Whole-milk feeding duration, calf growth, and profitability of group-fed calves in an organic production system

E. A. Bjorklund, B. J. Heins,¹ and H. Chester-Jones

Department of Animal Science, University of Minnesota, St. Paul 55108

ABSTRACT

The objective of this study was to evaluate the effect of early-life feeding duration on growth and economics of group-fed organic dairy calves. Heifer calves born during the spring of 2011 ($n = 67$) and the spring of 2012 ($n = 57$) were used to evaluate the effect of weaning age, growth, and profitability of group-fed calves fed once per day in an organic dairy production system. Calves were assigned to replicate feeding groups of 10 in super hutches by birth order, and were born at the University of Minnesota West Central Research and Outreach Center, Morris organic dairy. Breed groups were Holsteins ($n = 15$) selected for high production, Holsteins ($n = 23$) maintained at 1964 breed-average level, crossbreds ($n = 54$) including combinations of Holstein, Montbéliarde, and Swedish Red, and crossbreds ($n = 32$) including combinations of Holstein, New Zealand Friesian, Jersey, and Swedish Red. Groups of calves were weaned at 30 (EW, early weaning), 60 (MW, mid weaning), or 90 (LW, late weaning) d of age, and groups were fed 1.5% of birth weight of 13% total solids organic whole milk once daily and weaned when the group of 10 calves consumed an average of 0.91 kg of organic calf starter per calf per day for 4 consecutive days. Body measurements were recorded at birth, weekly during the preweaning period, at weaning, and monthly thereafter. Profitability was estimated as a function of the total cost for organic milk and organic calf starter for weaning groups to weaning and to the first 90 d of age. Preweaning group performance was weaning age, EW: 47.6 d, MW: 64.5 d, LW: 93.7 d; weaning weight, EW: 61.8 kg, MW: 79.2 kg, LW: 108.1 kg; and gain per day, EW: 0.51 kg/d, MW: 0.63 kg/d, LW: 0.75 kg/d. Body weight (BW) did not differ among weaning groups at 90 d of age; however, MW calves had lower 120-d BW than did LW calves. The EW calves did not differ from either MW or LW calves for 120-d BW. Total feed costs to weaning for groups were \$1,092.97 for EW calves, \$1,871.24 for MW calves, and

\$2,956.64 for LW calves. The cost per kilogram of gain was higher for the EW (\$5.54) group of calves than for the MW (\$4.60) or LW (\$4.14) groups during the preweaning period. Total costs and cost per kilogram of gain for the first 90 d of age were lowest for EW (\$1,595.59, \$3.02) calves and highest for LW (\$2,956.64, \$4.13) calves, respectively.

Key words: group housing, organic dairy, profitability

INTRODUCTION

Dairy producers from around the United States have turned to an organic production system to capitalize from the higher milk price received for organic milk. The number of organic dairy farms has increased during the past decade (McBride and Greene, 2009), slowing the decline of smaller dairy operations in the Upper Midwest. According to the US Department of Agriculture (USDA), the number of certified organic dairy cows in the United States increased 271% from 2002 to 2008, and Minnesota had over 10,000 certified organic dairy cows in 2011 (USDA, 2012a). The number of organic dairy farms has increased due to the fact that during 2002, the USDA introduced the National Organic Program (NOP) as a method of standardization for organic agriculture (USDA, 2012b).

Raising heifers, either conventional or organic, is an expensive investment for a dairy operation; therefore, early-life feeding of calves is critical to the subsequent productivity and longevity of dairy cattle (Soberon et al., 2012). After feed costs, raising replacement heifers is the second largest expense on a dairy farm, accounting for 25% of the total cost of milk production (Zwald et al., 2007). The cost of feeding preweaned organic calves may depend largely upon how much nonsaleable or saleable milk is fed to calves. According to the NOP, organic dairy farms are required to feed only whole milk to dairy calves (USDA, 2012b). This milk can be either nonsaleable (milk from newly freshened cows, sick cows, or high SCC cows) or saleable.

Currently, an increasing number of dairy producers are choosing group housing over individual hutches for calf rearing, but many questions remain in regards to costs and performance of calves raised in group housing.

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¹Corresponding author: hein0106@umn.edu

The benefits of group housing include reduced labor and bedding costs, socialization among calves, greater growth rates, and greater calf starter intake (Chua et al., 2002; Bernal-Rigoli et al., 2012). De Paula Vieira et al. (2010) reported that group-fed calves after weaning consumed more feed but had higher weight gains compared with individually fed calves.

The most common weaning age of calves on dairy farms in the United States is between 6 and 8 wk (USDA, 2010); however, de Passillé et al. (2011) found that calves weaned at 12 or 13 wk of age had greater growth rates and decreased signs of hunger during weaning and postweaning compared with early-weaned calves. On organic dairy farms in the United States, most dairy producers choose to wean calves much later than 8 wk and some later than 16 wk.

There are small differences in raising dairy calves between organic and conventional dairy farms; however, no organic milk replacers are available in the United States, and therefore, whole milk from high-SCC organic cows or bulk tank organic milk must be fed (UDSA, 2012b). The cost versus benefit of milk consumption and weaning age is very important to organic dairy producers and has not been researched with organic dairy calves. The hypothesis of the current study was that organic group-fed calves weaned at 90 d of age would have greater growth rates and higher costs of rearing to 90 d of age than calves weaned at 30 or 60 d of age. Therefore, the objective of this study was to investigate the effect of early-life feeding duration on growth and profitability of group-fed dairy calves in an organic dairy production system.

MATERIALS AND METHODS

Experimental Design and Collection of Data

This study was conducted at the University of Minnesota West Central Research and Outreach Center (WCROC; Morris, MN), and all animal procedures involving animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee. The research dairy at the WCROC has a 200-head, low-input and organic grazing system. The research herd has implemented a crossbreeding approach since 2000, and details are thoroughly described in Heins et al. (2010), and the 1964 Holstein control population design is described in Hansen (2000). Data were collected for 124 organic dairy heifer calves from 2 spring-calving seasons: 67 heifer calves were born from March 13 to May 21, 2011, and 57 heifer calves were born from March 19 to May 29, 2012. Breed groups of calves were Holsteins ($n = 15$) selected for high production (**HO**), Holsteins ($n = 23$) maintained at

Table 1. Distribution of organic dairy calves by breed group and weaning group

Breed group	Weaning group ¹		
	EW	MW	LW
1964 Holstein	4	11	8
Holstein	4	6	5
HMS ²	14	23	17
HJS ³	12	10	10
Total calves	34	50	40

¹EW = early-weaned calves (weaned at 30 d of age); MW = mid-weaned calves (weaned at 60 d of age); LW = late-weaned calves (weaned at 90 d of age).

²HMS = crossbreds of Holstein, Montbéliarde, and Swedish Red.

³HJS = crossbreds of Holstein, New Zealand Friesian, Jersey, and Swedish Red.

1964 breed-average level (**H64**), crossbreds ($n = 54$) including combinations of HO, Montbéliarde, and Swedish Red (**HMS**), and crossbreds ($n = 32$) including combinations of HO, New Zealand Friesian, Jersey, and Swedish Red (**HJS**). The distribution of calves by breed group and weaning group is presented in Table 1.

Calf growth and economics of crossbred dairy cattle has seldom been studied, and these data are not routinely recorded by dairy producers. Therefore, data from institutional research herds, although limited in scope, are valuable to assess traits such as growth and economics of group-fed calves in an organic production system. The breed groups varied in the number of calves; however, these observations were spread across 2 calving years, so they contributed meaningful information for breed group comparisons.

At birth, calves were separated from their dams, housed indoors in individual pens, and fed 1.89 L of colostrum per 41 kg of BW twice a day for 2 d. Calves that were healthy and aggressive were moved to group housing at 3 d of age after the morning feeding. For this study, all calves were healthy and moved to group housing. The pens or super hutches for group housing included an indoor area (3.66×6.10 m) bedded with organic wheat straw plus an outside access space that measured 3.66×6.10 m (7.32 m^2 per calf inside and outside).

Heifer calves were randomly assigned to 1 of 3 replicated weaning groups of 10 calves per super hutch based on birth order. The time for group formation ranged from 5 to 15 d in 2011 and from 2 to 21 d in 2012. Early-weaning (**EW**) groups were fed 1.5% of birth weight of 13% total solids organic milk (unpasteurized whole organic milk from high-SCC cows or from the bulk tank) once daily and weaned when the youngest calf in the group reached 30 d of age and consumption of organic calf starter averaged 0.91 kg/calf per day. Mid-weaning (**MW**) and late-weaning

(LW) groups were fed in the same manner as EW groups but were weaned at 60 d and 90 d of age, respectively. Groups of calves were fed with a 10-calf Skellerup peach teat feeder with 61-L liquid volume capacity (Skellerup Industries, Christchurch, New Zealand), which was washed and disinfected daily. Calves were fed an organic calf starter beginning on the third day of age with weighbacks collected every other day. The texturized organic calf starter was mixed at the WCROC dairy, and consisted of organic corn, organic wheat, organic expeller soybean meal, organic soybean oil, and organic-certified minerals. The organic starter contained 87.6% DM, 18.9% CP, 27.7% NDF, 5.95% crude fat, 7.5% ash, 1.43% calcium, 0.67% phosphorus, 39.9% NFC, 0.27 Mcal/kg NE_G, and 0.40 Mcal/kg NE_M. Water was provided ad libitum from 3 d of age, and organic hay was provided ad libitum at 3 wk of age.

While in group housing, calves were weighed on a digital scale before and after milk feeding once per week to evaluate milk intake. Furthermore, BW, hip height, and heart girth were recorded at weaning, 90 and 120 d of age, and monthly thereafter. Health treatments and mortality records were recorded on an individual calf basis. Body measurements were birth weight, weaning weight, weaning hip height, weaning heart girth, total gain, ADG, 90-d weight, and 120-d weight. The amount of liquid milk and calf starter offered and refused at each feeding was recorded daily for group pens.

Postweaning, calves were moved to longer term group pens; however, calves remained in their particular treatment group until 90 d of age. Subsequently, heifers were grouped into 20 to 30 calves based on similar BW, and all calves were merged together at 5 mo of age. At 6 mo of age, heifers were moved to pasture for grazing and were supplemented with a TMR during the nongrazing season.

Profitability

Total feed cost was estimated as a function of the total cost for organic milk and organic calf starter for weaning groups to weaning and to the first 90 d of age. The default milk price was \$0.6166/kg, which was the mean organic mailbox milk price from 2011 to 2012 for the University of Minnesota WCROC organic dairy. The average organic grain starter mix was \$0.564/kg. Total feed cost was the sum of milk intake and starter intake for a group of dairy calves. Average cost per kilogram of gain was the total feed cost divided by the total sum of weight gain for a group of dairy calves. The profitability analysis was calculated for the preweaning period and for the first 90 d of life for a group of 10 calves; however, 4 calves were removed from the 30-d group for profitability because they were not in a group

of 10. Sensitivity analyses were performed to evaluate the effects of changes in organic milk price on total feed cost and the average cost per kilogram of gain for dairy calves. Alternative milk prices were used for sensitivity analysis. Three alternative milk price scenarios were a higher milk price (25% higher at \$0.7707/kg), a lower milk price (25% lower at \$0.4608/kg), and a lowest milk price (\$0.2205/kg).

Statistical Analysis

For statistical analysis of birth weight, weaning weight, DIM, total gain, ADG, hip height at weaning, heart girth at weaning, 60-d weight, 90-d weight, and 120-d weight, independent variables were fixed effects of year of birth, weaning group, breed group, and the interaction of weaning group and breed group with super hutch as a random replicate effect. For all body measurements except birth weight, birth weight was a covariable in the statistical model. For statistical analysis of milk intake, starter intake, milk price, total feed costs, total gain from birth to weaning, total gain from birth to 90 d of age, and cost per kilogram of gain, independent variables were fixed effects of year of birth and weaning group, along with super hutch as a random effect. Preliminary analysis for all traits indicated that interactions of year and weaning group and year and weaning group and breed group were not significant, so the interaction effects was removed from the model.

A subset of heifers ($n = 65$) from the study born during 2011 was used for an analysis of BW through 505 d of age to evaluate postweaning heifer growth. The BW was recorded monthly from 90 to 505 d of age; therefore, most heifers had 9 observations for BW at 45-d intervals (90 to 134 d, 135 to 180 d, 181 d to 225 d, and so on). For statistical analysis of BW, independent variables were fixed effects of weaning group, breed group, and 45-d interval nested within weaning group, with heifer nested within breed group with repeated measures and super hutch as random effects. The compound symmetry covariance structure was used because it resulted in the lowest Akaike information criterion (Littell et al., 1998.) Days to first breeding was analyzed for 65 heifers born during 2011, because 2 heifers from the EW group did not achieve breeding age. For statistical analysis of days to first breeding, independent variables were fixed effects of weaning group and breed group.

For all measurements, the MIXED procedure (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. All treatment results were reported as least squares means, with significance declared at $P < 0.05$. Of the 124 calves in the study, only 5 were treated for health problems in 2011, and none were

treated for health problems in 2012. Because of the small number of health events, health comparisons were not evaluated in this study.

RESULTS AND DISCUSSION

Body Measurements

Results for preweaning and early postweaning body measurements for the organic heifer calves are in Table 2. The weaning groups were different ($P < 0.05$) from each other for the duration on milk (47.6 d for EW calves, 64.5 d for MW calves, and 93.7 d for LW calves, respectively). The EW group was weaned at 47.6 d, contrary to the planned 30 d, because the calves in the EW group were not eating the required 0.91 kg of calf starter per head per day at 30 d of age. Therefore, the EW calves were weaned about 2 wk later than planned because they were simply not ready to be weaned. Roth et al. (2009) recommended that producers apply a concentrate-dependent weaning method to attend to the nutritional needs of calves, which was the procedure used in the current study. Consequently, weaning for EW calves was delayed more than 2 wk because stunted growth of calves may have resulted from lower starter intake and no milk intake postweaning.

As expected at weaning, EW calves had lower ($P < 0.05$) BW, hip height, heart girth, and total gain to weaning than the MW and LW calves; however, the EW calves were not statistically different from MW calves for hip height at weaning. Kehoe et al. (2007) reported that calves fed once daily and weaned at 4 wk of age had lower BW than those weaned at 6 and 12 wk of age, which is in agreement with the findings of this study. Furthermore, ADG for weaning groups was lower ($P < 0.05$) for the EW (0.51 kg/d) calves compared

with the MW (0.63 kg/d) and LW (0.75 kg/d) calves. The ADG results for MW and LW calves are consistent with the results of Kmicikewycz et al. (2013), who reported ADG of 0.63 to 0.72 kg/d for Holstein and crossbred calves fed 2 or 4 times a day in a University of Minnesota confinement dairy herd with the same crossbreeding design. Conversely, calves in this study were fed once per day and achieved similar growth rates. Most dairy calves in the United States are fed at least twice daily (USDA, 2010); however, once-a-day milk feeding of calves may reduce labor costs. Galton and Brakel (1976) reported that feeding calves once per day required about 40% less labor than calves fed 2 times per day. Additionally, Stanley et al. (2002) found that feeding milk replacer once versus twice daily to dairy calves had no adverse effects on weight gain.

Doubling a calf's birth weight by 60 d of age has become an industry standard for Holstein calves (Dairy Calf and Heifer Association, 2012a). However, for the current study, only 42 to 51% of calves doubled their birth weight during the first 60 d of life, and weaning groups were not different ($P > 0.05$) from each other. For breed groups, 50% of HO calves and 55% of HMS calves doubled their birth weight by 60 d, whereas only 39% of H64 calves and 34% of HJS calves doubled their birth weight by 60 d. Although some calves did not double their birth weight in 60 d, all calves at 60 d were at least 1.5 times greater in BW than their birth weight, and some calves tripled their birth weight. Van Amburgh et al. (2008) suggested that calves should double their birth weight by weaning to achieve higher future milk production; however, doubling calf birth weight by 60 d of age in this study may not be achievable for all calves due to the differences in genetic composition of the calves. Furthermore, individual animal variation within breed group may have contributed to calves not

Table 2. Preweaning and early postweaning body measurements of group-fed organic dairy calves by weaning group

Measurement	Weaning group ¹					
	EW (n = 34)		MW (n = 50)		LW (n = 40)	
	Mean	SEM	Mean	SEM	Mean	SEM
Birth weight (kg)	38.4	1.2	37.5	1.0	37.7	1.0
Time on milk (d)	47.6 ^a	1.2	64.5 ^b	1.1	93.7 ^c	1.0
Weaning weight (kg)	61.8 ^a	1.8	79.2 ^b	1.4	108.1 ^c	1.5
Weaning hip height (cm)	89.7 ^a	0.88	91.8 ^a	0.70	96.9 ^b	0.75
Weaning heart girth (cm)	95.8 ^a	1.4	100.3 ^b	1.4	112.2 ^c	1.4
Total gain (kg)	24.1 ^a	1.8	41.6 ^b	1.4	70.4 ^c	1.5
ADG (kg/d)	0.51 ^a	0.02	0.63 ^b	0.02	0.75 ^c	0.02
Double weight by 60 d (%)	42.9	13.5	50.5	11.7	41.7	11.3
90-d weight (kg)	102.5	3.9	104.4	3.4	108.5	3.3
120-d weight (kg)	139.0 ^{ab}	6.4	130.7 ^a	5.9	140.4 ^b	5.5

^{a-c}Means within a row without common superscripts are different at $P < 0.05$.

¹EW = early-weaned calves (weaned at 30 d of age); MW = mid-weaned calves (weaned at 60 d of age); LW = late-weaned calves (weaned at 90 d of age).

Table 3. Preweaning and early postweaning body measurements across weaning groups of group-fed organic dairy calves for 1964 Holstein, Holstein, and crossbred calf groups

Measurement	1964 Holstein		Holstein		HMS ¹		HJS ²	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Birth weight (kg)	39.0 ^a	1.2	39.3 ^a	1.3	39.0 ^a	0.8	34.3 ^b	1.0
Time on milk (d)	68.0	1.1	69.8	1.2	68.6	0.9	68.1	1.0
Weaning weight (kg)	78.5 ^b	2.0	87.4 ^a	2.3	85.1 ^{ac}	1.2	81.1 ^{bc}	1.7
Weaning hip height (cm)	91.7 ^a	0.98	94.7 ^b	1.1	92.4 ^{ab}	0.61	92.2 ^{ab}	0.82
Weaning heart girth (cm)	100.1 ^a	1.7	107.1 ^b	2.1	100.8 ^a	1.1	103.1 ^{ab}	1.6
Total gain (kg)	40.8 ^b	2.0	49.7 ^a	2.3	47.5 ^{ac}	1.2	43.4 ^{bc}	1.7
ADG (kg/d)	0.58 ^a	0.03	0.69 ^b	0.03	0.65 ^{bc}	0.4	0.60 ^{ac}	0.02
Double weight by 60-d (%)	30.0	12.9	56.8	14.2	52.2	9.6	41.5	10.9
90-d weight (kg)	97.6 ^b	3.7	113.9 ^a	4.0	108.0 ^a	2.8	100.9 ^b	3.3
120-d weight (kg)	131.8 ^a	5.7	142.1 ^b	5.9	138.4 ^{ab}	5.1	134.6 ^{ab}	5.4

^{a-c}Means within a row without common superscripts are different at $P < 0.05$.

¹HMS = crossbreds of Holstein, Montbéliarde, and Swedish Red.

²HJS = crossbreds of Holstein, New Zealand Friesian, Jersey, and Swedish Red.

doubling their birth weight by 60 d of age. The range of unadjusted ADG for H64 (0.39 to 0.82 kg/d), HO (0.22 to 1.04 kg/d), HMS (0.44 to 0.95 kg/d), and HJS (0.27 to 0.86 kg/d) calves indicates that individual animal variation may contribute to calves doubling or not doubling their birth weight by 60 d.

The EW and LW calves were not significantly different for 90-d and 120-d weight; however, the MW (130.7 kg) calves had lower ($P < 0.05$) BW than did LW (140.4 kg) calves at 120 d of age. Growth differences had dissipated by 120 d of age for EW and LW calves, which was also reported by Kehoe et al. (2007), who found that calves weaned at 3 wk of age had growth rates postweaning similar to calves that were weaned at 4, 5, and 6 wk of age. The 120-d weight for the MW calves may have been lower because all calves were commingled with larger groups of calves at 90-d of age, and therefore, the lower weights of the MW calves at 120 d may be more related to socialization of calves rather than a treatment effect.

Preweaning and early postweaning body measurements across weaning groups for breed groups are given in Table 3. The HJS (34.3 kg) calves had lower ($P < 0.05$) birth weight than the H64 (39.0 kg), HO (39.3 kg), and HMS (39.0 kg) calves. Results for birth weight of calves are similar to those of Heins et al. (2010), who reported that Montbéliarde-sired 3-breed crossbred calves had similar birth weights to pure Holstein calves. The lower birth weight of the HJS calves in this study was expected because Olson et al. (2009) and Dhakal et al. (2013) found that Jersey-sired calves had lower birth weights than HO calves. The HO (0.69 kg/d) and HMS (0.65 kg/d) calves were not different for ADG; however, the HO calves had higher ($P < 0.05$) ADG than the H64 (0.58 kg/d) and HJS (0.60 kg/d) calves. The H64 calves were not ($P > 0.05$) different for weaning weight, hip height, or heart girth compared with

the HJS calves. Although the BW of the H64 and HJS calves were lower ($P < 0.05$) than that of the HO calves before weaning, the difference between the HO, HMS, and HJS calves was not significant ($P > 0.05$) by 120 d of age.

The BW from 90 to 505 d of age for calves born during spring 2011 are given in Table 4. Within each 45-d period, the EW calves had lower ($P < 0.05$) BW than the LW calves, except during the first 45-d period. The MW and LW calves had similar BW for all 9 periods except for the fourth period. The Dairy Calf and Heifer Association (2012b) recommends that Holstein heifers achieve a target weight of 374 to 408 kg by 13 to 15 mo of age. Heifer calves born in 2011 in the present study attained an average weight of 356 kg between 13 and 15 mo of age, which is lower than the Dairy Calf and Heifer Association (2012b) standards. However, the dairy calf recommendations are for Holstein calves, and the lower BW of the heifers observed in this study is most likely due to the genetic composition of the animals and because the calves were raised on pasture during the grazing season from May to November. Higher growth rates early in life are associated with reduced age at first breeding and increased milk yield in mature dairy cows (Khan et al., 2011). For fertility of calves born during 2011, the EW calves (426 d) had lower ($P < 0.05$) days to first breeding than the MW (447 d) and LW (462 d) calves. Additional research with fertility and production information from both years of the study is needed to determine the effect of early-life weaning of group-fed calves.

Profitability

Least squares means for organic milk intake, organic starter intake, and economic sensitivity analysis of milk and starter for a group of 10 calves for weaning groups

Table 4. Least squares means and standard errors of means for BW of 2011 spring-born heifers from d 90 to 505 of life for weaning groups

45-d period	Weaning group ¹					
	EW		MW		LW	
	Mean	SEM	Mean	SEM	Mean	SEM
d 90–134	111.7	7.3	110.8	5.7	118.4	6.3
d 135–179	135.8 ^a	8.2	146.5 ^{ab}	5.7	160.9 ^b	7.4
d 180–224	162.7 ^a	7.1	175.2 ^{ab}	5.7	184.2 ^b	7.0
d 225–269	198.6 ^a	7.4	204.5 ^a	5.4	221.2 ^b	6.4
d 270–314	234.5 ^a	7.0	250.9 ^{ab}	5.5	262.7 ^b	6.7
d 315–359	262.3 ^a	7.4	284.1 ^b	5.4	292.1 ^b	6.4
d 360–404	298.1 ^a	7.8	316.3 ^{ab}	5.6	323.4 ^b	6.6
d 405–460	328.9 ^a	7.9	354.9 ^b	5.6	368.6 ^b	6.8
d 461–505	342.3 ^a	7.7	368.3 ^b	6.3	375.6 ^b	12.4

^{a,b}Means within a row without common superscripts are different at $P < 0.05$.

¹EW = early-weaned calves (weaned at 30 d of age); MW = mid-weaned calves (weaned at 60 d of age); LW = late-weaned calves (weaned at 90 d of age).

during the preweaning period are given in Table 5. All weaning groups of calves were different ($P < 0.05$) from each other for all economic variables. As expected, the group of EW calves had lower starter intake, lower total feed cost, and less weight gain during the preweaning period because they were weaned earlier than the MW and LW calf groups. However, the average cost per kilogram of gain for the EW (\$5.54/kg) calves was higher ($P < 0.05$) than that of the LW (\$4.14/kg) calves, but was similar to that of the MW (\$4.60/kg) calves. With the lowest milk price, the cost per kilogram of gain was similar for all 3 weaning groups. The group of EW calves did not have rapid preweaning growth, and therefore, had a higher cost per kilogram of gain compared with the MW and LW calves. Based on the results of this study, group-fed calves perhaps should not be weaned earlier than 7 to 8 wk of age. de Passillé et al. (2011) reported that weaning calves at 12 to 13 wk of age was more advantageous for energy intake and growth of calves compared with weaning earlier than 12 wk.

During the first 90 d of life (Table 6), no differences ($P > 0.05$) were observed between weaning groups for starter intake, total starter cost, or gain from birth to 90 d of age. During the postweaning phase, the group of EW calves consumed more organic starter than the group of LW calves because they were not provided milk after 45 d of age, and therefore, had similar starter intake compared with the LW calves. Consequently, the total feed cost for the group of EW (\$1,595.59) calves was lower ($P < 0.05$) than that of the MW (\$2,239.95) and LW (\$2,956.64) calves, which was simply a reflection of the lower milk intake of the EW calves. Decreasing the time of the calf rearing period, which reduces the cost of production, is achievable for producers who attain efficient calf growth from a successful feeding program (Hessle et al., 2004).

During the preweaning period, the EW calves had fewer economic advantages compared with the LW calves. Conversely, when all calves were compared at 90 d of age, the EW calves had significant advantages for cost per kilogram of gain. Feed costs had a proportionately greater effect for the group of LW (\$4.13/kg) calves compared with the group of EW (\$3.02/kg) calves for cost per kilogram of gain. For cost per kilogram of gain, a higher milk price resulted in higher ($P < 0.05$) cost per kilogram of gain for the EW calves compared with the LW calves, and the difference increased from 26 to 29% with the higher milk price. However, the gap between the EW and LW calves was substantially reduced for cost per kilogram of gain (−\$1.11 to −\$0.18) at the lowest milk price. At the lowest milk price, none of the weaning groups differed ($P > 0.05$) from each other for cost per kilogram of gain. For the current study, cost per kilogram of gain was 2.6 to 3.5 times greater than that reported by Raeth-Knight et al. (2009) for calves raised in Minnesota, because the price of organic milk and organic starter had an enormous effect on the cost of production.

The cost of labor is often cited as a major reason to wean calves early. Labor costs were not included in the profitability estimates because all calves were fed in the same manner but weaned at different ages. In this experimental herd of calves, the average time to feed a group of 10 calves was about 12 min, which corresponds to 1.2 min per calf. If labor is valued at \$25/h to feed the group of calves, the cost per day per calf is \$0.50 to feed each calf. Therefore, labor to feed a group of 10 calves for an additional 46 d (difference of EW and LW calves) would cost a dairy producer an extra \$230, or \$23 per calf.

The source of milk on an organic dairy farm is the predominant driver of profitability. As no organic milk

Table 5. Milk intake, starter intake, and economic sensitivity analysis of milk and starter for weaning groups during the preweaning period

Measurement	Weaning group ¹					
	EW		MW		LW	
	Mean	SEM	Mean	SEM	Mean	SEM
Milk intake (kg)	1,659.2 ^a	84.6	2,671.7 ^b	75.7	3,921.9 ^c	79.6
Average milk price (\$0.62/kg)	1,023.09 ^a	52.14	1,647.40 ^b	46.68	2,418.26 ^c	49.09
Higher milk price (\$0.77/kg)	1,278.78 ^a	65.17	2,059.12 ^b	58.35	3,022.63 ^c	61.36
Lower milk price (\$0.46/kg)	767.40 ^a	39.11	1,235.68 ^b	35.02	1,813.89 ^c	36.82
Lowest milk price (\$0.22/kg)	365.86 ^a	18.65	589.12 ^b	16.69	864.79 ^c	17.56
Starter intake (kg)	129.3 ^a	30.2	386.3 ^b	27.0	940.7 ^c	26.6
Starter cost (\$0.564/kg)	72.98 ^a	17.0	218.03 ^b	15.25	530.90 ^c	15.02
Total gain, birth to weaning (kg)	201.7 ^a	19.7	409.13 ^b	17.8	716.6 ^c	19.7
Average total feed cost (\$)	1,092.97 ^a	44.65	1,871.24 ^b	40.25	2,956.64 ^c	44.65
Higher total feed cost (\$)	1,349.41 ^a	56.46	2,283.07 ^b	50.89	3,563.17 ^c	56.46
Lower total feed cost (\$)	836.53 ^a	33.24	1,459.40 ^b	29.96	2,350.11 ^c	33.24
Lowest total feed cost (\$)	433.82 ^a	18.00	812.65 ^b	16.22	1,397.62 ^c	18.00
Average cost (\$)/gain (kg)	5.54 ^a	0.23	4.60 ^{ab}	0.21	4.14 ^b	0.23
Higher cost (\$)/gain (kg)	6.83 ^a	0.28	5.61 ^b	0.25	4.99 ^b	0.28
Lower cost (\$)/gain (kg)	4.24 ^a	0.17	3.58 ^{ab}	0.16	3.29 ^b	0.17
Lowest cost (\$)/gain (kg)	2.20	0.09	1.99	0.08	1.95	0.09

^{a-c}Means within a row without common superscripts are different at $P < 0.05$.

¹Means for groups are expressed for a group of 10 calves. EW = early-weaned calves (weaned at 30 d of age); MW = mid-weaned calves (weaned at 60 d of age); LW = late-weaned calves (weaned at 90 d of age).

replacers are available, whole milk from high-SCC organic cows, as well as organic bulk tank milk, must be fed. Therefore, organic dairy producers will have to decide whether to use high-SCC cows from the herd to feed calves or to use expensive milk from the bulk tank. The cost versus benefit of milk consumption and weaning age is very important and may affect important decisions on an organic dairy. Organic dairy producers should regularly evaluate their costs for organic milk and organic starter fed to calves, along with growth rates, to determine the optimum time for weaning on their farms. Organic milk price had a greater effect on

total feed cost for the LW calves compared with the EW and MW calves because the LW calves consumed more milk during the first 90 d of life than the other 2 weaning groups.

Future research with these organic dairy calves should explore the effect of weaning age of organic dairy calves with heifer growth, fertility, and first lactation and subsequent lactation performance. Results of research will provide guidance to organic dairy producers for methods of feeding organic dairy calves for specific management systems. Irrespective of feeding system, successful management of dairy calves is of critical importance to

Table 6. Milk intake, starter intake, and economic sensitivity analysis of milk and starter for weaning groups during the first 90 d of life

Measurement	Weaning group ¹					
	EW		MW		LW	
	Mean	SEM	Mean	SEM	Mean	SEM
Starter intake (kg)	1,009.1	45.1	1,049.1	40.6	938.6	45.1
Starter cost (\$0.564/kg)	569.50	25.50	592.10	22.90	529.80	25.50
Total gain, birth to 90 d (kg)	529.16	48.0	666.74	43.3	716.6	48.0
Average total feed cost (\$)	1,595.59 ^a	46.88	2,239.95 ^b	42.26	2,956.64 ^c	46.88
Higher total feed cost (\$)	1,852.03 ^a	57.85	2,651.79 ^b	52.15	3,563.17 ^c	57.86
Lower total feed cost (\$)	1,339.15 ^a	36.79	1,828.12 ^b	33.16	2,350.11 ^c	36.79
Lowest total feed cost (\$)	936.43 ^a	25.34	1,181.36 ^b	22.84	1,397.62 ^c	25.34
Average cost (\$)/gain (kg)	3.02 ^a	0.26	3.41 ^b	0.23	4.13 ^c	0.25
Higher cost (\$)/gain (kg)	3.50 ^a	0.31	4.04 ^{ab}	0.28	4.98 ^b	0.30
Lower cost (\$)/gain (kg)	2.54	0.20	2.78	0.18	3.29	0.20
Lowest cost (\$)/gain (kg)	1.77	0.12	1.79	0.11	1.95	0.12

^{a-c}Means within a row without common superscripts are different at $P < 0.05$.

¹Means for groups are expressed for a group of 10 calves. EW = early-weaned calves (weaned at 30 d of age); MW = mid-weaned calves (weaned at 60 d of age); LW = late-weaned calves (weaned at 90 d of age).

an organic dairy. Organic dairy producers must focus on all aspects of dairy calf management to maintain growth rates and minimize health problems to ensure future profitability for the dairy farm.

CONCLUSIONS

We found that EW calves had lower weight gains and body dimensions than MW or LW calves; however, by 120 d of age, the EW and LW calves had similar BW. Furthermore, the EW calves were not weaned until 45 d of age, because they were not consuming the required 0.91 kg/calf per day of starter. For the first 90 d of life, the EW calves had lower cost per kilogram of gain than the MW and LW calves. Based on the results of this study, organic dairy producers may achieve adequate BW gain in group-fed dairy calves.

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