CALF AND FLY MANAGEMENT OPTIONS FOR ORGANIC DAIRIES

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Whatever you do, do it well. Do it so well that when people see you do it they will want to come back and see you do it again and they will want to bring others and show them how well you do what you do.

~Walt Disney

The adventure seeker, faithful believer, and determined dreamer instilled in me from the beginning is thanks to all those who chose to share their time and love with me. To all of them, I dedicate this thesis. My parents, who have always been there for me through thick and thin, I owe all of my successes in life. In the moment, they were always able to provide wise guidance, comforting hugs, encouragement, and love, if I admitted to the difficulties of life or not. Coming home to a father who would always be available to play games to help me unwind, or cook me dinner after a long day at work was a sweet release I could never thank him enough for. Keeping up with my ever changing schedule, my mother could do it all, from the late nights to the long races to run she kept me sane throughout this process and for that I will be forever thankful. Even though I am an only child, my dog Maley has been with me throughout my entire college career and she has provided me with endless kisses, cuddles, and love. Yet some of the greatest sparks for my career came from my grandparents through the raising of large animals out on their farm. My love and understanding of the importance of livestock, as well as all animals, grew through getting to know how my Opa cared for each living thing on his farm. To my Oma who showed me what true strength means, both physically and spiritually, and how to take mistakes as a learning tool, thank you. My Oma and Opa, you both were a strong force in my life and I was so blessed to have you there to teach me along the way. Thank you to the rest of my family and friends as well who have always been around to make me smile, send up a multitude of prayers, and offer unfailing love when I needed it the most.

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Trust in the LORD with all your heart and lean not on your own understanding; in all your ways acknowledge him and he will make your paths straight.

Proverbs 3: 5-6

ABSTRACT

Heifer calves (n = 102) were used to evaluate the effect of once or twice daily feeding on growth and behavior of calves in an organic group management system. Calves were assigned to replicate feeding groups of 10 in super hutches by birth order, during two seasons from September to December 2013 and March to May 2014 at the University of Minnesota West Central Research and Outreach Center, Morris. Calves in groups were the experimental unit. Breed groups of calves were: Holsteins (HO; n = 26), crossbreds (n = 45) including combinations HO, Montbéliarde, and Viking Red selected for high production, and crossbreds (n = 31) including combinations of HO, Jersey, Normande, and Viking Red selected for robustness. Treatment groups were 1) once daily feeding (1X) or 2) twice daily feeding (2X). Calf groups were fed 6 L per calf/daily (2X, 3 L/feeding) of 13% total solids organic milk then weaned at 60 d when the group consumption averaged 0.91 kg starter/calf daily. Body weight and hip height were recorded at birth, once/wk, at weaning, and at 90 d of age. Hobo Pendant G loggers were applied to the right rear leg of calves to measure total lying and standing time. Data were analyzed using PROC MIXED of SAS. Independent variables for analyses were the fixed effects of birth weight (co-variable), season of birth, treatment group, along with replicate as a random effect. Weaning group performance was gain per day, 1X (0.79 kg) and 2X (0.81 kg); weaning weight, 1X (92.7 kg) and 2X (93.3 kg); and weaning hip height, 1X (95.2 cm), and 2X (95.3 cm). Daily gain to 90d were 0.85 vs. 0.85 kg, and daily gain to 120 d were 0.85 vs. 0.83 kg for 1X and 2X calves, respectively. For lying time, 1X (988 min/d) and 2X (995 min/d) were not different from each other. During the evening hours, the 2X calves had lower lying times (34 min/hr for 1X; 28 min/hr for 2X) per hr because they were fed at 6pm every evening. In summary, group-fed calves fed once per day in an organic production had similar average daily gains and body dimensions compared to calves fed twice per day.

Key words: group housing, organic dairy, profitability

The objective of this study was to evaluate the efficacy of a commercial vacuum fly trap (TRAP; CowVac, Spalding Laboratories, Reno, NV) in on-farm organic dairy production systems to control horn flies, stable flies, and face flies. The TRAP utilizes a chute apparatus and powerful vacuums to suction flies off the cows as they walk through the system. The study utilized eight organic dairy farms during the summer of 2015 in Minnesota, and herds ranged from 30 to 350 cows in size. The farms were divided into pairs by location and during the first period of the summer (June to July) the TRAP was set up on one farm and during the second period of the summer (August to September) the TRAP was sent to its paired farm. Farms were visited once per week to collect flies (or collect and count flies) from the TRAP, as well as count and record flies on cows. Bulk tank milk, fat, and protein production and SCC were collected on farms during the entire study period. Data were analyzed using the GLM procedure of SAS. Independent variables for analyses were the fixed effects of farm, TRAP presence, housing scenario, and period. Horn fly numbers on cows were reduced by 44% on farm in the presence of a TRAP (11.4 vs. 20.5 flies/side) compared to the absence of a TRAP. Stable fly (5.4 vs. 7.1 fly/leg) and face fly (1.0 vs. 1.0 fly/cow) numbers were similar on farm whether the

TRAP was present or absent on farms, respectively. Milk production was similar for farms with the TRAP (15.5 kg/d) compared to without (15.3 kg/d) the TRAP. Both bulk tank milk and milk components were statistically similar in the presence and absence of the TRAP, so benefits of the TRAP were too small to measure. The presence of a TRAP on farm reduced horn fly population growth rates (-1.01 vs. 1.00 flies/d) compared to the absence of a TRAP. Cows on farms with no housing (100% pasture) tended to have reduced horn fly numbers (11.7 vs. 28.3 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm. Cows on farms with housing had similar horn fly numbers (11.2 vs. 14.8 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm. In summary, these results indicate the TRAP was effective in reducing horn fly numbers on cows and reduced horn fly growth rates during the pasture season in organic dairy production systems but benefits in improved milk production were not evident.

Key words: organic dairy, horn fly, stable fly

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INTRODUCTION

Organic Dairy Production in the United States

The National Organic Program (**NOP**), part of the Unites States Department of Agriculture, regulates the organic label and ensures the agricultural products under this label are produced in accordance to the approved methods. The organic standards require the "use of cultural, biological, and mechanical practices that support the cycling of on-farm resources, promote ecological balance, and conserve biodiversity" (USDA, 2015). The NOP Final Rule was effective on October 21, 2002 and put in place strict standards for the production, processing and labeling, certification, recordkeeping, and inputs for organic farming (USDA National Organic Program, 2012). All products labeled as USDA organic must be certified by an accredited USDA organization to "assure consumers that the product was grown and processed in compliance with the National Organic Standards" (Moynihan, 2010).

Organic livestock production has many specific guidelines in regards to the feeding and care provided to the animals. These animals must receive a diet which is 100% organic, where ruminants six months of age and older are required to have 30% of their dry matter intake to come from pasture for at least 120 days of the grazing season each year (USDA-NOP, 2015). The animals who do have access to a housing structure must also have free choice access to the outdoors at all times and allow for the freedom of movement. The pasture land along with other organic crops must not be grown with the use of prohibited substances for three years prior to the first use of the land for organic agriculture (NOP, 2012).

Dairy animals producing organic milk need to be managed under organic practices from at least the last third of gestation (NOP, 2012). Calf milk replacers for organic production are not available so the use of whole milk must be used in its place. Growth hormones and antibiotics are also not allowed in organic production; however, sick animals must not be denied treatment for the sole purpose to keep the animal "organic." Any livestock medically treated through non-organic methods will no longer be qualified as an organic (Moynihan, 2010).

The organic industry has experienced immense growth nationally with organically certified dairy cows at a rate of 553% from the years of 2000 to 2008 (USDA, 2010). The United States has over 19,000 certified organic operations as of 2014 and has produced a "new record of $39.1 billion in U.S. organic sales" (USDA, 2015).

Management and Housing of Dairy Calves

Whole milk feeding

Feeding young calves a liquid diet in an organic dairy system includes the use of raw or pasteurized saleable and nonsaleable waste whole milk, since the use of commercial milk replacer is not allowed. As explained by Godden et al. (2005), nonsaleable whole milk produced from fresh, ill, or medically treated cows is estimated between 22 to 62 kg of milk per cow in the United States dairy productions. This nonsaleable whole milk is utilized for feeding calves on 87.2%, where 59% of dairy producers in the United States utilize milk replacer (Godden et al., 2005).

The use of whole milk is common in organic production but there are still some precautions when using it. Most of the whole milk used for feeding calves comes from waste milk in the bulk tank which has an amplified bacterial count when compared to bulk tank milk. Bacteria can shed into this milk directly from a cow (a cow with mastitis), or through the milking process and storage of milk (Moore et al., 2009). These bacteria can put the calves at higher risk of contracting disease in immature calf immune systems. Therefore, Hoffman et al. (2003) recommends that if waste milk is to be utilized in calf rearing the milk should be pasteurized to reduce the concentration of bacteria.

The University of Minnesota Extension (2011) recommends in the first week of life dairy calves should be fed 1.5% of body weight as total milk solids, and 2% of body weight from 2 weeks of age until the weaning period begins. This recommendation is vital for checking milk quality before feeding to calves with whole milk quality differing greatly between animals (Moore et al., 2009). Moore et al. (2009) also compared milk replacer and whole milk and found whole milk to be advantageous do to the higher caloric intake for calves compared to milk replacer with a 20% protein: 20% fat ratio.

Whole milk is also beneficial to calves and increase the consumptions of dry matter, crude protein, and metabolizable energy than calves fed milk replacer (Shamay et al., 2005). At 60 days of age the calves that drank whole milk had significantly greater weight gain, wither height, heart girth, and hip width measurements. Puberty was also reached 23 days earlier for calves raised on whole milk than the calves fed milk replacer (Shamay et al., 2005).

In the comparison study performed by Godden et al. (2005), pasteurized nonsaleable milk raised calves had higher growth rates and fewer health problems than the calves raised on conventional milk replacer. "On a dry-matter basis, the crude protein and crude fat contents of the milk replacer were both 20%. In contrast, the crude protein and crude fat contents of whole milk would be expected to average 25.6% and 29.6%, respectively" (Godden et al., 2005). From this information, the calves who were drinking whole milk were consuming more Mcal of metabolizable energy than calves fed conventional milk replacer. The results from the study show higher growth rates and lower morbidity and mortality rates for calves raised on pasteurized nonsaleable milk, which may be due to higher immunoglobulin in whole milk.

Group housing

Group housing systems are becoming more popular in the United States, even though the most popular option is individual housing (USDA, 2010). Socialization between calves, reduced labor, and bedding costs are among the main benefits of group housing (Moore et al., 2010). Calves are social animals (Jensen et al., 2006) and it is important for them to develop these social skills at a young age.

Communicable diseases are a huge consideration when looking at group housing when the calves will be in such close contact with each other. Individual calves should be watched carefully after birth to ensure healthy and strong suckling calves are put into group housing together. An observant calf management team is essential when housing calves in groups to ensure the calves are thriving in this type of housing situation. Calves who have adequate passive immunity should be allowed into group housing (Quigley, 2010).

Sucking on another calf's head or body, cross-sucking, is an issue for group housed calves. Jensen et al. (2006) found more cross-sucking and licking in pens of calves fed in buckets than calves fed through teats. These teat fed calves spent their feeding time sucking on the teats for their meal as well as sucking on the empty teats after the feeding was over. This provided those calves with another outlet for the sucking instinct while the other group of calves utilized each other for sucking.

There has also been research done to show calf growth rates differ based on the type of housing the calves are subjected to. Calves who were housed in groups had a higher dry matter intake and body weights at weaning than the calves housed individually (Bernal-Rigoli et al., 2012). Calves raised in pairs also show the capability to consumer a higher amount of starter that calves housed individually (De Paula Vieira et al., 2010). The research performed by De Paula Vieira et al. (2010) also found that group housed calves exhibiting higher feed intake and weight gain while also decreasing the amount of negative behaviors.

Once a day feeding

In the United States, more dairy producers feed their calves twice daily, despite the expectations of lower labor costs with once-a-day feeding (USDA, 2010). 40% less labor was reported for calves fed once daily in research performed by Galton et al. (1976). Starter consumption, weight gain, and glucose metabolism were not affected significantly through milk replacer once versus twice daily and there were also no adverse effects on weight gain (Stanley et al., 2002). Also research performed by Kehoe et al. (2007) showed there could be economic benefit to dairy farmers, with no adverse effect on calf health and growth, to feeding calves milk once daily.

Weaning

When weaning claves there are many considerations to be taken in the health and growth of the calf, with rumen development being a deciding factor. According to Hoffman et al. (2003), rumen development is considered adequate when calves are able to consumer 0.91 to 1.36 kg of grain daily, eat hay or forage, and have a healthy body condition. Dairy calves are commonly weaned between 6 and 8 weeks in the United States. Research by de Passille et al. (2011) found greater growth rates for calves weaned between 12 and 13 weeks of age. As stated above, a better way of considering when to wean is based off of solid feed intake instead of a specific time period. Calves who would be more prepared for weaning would be consuming 1.3 to 1.5% of their body weight in dry feed (Hoffman et al., 2003).

A concentrate dependent weaning method is a recommended way to wean calves; it utilizes reduced milk feeding based on the calf's consumption of grain (Roth et al., 2009). Beginning at week eight of age milk was gradually reduced and was completely removed at 12 weeks of age. The study found calves were weaned at a younger age due to the concentrate dependent diet when compared to a conventional 12 week weaning program (Roth et al., 2009).

Nutrient balance is key when weaning calves and is why a gradual weaning program may work better for calves than immediate weaning. In gradual weaning, the calves are gradually reduced their milk diet while steadily increasing their solid diet and this lessens the negative growth effects seen in immediate weaning (Khan et al., 2011). This research found calves to significantly increase their solid feed intake with the reduction of their milk diet starting at 14 days of age. There was also a group of calves which started gradual weaning at 19 days of age but were not successful in staying balanced for nutrition than the calves that started weaning at 14 days of age (Khan et al., 2011).

Calf growth

Monitoring calf's health and development is important to any successful dairy production system. Body condition scoring will look at the amount of fat found on the calf's body (Wildman et al., 1982), and it also aiding in looking at the calf's health, reproduction, productivity, and longevity (Shamay et al., 2005).

Shamay et al. (2005) looked into growth parameters when comparing calves fed whole milk and calves fed milk replacer. Measurements which were tracked were body weight, hip height, wither height, and heart girth. At 180 days of age the skeletal capacities were higher in calves fed whole milk. Body weights from day 180 to 550 of age were significantly higher for calves raised on whole milk than those raised on milk replacer.

Fly Management of Dairy Cattle

Horn Fly

Organic dairy production has a multitude of pests to control without the use of synthetic pesticides. The most common muscid fly pest which does harm by biting is the horn fly (*Haematobia irritaus* (L.)) and is found in abundance on cattle in the summer heat. The horn fly is one of the smallest flies found on dairy cattle and when searching for blood to feed on, they will favor the back of the animal. The female filth flies, another categorization for horn flies, will oviposit in organic debris, mainly manure (Moon, 2002). The eggs will develop in the undisturbed dung pats on pasture between 10 to 20 days normally and then emerge as adults to continue this life cycle of attacking grazing livestock.

The effects of these flies on cattle production traits range from non-existent to significant effects which could be detrimental to the animal or farm. Byford et. al. (1992) discussed how researchers have found significant differences in “nitrogen retention, blood cortisol concentration, vital signs, water consumption, and urine production,” when cows are attacked by horn flies. There are also behavior influence due to the cow's self-protection from the fly's irritating feeding habits including excessive movement of the head, tail, and feet. These ectoparasites can also cause massive economic losses through reduced weight gains, decreased feed efficiency, and decreased milk production. The economic losses and lower cow production combination can cause management problems for farmers and has the potential to become detrimental to their organic production system.

In a study looking at horn fly populations in a conventional beef production system, Boland et. al. looked at the differences in behavior of both the flies and cattle before and after an insecticide was applied. Cows were monitored two day prior and three days post treatment and the number of horn flies were counted along with behaviors such as "tail flick, leg stomps, skin twitches, and head throws." The research was able to show with the treatment was effective in reducing fly numbers on beef steers, which would be expected with the treatment of an insecticide. The research also concluded there to be a positive correlation for both head throws ($r = 0.20$, $P = 0.003$) and tail flicks ($r = 0.54$, $P = 0.0003$) compared to the number of flies present on the steers but only trends for leg stomps ($r = 0.30$, $P = 0.06$) and skin twitches ($r = 0.29$, $P = 0.07$). The reduction of flies on the animal itself will reduce the amount of negative behaviors exhibited which can waste the cattle's energy.

Stable Fly

The stable fly (*Stomoxys calcitrans* (L.)) is another filth fly can also cause huge economic losses. They are similar to the horn fly because of their piercing and sucking mouth part which aid in providing blood meals. Stable flies mainly attack the legs and can complete their once a day feeding in about two to five minutes (Moon, 2002). They are easy to spot on livestock due to the excessive stomping and kicking required to remove the irritating pest. These flies are considered confinement breeding due to their preferred type of breeding material which includes any wet or rotting bedding or feed material.

Behavioral research has been conducted to show where these type of flies like to live and how farmers can utilize the information and plan for better pest management. Stable flies are found "seeking warmer and more sheltered areas" due to their usual eastern directional orientation when resting (Lysyk et. al. 1993). They also breed and emerge predominantly before mid-July and it is recommended to start preparing for their arrival, through sanitation management, in June to reduce the amount of substrate for breeding. Waste management is a large aspect of pest control and must be taken into account, especially in organic livestock systems.

Economic losses can also be accounted for by stable flies where the last estimated losses were placed at $608 million (Byford et. al. 1992) over 20 years ago. A study performed Taylor et. al., reviewed past literature and compared the economic impacts of stable flies found in different aspects of dairy and beef production. For dairy cows they were able to find the median annual production loss to be 139 kg of milk per cow and there was also a loss of 6 kg of body weight in preweaned calves. From this information, along with the average milk prices for dairy cows and monthly infestation levels the "national losses are estimated to be $360 million for dairy cattle" (Taylor et. al. 2012). The overall estimate for an annual loss for the cattle industry in the United States would equal $2,211 million showing the devastating impact of this one pest.

Face Fly

Face flies (*Musca autumnalis* (L.)) are another common pest found on grazing livestock and can cause harm to the animal other than just attacking the animal. These flies do not possess the biting mouthparts and the prior two flies do so these flies mainly feed off the tear, sweat, and mucous of the cow. These flies, like horn flies, will breed mainly in undisturbed dung pats out on pasture where they can ferment. There are other implications which are more disastrous to the animal's health caused by the face fly's feeding habits through bringing in unwanted pathogens. The most common pathogen passed is caused by the bacterium *Moraxella bovis* which causes pink eye (infectious bovine keratoconjunctivitis) (Moon, 2002). "Expenses associated with pinkeye involve surveillance and treatment of affected animals, and retarded growth and blindness in cases that go undetected" (Moon, 2002).

The economic impact of these flies might not be as influential as with the horn fly or stable fly but they still can impact herd health. Research has shown the effectiveness of the use of both insecticides and baited traps (Ode et. al., 1964) for use in a pest control management plan. Synthetic insecticides showed up to 90% reduction in fly numbers while dusts and baited traps showed moderate to no effect on fly populations. There is also data that suggests the larger amount of biting flies, mainly horn flies, will increase the amount of face flies seen during the grazing season (Brown et. al., 1994). This research also hints to a possible interaction between the breed of animals to the amount of flies found on the animal where the second angus group of the experiment experiences less horn flies and face flies producing a negative coefficient of regression of -0.0032 (Brown et. al., 1994). For best control methods of this pest, there should be equal effort in sanitation along with consistency of observation in the herd.

Fly Prevention and Control

Synthetic pesticides are not allowed by the NOP for use in organic agriculture so farmers must find other ways to control for pests in their production system. There are three main methods to utilize to reduce fly pest populations on farms, "prevention of breeding, killing adults before they cause harm or produce offspring, and exclusion of adults with screens and other barriers" (Moon, 2002). While the NOP has strict guidelines for what products can and cannot be used in organic agriculture there are some synthetics producers can use.

Prevention is key and when used effectively will reduce the number of flies on the farm and the cows. Cleanliness is very important to farms since the pests previously mentioned breed in rotting organic substrate or manure. The proper management of waste on farms will decrease the amount of breeding material these flies can use to breed and multiply. Research has shown in a side by side comparison between organic and conventional production systems, "organic farms did have, on average, higher egg counts than conventional dairy farms" (Sorge et. al., 2015). Along with cleanliness, bedding choices play a huge role in fly populations as well. All bedding will eventually become dirty and at optimal conditions for breeding and choosing the correct substrate could mean the difference in fly numbers on the farm. Bedding with smaller particles, like sand and wood chips, provide the fly with a smaller surface area to breed which is inconvenient to the fly itself. Bedding choices along with management of other food waste provide the prevention needed for fly control.

Many companies offer natural fly sprays and fly bait traps to use in a pest management plan including, homemade fly spray, barrel traps, fly tape, and biological control. Biological pest control has become a new emerging option for farmers utilizing other insects to control for ectoparasites. One of the most popular options is the use of parasitoid wasps, which lay their eggs in the pupae of the flies, killing them, and increasing their populations on farms (Moon, 2002). Research performed by Mills et. al. shows these parasitoid populations are limited to the amount of host organism located on the farm. There are also many other factors which must be taken into consideration when choosing this as a means of fly control since the insect populations are sporadic and unpredictable, even with the most up to date population model predictors. A combination of different fly control methods should be used in an organic farms pest management plan to effectively decrease the amount of harm done on their livestock.

Walk-Through Traps

The use of walk-through traps provide an instantaneous relief for cattle who enter them because they are built to remove the flies directly off the animal. The Bruce trap has a chute-like apparatus which has burlap or plastic strips which come down in the middle of the trap to brush off flies as the cow is pushed through the trap. They also make an electrified version of this with the use of black lights and electrocution grids which attracts and kills the flies when they walk through the trap. Research with this trap has shown a novel walk through trap is effective when reducing horn fly populations on farms. In the first season of this study the group of cows who walked through the trap twice daily decreased averaged about 270 horn flies per cow while the control group averaged about 400 horn flies per cow (Watson et. al., 2002). With lower horn fly densities on cows, researchers continued to improve this model of a walk through trap to increase efficiency.

The Cow-Vac is another type of walk through trap which utilizes vacuums to remove flies off of cows instead of electricity. This novel walk-through trap is quite new to the industry and is now commercially available since 2012 through Spalding Laboratories. This trap utilizes the air flow and placement of the vacuums to take the flies directly off the cow's back and legs. Spalding Laboratories markets this device to "blow horn flies, face flies, stables flies and house flies off the back, belly, face, flanks and legs into a vacuum system that collects them in a removable bag for disposal" (Spalding Laboratories, 2014).

Prototype models of this system have been tested for efficiency before this commercial model was on the market. In research performed by Denning et. al. a walk-through fly vacuum system was used for fly control on a research farm. Over the course of this four year study, one year was also devoted to counting flies at seven surrounding farms to receive an idea of fly populations in the area. "Cattle using the fly trap at the research farm had only about 28% the number of horn flies as untreated cattle, and reductions ranged from 67.5 to 74.5% across the 4-yr study" (Denning et. al., 2014). The use of this walk-through trap proved to be an efficient way of fly control for farms utilizing grazing techniques.

Manuscript 1

Growth, behavior, and economics of group-fed dairy calves fed once or twice daily in an organic production system.

INTERPRETIVE SUMMARY

The objective of the study was to compare the growth, health, and profitability of feeding organic dairy calves once per day versus twice per day. Calves fed once per day were similar for growth, health, and daily activity compared to calves fed twice per day. Labor hours were significantly lower for calves fed once a day. The average cost per kg of gain was significantly lower for calves fed once per day compared to twice per day.

CHAPTER SUMMARY

Heifer calves (n = 102) were used to evaluate the effect of once or twice daily feeding on growth and behavior of calves in an organic group management system. Calves were assigned to replicate feeding groups of 10 in super hutches by birth order, during two seasons from September to December 2013 and March to May 2014 at the University of Minnesota West Central Research and Outreach Center, Morris. Calves in groups were the experimental unit. Breed groups of calves were: Holsteins (HO; n = 26), crossbreds (n = 45) including combinations HO, Montbéliarde, and Viking Red selected for high production, and crossbreds (n = 31) including combinations of HO, Jersey, Normande, and Viking Red selected for robustness. Treatment groups were 1) once daily feeding (1X) or 2) twice daily feeding (2X). Calf groups were fed 6 L per calf/daily (2X, 3 L/feeding) of 13% total solids organic milk then weaned at 60 d when the group consumption averaged 0.91 kg starter/calf daily. Body weight and hip height were recorded at birth, once/wk, at weaning, and at 90 d of age. Hobo Pendant G loggers were applied to the right rear leg of calves to measure total lying and standing time. Data were analyzed using PROC MIXED of SAS. Independent variables for analyses were the fixed effects of birth weight (co-variable), season of birth, treatment group, along with replicate as a random effect. Weaning group performance was gain per day, 1X (0.79 kg) and 2X (0.81 kg); weaning weight, 1X (92.7 kg) and 2X (93.3 kg); and weaning hip height, 1X (95.2 cm), and 2X (95.3 cm). Daily gain to 90d were 0.85 vs. 0.85 kg, and daily gain to 120 d were 0.85 vs. 0.83 kg for 1X and 2X calves, respectively. For lying time, 1X (988 min/d) and 2X (995 min/d) were not different from each other. During the evening hours, the 2X calves had lower lying times (34 min/hr for 1X; 28 min/hr for 2X) per hr because they were fed at 6pm every evening. In summary, group-fed calves fed once per day in an organic production had similar average daily gains and body dimensions compared to calves fed twice per day.

Key words: group housing, organic dairy, profitability

INTRODUCTION

Organic dairy production has begun to gain more attention for the increased demands for organic products which in turn has offered farmers a higher milk premium for organic milk. Organic dairy production accounts for the second largest category in organic food production and produces $4.9 billion a year (USDA-NOP, 2015). It is estimated that there was an 11% increase in total organic dairy farms in 2013 (USDA-NOP, 2015), and this transition has increased the total number of organic dairy production (USDA, 2013). This growth in organic dairy has slowed the number of smaller operations from losing profit in the Upper Midwest. In the United States, the number of certified dairy cows has increased 271% from 2002 till 2008, and totaling 254,700 certified organic dairy cows in 2011 (USDA, 2012). Minnesota alone has over 10,000 organic dairy cows and this increase is due to the fact, in 2002, the United States Department of Agriculture introduced the National Organic Program (NOP) which aided in standardizing organic agriculture.

Dairy heifers are an important and expensive aspect for a dairy farmer and beginning these heifers on a balanced diet is critical to the future efficiency and permanency of the cow (Soberon et al., 2012). Behind feed costs, replacement heifers are the second largest expense a dairy farmer can face and with increased production there has been a greater need for these animals. The cost for these heifers depends on the amount of nonsalable or saleable milk fed to the calves. The NOP states organic dairy farms are required to feed only whole milk to dairy calves (UDSA, 2012) and this milk can be either nonsalable or saleable.

Group housing dairy calves has become a more popular option with producers over individually housing calves. Calves are the building blocks of dairy production and why their health, nutrition, socialization, and growth is well monitored for each individual animal. Group housing calves has shown to have a multitude of benefits including reduced labor and bedding costs. In large numbered herds, it is quite difficult to raise calves individually in hutches because of the large amount of labor hours it requires. Large and small scale operations alike both attempt to lower input cost while keeping production levels the same or aim to improve them.

With the benefits of group housing calves there is also a discussion on how many times a day we should be feeding our dairy calves. According to a study done by Galton et. al., for calves fed once a day versus twice a day there was no found difference in rumen development along development of other vital organs such as the heart and liver. They were also able to present data showing no significant difference in average daily gain between the two different feeding practices. However for producers who desire to feed their calves more than once a day we see a significant increase in labor hours and cost which comes from the increased amount of feeding times per day per calf (Galton et. al.).

Currently, an increasing number of organic dairy producers are choosing feed calves once per day because of high labor costs or a reduced labor force on smaller sized organic dairy farms, but there remain many questions in regards to costs, performance, and behavior of calves fed once per day raised in group housing. The cost effectiveness of feeding calves once daily and productivity of calves takes precedence for organic farmers because with a healthy start to life their calves will become productive for their system in the future. The hypothesis of this study was calves that are fed once per day versus twice per day would have similar growth rates and reduced costs of rearing to 90 d of age, as well as similar behavior levels than calves fed twice per day. Therefore, the objective of this study was to investigate the effect of feeding frequency on growth, profitability, and behavior 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, Minnesota, and all the animal procedures involving animal care and management were approved by the University of Minnesota Institutional Animal Care and Use Committee (#1305-30661A). The research dairy at WCROC has a 250-head low-input and organic grazing system. The research herd has applied 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 was collected for 102 organic dairy heifer calves from two calving seasons: 35 heifer calves were born from September 18 to November 30, 2013 and 67 heifer calves were born from March 24 to May 31, 2014. Breed groups of calves were: Holsteins (n = 26) including both 1964 genetics and contemporary genetic heifer calves, a Hi-input crossbred (n = 45) including combinations of Holstein, Montbéliarde, and Swedish Red, and crossbreds (n = 31) including combinations of Holstein, Jersey, Swedish Red, and Normande. The distribution of calves by breed group and feeding group are presented in Table 1.

Calves were separated from their dams at birth and moves to indoor housing in individual pens and fed 2 quarts of colostrum per 41 kg of BW 2 times per day for two days. Healthy calves which showed aggressive suckling ability were moved to group housing usually by day four. The super hutches used for group housing had an indoor area (3.66 x 6.10 m) bedded with organic wheat straw with access to an outdoor area which measured 3.66 x 6.10 m (7.32 m2 per calf inside and outside area).

Calves were randomly allocated to one of two replicated feeding groups of ten calves per super hutch based on birth order. Calves which were fed once a day (1X) were fed 6 L of organic milk per calf per day at 8 am and the heifer calves fed twice daily (2X) were fed two feedings of 3 L of organic milk at 8 am and 6 pm. Organic milk utilized accounted for 13% of total solids (unpasteurized whole organic milk from the bulk tank or high somatic cell count cows). Both groups of calves were weaned at 60 days of age as the youngest calf in the pen and then moved to separate housing on site. Heifer calves were fed with a 10-calf Skellerup peach teat feeder with 61 L liquid volume capacity (Skellerup Industris, New Zealand), and it was disinfected daily after each feeding. Calf starter was provided starting immediately when calves were moved to the super hutches as free choice and was 18% crude protein of the diet (including corn, wheat, soybean meal, soybean oil and minerals). The organic calf starter was mixed on site at WCROC and 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 NEG, and 0.40 Mcal/kg NEM.

Calves also received free choice water from day 3 of age, and organic hay was also provided at free choice starting at seven weeks of age.

Group housed calves were weighed after AM feeding (8 am) once a week to measure individual milk intake utilizing a digital scale. At weaning, 90 and 120 days of age, body weight, hip height, and heart girth were recorded for each individual calf. Mortality record and health treatments were documented on an individual calf basis. Measurements of the body include birth weight, weaning weight, weaning hip height, weaning heart girth, total gain, average daily gain, 90-d weight, and 120-d weight. Liquid milk and calf starter which was consumed and refused at each feeding was recorded for the pen as a group.

Once calves were weaned, they were moved to long term group pens but remained in their specific treatment groups until 120 days of age. The long term group pens housed 20 to 30 calves based on body weight and at five months of age all heifer calves are moved together. When heifer calves reach six months of age they are moved out on pasture and are supplemented with a total mixed ration during the non-grazing season.

Activity of the heifer calves was recorded utilizing HOBO pendant G loggers. Loggers were attached to two to three calves per super hutch on the day they were moved from individual housing to group housing (they were on the calf from day 4 to 56 of life). The HOBO pendant G loggers were attached to the right side of the right rear leg of the calf and was oriented so the Y-axis of the logger was pointing dorsally towards the calf's tail. The loggers track the X, Y, and Z-axis of the calf which translated into standing and lying behaviors; these data points were recorded every five minutes. The changing of the loggers took place on Wednesdays and attached utilizing VetWrap and Duct Tape.

Lying Behavior

A total of 48 focal animals were used to describe superhutch lying behavior. Lying time, lying bouts, and lying-bout duration were measured using HOBO Pendant G data loggers (Onset, Bourne, MA). Data loggers were set to collect lying behavior at 30-s intervals (Ledgerwood et al., 2010) and placed on the right hind leg of the calf at 3 d of age after entrance into the superhutch. Loggers were kept on the calf through weaning, and was attached for 15 d and removed, data was downloaded, and reattached for another 15 d or until the calf was weaned. Daily lying times, frequency of lying bouts, and lying-bout duration were computed for each calf using a macro in SAS (SAS Institute Inc., Cary, NC) developed by N. Chapinal (University of British Columbia, Vancouver, BC, Canada, personal communication).

Profitability

Total feed cost was estimated as a function of the total cost for organic milk and organic calf starter for feeding frequency 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 2013 to 2014 for the University of Minnesota WCROC organic dairy. The average organic grain starter mix was $0.564/kg. Labor was valued a $10/hr to feed calves. Total feed cost was the sum of milk intake and starter intake for a group of dairy calves. Average cost per kg 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 pre-weaning period and for the first 90 d of life for a group of 10 calves.

Statistical Analysis

For statistical analysis of birth weight, weaning weight, days on milk, total gain, average daily gain, hip height at weaning, heart girth at weaning, 90-d weight, and 120-d weight, independent variables were fixed effects of season of birth, and feeding group (1X or 2X), 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 kg of gain, independent variables were fixed effects of year of birth and weaning group, along with superhutch as a random effect. Preliminary analysis for all traits indicated that interactions of season and feeding group were not significant, so the interaction effects.

For analysis of lying behavior (daily lying time, number of lying bouts per day, and lying-bout duration), independent variables were fixed effects of season of birth, and feeding group (1X or 2X), with super hutch and calf nested within superhutch as a random replicate effect. The interaction of time of day and treatment was also included in the statistical model. The compound symmetry covariance structure was used because it resulted in the lowest Akaike information criterion for repeated measures (Littell et al., 1998.) A repeated statement included day and calf nested within superhutch as the subject.

Pen was used as the experimental unit for all statistical analysis. For all measurements, the MIXED procedure (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. All treatment results were reported as LSM with significance declared at $P < 0.05$.

RESULTS AND DISCUSSION

Body Measurements

Results for preweaning and early postweaning body measurements for the organic heifer calves are in Table 2. As hypothesized at the beginning of the experiment, we did not see any significant differences in body measurements between the calves fed once daily and calves fed twice daily. Birth weight, weaning weight, 90-day weight, and 120-day weight showed no significant differences between the 1X calves and the 2X calves. This is consistent with what has already been found in previous papers (Galton and Brakel, 1976) which show similar growth characteristics (birth weight and average daily gain) between calves fed once or twice daily. Weaning hip height (95.24 cm for 1X and 95.30 for 2X) and weaning heart girth (42.13 cm for 1X and 42.47 cm for 2X) were not different between feeding groups. Furthermore, we compared the ADG of the 1X heifer calves to the 2X calves (0.79 kg/d vs. 0.81 kg/d). The ADG results for MW and LW calves are consistent with the results of Kmicikewycz et al. (2012), 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. Most dairy calves in the United States are fed at least twice daily (USDA, 2010b); however, once-a-day milk feeding of calves may reduce labor costs. Galton and Brakel (1976) reported feeding calves once per day required about 40% less labor than calves fed 2 times per day. Additionally, Stanley et al. (2002) found 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 Assoc., Gold Standards I, 2012). However, for the current study only 85 to 95% of calves doubled their birth weight during the first 60 d of life, and feeding groups were not different ($P > 0.05$) from each other. 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 doubling their birth weight by 60 d of age. The range of unadjusted ADG for HO (0.55 to 0.97 kg/d), HMS (0.40 to 1.07 kg/d), and HJS (0.50 to 0.98 kg/d) calves, indicates individual animal variation.

Profitability

Least squares means for organic milk intake, organic starter intake, and economic analysis of milk and starter for a group of 10 calves for weaning groups during the pre-weaning period are in Table 3. Feeding groups of calves were different ($P < 0.05$) from each other for all economic variables, except labor cost. As expected, the group of 1X calves had lower (P < 0.05) labor cost during the pre-weaning period because they were only fed once per day compared to 2X calf groups. However, the average cost per kg of gain for the 2X ($4.03/kg) calves was higher ($P < 0.05$) than the 1X ($3.56/kg) 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). For the current study, cost per kg of gain was 2.6 to 3.5 times greater than 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 that organic dairy producers have switched to feeding 1X in group fed calves. In this experimental herd of calves, the average time to feed a group 10 calves was about 12 minutes, which corresponds to 1.2 minutes per calf.

Lying Behavior

HOBO pendant G loggers utilized also found no significant differences between overall standing time and lying time (min/d) for the 1X calves versus the 2X calves (Table 4). Standing time was not different between the 1X and 2X heifer calves (452 min/d vs 445 min/d), respectively. This is consistent with past research with the HOBO loggers that reported calves stand an average of 350 to 550 minutes a day (Hill et. al. 2013; Bonk et. al., 2013) Lying times for the 1X heifer calves was 988 min/d while the 2X heifer calves had a lying time of 995 min/d, and was not different from each other.

Logger data was also analyzed by hour during the day which is reported in Figure 1. There was a sharp drop for both feeding groups at 8 am which corresponds to the time of feeding in the morning when both calf groups are fed. We found significant differences for lying time ($P < 0.05$) where the 2X calves had higher lying time at 9 am, 11 am, 1 pm, and 2 pm during the day and the 1X calves had significantly higher lying time at 5 pm, 6 pm, 7 pm, and 9 pm. This is consistent with feeding times during the day, because the 2X calves will have less energy than the 1X calves because they received half of the milk portion the other group. The 1X calves do have higher lying time in the early evening because they are settling down for the night while the 2X calves are preparing for their second meal for the day. These results lead us to assume calf activity during the day is correlated to feeding times.

Future research with these organic dairy calves should explore the impact of feeding frequency 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 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

The results of this study found 1X calves had similar weight gains and body dimensions than 2X calves. For the first 90 d of life, the 1X calves had lower cost per kg of gain than the 2X calves. Lying and standing time were directly affected by feeding time, and the twice fed calves had significantly higher standing time in the evening hours during their second feeding. Based on the results of this study, organic dairy producers may achieve adequate BW gain in group-fed dairy calves fed once per day.

ACKNOWLEDGEMENTS

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

Breed group	Once-per day feeding (n)	Twice-per day feeding (n)
Holstein	13	13
HMS[1]	22	23
HJS[2]	17	14
Total calves	52	50

[1]HMS = Crossbreds of Holstein, Montbéliarde, and Swedish Red
[2]HJS = Crossbreds of Holstein, Jersey, Normande, and Swedish Red

Table 2. Least squares means and standard errors of means for pre-weaning and early post-weaning body measurements of group-fed organic dairy calves by feeding group.

	Once-per day feeding (n=52)		Twice-per day feeding (n=50)	
Measurement	Mean	SEM	Mean	SEM
Birth weight (kg)	37.0	0.9	37.5	0.9
Total serum protein	6.4	0.1	6.6	0.2
Time on milk (d)	68.5	1.9	67.6	1.9
Weaning weight (kg)	92.7	1.6	93.3	1.7
Weaning hip height (cm)	95.2	0.6	95.3	0.6
Weaning heart girth (cm)	107.0	0.8	107.9	0.8
Total gain (kg)	54.7	1.8	55.3	1.7
ADG (kg/d)	0.79	0.01	0.81	0.01
Double weight by 60-d (%)	84.9	4.5	95.9	4.6
90-d weight (kg)	123.5	2.4	121.2	2.5
90-d hip height (cm)	99.9	0.6	100.0	0.7
90-d heart girth (cm)	119.6	5.2	120.1	5.1
ADG to 90-d (kg/d)	0.85	0.2	0.85	0.2
120-d weight (kg)	145.4	3.1	139.5	3.1
120-d hip height (cm)	104.3	0.9	103.4	0.9
120-d heart girth (cm)	123.2	1.4	122.8	1.6
ADG to 120-d (kg/d)	0.85	0.02	0.83	0.02

No significant difference between feeding groups for all variables.
ADG = Average daily gain

Table 3. Least squares means and standard errors of means for milk intake, starter intake, and economic analysis of milk and starter for individual calves during the first 90 days of life[1]

	Once-per day feeding		Twice-per day feeding	
Measurement	Mean	SEM	Mean	SEM
Milk cost ($)	255.04	48.0	265.96	39.14
Starter intake to weaning (kg)	66.51	64.3	78.47	55.1
Starter intake to 90-d (kg)	107.27	33.9	103.91	28.2
Starter cost ($)	66.22	20.90	64.14	17.44
Total gain, birth to 90-d (kg)	83.71	23.7	84.30	20.1
Average total feed cost ($)	320.20	58.74	330.40	47.46
Health cost ($)	0.02	1.1	0.14	0.9
Labor cost ($)	24.50[a]	8.6	50.79[b]	7.0
Average cost ($)/gain (kg)	3.56[a]	0.07	4.03[b]	0.06

[a,b] = Means within a row without common superscripts are different at $P < 0.10$
[1] = Means for groups are expressed on an individual calf basis

Table 4. Least squares means and standard errors of means for behavior measurements of group-fed organic dairy calves by feeding group.

	Once-per day feeding (n = 25)		Twice-per day feeding (n = 23)	
Measurement	Mean	SEM	Mean	SEM
Lying time (min/d)	988	1.2	995	1.0
Standing time (min/d)	452	1.2	445	1.1
Lying time on the left side of calf (min/d)	487	1.8	491	1.4
Lying time on the right side of calf (min/d)	500	0.9	501	0.7

No significant difference between feeding groups for all variables.

Figure 1. Least squares means and standard errors of means for lying time by hour of day for feeding groups for group-fed organic calves

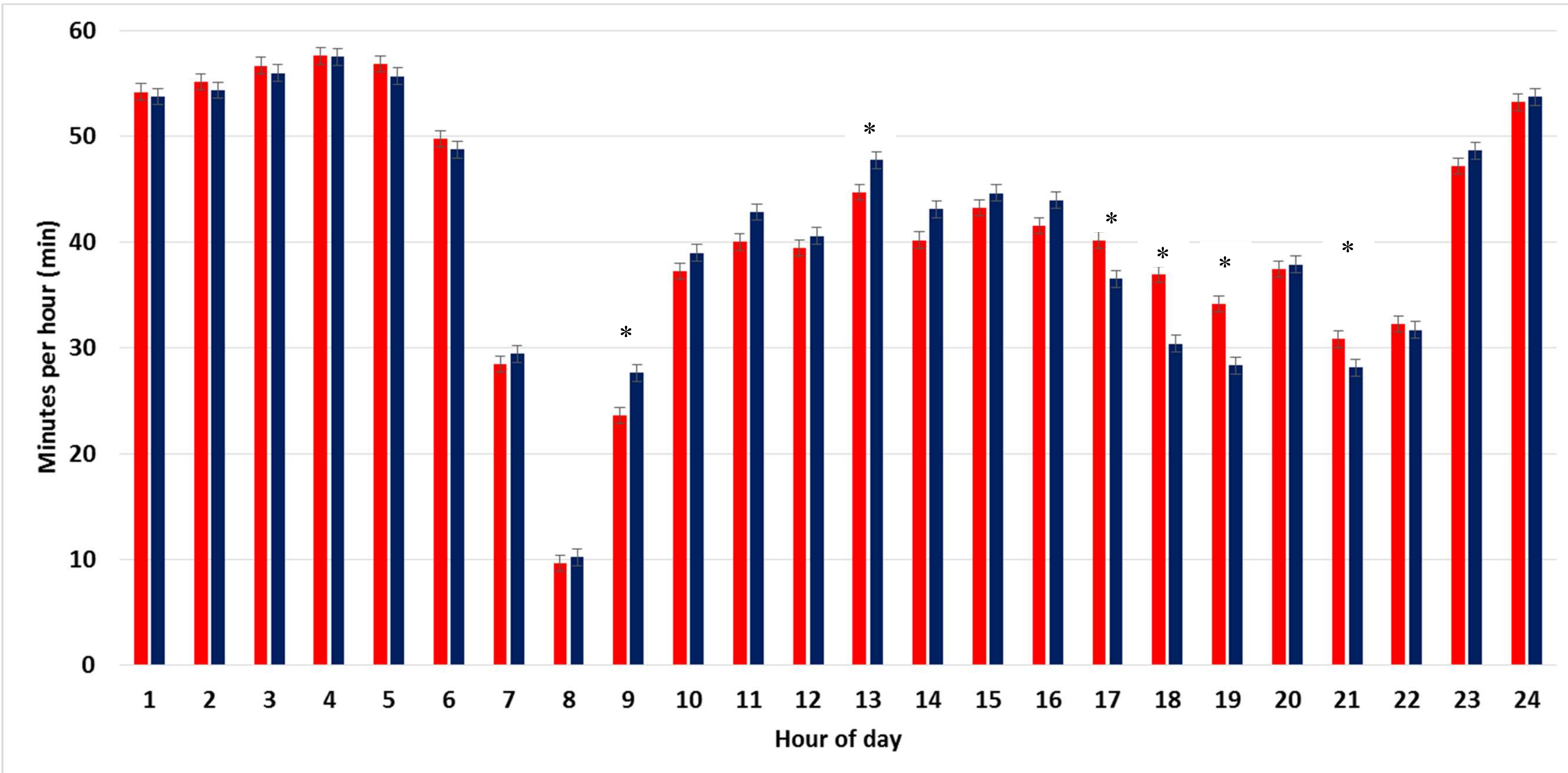

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Figure 1. Least squares means for lying time by hour of day for group-fed organic calves feed once (red) versus twice (blue) per day. *= Means within an hour of day for feeding groups are different at $P < 0.05$

Manuscript 2

Evaluation of a Commercial Vacuum Fly Trap for Controlling Flies on Minnesota Organic Dairy Farms

INTERPRETIVE SUMMARY

The objective of the study was to evaluate the effectiveness of a commercial vacuum fly trap in organic dairy production systems to reduce fly numbers on cows and overall fly populations. During the summer grazing season, a commercial vacuum fly trap (TRAP; CowVac, Spalding Laboratories, Reno, NV) reduced horn fly numbers on cows by 44%. Horn fly population growth rates were also reduced significantly for farms that had a TRAP being utilized on farm. Milk production and SCS were similar for farm where a TRAP was present compared to farms when a TRAP was absent.

CHAPTER SUMMARY

The objective of this study was to evaluate the efficacy of a commercial vacuum fly trap (TRAP; CowVac, Spalding Laboratories, Reno, NV) in on-farm organic dairy production systems to control horn flies, stable flies, and face flies. The TRAP utilizes a chute apparatus and powerful vacuums to suction flies off the cows as they walk through the system. The study utilized eight organic dairy farms during the summer of 2015 in Minnesota, and herds ranged from 30 to 350 cows in size. The farms were divided into pairs by location and during the first period of the summer (June to July) the TRAP was set up on one farm and during the second period of the summer (August to September) the TRAP was sent to its paired farm. Farms were visited once per week to collect flies (or collect and count flies) from the TRAP, as well as count and record flies on cows. Bulk tank milk, fat, and protein production and SCC were collected on farms during the entire study period. Data were analyzed using the GLM procedure of SAS. Independent variables for analyses were the fixed effects of farm, TRAP presence, housing scenario, and period. Horn fly numbers on cows were reduced by 44% on farm in the presence of a TRAP (11.4 vs. 20.5 flies/side) compared to the absence of a TRAP. Stable fly (5.4 vs. 7.1 fly/leg) and face fly (1.0 vs. 1.0 fly/cow) numbers were similar on farm whether the TRAP was present or absent on farms, respectively. Milk production was similar for farms with the TRAP (15.5 kg/d) compared to without (15.3 kg/d) the TRAP. Both bulk tank milk and milk components were statistically similar in the presence and absence of the TRAP, so benefits of the TRAP were too small to measure. The presence of a TRAP on farm reduced horn fly population growth rates (-1.01 vs. 1.00 flies/d) compared to the absence of a TRAP. Cows on farms with no housing (100% pasture) tended to have reduced horn fly numbers (11.7 vs. 28.3 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm. Cows on farms with housing had similar horn fly numbers (11.2 vs. 14.8 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm.   In summary, these results indicate the TRAP was effective in reducing horn fly numbers on cows and reduced horn fly growth rates during the pasture season in organic dairy production systems but benefits in improved milk production were not evident.

Key words: organic dairy, horn fly, stable fly

INTRODUCTION

Important blood sucking pest flies on organic grazing cattle in the Upper Midwest are the stable fly and the horn fly (Moon, 2002). Stable flies (Stomoxys calcitrans (L.)) are blood feeding flies typically found on the legs of cattle, and were estimated to cause annual losses of $360 to $920 million to US dairy cattle in 2005–2009 (Taylor et al., 2012). Stable flies develop as maggots in a wide array of decomposing organic matter, including soiled animal bedding and soiled feed debris that accumulates wherever cattle are confined (Moon, 2002). Populations build exponentially by continuous reproduction from spring to fall in northern temperate localities (Beresford and Sutcliffe, 2010; Taylor et al., 2012). Dairy farm surveys indicate calf hutch bedding is a prominent source of stable flies around dairies (Schmidtmann, 1988), and choice of bedding material can minimize stable fly production (Schmidtmann, 1991). More recently, it has also become apparent that feed debris and manure that accumulate during winter are also important sources of stable flies, especially where overwintered debris piles remain intact into the following summer (Talley et al., 2009, Taylor and Berkebile, 2011).

The horn fly (Haematobia irritans (L.)) is a second kind of biting fly that attacks cattle. They develop in intact, fresh cattle dung pats and nowhere else, so they are troublesome to organic herds when pastured. Horn fly control leads to increased milk production and calf growth (Johnsson and Mayer, 1999). Unlike other kinds of flies that just visit cattle for brief moments, adult horn flies reside on their host animals, which makes then especially vulnerable to control. The face flies (Musca autumnalis DeGeer) is a nonbiting fly that feeds on liquid secretions, typically around the eyes and muzzle of cows. These flies cause irritation and they can vector eye inhabiting parasites and pathogens.

To combat horn flies, W. G. Bruce, a USDA entomologist, built a box with one-way fly-screen baffles on its otherwise transparent sides, and walked fly infested cattle through it to remove and capture their flies (Bruce, 1938). Bruce's simple design is now known as the Bruce walk-thru fly trap, and different versions have been studied for horn fly control in various parts of North America (Hall and Doisy 1989; Meyer et al., 1989; Tozer and Sutherst, 1996; Watson et al., 2002) and Ontario, Canada (Surgeoner et al., 1998). Those studies showed that walk-thru traps can reduce horn fly burdens by 50–90%. Most recently, North Carolina State University replaced the side baffles with a system of blowers and vacuums (Denning et. al, 2014). Bruce traps and the newer vacuum traps are compatible with organic dairying, because a trap can be positioned at the entrance to a milking parlor, where cows come and go twice per day. Efficacy of any kind of trap will depend on the balance between the rate at which the flies are removed and killed by a trap and the rate at which the population naturally increases in the cows' pastures.

Organic dairy farmers rely on essential oil repellents and sticky tapes to alleviate horn fly problems, but success of these products is limited (Sorge et al., 2015). Because horn flies spread easily among adjacent pastures, efficacy for a whole herd will be modeled as a difference between the rate at which traps can remove and kill flies on cattle and the rate at which they are produced naturally in pastures. Our hypothesis was that summer growth of horn fly populations in June to August will be lowest on commercial organic dairies where a commercial vacuum fly trap (TRAP; CowVac, Spalding Laboratories, Reno, NV) is used and greatest where no TRAP is used. Therefore, the objective of this study was to determine removal rates of walk-thru fly traps, measure natural fly reproduction rates in organic dairy pastures, and then evaluate herd-level control using the TRAP.

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) and 7 other organic dairy farms during the summer of 2015 in Minnesota. The study period was from June 4 to September 30, 2015. All animal procedures involving animal care, management, and the client consent forms were approved by the University of Minnesota Institutional Animal Care and Use Committee (#1508-32966A).

The organic dairy farms utilized in this study spanned from Southeast, to Central, to Northwestern Minnesota, and ranged in herd size from 30 to 350 cows. The WCROC organic dairy herd had 130 milking cows. All herds had cows that were of numerous breeds of cattle and consisted of pure Holstein, pure Jersey and crossbreds of Holstein and Jersey, and European dairy breeds. The 8 herds averaged in milk production from 7 to 23 kg per cow per day. Six herds milked cows in a milking parlor twice daily; however, 2 herds had a Lely Robotic Milking system (Lely, Maassluis, the Netherlands). For all herds and cows, at least 30% of their diet consisted of high-quality organic pasture during the grazing season which is in accordance with USDA-NOP organic regulations (USDA-NOP, 2015).

Four TRAPS were acquired during the spring of 2015 from Spalding Laboratories, Reno, NV for use in the experiment. The TRAP is a new way to control pasture flies on dairy cows. It can be placed at the entry or exit of the milking parlor or barn. As the cows walk through, the TRAP will blow horn flies off the back, belly, face, flanks and legs into a vacuum system that collects them in a removable bag for disposal (Denning et al., 2014). Six herds had the TRAP positioned at the entry into the milking parlor. One TRAP at a robotic herd was placed in the entry to the barn from the pasture, so cows could move in both directions through the TRAP. The other robotic dairy had the TRAP placed into the Lely Grazeway gates to allow for one direction movement through the TRAP from pasture into the holding area of the robotic barn. Both TRAPS set up on robotic dairies were running 24 hours a day 7 days a week during the experimental period. The only adjustments which were made to TRAP was the height of the TRAP to ensure proper air flow for different breeds of cows. For the cows at each dairy, it was about 2 to 5 days to get cows conditioned to going through the TRAP.

The farms were divided into pairs by location in Minnesota and during the first period of the summer (June 4 to July 18) the TRAP was set up on one farm and during the second period of the summer (July 20 to September 30) the TRAP was sent to its paired farm. The time between July 18th and July 20th was the time the TRAP were moved to the other four farms. During this time of moving the TRAPS were inspected for any mechanical function and cleaned for any excess flies left in the system. The two treatments were operated in a crossover design among farms and months (June, July, August, and September), such that each farm received both treatments (TRAP or no TRAP) within the summer. Farms with the TRAP on their farm had the machine's' filters cleaned weekly by removing them from the inside of the TRAP and lightly brushing them off to ensure all the fly debris and cow hair was removed. The inside of the TRAP was cleaned and clear of any excess flies which did not make it to the collection chamber bag for removal. The machine and generators were also checked to ensure they were in proper working order.

Farms were visited once per week to collect flies from the TRAP, as well as count and record horn flies, stable flies, and face flies on cows. Farms that did not have TRAPS were also visited to count and record fly numbers. Numbers of flies on cows in each herd were counted by trained observers once per week during the 2015 grazing season. Flies were counted on either all the cows in the herd or if there were more than 100 cows in the herd then half of the herd's cows were counted for flies. Fly identification and counting methods were similar to those used by Denning et al. (2014). Observers distinguished horn flies from face flies, and stable flies. Horn flies were counted individually or in groups of 10 on one side of each cow. Face flies were counted on the animals' faces viewed head on, from poll to jawline and muzzle. Stable flies were counted on the visible faces of front and rear legs separately. For stable flies, the front leg and back leg counts were added together for analysis   Counts were made from a distance of 2 to 4 m (Watson, et al., 2002; Denning et al., 2014).

Furthermore, for farms that had TRAP, the TRAPS were emptied weekly to determine the number of flies captured. The flies collected from the chamber bags were separated by date and farm, and then individually counted to see what types of flies were being caught in the TRAP. Flies from individual bags were counted using a method requiring the plastic bag of flies to be emptied into petri dishes. The petri dishes were equally filled by weight until the bag was empty and if the last dish was not filled in a similar way the dish was labeled as a leftover dish. Two petri dishes, along with the leftover dish if applicable, were chosen at random using a random number generator and were counted for individual fly numbers. The petri dishes were divided into piles of horn flies, stable flies, face flies, and other insect which were caught in the TRAP. The mean, standard error and variance of the two petri dishes were calculated and evaluated to ensure another petri dish did not need to be counted. The variance in fly numbers between the two dished needed to be below 0.10 and if not another dish was counted. After the correct variance was found the mean of the petri dish was multiplied by the total number of dishes filled from the bag of flies from each farm. The leftover dish was then added to that extrapolated number to get an estimate number of horn, stable, and face flies collected on farm on each specific week.

Additionally, bulk tank production records (milk, fat percentage, protein percentage, and SCC), along with weekly cow numbers on farm were collected from each of the eight organic dairy farms. Daily milk production was calculated as total bulk tank production divided by the average cow numbers on farm.

Statistical Analysis

For analysis of data, fly numbers and milk production were averaged for each period (with or without TRAP) for each farm. Log transformations of fly counts were used as needed to satisfy analytical assumptions of equal variance and normal distribution in errors. Fly population growth rate was the slope of a linear line for the average individual weekly observation of fly numbers on cows for the period with and without the TRAP. The slope of the lines were analyzed for the horn fly, stable fly, and face fly and compared between the two periods.

Independent variables for statistical analysis of milk (kg/d), fat (kg/d), protein (kg/d), horn fly, stable fly, and face fly, and horn fly, stable fly, and face fly population growth rates were effects of summer period (with or without TRAP) and farm.

Independent variables for the statistical analysis of comparing TRAP location during the season included milk, horn fly, stable fly, and face fly. The effects of season (TRAPS out on farms during the first or second half of the summer) and TRAP presence were analyzed as dependent variables.

Farms were also characterized as to whether they had housing facilities for cattle to enter during the day for shade or for hot and humid weather or they had no housing facilities in a low input fashion and cows were on pasture at least 22 hours per day during the grazing season. Four farms had free-stall barn access for cows and four farms did not have any facilities or shade for cows in the pasture. For this analysis, the independent effects in the statistical model included housing facility (housing versus no housing), TRAP (with or without TRAP on farm), and the interaction of housing facility and

TRAP. For all statistical analysis listed above, the MIXED procedure (SAS Institute, 2015) was utilized for the output and utilized to conduct the ANOVA of the experiment. All treatment results were reported as least squares means, with significance declared at $P < 0.05$.

RESULTS AND DISCUSSION

Production and Fly Numbers

Least squares means and standard errors for milk, fat, protein production, SCC, and horn fly, stable fly, and face fly numbers for each of the eight farms are in Table 1. The table is separated based on the period of the summer in which the TRAP was placed on the farm (first or second period).

For milk production, farms ranged from 6.7 kg/cow/d to 22.7 kg/cow/day, and some farms were different ($P < 0.05$) from one another. The differences in milk production for herds was because of the management and nutritional program of the organic dairy. Some of the herds fed a partial-TMR during the summer grazing period that consisted of more grain, whereas some herds fed very little grain and thus had lower production. Fat and protein production and SCC followed milk production and was variable across the eight herds. Horn fly numbers were quite variable across the farms. A few farms had low number of horn flies (6.1 to 9.2 flies/side) on cows and some farms had high numbers of horn flies (27.5 to 29.5 flies/side). Stable fly and face fly numbers were also variable across the eight farms; however, they were not as prevalent on cows as horn flies. Denning et al. (2014) reported a wide range of values for horn flies on cows across 7 commercial dairy farms, which is in agreement with this study.

However, that study found fewer stable flies and similar face fly numbers per cow as the current study. The climate between North Carolina and Minnesota would significantly contribute the varying number of fly species per cow.

Results for milk production and fly counts in the presence or absence of the TRAP across the summer season are in Table 2. Milk production (15.5 kg/d vs. 15.3 kg/d) and SCC (315 vs. 322) were similar ($P > 0.05$) for farms when the TRAP was present compared to when the TRAP was absent on farms, respectively. Horn fly numbers were reduced ($P < 0.05$) by 44% when the TRAP was on the farm versus when the TRAP was removed from the farm (11.4 flies/side vs. 20.5 flies/side). Stable fly (5.4 vs. 7.1 flies/leg) and face fly (1.0 vs. 1.0 flies/cow) counts were similar for when the TRAP was present or absent. Reductions in horn fly numbers for the current study were less than those reported by Denning et al. (2014), who saw a 68% to 75% reduction in horn fly numbers across a 4-yr study. However, the number of horn flies observed in the North Carolina study were drastically higher than those observed in our study in Minnesota. Horn fly numbers can vary greatly among cows on farm, with some cows hosting large numbers of flies, while others attracting very few flies (Steelman et al., 1993, Jensen et al., 2004). Numerous factors may influence horn fly attraction to a particular cow, including color (Ernst and Krafsur, 1984, Schreiber and Campbell, 1986), breed (Steelman et al., 1991), and time of day (Schreiber and Campbell, 1986).

Horn fly population growth rates mirrored that of the horn fly results and are found in Table 3. While present on organic dairy farms, the TRAP reduced ($P < 0.05$) the growth rate of horn flies compared to when the TRAP was not on farms (-1.01 vs.

1.00). By reducing the growth rate, fewer numbers of horn flies were observed on cows on farm (Table 2), and indicates that the TRAP was successfully captured more flies quicker than horn flies could have reproduced in dung pats on pasture. Stable fly and face fly growth rates were not affected (P > 0l05) by the presence or absence on the TRAP on farm, and mirrors the results of the number of those specific fly species on cows.

Housing and TRAP

Least squares means and standard errors for daily fly counts and milk production across the summer season for organic housing systems and TRAP presence are in Table 4. For organic dairy farms that had no housing system on farm (cows were on pasture for at least 22 hours/d except for milking), the presence of a TRAP tended (P < 0.10) to reduced horn fly numbers on cows by 59% (28.3 flies/side to 11.7 flies/side) and tended (P < 0.10) to reduce face fly numbers on cows (1.7 flies/cow to 1.0 flies/cow). Stable fly numbers were not affected by the presence or absence of the TRAP on farms without barns. Furthermore, milk production was not different for farms that had no housing system in the presence of absence of the TRAP. For organic dairy farms that had a housing system or shade (4 farms had free-stall barns), milk production, face fly, and stable fly numbers were similar when the TRAP was present or absent on farms. Explanations for the number of face flies on farm with the presence of a TRAP tending to be greater (P < 0.10) compared to the absence of the TRAP are unknown. Horn fly numbers were reduced on farms with no housing facilities because horn flies develop in undisturbed, fresh dung pats and nowhere else. The cows that are in a housing facilities to consume a partial TMR or to find shade from the heat and humidity are defecating in the housing facilities where horn flies will not reproduce. Therefore, the results indicate that cows who remain outside on pasture for a majority of the day and evening would benefit from the presence of a TRAP on farm compared to farms that having housing facilities for grazing cows.

Table 5 has least squares means and standard errors for milk production and fly counts in the presence or absence of the TRAP for the first-half and second-half of summer for organic dairy cows. Milk production, and horn fly, stable fly, and face fly numbers were similar for the first-half of the experiment compared to the second-half of the experiment whether the TRAP was present or absent on farms.

Sanitation should be the primary control option on any organic dairy farm for stable flies. Because synthetic pesticides are not allowed on organic dairies, proper sanitation is of the utmost importance. Manure and feed provide the ideal habitat for stable fly production. Manure and old feed should be removed daily, or at least twice a week, from calf pens, holding areas, feed areas and milking areas. To ensure success on the organic dairy, producers need to properly identify key pests, understand their biology and habitat, monitor their populations, and then reduce the fly population through mechanical or biological management techniques. Ultimately, there are many tactics that producers can try out on their own farm.

CONCUSIONS

The results of the study found that horn fly numbers on cows and horn fly population growth were reduced with the use of the TRAP on organic dairy farms in Minnesota.

However, the TRAP did not reduce stable fly or face fly number on individual cows. Organic producers who do not have a shelter for their cows during the summer would benefit from a TRAP on farm. Benefits of improved milk production with the TRAP were not evident on a herd-basis in this study, so it remains to be determined if the use of the vacuum trap will improve dairy farm profitability.

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Table 1. Least squares means and standard errors for daily milk production and fly numbers by farm for organic dairy cows across the grazing season.[2]

		Milk		Fat		Protein		SCC		Horn fly		Stable fly		Face fly	
		(kg /d)		(kg/d)		(kg/d)		(cfu/mL)		(flies/side)		(flies/leg)		(flies/cow)	
Farm	Commercial vacuum trap Presence[1]	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
A	First	22.7[a]	2.9	1.7[a]	0.2	1.5[a]	0.1	568[a]	27.6	14.1[a,b,c,d]	1.2	1.1[a]	1.6	0.4[a,b]	1.2
B	First	16.0[b]	2.9	1.3[a,b]	0.2	1.1[a,b]	0.1	270[c,d,e]	27.6	9.2[c,d]	1.2	4.4[a]	1.6	1.4[a,b]	1.2
C	First	11.3[c]	2.9	0.9[b,c]	0.2	0.8[b,c]	0.1	385[b]	27.6	17.8[a,b,c]	1.2	6.2[a]	1.6	0.9[a,b]	1.2
D	First	6.7[d]	2.9	0.6[c]	0.2	0.4[c]	0.1	246[d,e]	27.6	24.1[a,b,c]	1.2	4.2[a]	1.6	1.6[a]	1.2
Average of farms		14.2		1.1		0.9		367		16.3		4.0		1.1	
E	Second	20.1[a,b]	2.9	1.6[a]	0.2	1.3[a]	0.1	295[b,c,d]	27.6	27.5[a,b]	1.2	7.1[a]	1.6	1.4[a,b]	1.2
F	Second	18.8[a,b]	2.9	1.6[a]	0.2	1.2[a]	0.1	270[c,d]	27.6	10.3[b,c,d]	1.2	1.6[a]	1.6	0.7[a,b]	1.2
G	Second	16.3[b]	2.9	1.7[a]	0.2	1.4[a]	0.1	176[e]	27.6	6.1[d]	1.2	2.9[a]	1.6	0.3[b]	1.2
H	Second	11.4[c]	2.9	0.9[b,c]	0.2	0.8[b,c]	0.1	351[b,c]	27.6	29.5[a]	1.2	3.5[a]	1.6	1.4[a,b]	1.2
Average of farms		16.6		1.4		1.2		273		18.3		3.8		1.6	

[a,b]= Means within a column for milk production and fly numbers without common superscripts are different at $P < 0.05$

[1] = The presence of the Commercial vacuum trap during the first 8 weeks or second 8 weeks of summer.

[2] = Fly counts were analyzed on a log scale and transformed back to the mean scale.

Table 2. Least squares means and standard errors for milk production and fly counts in the presence or absence of the Commercial vacuum trap across the summer season for organic dairy cows.

	Commercial Vacuum Trap Absent		Commercial Vacuum Trap Present	
	Mean	SE	Mean	SE
Milk (kg/d)	15.3[a]	1.4	15.5[a]	1.4
Fat (kg/d)	1.3[a]	0.08	1.3[a]	0.08
Protein (kg/d)	1.1[a]	0.06	1.0[a]	0.06
SCC (cfu/mL)	322[a]	13.8	315[a]	13.8
Horn fly (fly/side)	20.5[b]	1.1	11.4[a]	1.1
Stable fly (fly/leg)	7.1[a]	7.0	5.4[a]	7.0
Face fly (fly/cow)	1.0[a]	1.1	1.0	1.1

[a,b]= Means within a row for without common superscripts are different at $P < 0.05$

Table 3. Regression coefficients for fly population growth rates during periods presence and absence of the Commercial vacuum trap across the summer season for organic dairy cows

	Commercial vacuum trap Absent		Commercial vacuum trap Present	
	Mean	SE	Mean	SE
	Flies/d		Flies/d	
Horn fly	1.00[b]	1.01	-1.02[a]	1.01
Stable fly	-1.01[a]	1.01	-1.02[a]	1.01
Face fly	-1.00[a]	1.01	1.01[a]	1.01

[a,b]= Means within a row for without common superscripts are different at $P < 0.05$

Table 4. Least squares means and standard errors for daily fly counts and milk production across the summer season for organic housing systems and Commercial vacuum trap presence for organic dairy cows.

Commercial vacuum trap and Housing Scenario	Milk Production (kg /d)		Horn Fly (flies/side)		Stable Fly (flies/leg)		Face Fly (flies/ cow)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
No housing and Commercial vacuum trap	31.6	6.0	11.7	1.2	7.9	1.2	1.0	1.1
No housing and no Commercial vacuum trap	28.1	6.0	28.3	1.2	10.9	1.2	1.7	1.1
P-Value	*0.7*		*0.07*		*0.5*		*0.1*	
Housing and Commercial vacuum trap	36.7	6.0	11.2	1.2	3.6	1.2	0.9	1.1
Housing and no Commercial vacuum trap	39.5	6.0	14.8	1.2	4.4	1.2	0.4	1.1
P-Value	*0.7*		*0.6*		*0.7*		*0.1*	

Table 5. Least squares means and standard errors for milk production and fly counts in the presence or absence of the Commercial vacuum trap for the first-half and second-half of summer for organic dairy cows.

	Commercial Vacuum Trap Absent		Commercial Vacuum Trap Present	
	Mean	SE	Mean	SE
Milk				
First-half	28.6	6.1	33.9	6.1
Second-half	39.1	6.1	34.4	6.1
Horn fly				
First-half	19.1	1.4	12.5	1.4
Second-half	22.0	1.4	10.5	1.4
Stable fly				
First-half	5.3	1.2	9.0	1.2
Second-half	9.0	1.2	3.0	1.2
Face fly				
First-half	1.5	1.2	0.6	1.2
Second-half	0.6	1.2	1.0	1.2

No significant difference between Commercial vacuum trap presence or absence for the first-half or second-half of summer for all variables.

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