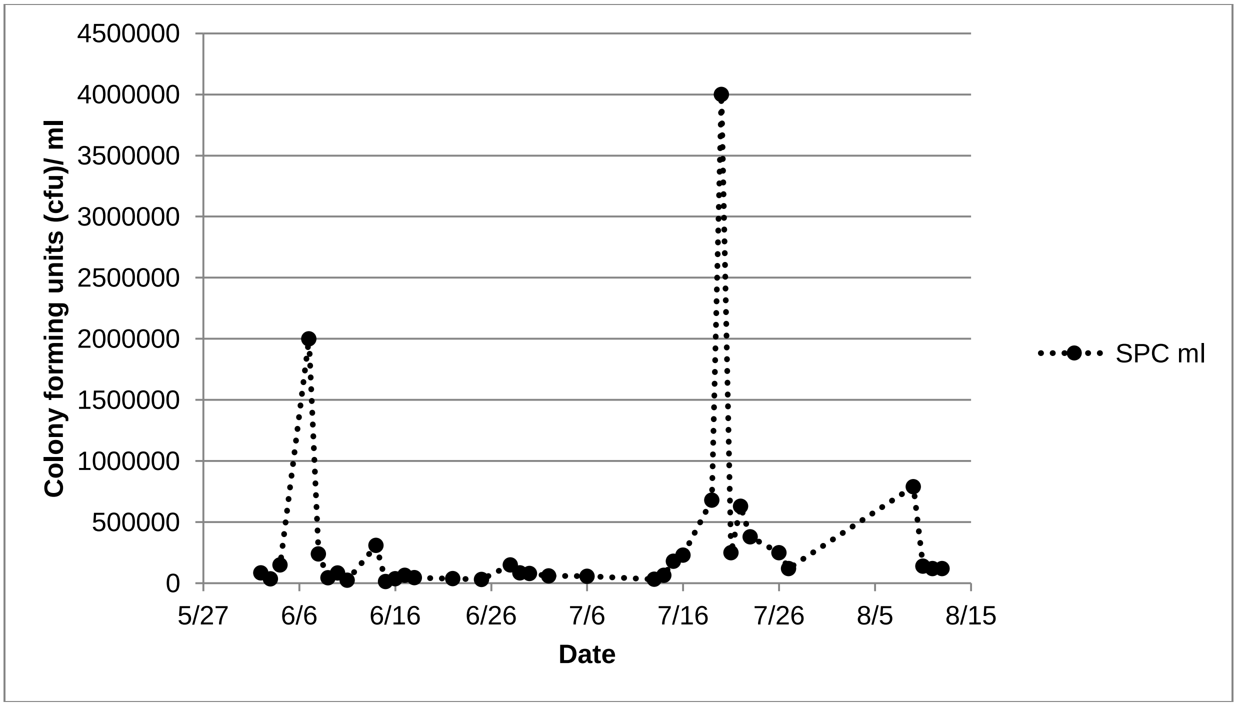

Figure 2.4 Standard plate counts for pasteurized waste milk (PWM) (cfu/ml)

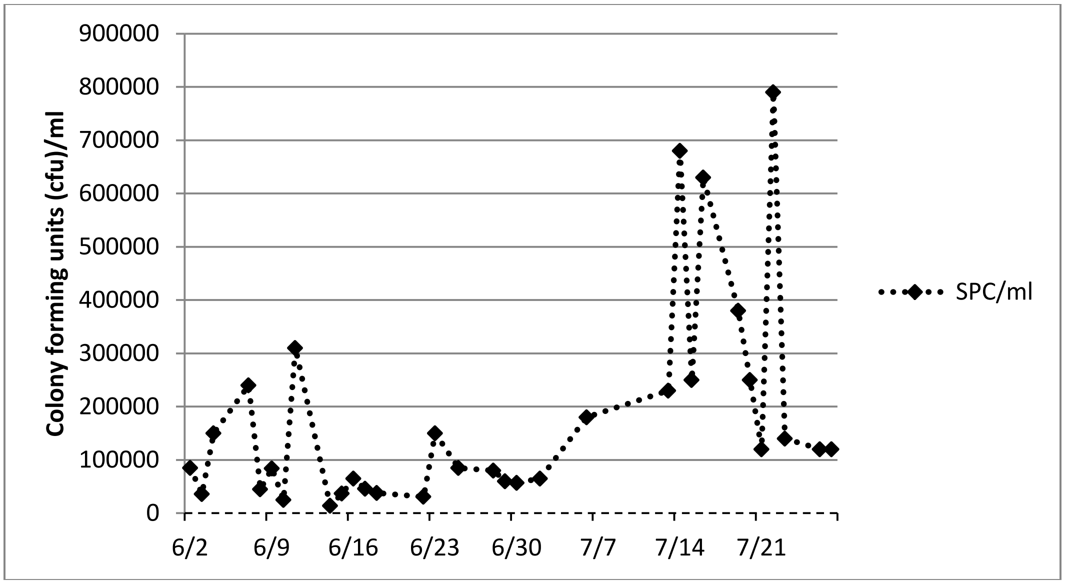

Figure 2.5 Standard plate counts for pasteurized waste milk (PWM) (cfu/ml) with the exclusion of outliers

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Chapter 3

EVALUATION OF MANAGEMENT, NUTRIENT CONSISTENCY, AND SANTITATION OF AUTOMATED CALF FEEDERS.

ABSTRACT

The objective of this study was to evaluate management, sanitation and consistency of liquid diets delivered to calves via autofeeders. Ten herds in Virginia and North Carolina with sophisticated (Förester-Technik, Germany) and basic (Biotic Industries Inc., TN, USA) machines were asked a 60-question survey concerning calf and autofeeder management. Duplicate milk replacer samples were obtained to measure standard plate count, dry matter content, and temperature of milk delivered by the autofeeder at the time of the survey. Six dairies were visited monthly for 3 mo for continued evaluation of standard plate count, dry matter, and temperature of milk replacer from the autofeeder. Seven herds utilizing basic machines had a mean SPC of 6,925,000 ± 7,371,000 cfu/ml. The mean dry matter and temperature readings were 12.0 ± 2.1 Brix and 38.8 ± 6.7 °C, respectively. Three dairies that used sophisticated autofeeders had a mean SPC of 1,339,000 ± 2,203,000 cfu/ml. The mean dry matter and temperature readings were 10.37 ± 1.68 Brix and 38.6 ± 6.76°C, respectively. Dairies were also categorized based on management strategies. Producers that purchased autofeeders to 1) manipulate feeding rates, 2) refocus labor to sanitation, and care and well-being of calves, or for 3) technological advancements were successful at rearing calves via autofeeders. Dairy producers who purchased an autofeeder to 4) explore feeding options were not as successful because proper time and management was not dedicated to calves on autofeeder or to maintenance of the autofeeder.

(Keywords: calves, automated feeders, management)

INTRODUCTION

Automated calf milk feeders have been well received in the European Union and have gained popularity in the United States over the last few years. The majority of automated calf feeder studies have focused on animal behavior, restricted versus ad libitum feeding, and calf health (Jensen, 2004, 2006, and Vieira et al., 2008). These studies have been conducted under research environments with little information to describe why and how dairy producers implement these systems. Likewise published information is not available indicating how these systems are managed and nutritional content, temperature and SPC of the liquid diet delivered to the calf.

Two calf autofeeders that are commonly used in the eastern United States; one is a sophisticated feeder (Förster-Technik, Engen, Germany), and the other is a basic feeder (Biotic Industries Inc., Bell Buckle, TN, USA). The basic feeders are less expensive (~$2,000) than the sophisticated machines (~$20,000) and keep records of each calf's feeding history for 24 hours, after which the information is deleted. There is also less flexibility in feeding rates. Sophisticated feeders are able to deliver the liquid diet to as many as four pens of calves and include an extensive software program. They records feeding history for the entire duration of the calf on the feeder, records the suckle speed per meal, feed time/meal, amount consumed/meal, meals/day, and allows for a variety of graphs to be used as management tools. They also offer flexible feeding programs and automated cleaning systems.

The objective of this study was to evaluate management strategies used by dairy producers in Virginia and North Carolina who have implemented use of calf autofeeders. Solids content and temperature of the liquid diet was measured along with bacterial growth to indicate equipment sanitation.

MATERIALS AND METHODS

Six Virginia and three North Carolina dairies that operated automated calf feeders participated in this study. These farms were identified by equipment dealers and represented the majority of such systems in these two states. Prior to the initial visit in June, 2011 a 60-question survey was developed and administered by personal interview to nine producers (Appendix). Participants answered questions concerning management of autofeeders, reasons for purchase, and management of calves prior to and after moving onto the system.

Duplicate milk replacer (MR) samples were obtained during each visit to enable estimation of solids with a Brix refractometer (Nasco, Fort Atkinson, WI), and temperature of liquid delivered to the calves from each machine. After the initial visits, 6 dairies were selected to be visited once each mo for 3 mo. These 6 herds were chosen based on location, willingness to participate, and to enable comparison of equal number of farms utilizing each type of autofeeder. At each monthly visit, duplicate MR samples were obtained aseptically. Refractometer and temperature readings were recorded at time of collection. Brix refractometer is commercially used to measure sugar content of fluids. Is has been adapted to estimate level of solids in milk or milk replacer diets and generally reads 2% less than true total solids. For example a Brix reading of 10 equates to 12% total solids (Bielmann, 2010).

All MR samples were immediately cooled on ice and frozen until lab procedures were performed. Twenty-four hr prior to determining standard plate counts (SPC) all samples were thawed (5°C). Samples were diluted using PBS to obtain dilutions of 10^4 and 10^5. One ml of diluted sample was plated onto a Petrifilm (3M Petrifilm Aerobic Count Plates, St. Paul, MN) to estimate cfu (Mizuochi and Kodaka, 2000). Petrifilms were incubated for 48 hr at 37°C. If there were more than 220 cfu/ petrifilm, then the sample was deemed too numerous to count (TNTC) (Petrifilm Aerobic Count Plate Interpretation Guide, 2011).

Statistical Analysis

Data analysis was conducted using standard software (version 9.2, SAS Institution, Cary, NC) and values of $P \leq 0.05$ were considered statistically significant.

Survey questions were analyzed by frequency (Proc Freq) of answers. Distribution of answers was compared by dairy, management strategies, and autofeeder type.

Nine producers surveyed were categorized by their most prominent reason for investment in autofeeders (technological advances, additional method, refocused labor, or feeding rates) and by type of automated feeder (sophisticated or basic). Dairy producers were perceived as rapid adopters of technology if their feeders were older than 2 yr and they have made technological advancements in other areas on the dairy, i.e. the milking parlor. This category was termed, technology. The second management strategy was additional method of feeding. These producers fed calves individually but used the autofeeders as an alternative method of feeding an abundant number of calves which exceeded current individual housing facility capacity. A third strategy was represented by producers' intention to reassign labor management from preparing and feeding milk to the care and well-being of calves. The final strategy represented producers who purchased automated feeders to manipulate feeding rates. These calf raisers desired to gradually increase milk intake until peak, at a higher rate than conventional feeding, followed by a gradual decrease of daily milk allotment until weaned.

The variables SPC, Brix, and temperature were analyzed with Proc Glimmix with a fixed effect of management strategy (or autofeeder type), a random effect of dairy nested in management strategy (or autofeeder type), and residual. Dairy(management strategy) is the error term that tested management strategy. Management strategy and autofeeder type could not be placed in the same model because some combinations had only one or no dairies. Repeatability was calculated for each variable. It is a correlation between samples in general, and is the variance of dairies divided by the sum of dairy and residual variances. It ranges 0 to 100%. The larger the repeatability, the less need for duplicate samples.

The survey study was approved by Virginia Tech IRB (11-478).

RESULTS AND DISCUSSION

Survey

Table 3.1 summarizes responses of herds by total herd size, management strategy, autofeeder type, range of calves per feeder, and MR used. Statistical analysis of the data from the survey yielded no significance, likely due to a small sample size.

Milk Replacer. Milk replacer used fluctuated from dairy to dairy. Half of the herds used 20:20 MR, with the remainder using 22:18, 22:20, 24:18, 25:20, and two dairies fed

28:20 MR. The first number representing the concentration of protein and the second number representing fat concentration on an air dry basis.

Feeding Program. All dairies surveyed in this study moved calves onto the autofeeder prior to 3 wk of age. However, there was a range of 3 to 14 d. Calves on the basic feeding system ranged from receiving 8 to 16 meals/d, with an average of 11 meals/d. Each meal with this machine was 473 ml. The mixing bowl with this system had the capacity to mix 473 ml /meal, meaning that calves received numerous small meals each day. This is not an ideal amount of milk per meal. It has been shown that calves consuming low milk allowances per d had 35 unrewarded visits at the feeder, likely due to hunger, compared to 15 unrewarded visits from calves receiving high milk allowances (Jensen, 2006). Refer Table 3.2 for NRC (2001) estimates of nutrient intake.

Three herds with the sophisticated feeder had different feeding programs. Dairy 1 fed calves 7 L/d at 2 L/meal at approximately 7 Brix. This dairy had an automated grain feeder; calves were weaned according to grain consumption monitored electronically. Dairy 5 and 8 had more complex feeding programs and averaged 2 L/meal. On dairy 5 calves were allocated 4 to 7 L/d from day 1 to 17; calves consumed 7 L/d from day 18 to 21, and on day 22 gradual weaning began. Calves at dairy 5 received milk containing approximately 10.5 Brix. Calves at dairy 8 were allowed to consume 4.7 to 5.7 L/d from day 1 to 6. For the next 28 d, calves consumed 5.7 L/d. At 34 d weaning began; calves intake was decreased over a 2 d period from 5.7 L/d to 3 L/d, where they remained on 3 L/d for 6 more days until fully weaned; at approximately 11 Brix.

Square Footage. Square feet/pen varied considerably. Some dairies utilized previously established space while others built new facilities. Of those that built new facilities their square footage was as follows: 5.5m x 13.7m /pen, 2 pens/barn; 9.1m x 30.5m /barn, 4 pens/barn; 15.2m x 21.3m /barn, 2 pens/barn; and 9.1m x 29.2m /barn, 2 pens/barn. In the farms in this study, square footage per calf ranged from 2.6 to 2.9 sq m/calf.

Categorized Management Strategies

There was no difference among management strategies for SPC (P=0.39), Brix (P=0.65), or temperature (P=0.24). The repeatability of SPC, Brix, and temperature were 73.2%, 49.0%, and 5.9%, respectively. There was more variation among machines for temperature compared to SPC and Brix. It would be more useful to estimate the repeatability of duplicate samples.

Technological advancements: The goal of these dairies was to interface novel technology into their dairy business. Two dairies in this category had basic feeders and one had a sophisticated feeder. The mean standard plate count (SPC) for this category of producers was 2,560,000 ± 5,430,000 cfu/ml. Mean refractometer and temperature readings were 9.7 ± 1.5 Brix and 37.2 ± 4.8°C, respectively, as shown in Table 3.2.

Additional method of feeding: The purpose of purchasing an autofeeder was to try an alternative method of feeding their abundant number of calves. Dairies 3 and 4 fed the majority of their calves housed individually via milk replacer (MR) or pasteurized waste milk (PWM). Basic autofeeders were purchased to feed additional calves and to investigate the technology before making a large financial commitment. The mean SPC for this category was 4,100,000 ± 5,580,000 cfu/ml. The mean refractometer and temperature readings were 10.2 ± 1.5 Brix and 39.2 ± 5.6°C, respectively.

Refocus of calf labor: One dairy owned a sophisticated machine, whereas two dairies owned basic autofeeder(s). Mean SPC for this category was 1,450,000 ±

4,580,000 cfu/ml. The mean refractometer and temperature readings were 11.9 ± 1.3 Brix and 39.0 ± 2.8°C, respectively.

Manipulate feeding rates: The dairies in this category were aware of the labor benefits but their main purpose of purchasing autofeeders was the ability to manage feeding rates more precisely during the young calf's life. One dairy had 2 sophisticated machines and another had eight basic feeders. The mean SPC for this category was 4,240,000 ± 5,350,000 cfu/ml, from 77 samples. The mean refractometer and temperature readings were 11.7 ± 1.3 Brix and 39.3 ± 6.6°C, respectively.

Autofeeder Manufacturer

Results for SPC, MR solids (refractometer), and temperature by autofeeder type are shown in table 3.3. There were no differences in SPC (P=0.32), Brix (P=0.08), or temperature (P=0.46). The repeatability of SPC, Brix, and temperature were 74.6%, 31.0%, and 32.8%, respectively. Seven herds utilizing basic machines had a mean SPC of 6,930,000 ± 2,870,000 cfu/ml with mean refractometer and temperature readings of 11.9 ± 0.61Brix and 38.8 ± 6.7°C, respectively. Three dairies that used sophisticated autofeeders had a mean SPC of 1,220,000 ± 4,590,000 cfu/ml. The mean refractometer and temperature readings were 9.8 ± 0.89 Brix and 38.6 ± 6.8°C, respectively.

Jensen, 2004, 2006, and Vieira et al., 2008, evaluated calf performance and behavior using sophisticated automated calf feeders. Suggested appropriate level of SPC for PWM is 20,000 cfu/ml (Godden, 2005). Several field studies (Jorgensen, 2006, Machado, 2011, Scott, 2006) have shown that this benchmark is achievable, but with varying levels of success on individual farms. Field studies measuring SPC in MR feeding situations have not been reported. However, mean SPC by management strategy and machine type were well over the benchmarks of 20,000 cfu/ml. It is uncertain how increased levels of bacteria may influence calf health and growth. High levels of bacteria during colostrum consumption appears to have a negative impact on Immunoglobulin absorption (James et al., 1981, Johnson et al., 2007). It has been suggested that during the first 3 wk of life increased levels of bacteria could predispose calves to enteritis and other infections. Calf health or performance was not measured in this study. Future field studies should identify the impact of increased bacteria on calf growth and health.

There is no goal for SPC for milk replacer. Although, bacteria should be less than 20,000 cfu/ml in pasteurized waste milk. These averages exceeded this level by a wide margin in nearly all cases. All herds were within the range of acceptable total solids. Whole milk has a percentage of total solids of approximately 12.5%. The lowest average refractometer reading was 10.1 Brix, which is equivalent to 12.1% total solids. However one dairy with a sophisticated feeder had fed a liquid diet measuring 7 Brix due to a calibration error. This was easily fixed by recalibration of the machine. The range of Brix readings was 7 to 18.

Calf liquid diets should be fed at a range of 37.8 to 40.6°C. The lowest average temperature was 37.2°C with the highest average being 39.3°C. Although the averages were within feeding guidelines the minimum and maximums indicated a lack of precision in several systems. The minimum was 27.2°C and the maximum was 47.8°C. These temperature extremes could cause cold stress or decrease milk intake.

CONCLUSIONS

Future research could help develop benchmarks to encourage improved sanitation and consistency of milk delivered to calves on autofeeders. Of the autofeeders studied, basic more than sophisticated machines appeared to require greater attention and maintenance. It became obvious from the fluctuations observed that monitoring temperature, dry matter percent of the liquid diet, and bacterial growth on a regular basis is advised. Producers with the assumption that calves can be fed and left alone were not satisfied with the autofeeder. Calves require monitoring and care while on the autofeeder. Those producers that understood this concept were satisfied and willing to purchase more feeders in the future. It was evident when evaluating SPC and solids percentages as these producers were more successful in limiting bacterial growth and delivering milk with desired solids percentages and temperature.

Table 3.1 Summarization of survey data by dairy

Dairy	Herd size	Management strategy	Feeder type	# calves/ feeder (range)	Milk replacer
1	280	Technology	Sophisticated	20	25:20
2	400	Technology	Basic	16-21	24:18
3	3,100	Additional method	Basic	20	20:20
4	900	Additional method	Basic	15-19	22:18
5	220	Labor	Sophisticated	12-35	20:20
6	250	Labor	Basic	11-20	28:20
7	190	Labor	Basic	25	28:20
8	500	Feeding rates	Sophisticated	25	20:20
9	1,300	Feeding rates	Basic	17	22:20

Table 3.2 NRC (2001) estimates of energy intake and allowable gain for a 60 kg calf at 27°C fed different milk replacers at7.6 L/d at 12.5% solids

Milk Replacer	Metabolizable energy (Mcal)	Energy allowable ADG (kg/d)	ADP allowable gain (kg/d)
20:20	4.5	0.70	0.59
28:20	4.6	0.73	0.89

Table 3.3 Least squares mean standard plate count (10^5), temperature (°C), and refractometer (Brix) reading categorized by management strategies

Category	Variable	N[5]	LSMean	SE[6]	Minimum	Maximum
Technology[1]	SPC	18	25.6	54.3	0.00	67.00
	Brix	5	9.7	1.5	7.00	12.50
	Temperature	4	37.2	4.8	33.9	39.4
Additional calves[2]	SPC	18	41.5	55.8	8.00	181.00
	Brix	8	10.2	1.5	9.00	13.00
	Temperature	7	39.2	5.6	35.2	43.3
Refocused labor[3]	SPC	12	14.5	45.8	0.00	54.00
	Brix	5	11.9	1.3	9.50	14.00
	Temperature	3	39.0	2.8	37.2	40.1
Feeding rates[4]	SPC	77	42.4	53.5	0.00	187.00
	Brix	30	11.7	1.3	7.00	18.00
	Temperature	29	39.3	6.6	27.2	47.8

[1]Technology: dairy producers that rapidly adapt to technology advances.
[2]Additional calves: an alternative method to feed an abundant number of calves.
[3]Refocused labor: reassignment of labor management to the care, sanitation, and well-being of calves.
[4]Feeding rates: producers purchased automated feeders to manipulate feeding rates.
[5]N= sample size
[6]SE based on farm(management strategy)
P-values for management strategy ranged from 0.24 to 0.65.

Table 3.4 Least squares mean standard plate count (10^5), temperature (°C), and refractometer (Brix) reading by machine type

Machine type	Variable	LSMean	SE[1]	Minimum	Maximum
Basic	SPC	69.3	28.7	0.00	500.00
	Brix	11.9	0.61	7.00	18.00
	Temperature	38.8	6.7	30.6	47.8
Sophisticated	SPC	12.2	45.9	0.00	88.00
	Brix	9.8	0.89	7.00	13.00
	Temperature	38.5	6.8	27.2	41.7

[1]SE based on farm(autofeeder type)
P-values for autofeeder type ranged from 0.08 to 0.46.

*Tables of individual herds and machines within herds are shown in the appendix.

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Overall Conclusions

Weight gain of preweaned calves is affected by diet and housing environment. Calves fed supplemented pasteurized waste milk or raised on the ground in polyethylene hutches achieved greater gains compared to calves fed pasteurized waste milk or housed in elevated wooden crates.

Variation of waste milk was measured in protein and fat. Therefore calves consumption of total solids varied on a daily basis. It was also found that pasteurizers must be monitored. The pasteurizer on this farm was not functioning adequately and standard plate counts were well above the acceptable level of 20,000 cfu/ml. Although high levels of bacteria were in the milk it did not have an effect on calf morbidity. Further research should be conducted to determine the relationship of SPC of waste milk or MR diets with morbidity. Likewise the relationship of daily variation in nutrient content of PWM and MR to animal growth and health should be studied.

Producers that decided to fed and manage calves through automated feeders found that maintenance of the autofeeders is essential. Autofeeders must be calibrated on a biweekly or monthly basis to deliver a liquid diet containing consistent and nutritionally adequate content (12.5 to 15% total solids) at 40.5°C. Sanitation can be a challenge, especially for the producers that chose to purchase basic machines, as those machines do not have automated cleaning. For those producers that purchased sophisticated machines significant data are available that can be useful in monitoring calf dietary intake and possibly detect health events earlier by indication of abnormal consumption or eating patterns. Further research is warranted to evaluate the effects of bacteria concentration and dry matter and temperature consistency in group-housed calves fed via autofeeders.

Appendix

Survey:

Management of Automatic Calf Feeders Survey

Producer information

Name:
Address:
Email:
Phone:

General herd information

Herd size:
Breed:
DHI HERD CODE/RAC CODE:
Autofeeder manufacturer and model:
Date purchased:

SECTION I: Calves & Management

Newborn Calf Care

1. If a cow calves during the following times of day, how many hours after birth does the first feeding of colostrum normally occur? Please check the box below.

	Within 2 hrs of calving	**2-6 hrs**	**6-12hrs**	**>12 hrs**	**As soon as the calf gets up to suckle**
Morning (5-11am)					
Afternoon (11am-5pm)					
Evening (5-11pm)					
Night (11pm-5am)					

2. What percentage of calves is routinely fed the majority of their first feeding of colostrum by the following method: (percentages should Total: 100 %)

   a. Nursing the dam? ____% of calves

b. Hand feeding by nurse bottle?____% of calves
c. Hand feeding by bucket?____% of calves
d. Esophageal (tube) feeder?____% of calves

3. How many quarts of colostrum (first milking) are routinely hand-fed or tubed to each calf in the first feeding:

a. 2 quarts (.5 gallon)
b. 3 quarts
c. 4 quarts (1 gallon)
d. More than 4 quarts

4. At the time of colostrum feeding, which type(s) of colostrum are fed?

1 = never used → 4 = always used

Commercial colostrum replacer 1 2 3 4 (circle)
MANUFACTURER________________________
Fresh colostrum from dam only 1 2 3 4 (circle)
Fresh colostrum from another cow 1 2 3 4 (circle)
Pooled colostrum from the herd 1 2 3 4 (circle)
Frozen Colostrum 1 2 3 4 (circle)
Pasteurized colostrum 1 2 3 4 (circle)
Acidified/preserved colostrum 1 2 3 4 (circle)
Colostrum plus colostrum supplement 1 2 3 4 (circle)

5. Is quality of colostrum evaluated before feeding?
□Yes □ No

If yes, how is quality evaluated?

6. Is the success of passive transfer of immunity in newborn calves monitored, using a blood test (total proteins), to assess colostrum management on the farm?
□ Yes □ Occasionally □ No

7. Do bull calves normally remain on the farm?

   □Yes □ No

   a. If so, are the bull calves managed the same as the heifer calves?
      a. Yes
      b. No

8. What is the typical age that bull calves leave the farm?

Calf feeding prior to purchase of autofeeder

9. Who is the primary calf care provider?
   a. Owner/Spouse
   b. Family member (i.e. children or other relative)
   c. Herdsman
   d. Employee – one employee with responsibility for calf program
   e. Multiple individuals –no one has primary responsibility.

   (Male vs. female? Employee vs. family? Owner vs. other. Or maybe, calves are what percent of this person's job?)

10. How were calves housed?

11. How many hours /d were spent feeding calves? (prior to autofeeder)

12. How many hours/d were spent monitoring/caring for calves other than labor for feeding?

13. What was the scour treatment protocol?, Was there one?

14. What was the respiratory treatment protocol?, Was there one?

15. Describe the feeding plan.
    a. Solids level (% DM or dilution of powder with water if milk replacer used) - – *Solids level might be miscalculated, so you might want to know the exact mixing quantities of powder and water*.

a. Amount per feeding – volume

b. Number of times calves fed per day

c. Time(s) of calf feeding

d. Liquid fed to calves
    i. Waste milk
        ✓ Pasteurized
    ii. Saleable milk
    iii. Milk replacer
        ✓ Manufacturer
        ✓ %CP
        ✓ %FAT

16. What measurements were used before purchase of autofeeder(s) to evaluate calf performance?
    a. Scale weights
    b. Tape weight
    c. Mortality rates
    d. Morbidity rates
    e. None
    f. Other________________

Calf management after purchase of autofeeder
- - ***Management of calves prior to their assignment to autofeeder***

17. What age are calves moved to autofeeders?

18. Under what circumstance do you delay sending a calf to the autofeeder? (i.e. age, health, size)

19. How many hours per day are normally spent feeding, managing and caring for calves before they are transitioned to the autofeeder?

20. What milk diet are calves fed?
    (i.e. Milk Replacer: Brand & type ________________
    include if there are antibiotics/additives – get a tag)

21. Describe the feeding plan.
    a. Solids level
        a. Amount per feeding

        b. Number of times calves fed per day

        c. Time of calf feeding

        d. Liquid fed to calves

            iv. Waste milk
            v. Saleable milk
            vi. Milk replacer
                ✓ Manufacturer
                ✓ %CP
                ✓ %FAT

22. What type of housing is used?

23. Ventilation? Tube, fan, outdoors?

-- Calves ON-autofeeder

24. How many square feet /pen? (I may need to measure pens)

25. Calves: all in all out? Or add animals?

26. How many animals /pen? Range? (How many animals/nipple?)

27. What liquid diet is used? (I.e. Southern States 22:20 (include if there are antibiotics)), Same for all ages?

28. Why did you select the %CP and % Fat MR (or whole milk)?

29. Describe autofeeder program. Are there different feeding rates at different ages?

a. Amount fed 1st week on feeder
b. Amount fed 2nd week on feeder.
c. Amount fed 2 - ? week on feeder.

30. What is the size of one meal allocation/ calf?

31. How many meals /day are required to achieve desired daily intake?

32. Does the feeder show alarms for calves' not consuming daily allotment?

33. If the calf does not consume the allocation is it discarded or retained for the next calf?

34. How frequently are the feeders cleaned?

35. Describe cleaning procedures used.

36. Are the lines between the mixing bowl and the nipple cleaned/replaced? What frequency?

37. What measurements are used to evaluate calf performance for calves on the autofeeder(s)?
    a. Scale weights
    b. Tape weights
    c. Mortality rates
    d. Morbidity rates
    e. Other__________________
    f. None

38. Who regularly has responsibility for care of calves on the autofeeder?
    f. Owner/Spouse
    g. Family member (i.e. children or other relative)

h. Herdsman
i. Employee
j. Multiple individuals

39. What other duties does the primary calf care-giver regularly complete on the farm?
(check all that apply)
    a. No other duties
    b. Milking the cows
    c. Feeding mature cattle
    d. Feeding the heifers
    e. Other duties with mature cattle (i.e. breeding, health care)
    f. All of the above duties

40. Ventilation? Tube, fan, outdoors, nothing

41. Are scours/scour treatments recorded?

□ Yes □ Occasionally □ No

42. What is the scour treatment protocol, if there is one?

43. Are respiratory/respiratory treatments recorded?

□ Yes □ Occasionally □ No

44. What is the respiratory treatment protocol if there is one?

45. How often are alarms checked during a day?

SECTION II: The automatic feeder

Evaluation

46. How do you evaluate sanitation of the feeder?

47. Have you ever measured bacterial growth using standard plate counts?

□ Yes □ No

If yes, how often?

48. Where is the sample obtained? (exactly where)

49. Do you measure total solids content of the liquid fed to calves?

□ Yes □ No

a. How often?

Autofeeder information

50. Purchase price?

51. Costs associated with installation? (building modification, water lines, drainage, electrical…..)

52. Has the autofeeder been serviced?
    d. Who performed service?

    e. What problems have been encountered with the feeder?

    f. Cost of service?

53. What are the daily, weekly, monthly costs associated with the auto feeder?

54. What are electric rates for your farm? $/kwh

Decision making

55. What is your primary reason for choosing autofeeders to deliver nutrition to young calves?
    a. Labor: manage calves rather than feed calves
    b. Health reasons
    c. Utilize new technologies
    d. Manipulate feeding rates
    e. Other ______________________

56. Were other types of autofeeders evaluated before your decision to purchase?

a. Yes
b. No

57. If yes, then what were your sources of information?
    a. Autofeeder salesman
    b. Other producers with autofeeders
    c. Seminars
    d. Magazines
    e. Other_____________

58. Would you make the same purchase again? Why or why not?

59. Do you plan to purchase more or upgrade?

60. Do you have any suggestions for feeder manufacturers?

61. Do you have any suggestions for producers considering such a purchase?

Appendix 4.1 Mean standard plate counts (10^5), temperature, and refractometer reading (BRIX) by dairy.

Dairy	Variable	N	Mean	SD	Minimum	Maximum
1	SPC	8	22.13	24.50	0.00	67.00
	brix	2	7.00	0.00	7.00	7.00
	temp	2	102.75	0.35	102.50	103.00
2	SPC	10	29.00	7.62	19.00	43.00
	brix	3	12.17	0.29	12.00	12.50
	temp	2	95.00	2.83	93.00	97.00
3	SPC	16	70.00	43.47	37.00	181.00
	brix	7	10.36	1.31	9.00	13.00
	temp	7	102.57	5.62	95.40	110.00
4	SPC	2	8.50	0.71	8.00	9.00
	brix	1	10.00	.	10.00	10.00
	temp	0	.	.	.	.
5	SPC	6	0.50	1.22	0.00	3.00
	brix	2	10.50	1.41	9.50	11.50
	temp	2	103.80	0.57	103.40	104.20
6	SPC	4	2.75	2.50	0.00	6.00
	brix	2	14.00	0.00	14.00	14.00
	temp	1	99.00	.	99.00	99.00
7	SPC	2	43.00	15.56	32.00	54.00
	brix	1	11.00	.	11.00	11.00
	temp	0	.	.	.	.
8	SPC	30	13.63	22.78	0.00	88.00
	brix	11	10.95	1.06	10.00	13.00
	temp	10	100.60	7.97	81.00	107.00
9	SPC	47	71.02	40.05	15.00	187.00
	brix	19	12.42	2.36	7.00	18.00
	temp	19	103.78	5.76	96.60	118.00
10	SPC	4	290.75	208.64	100.00	500.00
	brix	2	13.00	1.41	12.00	14.00
	temp	2	88.00	1.41	87.00	89.00
11	SPC	4	34.50	16.01	16.00	53.00
	brix	0	.	.	.	.
	temp	0	.	.	.	.

Appendix 4.2 Mean standard plate count (10^5), temperature, and refractometer (BRIX) reading by machine/ dairy

Dairy	Machine	N	Variable	N	Mean	SD	Minimum	Maximum
1	1	8	SPC	8	22.13	24.50	0.00	67.00
			brix	2	7.00	0.00	7.00	7.00
			temp	2	102.75	0.35	102.50	103.00
2	1	4	SPC	4	32.25	9.91	19.00	43.00
			brix	1	12.00	.	12.00	12.00
			temp	1	93.00	.	93.00	93.00
	2	6	SPC	6	26.83	5.60	20.00	33.00
			brix	2	12.25	0.35	12.00	12.50
			temp	1	97.00	.	97.00	97.00
3	1	6	SPC	6	55.17	12.89	37.00	76.00
			brix	2	9.25	0.35	9.00	9.50
			temp	2	102.70	10.32	95.40	110.00
	2	6	SPC	6	95.83	64.81	43.00	181.00
			brix	3	11.33	1.53	10.00	13.00
			temp	3	101.53	6.05	96.00	108.00
	3	4	SPC	4	53.50	5.80	48.00	59.00
			brix	2	10.00	0.00	10.00	10.00
			temp	2	104.00	1.41	103.00	105.00
4	1	2	SPC	2	8.50	0.71	8.00	9.00
			brix	1	10.00	.	10.00	10.00
			temp	0	.	.	.	.
5	1	6	SPC	6	0.50	1.22	0.00	3.00
			brix	2	10.50	1.41	9.50	11.50
			temp	2	103.80	0.57	103.40	104.20
6	1	2	SPC	2	4.50	2.12	3.00	6.00
			brix	1	14.00	.	14.00	14.00
			temp	1	99.00	.	99.00	99.00
	2	2	SPC	2	1.00	1.41	0.00	2.00
			brix	1	14.00	.	14.00	14.00
			temp	0	.	.	.	.
7	1	2	SPC	2	43.00	15.56	32.00	54.00
			brix	1	11.00	.	11.00	11.00
			temp	0	.	.	.	.
8	1A	8	SPC	8	24.88	29.44	0.00	76.00
			brix	3	11.00	1.00	10.00	12.00
			temp	2	104.50	2.12	103.00	106.00

	1B	8	SPC	8	7.13	9.08	0.00	22.00
			brix	3	11.33	1.53	10.00	13.00
			temp	3	101.93	6.03	95.00	106.00
	2A	6	SPC	6	1.83	1.94	0.00	5.00
			brix	2	11.00	1.41	10.00	12.00
			temp	2	100.05	5.16	96.40	103.70
	2B	8	SPC	8	17.75	29.44	0.00	88.00
			brix	3	10.50	0.87	10.00	11.50
			temp	3	97.03	14.02	81.00	107.00
9	1	6	SPC	6	33.67	18.70	15.00	69.00
			brix	3	12.17	4.65	7.00	16.00
			temp	3	99.87	3.78	96.60	104.00
	2	8	SPC	7	79.86	39.86	40.00	136.00
			brix	3	12.00	1.00	11.00	13.00
			temp	3	107.80	9.43	99.40	118.00
	3	8	SPC	8	104.38	33.84	54.00	165.00
			brix	3	11.17	1.04	10.00	12.00
			temp	3	102.57	5.52	98.00	108.70
	4	6	SPC	6	66.50	38.66	23.00	119.00
			brix	2	10.50	0.71	10.00	11.00
			temp	2	111.25	2.47	109.50	113.00
	5	8	SPC	8	78.25	48.23	40.00	187.00
			brix	3	14.67	2.89	13.00	18.00
			temp	3	102.07	4.41	97.00	105.00
	6	6	SPC	6	63.33	22.73	42.00	98.00
			brix	2	12.00	0.00	12.00	12.00
			temp	2	101.50	6.36	97.00	106.00
	7	4	SPC	4	69.00	45.14	29.00	117.00
			brix	2	13.00	0.00	13.00	13.00
			temp	2	103.50	3.54	101.00	106.00
	8	2	SPC	2	30.50	0.71	30.00	31.00
			brix	1	15.00	.	15.00	15.00
			temp	1	102.50	.	102.50	102.50
10	1	2	SPC	2	470.00	42.43	440.00	500.00
			brix	1	12.00	.	12.00	12.00
			temp	1	89.00	.	89.00	89.00
	2	2	SPC	2	111.50	16.26	100.00	123.00
			brix	1	14.00	.	14.00	14.00
			temp	1	87.00	.	87.00	87.00
11	1	2	SPC	2	22.00	8.49	16.00	28.00

		brix	0	.	.	.	.
		temp	0	.	.	.	.
2	2	SPC	2	47.00	8.49	41.00	53.00
		brix	0	.	.	.	.
		temp	0	.	.	.	.