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Comparisons of housing, bedding, and cooling options for dairy calves

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ABSTRACT

Housing, bedding, and summer cooling were management options evaluated. Holstein calves (42 ± 2 kg of body weight) initially 2 to 5 d of age were managed in southwest Ohio in poly hutches or wire mesh pens in a curtain-sided nursery with no supplemental heat. Calves were fed milk replacer (27% crude protein, 17% fat fed at 0.657 kg of dry matter per calf daily), starter (20% crude protein dry matter, textured, fed free-choice), and water (free-choice). Measurements were for 56 d. In trial 1, 28 calves per treatment were bedded with straw and housed in either hutches or nursery pens. This trial was conducted from September to March; the average temperature was 8°C and ranged from −17 to 31°C. In trial 2a, 16 calves per treatment were managed in nursery pens bedded with straw, in nursery pens bedded with sand, or in hutches bedded with sand. This trial was conducted from May to September; the average temperature was 21°C and ranged from 7 to 33°C. In trial 2b, 26 calves per treatment were housed in nursery pens and bedded with straw. This trial was conducted from May to September; the average temperature was 22°C and ranged from 8 to 34°C. One treatment was cooled with fans between 0800 and 1700 h and the other was not. Data were analyzed as repeated measures in a completely randomized block design by trial, with calf as the experimental unit. In trial 3, air in the nursery and calf hutches used above was sampled 35 d apart for calves aged 5 and 40 d. Air in individual hutches on 2 commercial farms was sampled for 5- and 40-d-old calves for 2 hutch types. Air in the multi-calf hutches was sampled for calves of 75 and 110 d of age. Bacterial concentrations of air samples were analyzed ($\log_{10}$) as odds ratios by Proc Logistic in SAS software (SAS Institute Inc., Cary, NC); differences were declared at $P < 0.05$. In trial 1, weight gain of calves in nursery pens was 6% greater and feed efficiency was 4% greater than that of calves in hutches. In trial 2a, weight gain and starter intake of calves in the nursery with straw bedding were greater and scouring was less than that in calves bedded with sand in the nursery or hutches. The relative humidity was greater in the hutches than in the nursery pens. In trial 2b, weight gain, feed efficiency, and hip width change were greater and breaths per minute were less for calves cooled with fans compared with calves that were not cooled. In trial 3, airborne bacteria concentrations were greater in the hutches than in the nursery pens. Straw bedding (vs. sand), nursery pens (vs. hutches), and summer daytime cooling with fans improved calf weight gain.
Key words: housing, bedding, air quality, cooling

INTRODUCTION

In 1954, researchers in Alabama compared calves housed indoors in individual pens with solid sides to (a new concept at the time) calves housed outdoors in portable pens made with sides and a roof constructed from metal roofing material (Davis et al., 1954). The researchers were concerned with calf exposure to pathogens (especially coccidia) that build up over the years in a barn, poor ventilation, and direct transmission of pathogens from older animals in a barn to the neonates. Davis et al. (1954) reported heavier and taller calves with fewer coccidia infections in the outdoor portable pens compared with calves housed in the barn. In North Carolina, Murley and Culvahouse (1958) confirmed the Alabama results of Davis et al. (1954) with similarly constructed, movable pens. The same findings were confirmed in the warm climate of Florida (Van Horn et al., 1976) and the cold climates (minimum temperature of 10°C in the study) of South Dakota (Jorgensen et al., 1970) and Ontario (McKnight, 1978). Quigley et al. (1994, 1995) reported less scouring from *Cryptosporidium*, *Eimeria*, and rotavirus in calves housed in outdoor commercial fiberglass hutches compared with a barn. However, surveys of dairies in California (Martin et al., 1975), Virginia (James et al., 1984), and Pennsylvania (Heinrichs et al., 1987) reported that housing did not influence calf health and performance. James et al. (1984), Heinrichs et al. (1987), and Quigley et al. (1995) suggested that management, housing, and nutrients interact to affect calf health and performance.

Lago et al. (2006) collected data from 13 commercial, cold, enclosed calf nurseries of newer construction (<6 yr of age) with natural ventilation in Wisconsin. They reported that as the concentration of airborne

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bacteria increased within a calf pen, the incidence of respiratory infection increased. Other factors related to concentrations of airborne bacteria and respiratory infection in calves was the depth of bedding, number of solid pen sides, and age of calf. As bedding depth decreased, incidence of respiratory infection increased. More than 2 solid panels on a calf pen increased the incidence of respiratory infections. The incidence of respiratory infection increased as calf age increased to 6 wk of age, the approximate time of weaning in the nurseries surveyed.

Deep straw bedding was important in reducing respiratory infection in the cold nurseries studied by Lago et al. (2006). Hill et al. (2007) reported greater ADG in calves for 0 to 8 wk of age bedded with deep straw versus hardwood shavings in 2 cold, naturally ventilated nursery trials in Ohio (mean temperatures of 6°C). However, no apparent incidence of respiratory infection was reported in these trials.

Spain and Spiers (1996; Missouri) and Coleman et al. (1996; Alabama) reported fewer breaths per minute in calves under shade compared with those not under shade. Calves were housed within opaque polymer outdoor hutches during hot weather. Neonatal calves have difficulty with thermoregulation compared with older cattle and heat stress might be expected to impair calf growth or health, yet it is not well defined (NRC, 2001). Recent summaries of data collected in Minnesota (Chester-Jones et al., 2008) and our facility in Ohio (Bateman et al., 2010), which are similar types of nurseries, suggest that warm weather reduces calf performance compared with cold weather. These results are similar to those of McKnight (1978), who reported greater ADG during winter versus summer, spring, and fall, challenging 15°C ambient temperature as the lower critical temperature for neonatal calves (NRC, 2001).

The overall objective was to systematically evaluate housing options for young dairy calves. One objective was to evaluate calf performance in translucent polyethylene hutches versus a modern, well-ventilated, unheated nursery. A second objective was to evaluate the performance of calves during summer months bedded on straw or sand and housed in translucent polyethylene hutches or a modern, well-ventilated nursery. This trial led to third objective to survey hutches on commercial farms and our research farm for concentrations of airborne bacteria. A fourth objective was to evaluate the use of fans for cooling calves during summer months.

MATERIALS AND METHODS

In trial 1, 56 calves over 4 periods (equal number of calves per period) were bedded with straw and housed either in hutches or nursery pens. Hutches were translucent polyethylene hutches (EZ Hutch, Kettersville, OH) with inside dimensions of 0.8 m wide by 1.05 m long at the base, 1.2 m tall in the front, and 1.05 m tall in the back. Calves wore a collar and were tethered to the hutch with a 1.5-m-long chain that slid on a rod within the top length of the hutch. Hutches were 3 m apart to prevent calf contact. The nursery consisted of 1.2- × 2.4-m individual pens with wire mesh (approximately 10 cm square mesh) on 3 sides. The front gate was aluminum square tubing that provided a mostly open front. Pens were immediately adjacent to each other, which allowed for calf contact. A schematic is shown in Figure 1. The nursery had 4 rows of pens: 2 rows of 13 pens were along the outer walls next to the curtains, and 2 rows of 12 pens were adjacent to each other in the center of the nursery (total of 50 pens within a nursery room). Pens were within a curtain sidewall barn with no added heat. The curtain could be lowered from the top of the sidewalls to the ground. The side curtains were down 5 cm or more, except during high winds when they were completely up. The roof had a center covered ridge vent. The ends for the barns had large overhead doors that were raised during daytime hours when the temperature exceeded 25°C to allow for natural ventilation. The hutches and nursery pens were over a coarse rock base that was covered with water-permeable geotextile fabric. The fabric served to keep considerable amounts of bedding material out of the rock, which could reduce drainage. In this trial, calves were bedded with unchopped wheat straw. Environmental conditions are reported in Tables 1 and 2. In trial 2a, calves over 2 periods (equal number of calves per period; Tables 3 and 4) during the summer months were managed 3 ways: (1) in nursery pens (inside rows of the nursery) bedded with straw, (2) in nursery pens (inside rows of the nursery) bedded with sand, or (3) in hutches bedded with sand. The hutches and nursery were the same as described in trial 1. In trial 2b, 52 calves were housed in nursery pens and bedded with straw during 2 summer periods (equal number of calves per period; same as trial 2a) with treatments being the use of fans between 0800 and 1700 h or no fans (Tables 3 and 4). The nursery was the same as that described in trial 1. Calves were grouped in the outside rows of 13 pens that were 9.6 m apart. For calves cooled by fans, 2 fans (each 1.1 m in diameter) were placed approximately 8 m apart. Treatment (fan use) was switched to the opposite side of the nursery room in period 2, determined randomly. Thus, 1 fan blew air across 6 or 7 pens angled to move air through the pens toward the outside of the nursery. Trials 2a and 2b were conducted simultaneously, but analyzed and conducted as separate trials to address the specific objectives of this report. In

Table 1. Average, low, and high temperatures (°C) of outside, nursery, and hutch air in the 4 blocks of trial 1

		Outside			Nursery			Hutch		
Block	Months	Average	Low	High	Average	Low	High	Average	Low	High
1	Feb–Mar	6	−15	28	6	−15	30	8	−13	29
2	Feb–Mar	6	−8	24	7	−7	25	8	−6	24
3	Sep–Nov	11	−9	31	12	−9	34	13	−7	31
4	Dec–Jan	2	−17	16	2	−18	20	3	−15	16
Mean[1]		6	−12	25	7	−12	27	8	−10	25

[1]Average temperature in hutch tended to be higher than average temperature outside ($P < 0.10$).

trial 3, the air in the nursery, individual calf hutches for calves less than 2 mo of age, group hutches with outside pens (4 calves per pen) for calves 2 to 4 mo of age, and outside air was sampled at the Nurture Research Center (Lewisburg, OH). Air samples were taken 35 d apart for calves aged 5, 40, 75, and 110 d. Additionally, the air in hutches and outside air on 2 commercial farms were sampled for 5- and 40-d-old calves. Samples were taken between 0900 and 1100 h.

Calves were fed a common milk replacer (Nurture Pinnacle Formula, Lewisburg, OH; 27% CP, 17% fat DM basis, fed at 0.655 kg of DM/calf daily), starter (20% CP, DM basis, textured, 37% whole corn, 35% supplement pellet, 25% whole oats, 3% molasses, fed free-choice), and free-choice water. Calves were weaned at 42 d by only feeding the morning milk replacer feeding on d 40, 41, and 42. Measurements were continued through d 56. The trials used Holstein bull calves that were initially 2 to 5 d of age from a single dairy farm. Calves were received at approximately 1100 h after a 3.5-h transit. At 1100 h on the day after arrival, the calves were weighed (initial BW), blood was sampled from the jugular vein into a red-topped tube (evacuated without preservatives or anticoagulants) to immediately

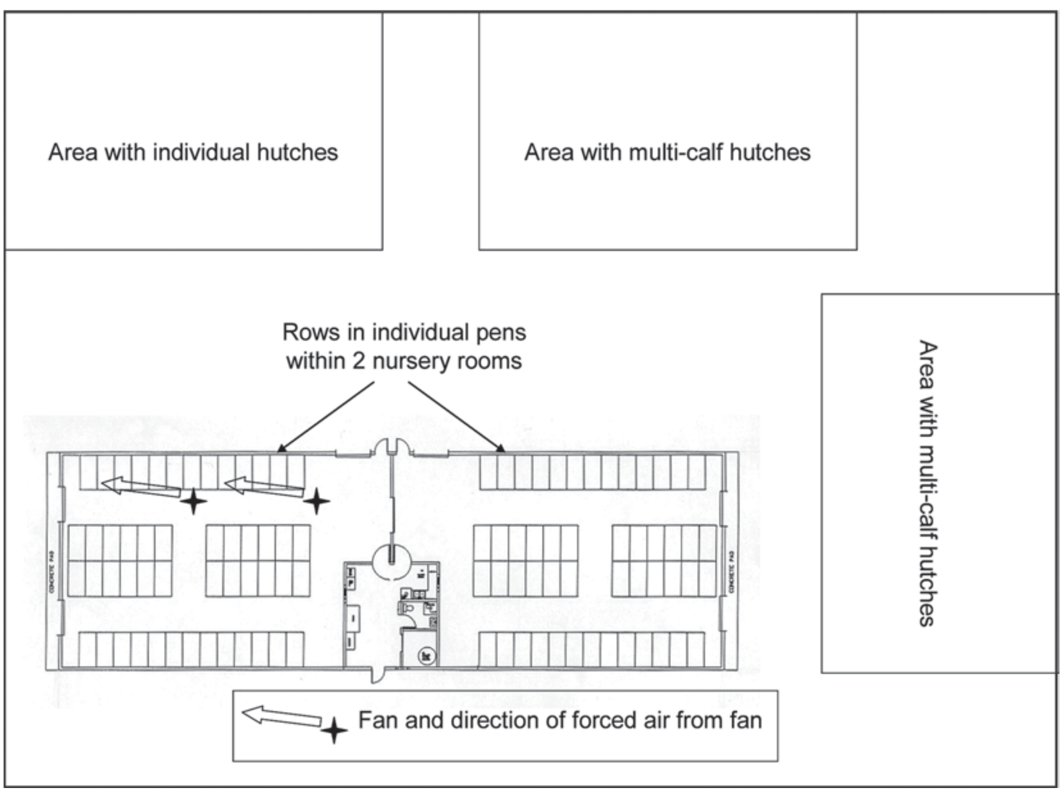

Figure 1. Schematic of Nurture Research Center (Lewisburg, OH). Two nursery rooms with 50 individual calf pens (1.2 by 2.4 m); alleys between pens are 2.4 m wide. Areas with individual calf hutches and group hutches are denoted outside the nursery. Placement of fans during trial 1b is noted.

Table 2. Average and low relative humidity (%) of outside, nursery, and hutch air and the total rainfall in the 4 blocks of trial 1[1]

Block	Months	Outside		Nursery		Hutch		Rainfall, cm
		Average	Low	Average	Low	Average	Low	
1	Feb–Mar	71	21	70	22	79	29	12.8
2	Feb–Mar	70	22	72	21	79	33	13.8
3	Sep–Nov	85	36	86	35	93	45	10.1
4	Dec–Jan	78	18	79	19	83	25	11.8
Mean[2]		76	24	77	24	84	33	12.1

[1]In all cases, the maximum relative humidity measured was greater than 97%.

[2]Average and low relative humidity in hutch was higher than average outside or in nursery ($P < 0.05$).

measure serum protein using an optical refractometer (Atago U.S.A. Inc., Bellevue, WA). Calves were randomly assigned to treatment (d 0).

In all trials, calves were weighed every 7 d until the end of the trial (d 56). Dry feed offered and feed refusals were weighed daily. Fecal scores were assigned daily based on a 1 to 5 system (1 being normal, thick in consistency; 2 being normal, but less thick; 3 being abnormally thin but not watery; 4 being watery; 5 being watery with abnormal coloring; modified from Kertz and Chester-Jones, 2004). Hip widths were measured with a caliper, and BCS of calves were measured during the initial (d 0) measurement period and every 14 d thereafter. A 1 to 5 system using 0.25-unit increments with 1 being emaciated and 5 being obese was used for BCS (Wildman et al., 1982). Scores were based on changes around the vertical and transverse processes of the spine as palpated by one experienced technician and ranged from 1.5 to 3.5. Bedding was sampled from the center of each hutch or pen with a bulb planter pressed down to the geotextile fabric on d 47 for DM determination (oven method 930.15, AOAC, 2000). Air temperature and humidity were recorded hourly using a battery-powered data logger (Dickson, Addison, IL). Loggers were mounted in the center of the nursery 1.5 m from the floor, on the inside wall of an occupied calf hutch 0.5 m from the ground, and outside in continuous shade 0.5 m from the ground. Loggers in the hutches were within corrugated plastic to prevent contact with the calves and were evenly rotated among all hutches. In the second period of trial 2b, respiration rates of all calves were measured on d 2 of each week between 1300 and 1500 h, corresponding with the hottest period of the day. In trial 3, air was sampled within the nursery pens and alleys and within and outside the hutches. Air sampling procedures and bacteria concentrations were determined as described by Lago et al. (2006) using an air sampler (airIDEAL, bioMérieux Inc., Hazelwood, MO) on soy agar plates (4 samples per treatment mean).

Calves were cared for by acceptable practices as described in the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999). Calves received an intranasal tissue-sensitive respiratory disease vaccine (TSV-2, Pfizer, Exton, PA) and subcutaneous injections of vitamins A, D, E (Vital E - A + D, Schering-Plough Animal Health, Union, NJ) and Se (MU-SE, Schering-Plough Animal Health) upon arrival. Calves received an intramuscular respiratory disease vaccine (Bovashield Gold 5, Pfizer) at d 7 and again at d 28. At d 14 and 49, calves received an intramuscular vaccine for types C and D clostridium (Vision 7 with Spur, Intervet Inc., Millsboro, DE) and a subcutaneous *Clostridium perfringens* type A toxoid (Novartis, Larchwood, IA). A pasteurella vaccine (Presponse HM, Fort Dodge, Fort Dodge, IA) was administered intramuscularly on d 35 and 49. Calves were castrated and dehorned at 39 d of age. Calves that scoured (fecal scores >2) were treated with oral electrolytes and subcutaneous ceftiofur sodium (Naxcel, Pharmacia & Upjohn, Kalamazoo, MI).

Data from trials 1, 2a, and 2b were analyzed as a completely randomized block design using repeated measures over time by Proc Mixed in SAS (SAS Institute Inc., Cary, NC). Pen was the experimental unit. In trial 3, bacteria concentrations of air samples were analyzed ($\log_{10}$) as odds ratios by Proc Logistic in SAS.

Table 3. Average, low, and high temperatures (°C) of outside, nursery, and hutch air in the 2 blocks of trials 2a and 2b

Block	Months	Outside			Nursery			Hutch		
		Average	Low	High	Average	Low	High	Average	Low	High
1	May–Jul	21	7	33	22	9	37	23	10	36
2	Aug–Sep	21	9	32	21	9	34	22	11	33
Mean		21	8	33	22	9	36	23	11	35

Table 4. Average and low relative humidity (%) of outside, nursery, and hutch air and the total rainfall in the 2 blocks of trials 2a and 2b[1]

Block	Months	Outside		Nursery		Hutch		Rainfall, cm
		Average	Low	Average	Low	Average	Low	
1	May–Jul	72	12	76	17	80	22	14.8
2	Aug–Sep	79	24	82	27	88	33	14.5
Mean[2]		76	18	79	22	84	28	14.7

[1]In all cases, the maximum relative humidity measured was greater than 97%.

[2]Average and low relative humidity in hutch was higher than average outside or in nursery ($P < 0.05$).

RESULTS AND DISCUSSION

In trial 1, average temperature in the hutch (8°C) tended to be higher ($P < 0.10$) than the average temperature outside (6°C) or in the nursery (7°C; Table 1). In addition, the relative humidity in the hutch (84%) was higher ($P < 0.05$) than the average outside (76%) or in the nursery (77%; Table 2). In trials 2a and 2b, average temperature in the hutch (23°C) was not different than the average temperature outside (21°C) or in the nursery (22°C; Table 3). The relative humidity in the hutch (84%) was higher ($P < 0.05$) than the average outside (76%) or in the nursery (79%; Table 4) as it was in trial 1. In the fall season in Utah, Macaulay et al. (1995) reported an average temperature within translucent calf hutches of 17°C, which was greater than that within opaque polymer (13°C) or wood hutches (14°C). Other temperature and humidity comparisons among housing types were not found in the literature.

In trial 1, calves housed in the nursery pens had a 6% greater ($P < 0.05$) ADG and 4% greater ($P < 0.05$) feed efficiency than calves housed in hutches (Table 5). No other measurements differed. These results were the opposite of reports by Davis et al. (1954) and Murley and Culvahouse (1958). However, the barn described by Davis et al. (1954) was very different from our nursery, having solid wood sides with small windows and solid wood panels between calves. It likely had less ventilation and poorer hygienic conditions than our nursery.

In trial 2a, calves housed in the nursery and bedded with straw had 9 to 13% greater ($P < 0.05$) ADG than calves bedded with sand in either the nursery or in hutches (Table 6). This compares to a 6% difference in ADG between nursery and hutch calves bedded on straw in trial 1. Calves housed in the nursery and bedded with straw had greater ($P < 0.05$) starter intakes and fewer days with abnormal fecal scores compared with calves bedded with sand either in the nursery or in

Table 5. Performance (56 d) of calves bedded with straw and housed either in hutches or in a nursery in trial 1

Item	Hutches	Nursery	SEM	*P*-value
Calves, n	28	28	—	—
Initial serum protein, mg/dL	5.7	5.5	0.1	0.21
Initial BW, kg	44.2	43.5	0.7	0.45
Final BW, kg	75.6	77.2	1.2	0.35
ADG, kg/d	0.561	0.601	0.015	0.05
Starter intake, kg/d	0.793	0.834	0.031	0.29
Milk replacer intake, kg/d	0.473	0.473	—	—
Feed efficiency[1]	0.443	0.460	0.007	0.05
Average fecal score[2]	1.5	1.6	0.3	0.13
Abnormal fecal score days	5.1	5.0	0.4	0.86
BCS[3]				
Initial	2.2	2.2	0.3	0.21
Final	2.7	2.8	0.4	0.62
Change	0.5	0.6	0.4	0.22
Hip width, cm				
Initial	17.8	18.0	0.1	0.32
Final	21.7	22.0	0.2	0.17
Change	3.9	4.0	0.2	0.63
Bedding DM, %	78	83	3.7	0.16

[1]Gain divided by milk replacer plus starter intake.

[2]Where 1 is normal, thick in consistency; 2 is normal, but less thick; 3 is abnormally thin but not watery; 4 is watery; 5 is watery with abnormal coloring.

[3]Scale of 1 to 5 based on Wildman et al. (1982).

Table 6. Performance (56 d) of calves bedded with sand or straw and housed either in hutches or a nursery in trial 2a

Item	Nursery, straw	Nursery, sand	Hutch, sand	SEM
Calves, n	16	16	16	—
Initial serum protein, mg/dL	5.0	4.7	5.1	0.17
Initial BW, kg	41.2	42.6	42.2	1.26
Final BW, kg	71.1[a]	69.8[ab]	68.1[b]	1.77
ADG, kg/d	0.534[a]	0.486[b]	0.462[b]	0.0238
Starter intake, kg/d	0.693[a]	0.623[b]	0.521[c]	0.0375
Milk replacer intake, kg/d	0.473	0.473	0.473	—
Feed efficiency[1]	0.458	0.444	0.465	0.0129
Average fecal score[2]	2.1[a]	2.2[a]	2.5[b]	0.07
Abnormal fecal score days	1.7[a]	3.1[b]	8.4[c]	0.61
BCS[3]				
Initial	2.1	2.1	2.2	0.05
Change	0.3	0.3	0.3	0.05
Hip width, cm				
Initial	17.0	17.1	16.8	0.33
Change	3.9	3.5	3.5	0.18
Bedding DM, %	81[a]	74[b]	71[b]	3.6

[a–c]Means within a row with different superscripts differ ($P < 0.05$).

[1]Gain divided by milk replacer plus starter intake.

[2]Where 1 is normal, thick in consistency; 2 is normal, but less thick; 3 is abnormally thin but not watery; 4 is watery; 5 is watery with abnormal coloring.

[3]Scale of 1 to 5 based on Wildman et al. (1982).

hutches (Table 6). Calves housed in the nursery bedded with sand had intermediate ($P < 0.05$) starter intakes and days with abnormal fecal scores compared with the other 2 treatment groups. Calves housed in hutches bedded with sand had the lowest ($P < 0.05$) starter intakes and had a higher ($P < 0.05$) average fecal score than calves housed in the nursery. These results are consistent with Panivivat et al. (2004), who reported that calves bedded with granite fines and sand had more fluid feces and more medical treatments for scouring than calves bedded with rice hulls, wood shavings, and straw bedding. Bedding DM content was greatest ($P < 0.05$) for calves bedded with straw (81%) compared with calves bedded on sand in the nursery (74%) or in the hutches (71%). These bedding DM appeared greater than those reported in the nurseries surveyed by Lago et al. (2006), which ranged from 27 to 68% DM with a mean of 47.6%. Reasons for our greater bedding DM could be the coarse rock base that drains well and evaporation in the well-ventilated nursery. A negative of straw bedding is the fly population that it can promote in hot weather. Schmidtmann (1991) reported that sand, gravel, and sawdust bedding supported fewer fly larvae than did long straw bedding; however, sand and gravel provided poor hygiene conditions in the pens and led to soiled calf hair coats.

Also in trial 2a, the resting posture of the calves bedded on sand at 0600 h just before the a.m. feeding was noticeably different from that of calves bedded on straw on cooler mornings. Their legs were more tucked under their bodies on most days, possibly indicating that they were colder than calves bedded on straw. Most nighttime low temperatures were 13 to 18°C, near the reported lower critical temperature of 15°C for neonatal calves (NRC, 2001). Calves on straw bedding rested with their more of legs exposed and they could "nest" within the straw bedding.

In trial 2b, calves cooled with fans had 23% greater ($P < 0.05$) ADG and 20% greater feed efficiency ($P < 0.05$), and tended ($P = 0.07$) to have a greater change in hip width compared with calves not cooled with fans (Table 7). Although a week by treatment interaction ($P < 0.05$) was observed, with differences in respiration rate declining with week, calves cooled with fans had fewer ($P < 0.05$) breaths per minute than calves not cooled with fans (Figure 2). Spain and Spiers (1996; Missouri) and Coleman et al. (1996; Alabama) did not report differences in ADG, but they reported fewer breaths per minute in calves under shade versus not under shade and housed in hutches, matching our observations.

In trial 3, concentrations of airborne bacteria around the calves in the individual nursery pens at the Nurture Research Center were lower ($P < 0.05$) compared with those around calves in the individual hutches (Table 8). Additionally, the concentrations of airborne bacteria around the 5-d-old calves were lower ($P < 0.05$) than those around 40-d-old calves. This is consistent with Lago et al. (2006), who reported that respiratory infections peak at 5 to 6 wk of age in calves within nurseries.

Air samples were taken at the Nurture Research Center from both the multiple and individual calf hutches and at 1.5, 3.0, and 7.5 m away from the hutch openings. Concentrations of airborne bacteria declined linearly ($P < 0.05$; Table 9), indicating that airborne bacteria were associated with the restricted airflow inside the hutch and not the conditions of the ground. When the rear of the individual hutches at the Nurture Research Center were elevated approximately 4 cm by setting the rear corners of the hutch on blocks, concentrations of airborne bacteria were lower ($P < 0.05$) compared with those in hutches that were not elevated (Table 9). Higher elevation may be necessary to prevent bedding from blocking the gap, especially if straw bedding was used. On commercial farm B, no differences were found in concentrations of airborne bacteria between the 2 individual calf hutch types (EZ Hutch or Calftel, Hampel Corp., Germantown, WI). The one mean not consistent with the airborne concentrations measured was the hutch with the 5-d-old calf on farm A. It was low (36,077 cfu/m^3 of air) compared with the other hutch means, which exceeded 226,000 cfu/m^3 of air. In general, the high concentrations of airborne bacteria within the hutches indicate a limitation with these types of hutches with few openings to allow airflow. This likely led to the higher levels of humidity in the hutches compared with the nursery at the Nurture Research Center.

Airborne bacteria concentrations in our nursery alley and pen were much lower compared with those reported in a survey of 13 barns in Wisconsin (Lago et al., 2006). Additionally, the use of fans did not appear to reduce airborne bacteria concentrations (Table 9). Low airborne bacteria concentrations may be the reason why we observed no symptoms of respiratory infections in our calves, which is typical of our nursery. The minimum measurements of Lago et al. (2006) were 5,274 and 29,644 cfu/m^3 of air in the alley and pens, respectively. No reports of airborne bacteria concentrations in hutches could be found in the literature.

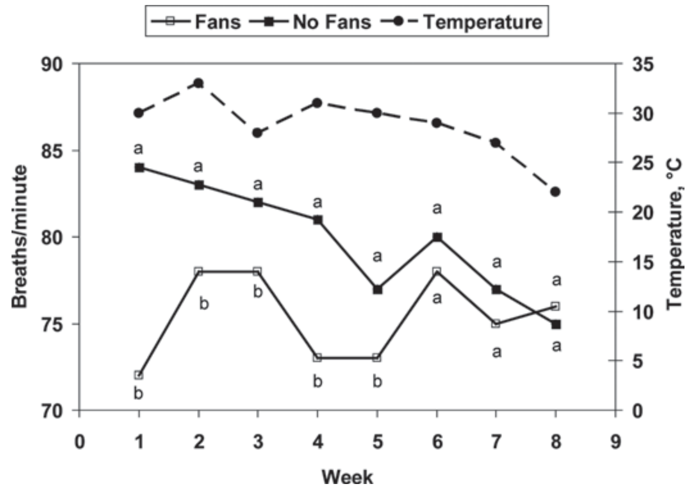

Figure 2. Effect of use of fans on breaths per minute and temperature of nursery at time of measurement each week in trial 2a. A week by treatment interaction ($P < 0.05$) was observed, with fans reducing breaths per minute ($^{a,b}P < 0.05$; SEM = 1.7 breaths per minute).

Calf nurseries vary in their design and characteristics, as measurements reported by Lago et al. (2006) demonstrated. Certainly, much has evolved in calf barn

Table 7. Performance (56 d) of calves housed in hutches or a nursery bedded with straw as affected by use of fans during summer months in trial 2b

Item	− Fans	+ Fans	SEM	P-value
Calves, n	26	26	—	—
Initial serum protein, mg/dL	4.8	5.0	0.14	0.22
Initial BW, kg	42.5	40.3	1.87	0.26
Final BW, kg	65.3	68.4	2.01	0.28
ADG, kg/d	0.407	0.501	0.0443	0.04
Starter intake, kg/d	0.585	0.603	0.0514	0.78
Milk replacer intake, kg/d	0.473	0.473	—	—
Feed efficiency[1]	0.385	0.466	0.0229	0.002
Average fecal score[2]	2.1	2.1	0.04	0.89
Abnormal fecal score days	1.3	1.5	0.04	0.71
BCS[3]				
Initial	2.1	2.2	0.24	0.25
Change	0.2	0.3	0.05	0.61
Hip width, cm				
Initial	17.3	16.9	0.036	0.45
Change	3.2	3.7	0.25	0.07
Bedding DM, %	80	83	3.9	0.38

[1]Gain divided by milk replacer plus starter intake.

[2]Where 1 is normal, thick in consistency; 2 is normal, but less thick; 3 is abnormally thin but not watery; 4 is watery; 5 is watery with abnormal coloring.

[3]Scale of 1 to 5 based on Wildman et al. (1982).

Table 8. Airborne bacteria concentrations at the Nurture Research Center and 2 commercial farms in trial 3

Housing[1]	Sample[2]	Age,[3] d	Bacteria,[4] cfu/m^3	SD
Nurture Research Center				
Outside air	—	—	2,118	756
Nursery alleys	Concrete	5	3,325	3,463
Nursery alleys	Concrete	40	12,301	12,887
Nursery pens	Fabric	5	5,720	2,260
Nursery pens	Sand	5	13,822	6,590
Nursery pens	Straw	5	9,500	7,021
Nursery pens	Fabric	40	23,498	8,530
Nursery pens	Sand	40	50,987	10,715
Nursery pens	Straw	40	27,218	14,361
Hutch, EZ	Sand	5	326,400	—
Hutch, EZ	Sand	40	326,400	—
Hutch, SCT	Straw	75	276,373	100,054
Hutch, SCT	Straw	110	326,400	—
Farm A				
Outside air	—	—	2,979	747
Hutch, EZ	Sand	5	36,077	30,946
Hutch, EZ	Sand	40	326,400	—
Farm B				
Outside air	—	—	2,661	297
Hutch, EZ	Sand	40	254,009	144,782
Hutch, CT	Sand	40	236,228	156,183

[1]Housing: Naturally ventilated nursery alleys, individual calf pens, EZ brand individual hutches (EZ Hutch, Kettersville, OH), Calftel brand super hutches with 4 calves per hutch (SCT; Hampel Corp., Germantown, WI), Caftel brand individual hutches (CT; Hampel Corp.), as well as outside air at each farm. Calves in nursery pens had lower concentrations of airborne bacteria than did calves in individual hutches at Nurture Research Center ($P < 0.05$).

[2]Concrete = concrete alleys; calves were housed over rock with bedding materials of porous geotextile fabric, sand, or long wheat straw.

[3]Five-day-old calves in nursery pens had lower concentrations of airborne bacteria than did 40-d-old calves ($P < 0.05$).

[4]Bacteria >326,400 cfu/m^3 was too numerous to count; 326,400 was used in the calculations. Conditions at each farm were similar at time of sampling. Samples were taken between 0900 and 1100 h (23 to 26°C, 71 to 82% relative humidity, <5 km/h winds) on clear days. Four samples per mean.

Table 9. Effect of distance from individual or multiple calf hutch opening, elevation of rear of individual calf hutch, and use of fans in a nursery on airborne bacteria concentrations in trial 3

Housing[1]	Parameter	Bacteria,[2] cfu/m^3	SD
	Meters from hutch opening		
EZ/SCT	0	326,400	—
EZ/SCT	1.5	190,960	150,574
EZ/SCT	3.0	9,364	6,668
EZ/SCT	7.0	2,875	894
	Linear effect ($P < 0.01$)		
	Elevation of rear of hutch		
EZ	0 cm	326,400	—
EZ	4 cm	88,474	27,830
	0 cm > 4 cm ($P < 0.01$)		
	Straw bedding, 40-d-old calves		
Nursery	No fans	35,499	19,712
Nursery	Fans	22,462	8,653

[1]EZ brand individual hutches bedded with sand (EZ Hutch, Kettersville, OH) or Calftel brand super hutches with 4 calves per hutch bedded with long straw (SCT; Hampel Corp., Germantown, WI) at Nurture Research Center.

[2]Bacteria >326,400 cfu/m^3 was too numerous to count; 326,400 was used in the calculations. Four samples per mean.

design since the early report by Davis et al. (1954). As pointed out by James et al. (1984), Heinrichs et al. (1987), and Quigley et al. (1995), a combination of management, housing, and nutrients likely interact to affect calf health and performance. Not every nursery is as well ventilated to support calf health and performance as the nursery we used. Additionally, management abilities differ among farms, as reported in the survey by Martin et al. (1975). Cost drives decisions on farms. Our current trials provide some research-based information from which to make decisions.

CONCLUSIONS

In these trials, a well-ventilated nursery with no added heat supported greater ADG than did translucent polyethylene hutches during cooler months when calves were bedded with straw. Calves housed in the nursery bedded with straw had greater ADG and starter intake and fewer days with scours compared with calves bedded with sand and housed in the nursery or hutches. Concentrations of airborne bacteria and humidity were lower in the nursery than in the hutches and 5-d-old calves had fewer airborne bacteria in the pen or hutch air compared with 40-d-old calves. Summer cooling of calves with fans improved ADG and feed efficiency and lowered the respiration rate of calves compared with not using fans.

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