Performance of Female Holstein Calves Grouped Post-Weaning According to Their Individual Feed Intake

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by

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

The purpose of the research in this thesis is to study and identify whether grouping calves post-weaning according to pre-grouping feed intake has an effect on their eating behavior and performance in weaning pens. The effect of grouping calves post-weaning according to pre-grouping feed intake on animal performance was evaluated using 755 replacement Holstein calves raised on a large commercial dairy operation in southern Idaho. In four different periods, individual feed intake was recorded 4 times a week during the last 3 weeks that calves were individually hutched (39 to 60 d of age, ± 3 d). Calves were classified as high eaters (highest feeding level quartile) or low eaters (lowest feeding level quartile). When leaving the individual hutches in each period, calves formed 6 groups: 20 animals randomly chosen without considering their level of feed intake (CTRL), 20 calves within the highest quartile of feed intake during the 3 weeks prior to leaving the hutches (HH), 20 within the lowest quartile (LL), 5 calves from the lowest and 15 from the highest feeding level (LHH), 15 calves from the lowest and 5 from the highest feeding level (LLH), and 10 calves from the highest and 10 from the lowest feeding level (HL). Thus, out of 755 initially-tracked calves, 480 calves were chosen to form the 20 groups (6 groups per period) that were studied. Pen feed intake was recorded during the first 4 weeks after grouping. Grouped calves received a TMR composed of 95% starter and 5% alfalfa. Final body weight was recorded at the end of the 12th week of the study. Pen was the experimental unit. Heifers in the highest feeding level quartile in the HL, HLL and HHL were differentiated from the lowest quartile in their groups by using a red plastic collar to follow their behavior. Reflective tape was used over the collars to facilitate the observations at night. A total of 192 d of recordings were collected and later analyzed for eating behavior and time spent at the feedbunk. Heifers were counted as eating

after 5 seconds of the activity at the feedbunk. Data were analyzed using a mixed-effects model. Least square means of dry matter intake (DMI) after grouping was greatest in HH (2.29 ± 0.05 kg/d) and HHL (2.23 ± 0.05 kg/d) followed by HL (2.13 ± 0.05 kg/d), CTRL (2.11 ± 0.05 kg/d), LLH (2.00 ± 0.05 kg/d) and LL (1.88 ± 0.05 kg/d). Similarly, average daily gain was greatest in HH (0.73 ± 0.04 kg/) and HHL (0.66 ± 0.04 kg/d) than in HL (0.58 ± 0.04 kg/d), LLH (0.57 ± 0.04 kg/d), CTRL (0.55 ± 0.04 kg/d), and LL (0.57 ± 0.04 kg/d). Least square means of body weight at 89 d old (BW89) was greatest in HH (96.33 ± 1.34 kg) and HHL (91.47 ± 1.35 kg) followed by HL (86.97 ± 1.36 kg), CTRL (85.79 ± 1.36 kg), LLH (83.52 ± 1.34 kg) and LL (77.06 ± 1.35 kg). Overall, there was no effect ($P > 0.05$) of grouping on eating behavior and performance of calves classified as high and low eaters with high eaters consistently performing better than low eaters.

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DEDICATION

This thesis is dedicated to my family and friends. To my father, that with his exemplary memory guides me in life, and to my mother, an intelligent woman who dedicated her life to care for the family. To my brothers and sister with whom I share my dreams, projects, and realities. To my nieces Paulina, Maria Elena, and Ilse Verónica with whom I share this milestone. To Bertha, for her constant care, love and support, and to my dear friends for their trust, encouragement, and for always believing in me.

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CHAPTER 1: LITERATURE REVIEW

Rearing of Calves

Female dairy calves are generally raised as replacement for culled cows and they also represent a potential of growth or extra income for the dairy. Most dairies in the United States (90.7%) raise replacement heifers on site while almost half of the large dairies' milking more than 500 cows, raise their heifers in offsite facilities (USDA, 2016). A regular practice in modern dairy systems is to remove calves from their dams shortly after birth or within a few d. Removing calves from their dams early in life minimize the bonding process and stress of separation between the dam and the newborn (De Passillé, 2008).

The majority of new born calves are manually fed with colostrum (USDA, 2010). Calves are regularly reared individually in hutches and most of calves in the U.S. are fed milk replacers and/or waste milk, starter grain, and possibly hay until weaning (Heinrichs et al., 1995). After weaning, calves are normally grouped in pens and fed a ration consisting of starter grain and hay. The female calves will remain grouped with other calves of similar age through puberty, breeding, and pregnancy before they are relocated to farms prior to calving as springers.

Rearing Methods

The rearing practices have an impact on performance and behavior of dairy calves (Arave et al., 1985). Warnick et al. (1976) studied the effects of rearing calves individually, in groups, or in isolation on body weight gain and behavior. After 10 weeks in the treatments, calves (n = 36) were weaned, and placed in groups of 13 calves for 7 more weeks. The calves reared in groups reached adequate grain and hay consumption at an earlier age and gained more weight (7.3 kg, $P < 0.05$) than calves raised individually or in isolation. Also, group reared calves tended to be more dominant, and had more vocalizations in a field test ($P < 0.05$) where the calves were in a 6.1 m diameter circular arena. There was a significant difference in exploratory activity in a field test among the calves reared in isolation individually, or in groups ($P < 0.05$), where calves entered more squares in a field test, and had a medium number of vocalizations. The calves reared individually tended to be healthier and gained more weight from 1 to 74 d and from 1 to 124 d of age ($P < 0.05$).

Arave et al. (1985) followed calves (n = 67) in 4 different treatments (groups of six, individual hutch, isolation, and isolation with handling) through the first lactation in four trials. Calves were weaned at 10 weeks of age and incorporated into the regular herd management. Only 73% of the calves survived through the end of the first lactation with 27% being lost due to culling decisions or death. Average daily gain fluctuated between 0.37 and 0.52 kg/d among the treatments in two trials, and individual calves performed slightly better but not different ($P > 0.05$) than grouped calves through weaning. Individually reared calves were least dominant ($P < 0.05$) and calves reared in groups were more aggressive approaching the feed bins and with higher dominance rank (DR, $P < 0.05$). A significant difference of 922 kg of fat corrected milk in first lactation cows was found in calves reared in isolation compared to individual and grouped calves ($P < 0.05$). Production was calculated in 305-d mature equivalent of milk and fat corrected milk (FCM).

Calf Feeding, Weaning, and Performance

Conventional methods of feeding limit the amount of milk provided to the calves to 10% of their body weight, while in step-down (STEP) methods of feeding, calves are either allowed a larger volume of milk or fed milk replacers mixed at higher ratios of powdered milk diluted per 1 L of water for a number of days before weaning starts (Appleman and Owen, 1975; Khan et al., 2007a, b; Eckert et al., 2015). Enhanced growth feeding programs improve growth during the pre-weaning period (Khan et al., 2011) and allow the weaning of calves at an early age (Khan et al., 2007a). In enhanced growth feeding programs, calves fed a higher amount of milk solids through larger volumes of milk, higher solids mix ratio, or *ad libitum* consumption of milk or milk replacer with a consequent increase in average daily gain (ADG) pre-weaning, but a common drawback with these programs is that calves struggle after weaning (Bar-Peled et al., 1997).

The average age at weaning is 8.2 wk of age, with large operations weaning calves at an older age, 9.1 wk (NAHMS, 2007). Eckert et al. (2015) studied the effect of weaning age on growth, feed intake, rumen development, and behavior on individually raised female Holstein fed a high plane of nutrition during the pre-weaning period and weaned through the step-down method at ages 36 and 50 d and reported in his study that age at weaning in STEP methods of feeding, may have an impact in the performance of the calves.

In the experiment by Eckert et al. (2015), calves were fed milk replacer (26% CP, 16% fat) mixed at a rate of 150 g/L of water per d in 2 meals starting with 6 L of milk replacer from d 1 to 3, 7 L from d 4 to 6, and 8 L from d 7 until d 36 for the 6WW, and d 50 for the 8WW treatments. During the step-down week, the calves received 4 L/d of the milk replacer for 7 more days for a complete weaning at d 42 (6WW) or d 57 (8WW). The calves weaned at 8 weeks had significantly higher starter intake and ADG ($P < 0.05$) during the weaning period compared to the calves weaned at six weeks. The ADG at 70 d of age was 1.29 vs. 0.94 kg/d ($P < 0.05$) for the 8WW and the 6WW calves, respectively. Overall starter intakes were very similar between d 63 and d 70. The study suggested that the calves in the 8WW treatments cope with the stress of weaning better than the calves in the 6WW treatment.

A general recommendation is to wean the calves when they reach a starter grain consumption of at least 300 g for 2 consecutive days (Bach et al., 2007). Starter grain can be fed to the calves in a pelleted or a multiparticle form. Small ration particles in starters grain can lower the rumen pH and alter the rumen papillae structure and function. Coarse starters favor the rumen health and development of rumen papillae and with thus starter grain intake in calves (Coverdale, et al. 2004).

The use of pelleted starters may result in less dry feed intake ($P < 0.01$) compared with multiparticle starters, especially when the milk replacer is removed. Bach et al. (2007) found that the difference in pre-weaning feed intake between a multiparticle and a pelleted form of starter with the same ingredients and nutritional content was 6.1 kg (51.1 vs. 45.0 kg, $P < 0.01$). The similar ADG (780.0 vs. 766.8 g/d; $P = 0.55$) suggesting a better feed efficiency with pelleted forms of starters and thus the use of starter grain to feed calves could be more economical in pelleted form due to the better feed efficiency with this presentation of the starter grain. In their study, the feed conversion efficiency (ADG/DMI) was greater ($P < 0.01$) in calves consuming pelleted starter than in the calves consuming a multiparticle starter.

Chua et al. (2002) studied weaned individually and pair grouped calves fed *ad libitum* by artificial teats at 5 weeks of age. They found no difference in growth of individually vs. pair grouped calves before or after weaning. The studies followed the calves until 56 d of age. Differences were reported on behavior where group paired calves spent more time standing and moving than did calves individually housed. The double space provided for the pair housed calves allowed the calves more movement within their assigned space, whereas individually housed calves spent more time with their heads facing out of their hutch. The behavior of calves was followed from weeks 2 through 8 where very low incidences of agonistic behavior was observed while the calves remained grouped in individual hutches with double space.

The performance of dairy calves weaned at 49, 56, and 70 d of age, and raised individually or in groups, was assessed by Bach et al. (2010) who conducted two studies. In a first experiment, 320 female calves were fed 2 L of milk replacer twice daily until age 49, and then 2 L once per d until weaning at 56 d of age. Half of the calves were allowed to stay in the individual hutches for six more d, and the other half were moved immediately after weaning to a group pen holding 8 calves. The calves gained significantly more weight (0.826 vs. 0.794 kg/d, $P = 0.05$) when they were grouped immediately at weaning (Table 1.1). In the second experiment, 240 female calves were fed 2 L of milk replacer twice daily until 49 d of age, and then 2 L of milk until 70 d of age. The starter grain was replaced by a dry TMR when calves were 49 d of age. Half of the calves were moved at 49 d of age to superhutches in groups of 8 with an elevated trough used to continually deliver milk replacer. The other half remained individually penned until 56 d of age, when the calves were moved to superhutches where they continued to receive milk replacer. The total ADG was greater ($P < 0.05$) in calves moved to groups at 49 than in those moved at 56 d of age that resulted in greater body weight (BW) of calves by the end of the study 70 d of age.

Enhanced-growth feeding programs allow the weaning of calves at an early age (De Passillé et al., 2011). Performance of the calves depends on nutrition, management, and overall health (USDA, 2016). The performance and behavior of calves reared in groups (GP) or individually (IP) following an enhanced-growth feeding program where milk replacer was offered at 15% DM was analyzed by Terré et al. (2006). Calves were fed 4 L/d milk replacer from 1-5 d, 5 L/d from 6-13 d. Milk replacer was then decreased to 4 L/d from d 20 to weaning at 28 d to stimulate starter intake. They reported no significant effects of housing type on final BW, starter and MR intakes, and gain to feed ratio. However, the evolution of ADG was different ($P < 0.05$) between treatments. Average daily gain of IP calves increased ($P < 0.05$) from 14 to 21 d of study (from 0.71 to 0.89 ± 0.071 kg/d, respectively). In divergence, ADG of GP calves was maintained constant (0.85 ± 0.099 kg/d) during this period. The week after weaning, calves in the GP treatment presented a further decrease in ADG (from 0.60 to 0.17 ± 0.099 kg/d; $P < 0.05$) in GP than in IP calves (from 0.47 to 0.33 ± 0.071 kg/d). After that, ADG increased linearly on both treatments, being 1.09 ± 0.071 and 0.93 ± 0.099 kg/d in IP and GP calves, respectively at 56 d of study. The authors did not observe a significant effect of treatment on final BW, starter and milk replacer intake, or in feed efficiency (Table 1.3).

Average daily gain can also be estimated using a heart-girth tape, or for a more precise measurement, a calibrated scale (Bach et al., 2010). Body weight is evaluated as a measure for growth in addition to ADG (Heinrichs and Losinger, 1998). Khan et al. (2007b) also measured body length (BL), heart girth (HG), body barrel (BB), withers height (WH), and hip height (HH) of the calves at birth, during the week of weaning (d 28), at weaning (d 49), and at post-weaning (d 63). DeVries and von Keyserlingk (2009b) measured BW with the aid of a heart-girth tape at an early age and later in life (≤35 d and >35 d).

Atkinson, et al., (2017) estimated growth (ADG) at 0.68 ± 0.09 kg/d as a mean in a benchmarking study involving 18 Canadian dairy farms. They divided calves into early (≤35 d, 0.51 ± 0.12 kg/d) and late (>35 d, 0.90 ± 0.19 kg/d) pre-weaning groups. Ten farms implemented changes in their colostrum and milk feeding protocols after the benchmarking report was sent, improving ADG from 0.66 ± 0.09 kg/d before the benchmarking report, to

0.72 ± 0.08 kg/d after making management changes. Taking into account only younger calves (≤35 d), the least square mean of ADG in these 10 farms increased significantly (*P* < 0.05) from 0.48 ± 0.15 kg/d to 0.61 ± 0.11 kg/d. For calves older than 35 d, ADG was not different after benchmarking at 0.84 ± 0.16 kg/d before and 0.81 ± 0.13 kg/d after (*P* > 0.1).

Feed Efficiency

Feed efficiency (FE) is used as a benchmark for profitability. In a study by Khan et al. (2007a), feed efficiency was calculated in female calves fed milk according a conventional or a step-down (STEP) method of feeding in four different time periods. The calves were also fed starter grain and chopped mixed grass hay. After colostrum feeding, calves were fed either milk at 10% of their BW (fed 2 times) until 44 d of age (conventional) or milk at 20% of their BW (fed 4 times) until 23 d of age and then gradually reduced to 10% of their body weight by d 28 and continued to be fed at that level until 44 d of age (STEP). Both groups were weaned watering down the milk until it reached 50% water and 50% milk for 5 more d, from 45 to 49 d of age. Feed efficiency was calculated as BW gain divided by dry matter intake (DMI). The feed efficiency was calculated in the periods of age where the calves were fed the different volumes of milk comparing the calves in the STEP vs. conventional method of feeding (23, 28, 44, and 50 d of age). The FE for the STEP method of feeding at 23 d of age for the STEP calves was significantly different (*P* < 0.002) at 0.52 vs. 0.47 for the conventional method of feeding. It was also different at d 28 but this time calves in the conventional method had 0.50 and calves in the STEP method had 0.47. The FE pre-weaning for the conventional vs. the STEP at 44 d of age and for the post-weaning at 50 d of age was no different between the two methods of feeding (0.49 vs. 0.50 and 0.32 vs. 0.30).

When the weather is cold and/or wet, calves have a greater requirement of energy and in the opposite, if the environment is too hot, calves tend to eat less. Feed efficiency decrease and weight gain may be lower during heat stress due to a lower grain intake and extra energy required to regulate the calves' body temperature increases and weight gain may be lower (Place et al., 1998).

Feeding Behavior of Calves

The first ingestive activity of calves is suckling. Maternal-newborn behavior in cattle as in other domestic species develops rapidly after birth, but can be easily broken when a calf is separated from their dam. In this separation period, when newborn calves are touched and handled, they can become less fearful of humans. This imprinting, allows human-animal interactions that would normally not be allowed. This management practice limits maternal and social interactions from one d of age and is in divergence to what occurs under natural conditions (Reinhardt et al., 1981).

All animals have an innate curiosity and a tendency to investigate their environment through seeing, hearing, smelling, tasting and touching. Cattle can adapt to a variety of housing systems like being held individually, or in small or large groups. Adaptation to housing often results in abnormal behavior such as tongue rolling, inter-suckling, and excessive licking and grooming (Phillips, 2002). Investigative behavior sometimes leads to the ingestion of non-nutritional objects (Albright, 1993).

In natural environments, the young grazing ruminant naturally learns to ingest solid feed by allelomimetic behavior, using its mother or peers as models. In lambs, the diets of the offspring may be influenced by the availability of plants and the presence of weeds (Provenza and Balph, 1987). Allelomimetic behavior is a mimicking behavior. When an individual of a group of cattle does something, another is inclined to act the same (Timbergen, 1951). Taking a group of cows to the milking barn is an example of this behavior. A cow will lead and another cow will follow, and since more animals are doing it, the first individual continues. In natural conditions, allelomimetic behavior has an important role in avoiding dangers as fleeing predators.

The rearing method influences the eating behavior and activity of the calves. In a study by Warnick et al. (1976) calves reared in groups reached higher levels of feed intake earlier in life, and gained more weight than calves reared individually or in isolation. Calves reared in groups had more vocalizations than individual or isolated calves while the isolated calves where more ambulatory and visited more squares than the individual or group housed calves ($P < 0.05$). Calves reared in isolation reached took longer to achieve the same level of feed consumption, had less weight gain, and seemed to be disoriented walking around several times over an open area novel for them and designated as a field test.

Fence line feeding of TMR allows calves to be eating at the same time when there is enough space in the feed manger, eat in a natural grazing position, and reduce competition (Greter, et al. 2010). Cows desire to eat in feed mangers or graze in pastures stop when they feel the urge to drink (Albright, 1993); they usually walk to the water trough and very seldom stop to graze more before they go and drink water. In the study by Mirzaei et al. (2017), calves supplemented with corn silage ruminated for longer periods of time when compared to the no forage or the alfalfa supplementation groups.

The number of visits to the water trough is different among calves, and the amount of water they drink varies from day to day (Albright, 1993). Dirt eating, a behavior widespread in confined cattle is limited by the environment and accessibility to dirt; concrete flooring and dirt covering with manure deflects cattle from eating dirt in ditches and perimeters of the pens when dirt is exposed (Grant and Albright, 2001).

The behavioral observations during the study by Bach et al. (2010) were related to stress at weaning, vocalizations, and non-nutritive oral behavior and were observed 3 d a week (Monday, Wednesday and Friday) for 1 hour (13:00 to 14:00 h) from d 35 to 63. Behavioral displays coincided with improved feed intakes during the week of weaning. Calves weaned at 8 weeks in the experiment by Eckert et al., (2015), spent more time eating starter grain (4.0 vs. 2.35 min/h; $P < 0.05$) and vocalizations were similar ($P > 0.05$) for calves in both treatments, possibly signaling hunger.

DeVries and Von Keiserlingk (2009a), in an experiment evaluating different methods of feeding, found that prepubertal dairy heifers (158.2 ± 4 d of age) ate more consistently throughout the day when provided a TMR than when provided *ad libitum* hay top dressed with grain or choice options of hay and grain. Establishing a balanced ration at every meal can help with consistency of digestion. They concluded that the availability of feed may be more important than ration balancing.

Social Dominance. Social dominance can be defined as a relationship where an animal through threat, force, or mere pleasure causes a subordinate animal to yield space (Albright, 1993). Signs of agonistic behavior like fighting are more common in un-castrated males or between dominant cows. Subordinate animals tend to avoid conflict and settle as second rank animals. Availability of food and space was an important factor (Albright, 1993). There is no evidence that subordinate animals will underperform if there is feed available. The use of automated head restraints prevents competition between cows at a feed manger (Phillips, 2002).

Dairy cows are reported to have low antagonic behavior or territoriality although aggression has been observed in all ages and regardless of the sex. Also, heart girth has been more associated with dominance than height at withers. Dominant calves or calves with higher drive to eat spend more time eating but make less visits to the feedbunk. Aggressive behavior of isolate calves generally is inhibited, sensory stimuli dampened, and close social contact with herdmates avoided (Arave and Albright, 1981).

Feeding patterns of dairy cattle are induced by the manner in which feed is presented and competition at the feedbunk. Delivering concentrate and forage as separate components encourages rapid intake of the concentrate component at the time of feed delivery before consuming forage in both growing heifers and cows (DeVries and von Keyserlingk, 2009a; Greter et al., 2010). The return from milking and the delivery of feed encourage feeding activity in milking cows (DeVries et al., 2003).

Feed competition is seen in situations of insufficient manger space or limiting feeding (Albright, 1993). Competition at the feedbunk alters the feeding behavior of dairy calves modifying the display of the activity by creating variability in feeding times, interval between meals and volume of the feed consumed. Differences in DM feed intake between the heifers fed competitively and non-competitively have not been observed (DeVries and Keiserlingk, 2009b), although heifers fed competitively had less visits to the feed bin, spent more time eating and ate more at each visit than the non-competitive heifers ($P < 0.05$). Heifers competing for feed at the feedbunk tend to have fewer meals and longer and larger meals. Post-weaned calves fed a TMR have a more equal distribution of feeding patterns than when fed grain and hay separately (DeVries and von Keyserlingk, 2009a). Feed intake depends more on feed availability, drive to eat, and health than on dominance rank, size, and behavior of the calves (Arave and Albright, 1981).

In a study by Greter et al. (2010) prepuberal heifers previously exposed to a TMR ration have shorter peaks of time eating at the feedbunk (P =0.03) and received less displacements (P < 0.001) than calves that didn't have a previous experience eating TMR but the ADG and DMI was no similar (P > 0.5) when heifers with and without previous exposure to a TMR were grouped together.

Play Behavior. Duve et al. (2012) investigated the effects of social contact and milk allowance on social and play behavior and how dairy calves responded to handling in 5 treatments: calves individually housed and fed 5 L milk/d (SL); calves individually housed and fed 9 L milk/d (SH); calves housed in pairs and fed 5 L of milk/d (PL); calves housed in pairs and fed 9 L of milk/d (PH); calves kept with the dam and fed 9 L of milk/d (CH). From 4 to 6 weeks all calves were offered 5 L of milk/d. At 6 weeks, all calves were weaned and at 7 weeks old were grouped, 1 calf from each treatment plus 2 companions. Play behavior was observed when the calves were provided fresh straw bedding on Wednesdays and before the weekly test on Sundays. The duration of play analyzed in weeks 2 through 6 peaked in week 3 and declined to low levels by week 6 (P < 0.01). The duration of play in the 3^{rd} week was affected by the interaction between social contact and milk allowance, with calves in the SL group spending less time playing than calves in the remaining treatments (P = 0.04).

Calf's Health

Bach et al. (2011) studied the performance and health status of transition calves housed in groups in 2 experiments that each included 144 female Holstein dairy calves.

Calves were individually housed until weaning at 58 d of age and all respiratory afflictions (BRD) were recorded on a daily basis. After weaning, calves were grouped in groups of 8 based on respiratory incidence in the first 58 d of life. In the first experiment, calves were divided into 3 treatments, and 6 super hutches per treatment. The studied groups were: HHH, calves with no previous history of pneumonia; HHR, 6 calves without incidences of BRD and 2 calves with previous respiratory afflictions; and HRR, 5 calves without previous incidences of pneumonia and 3 calves with a previous respiratory problem. Average daily gain was similar ($P = 0.20$) at 1.25, 1.15, and 1.16 kg/d, and the final body weight was also similar ($P = 0.90$) at 141.7, 137.8, and 137.7 kg for the HHH, HHR, and HRR respectively at 114 d of age. In experiment 2, calves were moved in groups of 8 based on 2 treatments, calves with no previous respiratory afflictions (HHH), and calves with a previous case of respiratory afflictions (RRR) in the first 58 d of life. The ADG for the calves in the HHH and the RRR treatments, tended to be different (1.21 and 1.13 kg/d; $P = 0.07$), but the final body weight at 114 d of age was significantly different (141.3 and 136.3 kg; $P = 0.01$).

Genetics and Milk Production

Nutrition and management of the pre-weaned calf have the foremost environmental influences over the expression of the genetic capability of the animal for milk yield. Average daily gain is significantly correlated with first-lactation milk yield. For every 1 kg of pre-weaning ADG, first lactation heifers produced on average 850 kg more milk (Soberon et al., 2012) during their first lactation ($P < 0.01$). The term lactocrine hypothesis was perceived to describe the effect of milk-borne hormones (Insulin, Glucagon, Prolactin, Growth hormone) in milk and colostrum, on the epigenetic development of specific tissues of physiological functions (Bartol et al., 2008). The implication of this hypothesis is that the neonate can be maternally influenced to foster the ability to develop a particular process. The lactation response to the increase of ADG could be a function of the total nutrient intake or the factors in whole milk could be responsible for the enhanced milk yield.

CHAPTER 2: PERFORMANCE OF FEMALE HOLSTEIN CALVES GROUPED POST-WEANING ACCORDING TO THEIR INDIVIDUAL FEED INTAKE

INTERPRETIVE SUMMARY

Dairy calves are usually housed individually until weaning and then they are grouped randomly. Within groups of calves we can find animals with low and high drive to eat. Social facilitation might play a role in modulating feedbunk behavior and intake in grouped calves. The objective of this research was to determine the effects on performance, feeding behavior and intake of weaned calves grouped according to their pre-grouping intake. Overall, there was no effect of grouping on eating behavior and performance of calves classified as high and low eaters with high eaters consistently performing better than low eaters.

ABSTRACT

Out of 755 calves, 480 calves (60 ± 3 d of age) from the high and the low quartile levels of feed intake in the last three weeks in hutches, were chosen for the treatments (4-repetitions; 6-treatments). The treatments were 20-control (CTRL), 20-high-high (HH), 20-low-low (LL), 10-low-10-high (HL), 15-high-5-low (HHL), and 5-high-15-low (HLL) calves. Calves were fed 95% grain and 5% alfalfa hay (TMR) and their eating behavior was video recorded 2-d a week for 4-weeks. Pen was the experimental unit. Data were analyzed using a mixed-effects model. Average DMI after grouping was greatest in HH (2.24 kg/d) and HHL (2.15 kg/d) followed by HL (2.07 kg/d), Control (2.06 kg/d), LLH (1.92 kg/d) and LL (1.77 kg/d). Similarly, ADG was greatest in HH (690 g/d) and HHL (674 g/d) than in HL (585 g/d), LLH (571 g/d), Control (545 g/d), and LL (526 g/d). The number of calves eating in periods of 3 hours following the first feeding was similar among treatments ($P > 0.05$). Overall, there

was no effect ($P > 0.05$) of grouping on eating behavior and performance of calves classified as high and low eaters with high eaters consistently performing better than low eaters.

INTRODUCTION

The young grazing ruminant naturally learns to ingest solid feed through allelomimetic behavior using its mother or peers as a model. The bond between the mother and the calf can influence the selection of diets by her offspring. Naturally, ruminants start to graze early in life but they will eagerly learn as they get older and are required to rely on solid feed after weaning (Provenza and Balph, 1987).

Dairy calves in the U.S. are mostly housed individually in hutches until weaning (63%) (USDA, 2016). In modern rearing systems, calves are offered starter grain early in life along with milk replacer (MR) as a replacement of cow's milk. Milk replacers with different content of protein and fat are available, and are used at different dry powder mixing ratios. Pasteurized hospital waste milk added with powder milk replacer for a set level of solids concentration is used in some instances to minimize the investment cost of raising heifers. Individually housed calves can equal social skills with group reared calves if they had visual contact with their peers (Le Neindre, 1993).

Weaning age varies from 4 to 13 weeks or more depending on the rearing system utilized. The weaning age average in the U.S. is 8.2 weeks (USDA, 2010). Weaned calves are then randomly grouped based on age and if they are consuming at least .9 kg of starter for 3 consecutive days (USDA, 2010). With feed and water accessible, the newly grouped calf has to learn to find food in a new and more spacious environment while comingled with more calves.

When a cow eats, another one might be stimulated to follow that behavior, regardless of hungriness (Albright, 1993). This social facilitation might play a role in modulating intake in grouped calves (Provenza and Balph, 1987). In experiments where calves are reared in pairs, grouped calves played, competed and learned to eat at an earlier age than individually housed calves (Warnick et al., 1976).

A limited number of studies have looked at the effects of birth weight, feed intake, average daily gain before weaning on the calves' feeding behavior, health, and performance when they are grouped post-weaning. We hypothesized that calves with lower drive to eat would be encouraged to eat more when they were grouped with calves with a high drive to eat.

The aim of this study is to analyze the eating behavior, feed consumption and weight gain of female Holstein-Frisian calves grouped in pens in several treatments according to their pre-grouping starter intake, and to analyze whether grouping calves post-weaning based on their feed intake pre-weaning had an effect on their performance, group intake, and eating behavior in weaning pens.

MATERIALS AND METHODS

Animals and Treatments

A total of 755 female Holstein calves (birth BW = 37.58 ± 2.35, SD 5.54 kg) were enrolled in a preliminary phase of the study. The calves were born at a commercial dairy calving facility and were immediately removed from the dam for disease prevention, weighed, navel dipped in 7% iodine solution, and fed 4 L of fresh pooled pasteurized colostrum in the first 30 minutes of life followed by 2 more L 8 hours later. The calves were raised in hutches at a calf raising facility in Southern Idaho and were enrolled for this study at 36 - 42 d of age

(BW = 54.73 ± 2.45 kg) in four different week periods. The calves were enrolled for the study starting on Mondays as follows, week 1 (n = 183), week 2, (n = 182), week 3 (n = 220), and week 4 (n = 170). The calves were housed individually from d 1 to 60 ± 3 in straw bedded solid wood hutches (.9 x 1.8 m A = 1.62 m^2) aligned in rows from east to west, with a wood roof, a closed back and an open front facing to the south and dividers providing limited visual contact from calves next to them. Straw bedding was re-applied to the hutches every other day. Upon arrival to the calf ranch, the calves were tested for BVD using tissue samples (ear notches). Blood samples were taken from the calves (jugular; vacuum tubes, no additives) every morning (0830 H) and evaluated for total serum protein determination at a local lab.

Twice daily (0630 and 1330 H), the calves were bottle fed twice a d a mix of pasteurized hospital milk and milk replacer (22% CP, 20% Fat) for a total of 480 grams of solids per day from d 2 to 45 ± 3 d. Following the twice-a-day feedings, calves were fed once a day (240 grams of solids) for seven more days for a complete weaning at d 52 ± 3. All milk bottles were washed and nipples sanitized after every use. All the weaned calves remained in hutches after weaning for nine more days. The calves had *ad libitum* access to fresh starter grain (16% CP, and a TDN content of 79.8%) and fresh water in clean galvanized pails each day. The complete nutrient content of the starter grain is presented in Table 2.1. The leftover grain was removed daily without weighing for the first 5 weeks of life. Only calves with a healthy status were enrolled in the study, and were identified with a plastic ID chain link inserted on the left plastic ear tag. The hutches were highlighted with water paint marks in a different color by period (orange, green, blue and yellow respectively), to aid with the identification, feeding program, and follow up of the calves. Commencing at d 39 ± 3, individual intake of starter grain was measured four days per week by offering the calves with

1.3 – 2.0 kg of starter grain in the morning (Monday, Tuesday, Wednesday, and Thursday) and with additional grain in the afternoon, if needed, during the pre-weaning, weaning, and post-weaning weeks. The leftover grain from each calf was weighed the next day, and the grain intake was calculated for weeks 6, 7, and 8 of life. A new plastic garden wagon was used to move the starter grain, and a wood frame attached to the cart was used to hang the electronic scale where the feed was weighed with a digital scale (Pelouze, mod. 7750; Rubbermaid, Inc.; Hunterville, NC 28078).

Experimental Design. Out of the 755 initial calves that were fed and their intake calculated, 480 heifers (60 ± 3 d of age) were assigned to 1 of 6 treatments, representing four repetitions of the study. At the end of the selection period of each replicate, a control group was randomly chosen then a mixed-effects model with time (week 6, 7, and 8) as a mixed effect and calf as the random effect was used to correct the intake data before the calves were categorized as low, medium, and high quartile eaters according to their feed intake quartile (Figure 2.15.) One hundred heifers in each period were then selected and randomly assigned into the other five treatments in the study. The six treatments were Control (CTRL; n = 20), High-High (HH; n = 20H), Low-Low (LL; n = 20L), High-Low (HL; n = 10H, 10L), High-High-Low (HHL; n = 15H, 5L),) and High-Low-Low (HLL; n = 5H, 15L). Calves remained in the experimental pen until 89 ± 3 d of age and were individually weighed at 89 ± 3 d of age. Calves assigned to the treatments were moved into partially covered group pens at 61 ± 3 d of age.

Measurements and Sample Collection. The calves were individually weighed at d 60 ± 3 d and at d 89 ± 3 d with an electronic scale (Salter Brecknell Mod. PS 1000; Illinois Tool Works; Fairmount, MN) contained in a hutch built out of welded mesh panels and other galvanized materials, and equipped with rotating tires for easier displacement. All health events and treatments were recorded from d 1 throughout the end of the study.

Grouped calves had simultaneous access to free choice total mixed ration (TMR) consisting of 95% starter grain and 5% alfalfa hay in a concrete feeding line added stardard tubular oblique feeder panels with .27 m of linear feeding space per calf, and to water in a single hole trough (Ritchie Industries, mod. Thrifty King CT2-2000) with a height of 0.48 m. Twice per week, the alfalfa/grain mix was prepared in large batches in a mixing wagon (Peecon, 8,300 kg capacity) when fresh starter grain was delivered to the calf raising facility. The feed was then transferred to 213 L plastic containers, weighed on an electronic scale with 500 kg capacity and 0.2 kg increments (Salter Brecknell Mod. PS 1000; Illinois Tool Works; Fairmount, MN), and offered in the morning to each of the treatment groups. The previous d's leftover grain was collected and weighed, and the information was recorded for future analysis.

Two calves died during the study due to pneumonia. One was a L calf from the HL treatment that died at 78 d of age during the 2nd period. The other, was a L calf from the LL treatment that died at 81 d of age in the 4th period.

Behavior Data Collection. The eating behavior of the treatment groups in each period was digitally video recorded (Q-See, Mod. QSDF8204) with a camera located in each pen (6 or 8 m away from the feed manger and 4 m high). The recordings were captured 2 days a week during a 4-week period resulting in 8 d of recordings per treatment.

The video recordings collected on the hard drive of the DVR were transferred to external hard drives in .afi format files and viewed on computers with the aid of a decoder downloaded from the internet. The entire 192 days (24 h periods) of video recordings of the calves' behavior were viewed, and the number of calves eating each minute were noted. Calves were counted as eating after 5 seconds of exhibiting the activity.

Any interruptions of the recordings due to management at the calf ranch was noted, and were taken into account. High eating heifers in the H and L mixed treatments (HL, HHL and HLL), were distinguished by wearing a collar, made out of two plastic red leg bands, wrapped around the neck and covered with retroreflective conspicuity tape to facilitate the differentiation of the calves eating at the feedbunk on the recordings when dark, and using the infrared properties of the cameras in the surveillance system. To ensure the heifers remained grouped correctly, every day each group was inventoried. While inventorying the groups, any collar or reflective tape that was missing was replaced after all management practices were finished at the calf ranch in the afternoon.

The number of calves observed eating were summarized in eight 3-hour segments starting around 9 am when the calves were first fed in the morning. The three-hour segments in a 24 h format were between 9-12, 12-15, 15-18, 18-21, 21-24, 24-3, 3-6 and 6-9 h. The calves eating in the first 15 minutes in each treatment group were not considered in the first 3-hour period (9-12) since not all the treatments were fed at the exact same time.

A behavioral assessment for health was performed each d. Animals exhibiting behavioral signs such as appearing depressed, apathetic and/or off feed were further checked to determine a diagnosis and potential treatment by the calf ranch staff. All diagnoses and treatments were recorded.

Calculations and Statistical Analyses

The statistical analysis for this research was conducted with SAS (version 9.4, SAS Institute, Cary, NC). A mixed–effects model with period (or replicate) as a random effect and treatment, time, and their 2-way interaction as fixed effects was used to analyze performance, intake data, and feeding behavior of the treatment groups, and the performance and intake of the individually fed calves. Time was included in the model as a repeated measure, and pen was the experimental unit. The results are presented as least squares means (±SEM) and their correspondent *P*-value. The same model was used to determine whether H or L calves did better or worse depending on the treatment they were assigned. Calf was the experimental unit in this case.

RESULTS AND DISCUSSION

Performance

Individual Starter Intake. The data for individual starter intake (DMI; kg/d) is presented in Table 2.2. (see also Figure 2.2.) Starter intake of dairy calves in the pre-selection phase (week 6, 7, and 8) was significantly different ($P < 0.0001$) between low, medium, and high groups with low eaters consuming 0.81 ± 0.01 kg/d, medium eaters consuming 1.15 ± 0.01 kg/d, and high eaters consuming 1.54 ± 0.01 kg/d of the starter grain. Feed consumption was significantly different ($P = 0.04$), but biologically irrelevant between control and medium calves with control calves consuming 1.19 ± 0.02 kg/d starter grain per d. Our results are similar to those reported by Bach et al. (2010) and Castells et al. (2012) but higher than reports of starter grain intake from birth to weaning by Dennis et al. (2018) and Pempek et al. (2017). These differences are likely due to the fact that our results were generated in the last 3 weeks the calves were in hutches and when their starter grain intake tended to increase due to weaning. The 0.73 kg/d difference in starter grain intake between high and low eaters highlights the innate difference encountered in starter grain intake of individual calves that are of similar ages. Jensen and Larsen (2014) reported lower starter grain intake for week 5 of age (.601 ± .03 for 35 d of age).

Group Feed Intake. This is the first study that measures individual starter grain intake in the last three weeks in hutches in order to group calves post-weaning according to their quartile level of feed intake. The group dry matter intake (DMI) of calves (60 ± 3 to 89 ± 3 d of age) in the CTRL and HL groups where similar ($P < 0.05$; Table 2.2.) which was expected between those two groups. The HHL group similar to the HH group but similar also to the HL and the CTRL group. Also, the groups HLL and the LL groups were similar ($P > 0.05$). Only groups HLL, HH and LL were significantly different ($P < 0.05$) among them and not similar to any other treatment. The least square means of the group feed intake for treatments HHL, HLL, HL, CTRL, HH, and LL can be found in Figures 2.3., 2.4, 2.5, 2.6, 2.7, and 2.8 respectively Sorting of the alfalfa hay component of the ration was not seen in our study (Miller-Cushon, et al. 2013).

Body Weight Before Treatments. The average weight of the calves in our study was 37.58 kg at birth before the colostrum feeding (Table 2.4. and Figure 2.12.) This average was lower than previous results reported by Khan et al. (2007a, b); Soberon et al. (2012) and Arave et al. (1985) who reported average birth weight of 42.13, 41.68, and 40 kg respectively. Bar-Peled et al. (1997) reported similar birth weight compared with our study. The average weight of the calves at 39 ± 3 d of age was 54.73 kg and 69.02 kg at 60 ± 3 d of age and 86.87 kg at 89 ± 3 d of age (Figure 2.14.) Body weight at 39 ± 3 and 60 ± 3 d old is lower when compared to weights reported at 1 and 2 months of age (Terré et al., 2006).

The weight of the high vs. low eating calves as expected, increased with time in each of the age groups. The birth BW was 39.85 for the H and 35.61 kg for the L calves, the calves' BW at 39 ± 3 d of age was 59.22 for the H and 51.03 kg for the L calves. Also, the weight of the calves at 60 ± 3 d of age was 76.47 for the H and 61.98 kg for the L calves. The weight of the calves at 89 ± 3 d of age BW was 96.63 vs. 77.36 kg.

Body Weight After Treatments. The body weight at 89 ± 3 d of age (BW89) was significantly different ($P < 0.0001$) within treatments (Table 2.2.). Calves in the HH treatment had the highest BW89 with 96.33 ± 1.34 kg followed by the HHL treatment with 91.47 ± 1.35 kg. The high-low (HL) and control (CTRL) treatment BW89 were 86.97 ± 1.36 kg and 85.79 ± 1.36 kg, respectively. The HLL treatment was 83.52 ± 1.34 kg and the LL treatment was 77.06 ± 1.35 kg. The BW89 reported in the study is lower than results reported by De Passillé et al. (2011), Bjorklund et al. (2013), and Kienitz et al. (2017).

The differences of BW89 between the HH treatment with other treatments were significantly different ($P < 0.05$): HH and LL (19.26 ± 1.91 kg; $P < 0.0001$), CTRL and HH (-9.35 ± 1.91 kg; $P < 0.0001$), HLL and HH (-12.80 ± 1.90 kg; $P = 0.0112$), HL and HH (-9.36 ± 1.91 kg; $P < 0.0001$), HHL and HH (-4.86 ± 1.91; $P = 0.0112$).

Also, the differences of BW89 between the LL treatment with other treatments were significantly different ($P < 0.05$): HHL and LL (14.41 ± 1.91 kg; $P < 0.0001$), HL and LL (9.91 ± 1.92 kg; $P < 0.0001$), CTRL and LL (9.91 ± 1.92; $P < 0.0001$), HHL and LL (6.46 ± 1.90, $P = 0.0008$). Likewise, the treatments with mixed type of calves were significantly different ($P < 0.05$) between HHL and HLL (7.49 ± 1.91; $P < 0.0001$), HL and HHL (-4.50 ± 1.91; $P = 0.0194$), and HHL and LL (5.68 ± 1.92, $P = 0.0032$), but not different between HL and CTRL (1.18 ± 1.92; $P = 0.5402$), and HLL and CTRL (-2.26 ± 1.91; $P = 0.2368$), while treatments HL and HLL were potentially different (3.44 ± 1.91 kg; $P = 0.0723$).

Body Weight by Type Within Treatments. The type of calves, H or L, assigned to the mixed treatments (HL, HHL, and HLL) had significantly different body weights ($P < 0.05$). However, no significant difference was found in body weight between high eaters in the treatments regardless of the percentage of low eaters they were grouped with ($P = 0.7$) which indicates that grouping calves based on their pre-weaned intake has no effect on their body weight (Table 2.3.) As expected the H calves in treatments HL, HHL, and HLL were significantly heavier ($P < 0.0001$) than the L calves (96.75 ± 1.05 kg/d vs. 76.92 ± 1.08 kg/d) in the same treatments.

Average Daily Gain. The ADG of calves (60 ± 3 to 89 ± 3 d of age) was significantly different ($P = 0.0016$) within treatments at the end of the study (Table 2.2.) As expected, calves in the HH treatment had the highest ADG of 0.73 ± 0.03 kg/d followed by the HHL treatment with an 0.66 ± 0.03 kg/d. Calves in the HL treatment had an ADG of 0.58 ± 0.03 kg/d which was significantly higher than the ADG of CTRL group which was 0.55 ± 0.03 kg/d. Treatments HLL and LL had the lowest ADG of 0.57 ± 0.03 kg/d and 0.57 ± 0.03 kg/d, respectively (Figure 2.1.) These ADG's were lower than what Coverdale, et al. (2004) reported post-weaning in calves that were fed a coarse starter with or without the addition of different levels of bromegrass hay (7.5% vs. 15%). Coarse starters favor the rumen health and the development of rumen papillae and with thus starter grain intake in calves (Coverdale, et al. 2004). The ADG pre-treatment is presented in Table 2.5.

Average Daily Gain by Type Within Treatments. The type of calves, H or L, assigned to the mixed treatments (HL, HHL, and HLL) had significantly different ADG ($P < 0.0001$). However, no significant difference was found in ADG between high eaters in the treatments regardless of the percentage of low eaters they were grouped with ($P = 0.7$) which indicates that grouping calves based on their pre-weaned intake has no effect on their ADG (Table 3). Unsurprisingly, the high calves in treatments HL, HHL, and HLL were significantly higher ($P < 0.0010$) than the L calves (0.68 ± 0.03 vs. 0.51± 0.03) in the same treatments. The ADG reported in the study compare to results reported by Arrayet et al. (2002) and are also in accordance to Heinrichs and Losinger (1998).

Feed Efficiency. The feed efficiency (FE = ADG/DMI) was estimated using the ADG of individual animals and the feed intake least square mean from the study treatments. The calculated FE for each treatment group are as follows: HL 0.27, HHL 0.29, HLL 0.27, CRTL0.26, HH 0.32, and LL 0.30. These values for feed efficiency are similar to values reported by what Coverdale et al. (2004) and Castells et al. (2012) but were almost half of what Khan et al. (2011) and Bach et al. (2007) described. The higher FE in the HH and LL treatments in our study, was probably due to the hegemony in those groups.

Feeding Activity and Calves Behavior

Ingestive Behavior. Least square means of calves eating at the feedbunk for the treatments in the study are presented in Figure 2.11. There was no effect ($P > 0.05$) of grouping on eating behavior and performance of calves classified as high and low eaters with high eaters consistently performing better than low eaters. The results are given as calves eating at the feedbunk in every three-hour period per pen vs. minutes per head as in the study by Keys et al. (1978). Displacements at the level of the feedbunk were not observed, probably because the calves were in pens with tubular oblique feeder panels, were fed a TMR, have feed available in 1.0 to 1.2 slots per calf per day, had 0.27 m wide slot per calf, and also because the calves were fed to have 10% of leftovers. Displacements are seeing when the animals per feeding slot increase from 1 to 4 (Huzzey et al. 2012). The homogeneity in age of the treatment groups and the number of calves per feeding space might also explain the lack of displacements. (Huzzey et al., 2006; Færevik et al., 2010).

Playing Behavior. Running, chasing, and mock fighting at the age of the calves in the study can be understood as play behavior. Play behavior in calves is associated with welfare, as social and nutrition needs are met (Jensen and Kyhn, 2000; Duve et al., 2012). Calves were regularly seen playing between 3 and 5 pm before the sunset feeding activity in all the treatments, although not in all 20 calves in the pen participated in the activity. Sudden jumps were observed as a demonstration of calves getting excited at the beginning of the play session. Straw play was observed at every straw change in our study, and when new straw was added every other day. Rushing and pushing the head hard against another calf was observed once, although none of the two calves involved in the incident, were performing the eating activity.

Other activity commonly seen in calves is self-grooming or grooming other calves but because of the amount of calves in the treatment groups, and the distance of the cameras from the calves we were unable to get an accurate count of these observations. Sexual behavior such as mounting other calves was not observed during this study possibly due the calves being pre-pubertal.

CONCLUSION

In this study grouping calves according to their individual feed intake during the last three weeks in hutches did not have any effect on the time spent at the feedbunk through the first four weeks in group pens.

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Table 1.1. Effect of time of grouping with respect to weaning at 56 d of age on body weight (BW) and average daily gain (ADG) of female Holstein calves (Bach et al., 2010).

Item	Grouped 6 d after weaning	Grouped at weaning	SE	P-value[1]
Initial BW, kg	41.8	42.4	0.52	0.51
Initial age, d	12.3	11.6	0.38	0.16
BW before grouping, kg	78.9	76.1	0.66	<.0001
Age before grouping, d	61.9	56.1	0.17	<.0001
ADG before grouping g/d	749	758	12.0	0.49
Final BW, kg	114.5	113.7	1.04	0.76
Final age, d	103.9	98.2	0.29	<.0001
ADG after grouping, g/d	847	894	19.9	0.09
Overall ADG, g/d	794	826	11.2	0.05

[1]Effect of time of grouping

Table 1.2. Growth performance and intake of female Holstein calves at 70 d of age as affected by time of socialization (Bach et al., 2010).

				P-value	
Item	Grouped 49 d of age	Grouped at 56 d of age	SE	Treatment	Treatment x week
Initial BW, kg	43.1	42.4	0.45	0.51	-
Initial age, d	13.9	12.6	0.91	0.16	-
Final BW, kg	147.5	145.1	2.92	<0.0001	-
Final age, d	111.5	112.3	0.45	<0.0001	-
70 d old BW, kg	92.7	91.2	0.95	0.49	0.05
ADG, kg/d	1.07	1.03	0.016	0.76	0.0001
Pen CV of BW, %	11.1	10.4	0.89	<0.0001	0.16
Pen CV of ADG, %	23.8	17.2	6.07	0.09	0.38
Solid feed consumption, kg/d	2.61	2.49	0.056	0.05	0.03

BW = Body weight, ADG = Average daily gain, CV = Coefficient of variation

Table 1.3. Housing effect on performance of female Holstein calves housed individually (IP) or in groups (GP) (Terré, et al., 2006).

	Housing			P value[1]		
	IP	GP	SEM	H	T	H x T
Final body weight, kg/d	83.3	78.9	2.29	0.44	-	
Average daily gain, kg/d	0.69	0.67	0.085	0.84	<0.01	0.03
Dry matter intake of milk replacer, g/d	936.1	642.0	7.52	0.63	<0.001	0.41
Dry matter intake of starter, g/d	975.2	954	.0119	0.91	<0.01	1.00
Gain: feed ratio	0.63	0.60	0.024	0.91	<0.001	0.99

[1]H, effect of housing type; T, time; H x T, interaction between housing type and time of socialization

Table 2.1. Chemical composition of the calf starter on a dry matter (DM) basis.

Composition:	%
DM	85.6
CP	17.5
Total digestible nutrients	79.8
NDF	12.3
ADF	3.5
Ash.	3.5
Ca	0.19
P, %	0.41
TOTAL	99.7

[1]Units are percentage of DM unless otherwise noted

Table 2.2. Least square means (± SE) of female Holstein calves' ADG, BW, starter DMI, and FE from the high (H) and the low (L) quartile level of feed intake (39 to 60 d of age, ± 3 d) grouped in six different treatments post-weaning (60 to 89 d of age, ± 3 d).

	TREATMENTS						
	HL	HHL	HLL	CTRL	HH	LL	*P*-value
BW, kg/d	$86.97^{c} \pm 1.36$	$91.47^{b} \pm 1.35$	$83.53^{c} \pm 1.34$	$85.79^{c} \pm 1.36$	$96.33^{a} \pm 1.34$	$77.06^{d} \pm 1.35$	<.0001
ADG, kg/d	$0.58^{b} \pm 0.03$	$0.66^{a} \pm 0.03$	$0.57^{b} \pm 0.04$	$0.55^{b} \pm 0.03$	$0.73^{a} \pm 0.03$	$0.57^{b} \pm 0.03$	<.0001
DMI, kg/d	$2.14^{b} \pm 0.05$	$2.23^{ab} \pm 0.05$	$2.00^{c} \pm 0.05$	$2.12^{b} \pm 0.05$	$2.29^{a} \pm 0.05$	$1.88^{c} \pm 0.05$	<.0001
FE, (ADG/DMI)	0.27	0.29	0.27	0.26	0.32	0.30	

Abbreviations: BW = body weight; ADG = average daily gain; DMI = dry matter intake; FE = feed efficiency.
[a–b] Means within a row with different superscripts differ ($P < 0.05$).
Means were adjusted by analysis of covariance for BW, ADG, and DMI for least square means by treatment.
Feed efficiency is an estimate of the individual weight gain (ADG, kg/d) divided by the group feed intake (DMI, kg/d) by treatment from 60 to 89 d of age, ± 3 d.
Treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

Table 2.3. Least square means (± SE) of female Holstein calves' BW and ADG from the high (H) and the low (L) quartile level of feed intake (39 to 60 d of age, ± 3 d) when calves were grouped in mixed treatments (H and L) post-weaning (60 to 89 d of age, ± 3 d) by type within treatments.

	Treatments						
	HL ± SE		HHL ± SE		HLL ± SE		
	High	Low	High	Low	High	Low	*P*-value
BW, kg/d	$97.87^{a} \pm 1.66$	$75.50^{b} \pm 1.70$	$96.41^{a} \pm 1.37$	$75.89^{b} \pm 2.40$	$95.97^{a} \pm 2.34$	$79.38^{b} \pm 1.37$	0.0010
ADG, kg/d	$0.71^{a} \pm 0.04$	$0.46^{b} \pm 0.04$	$0.70^{a} \pm 0.03$	$0.54^{b} \pm 0.06$	$0.65^{a} \pm 0.07$	$0.54^{b} \pm 0.05$	<.0001

Abbreviations: BW = body weight; ADG = average daily gain.
[a–b] Means within a row with different superscripts differ ($P < 0.05$).
Means were adjusted by analysis of covariance for BW and ADG least square means by treatment.
Treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 5H + 15L.

Table 2.4. Means (± SE) of female Holstein calves' BW at birth, 39 and 60 d of age, ± 3 d from the high (H) and the low (L) quartile level of individual feed intake pre-weaning (39 to 60 d of age, ± 3 d) grouped post-weaning (60 to 89 d of age, ± 3 d) mixed in treatments, and by type within treatments (H or L).

	Treatments					
	HL		HHL		HLL	
Item	H	L	H	L	H	L
BW, kg						
Birth	41.10 ± 2.17	34.83 ± 2.57	39.05 ± 2.40	33.57 ± 2.24	41.75 ± 2.07	36.68 ± 2.34
39 d of age, ± 3 d	59.99 ± 2.26	50.41 ± 2.31	58.91 ± 2.30	48.73 ± 2.04	60.58 ± 2.43	52.58 ± 2.31
60 d of age, ± 3 d	77.53 ± 2.35	61.62 ± 2.65	76.14 ± 2.37	59.93 ± 2.53	77.03 ± 2.58	63.62 ± 2.71

Means are average of heifers in the treatments.
Treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; and LL = 20L.

Table 2.5. Means (± SE) of ADG of female Holstein calves from the high (H) and the low (L) quartile level of feed intake pre-weaning (39 to 60 d of age, ± 3 d) grouped post-weaning (60 to 89 d of age, ± 3 d) in mixed treatments, and by type within treatments (H or L).

	Treatments					
	HL		HHL		HLL	
Item	H	L	H	L	H	L
ADG, kg/d						
1 - 38 d of age	0.49 ± 0.33	0.41 ± 0.33	0.51 ± 0.35	0.39 ± 0.27	0.48 ± 0.26	0.42 ± 0.30
39 - 60 d of age	0.61 ± 0.28	0.45 ± 0.34	0.61 ± 0.30	0.44 ± 0.32	0.58 ± 0.24	0.45 ± 0.30

Means are average of heifers in the treatments.

Treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; and LL = 20L.

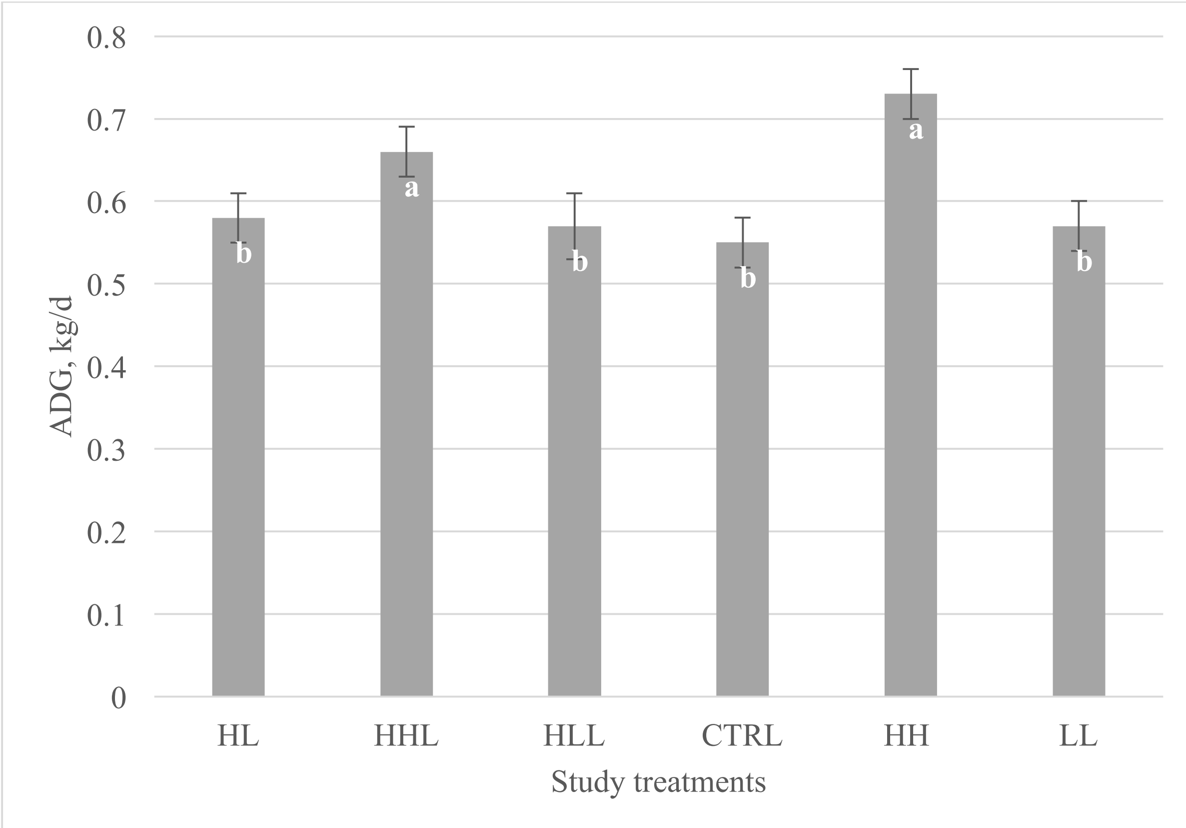

Figure 2.1. Least square means (± SE) of female Holstein calves' ADG from the high (H) and the low (L) quartile level of individual feed intake pre-weaning (39 to 60 d of age, ± 3 d) grouped in six different treatments post-weaning (60 to 89 d of age, ± 3 d).
($P < 0.05$)
Vertical bars represent the standard error of the mean.
Columns that do not share a common letter differ ($P < 0.05$).
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

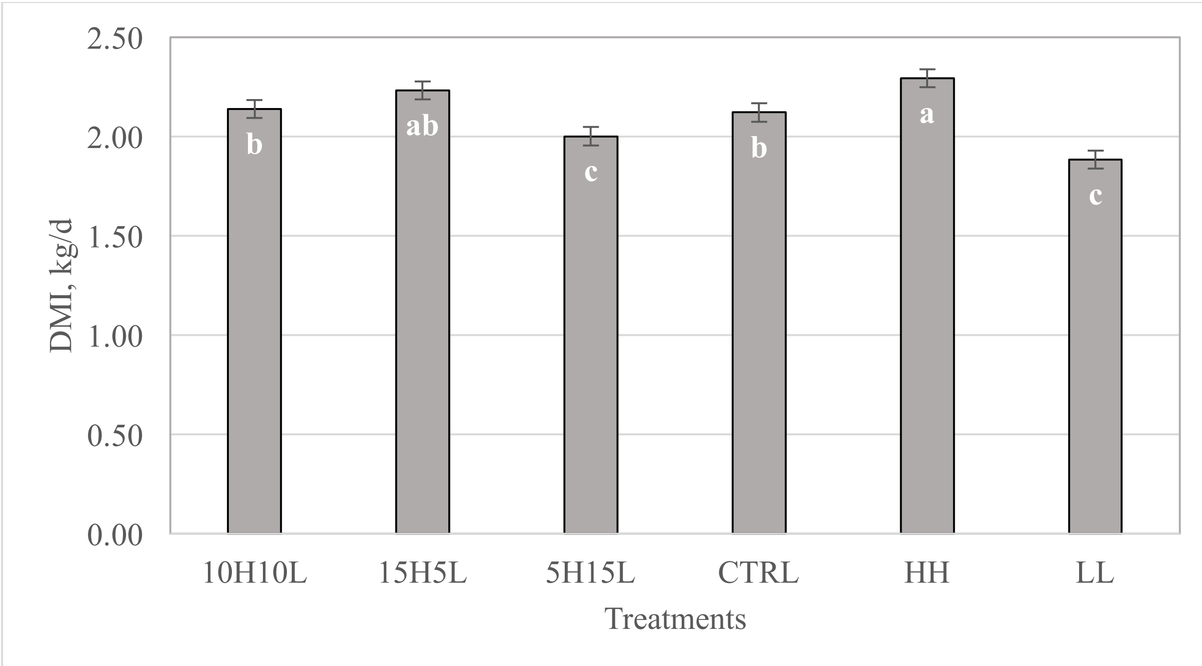

Figure 2.2. Least square means (± SE) of female Holstein calves' DMI from the high (H) and the low (L) quartile level of individual feed intake pre-weaning (39 to 60 d of age, ± 3 d) grouped in six different treatments post-weaning (60 to 89 d of age, ± 3 d).
($P < 0.05$)
Vertical bars represent the standard error of the mean.
Columns that do not share a common letter differ.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

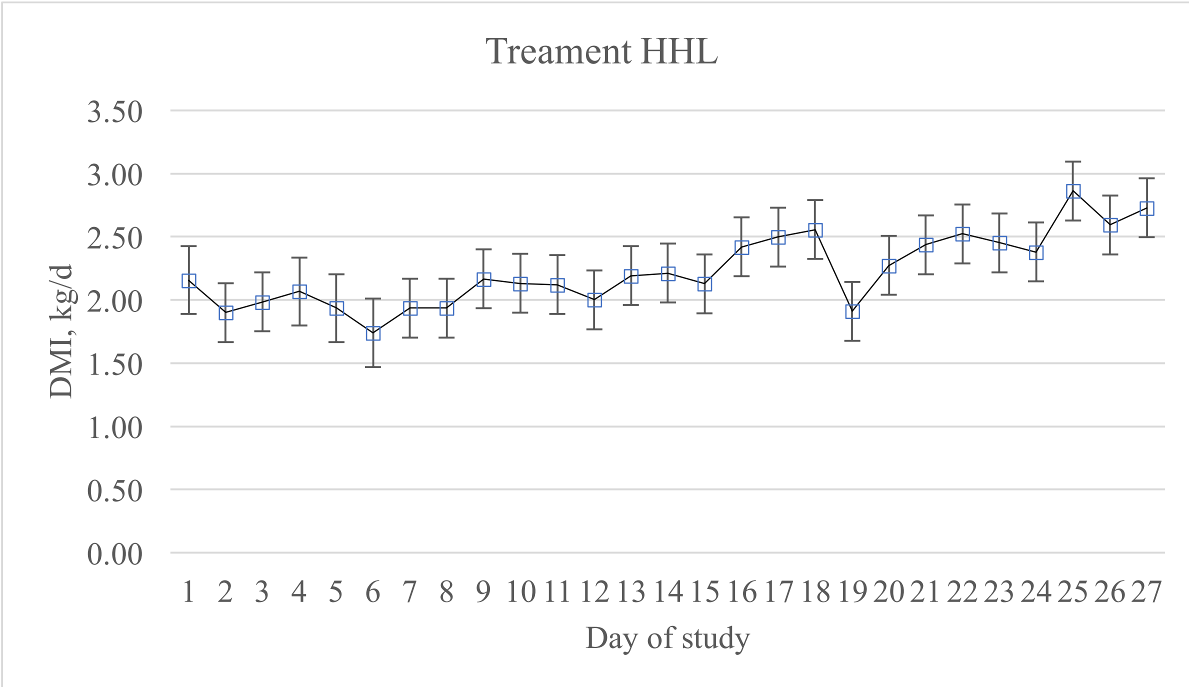

Figure 2.3. Least square means (± SE) of the female Holstein calves' daily group feed intake from the high (H) and the low (L) quartile level of individual feed intake (39 to 60 d of age, ± 3 d) grouped in treatment HHL post-weaning (60 to 89 d of age, ± 3 d).
($P > 0.05$)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

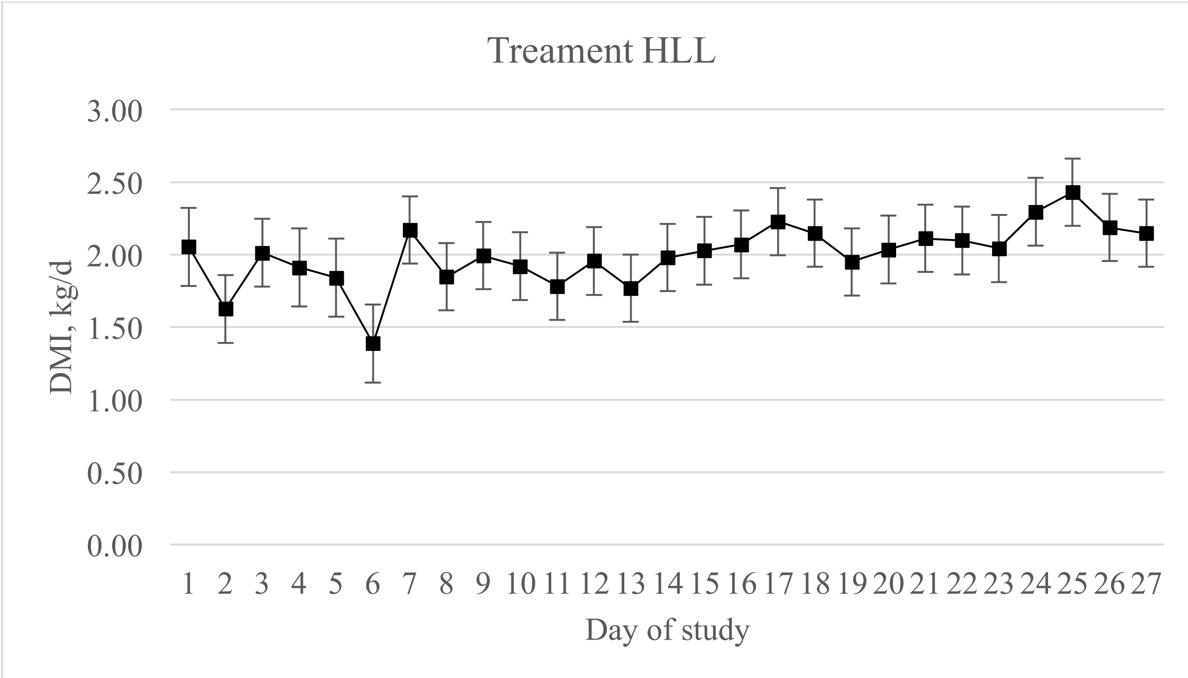

Figure 2.4. Least square means (± SE) of the female Holstein calves' daily group feed intake from the high (H) and the low (L) quartile level of individual feed intake (39 to 60 d of age, ± 3 d) grouped in treatment HLL post-weaning (60 to 89 d of age, ± 3 d).
($P > 0.05$)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

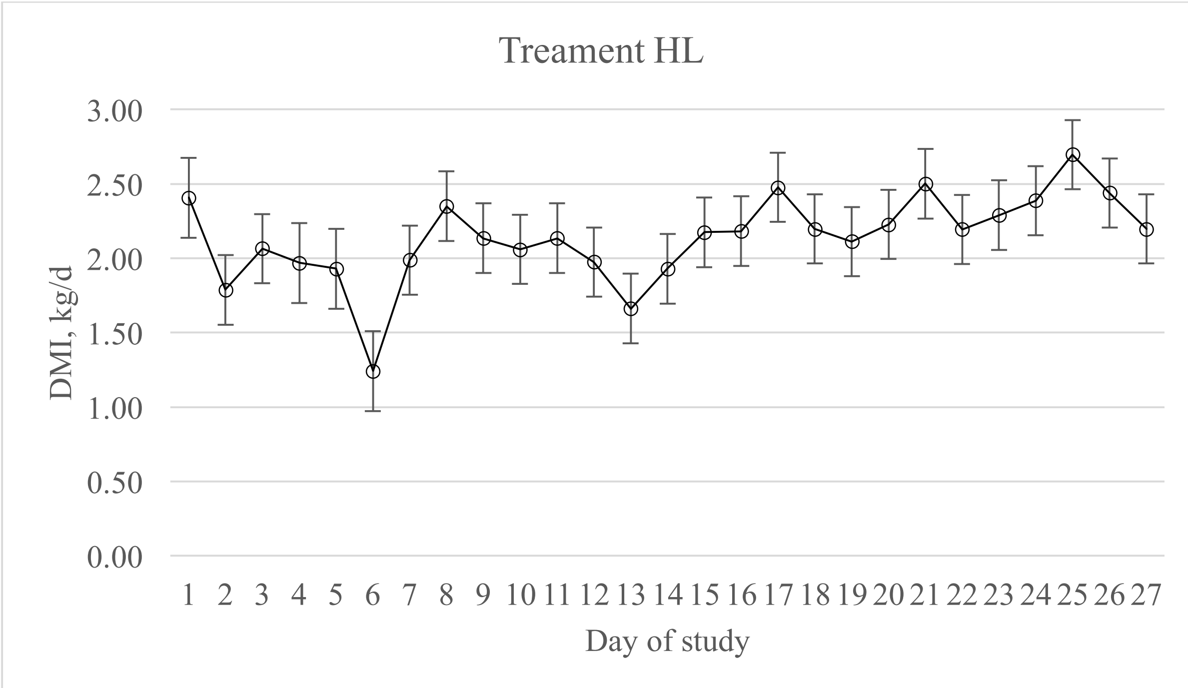

Figure 2.5. Least square means (± SE) of the female Holstein calves' daily group feed intake from the high (H) and the low (L) quartile level of individual feed intake (39 to 60 d of age, ± 3 d)) grouped in treatment HL post-weaning (60 to 89 d of age, ± 3 d).
($P > 0.05$)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

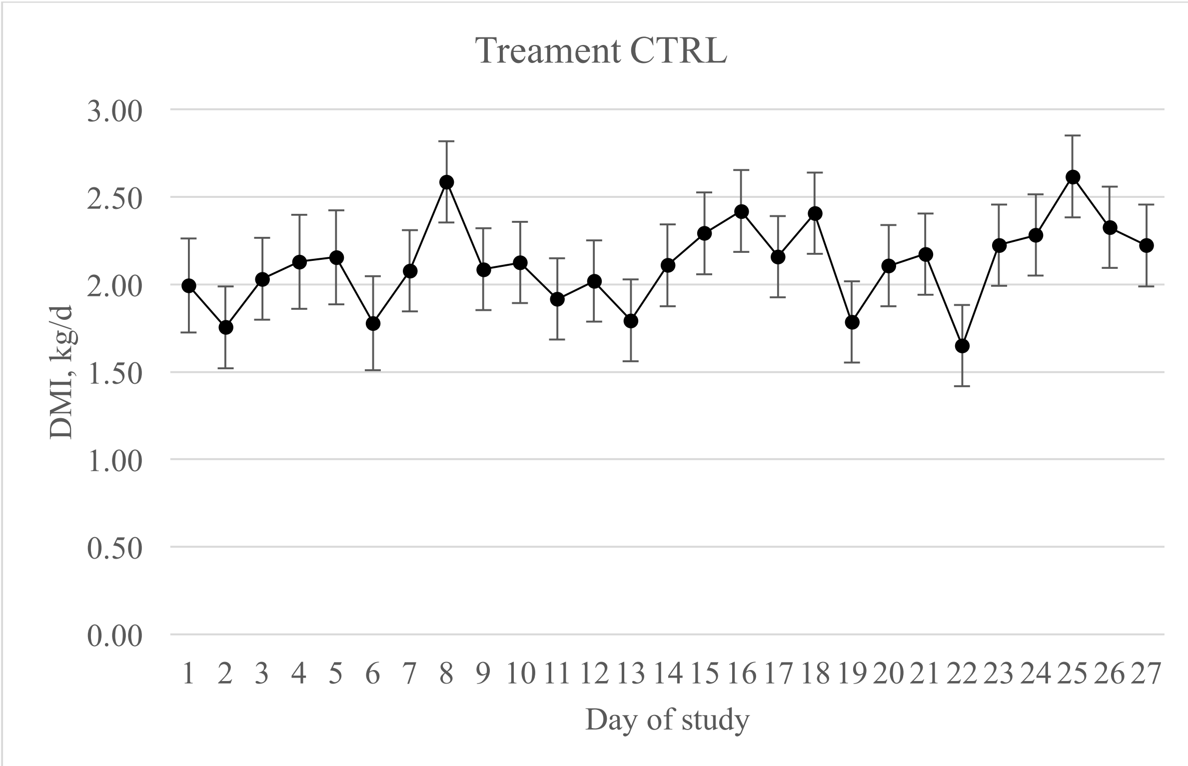

Figure 2.6. Least square means (± SE) of the female Holstein calves' daily group feed intake before considering the quartile level of individual feed intake (39 to 60 d of age, ± 3 d) and grouped in treatment CTRL post-weaning (60 to 89 d of age, ± 3 d).
(*P* > 0.05)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.
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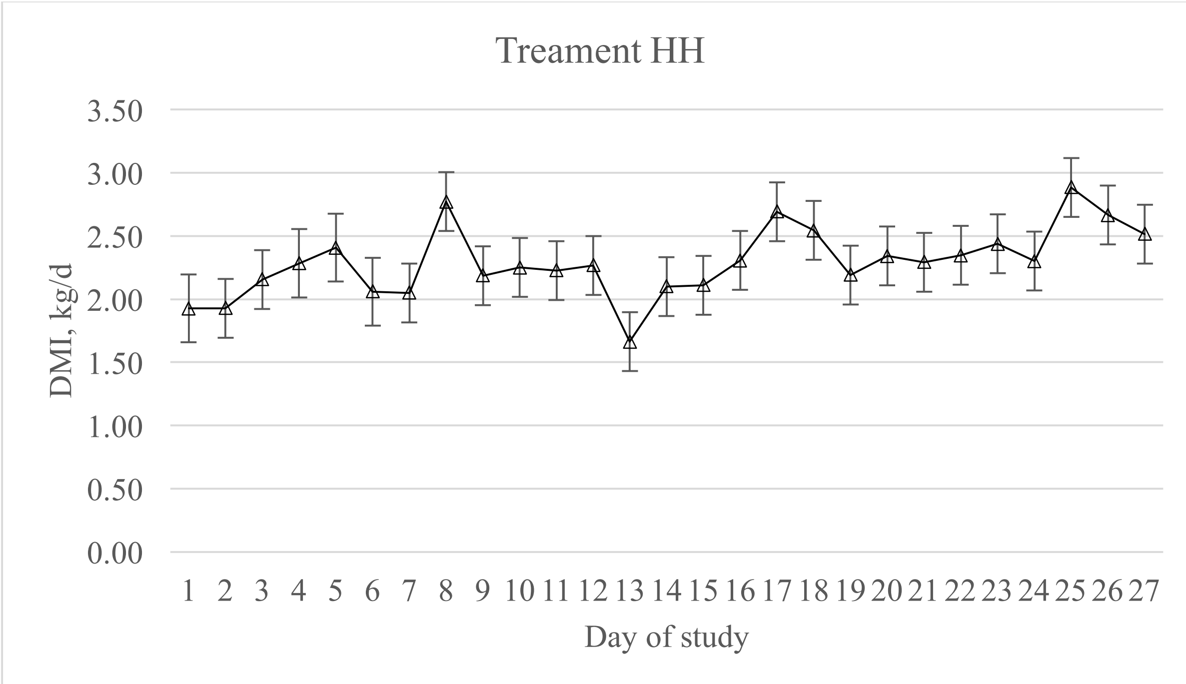


Figure 2.7. Least square means (± SE) of the female Holstein calves' daily group feed intake from the high (H) quartile level of individual feed intake (39 to 60 d of age, ± 3 d) grouped in treatment HH post-weaning (60 to 89 d of age, ± 3 d).
($P > 0.05$)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

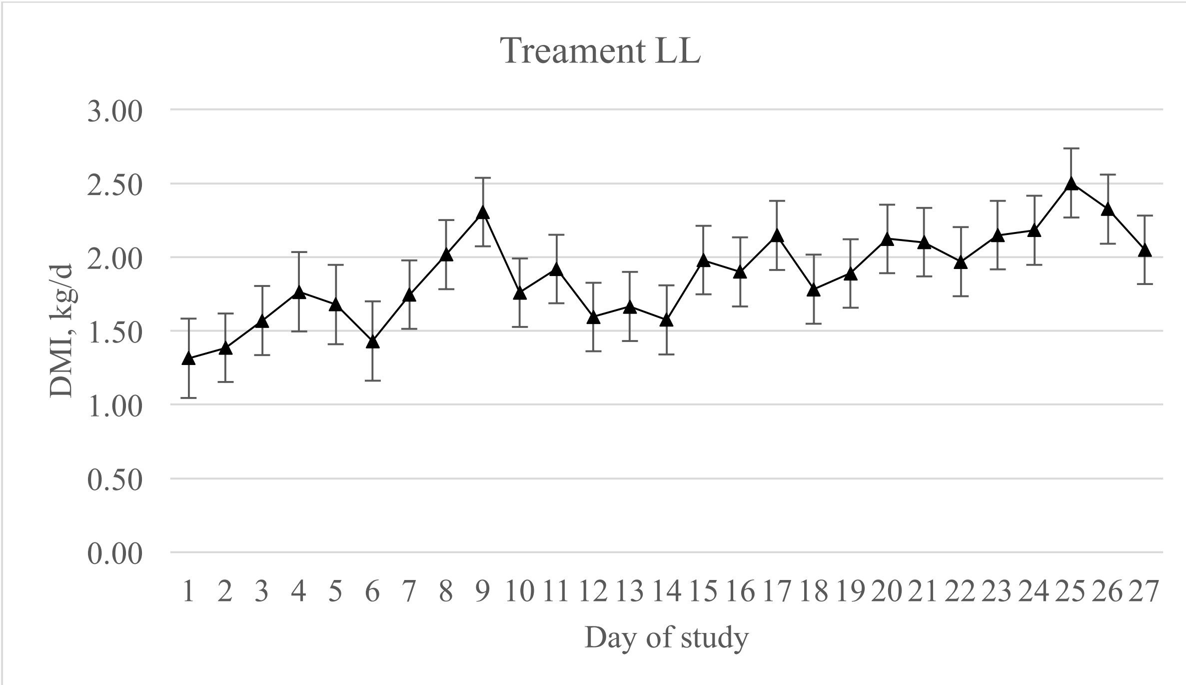


Figure 2.8. Least square means (± SE) of the female Holstein calves' daily group feed intake from the low (L) quartile level of individual feed intake (39 to 60 d of age, ± 3 d) grouped in treatment LL post-weaning (60 to 89 d of age, ± 3 d).
($P > 0.05$)
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

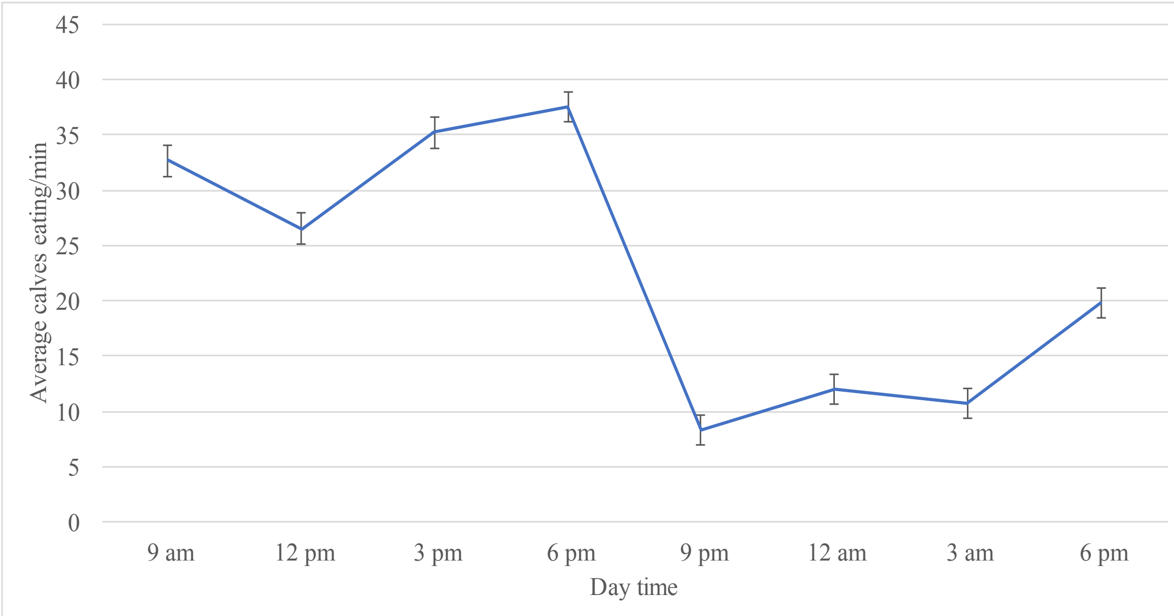


Figure 2.9. Least square means (± SE) of all female Holstein calves eating at the feedbunk arranged in treatments from 60 to 89 d of age, ± 3 d.
(*P* > 0.05)
Means were adjusted by the Mixed procedure of SAS for calves observed eating within 3 hour periods in the 192 d of recordings for all treatments that were fully watched.
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

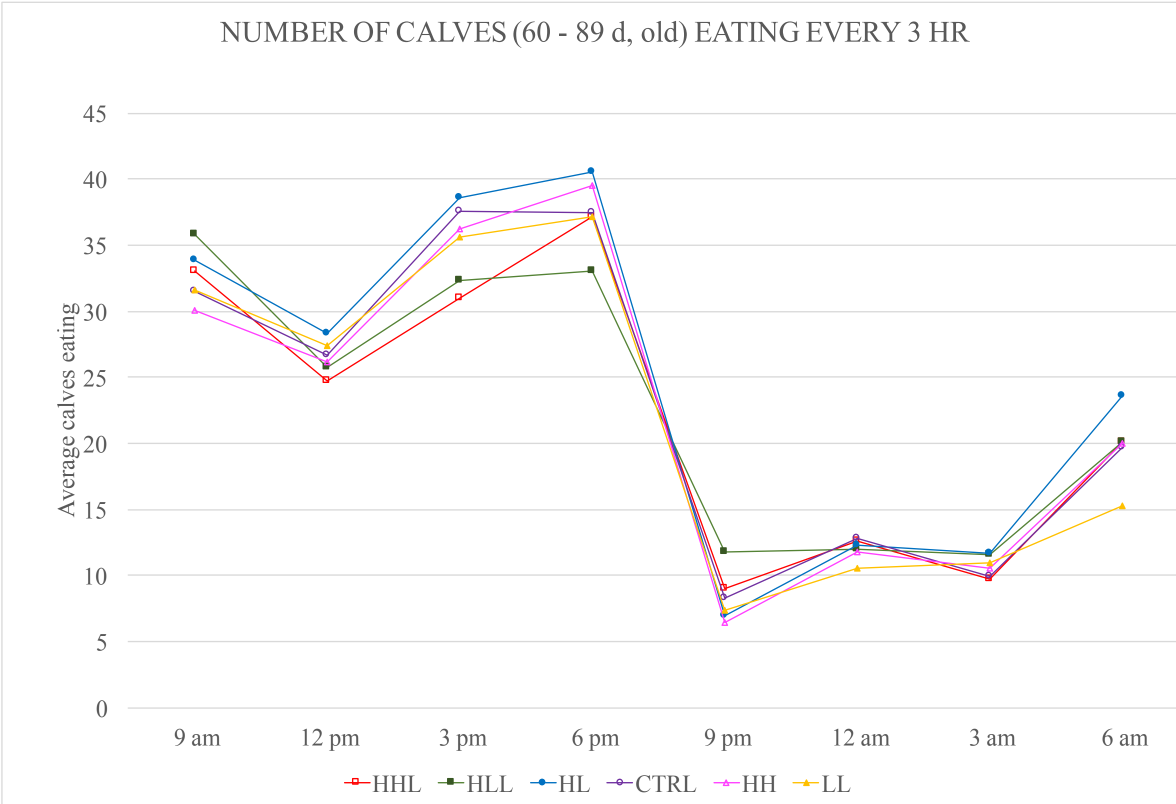


Figure 2.10. Least square means (± SE) of all female Holstein calves eating at the feedbunk arranged in treatments from 60 to 89 d of age, ± 3 d.
($P > 0.05$)
Means were adjusted by the Mixed procedure of SAS for calves observed eating within 3 hour periods in the 32 d of recordings per treatment that were fully watched.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

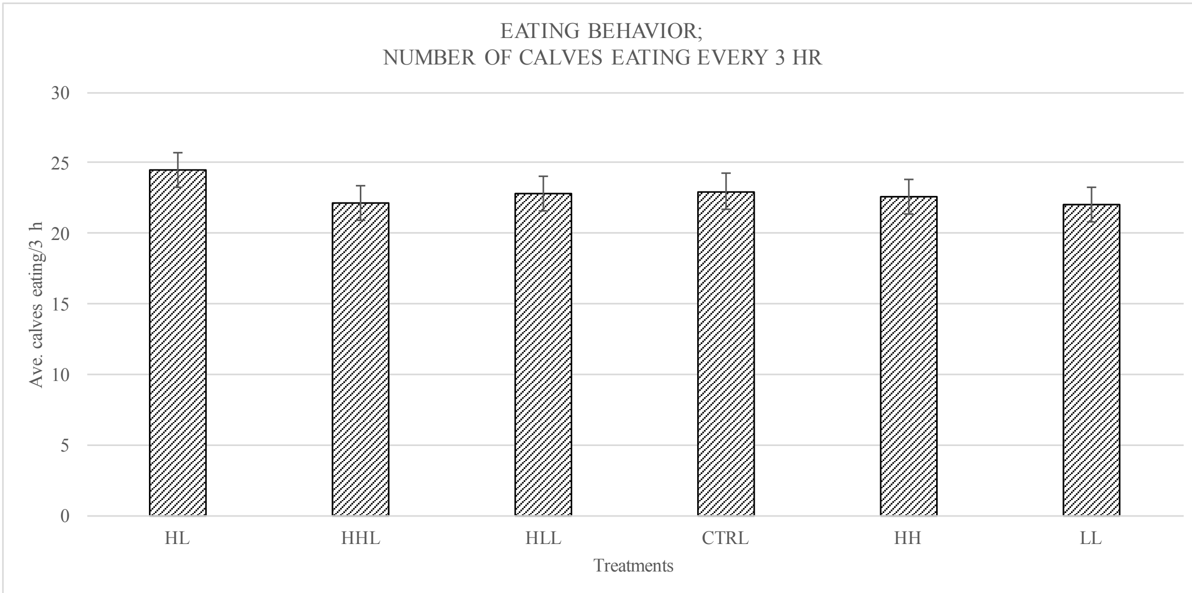


Figure 2.11. Least square means of female Holstein calves eating at the feedbunk arranged in treatments from 60 to 89 d of age, ± 3 d.
(*P* > 0.05)
Means were adjusted by the Mixed procedure of SAS for calves observed eating within 3 hour periods in the 32 d of recordings per treatment that were fully watched.
Vertical bars represent the standard error of the mean.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L.

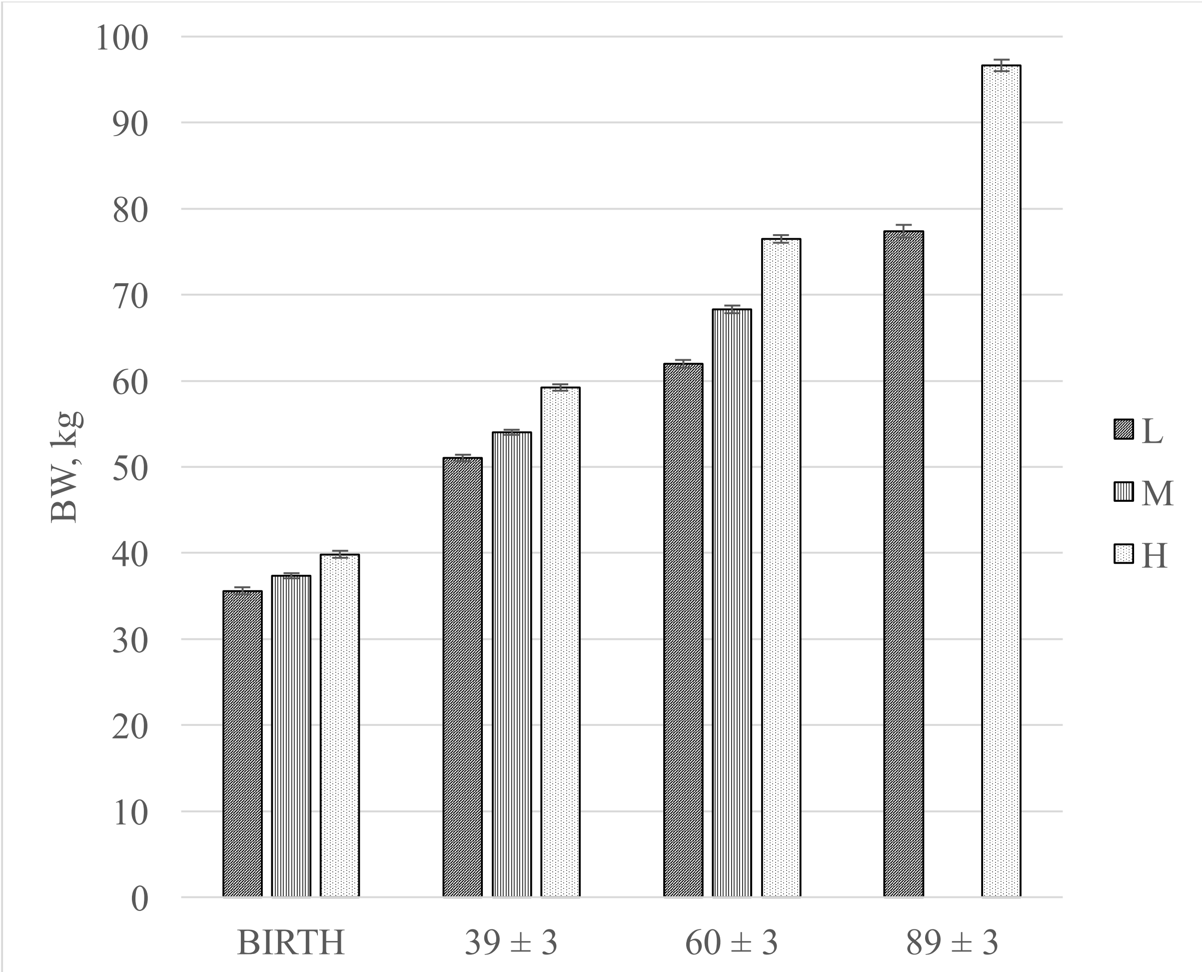


Figure 2.12. Means (± SE) of female Holstein calves' BW by age (birth, 39 ± 3 d, 60 ± 3 d, to 89 ± 3 d of age) from the high (H), the medium (M), and the low (L) quartile level of individual feed intake (39 to 60 d of age, ± 3 d).
Vertical bars represent the standard error of the mean.

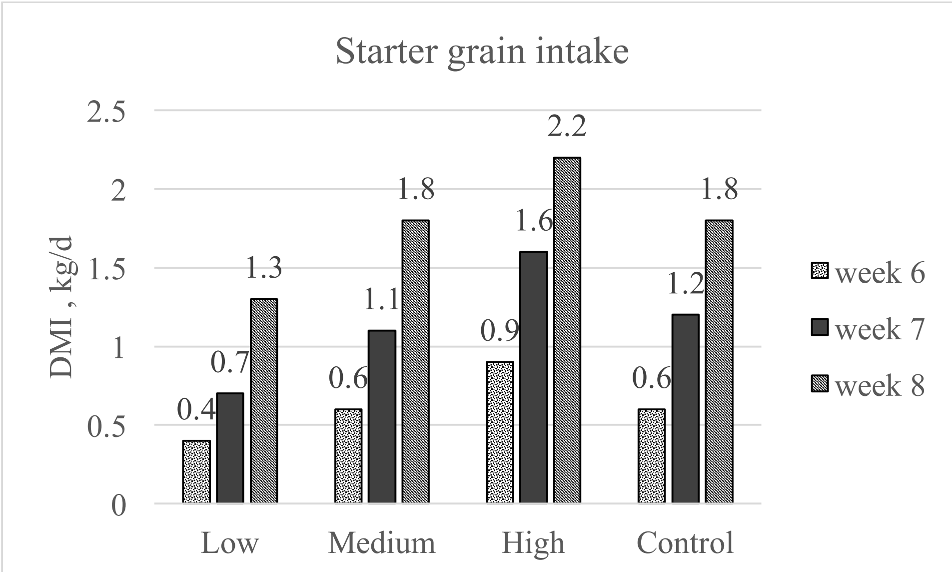


Figure 2.13. Means of female Holstein calves' starter grain DMI, kg/d (39 to 60 d of age, ± 3 d) 1 week before weaning (week 6), the weaning week (week 7), and one week after weaning (week 8). The starter grain intake was calculated 4 d each week. Results are presented by quartile level of feed intake (low, medium, and high) and the control calves.

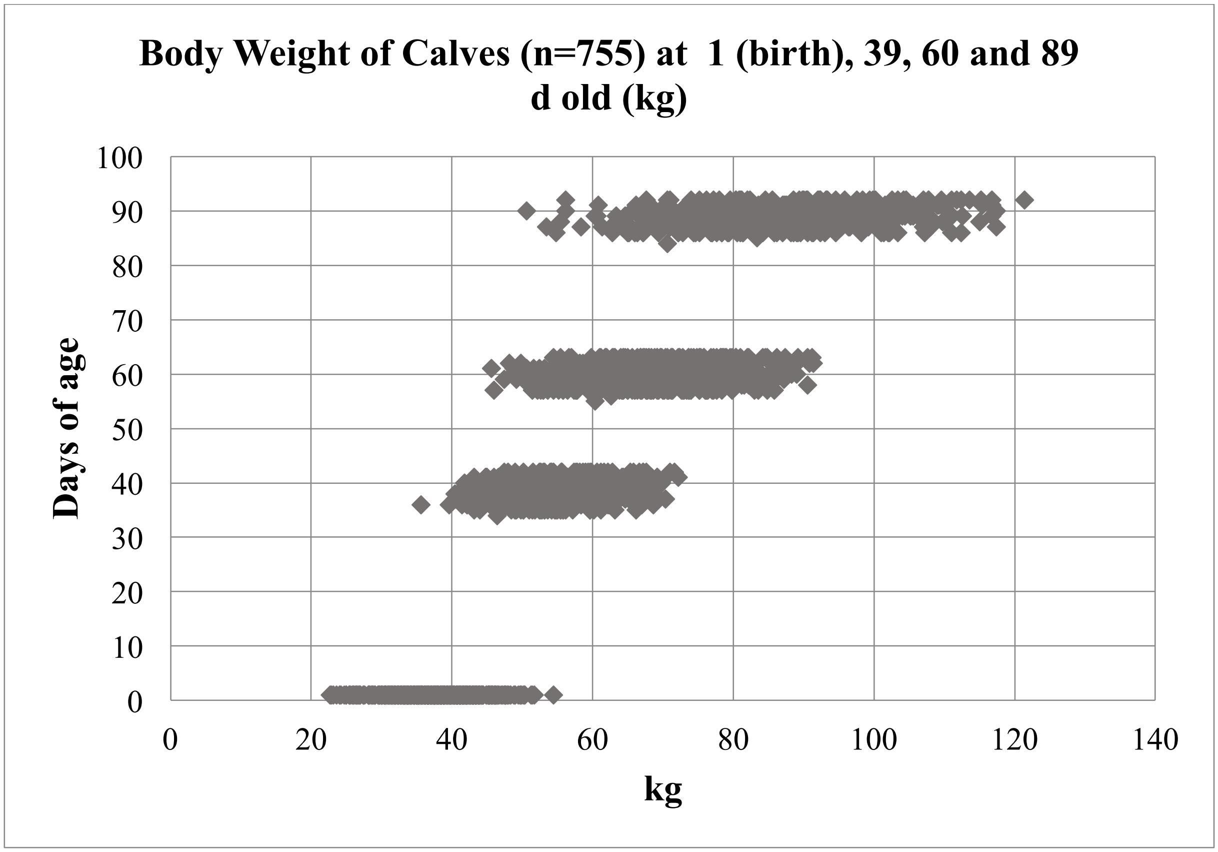
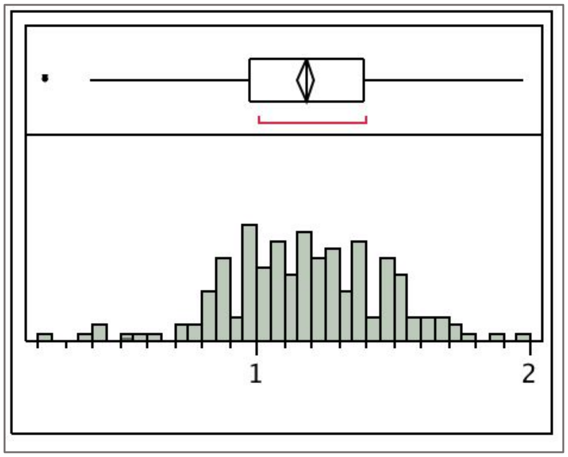
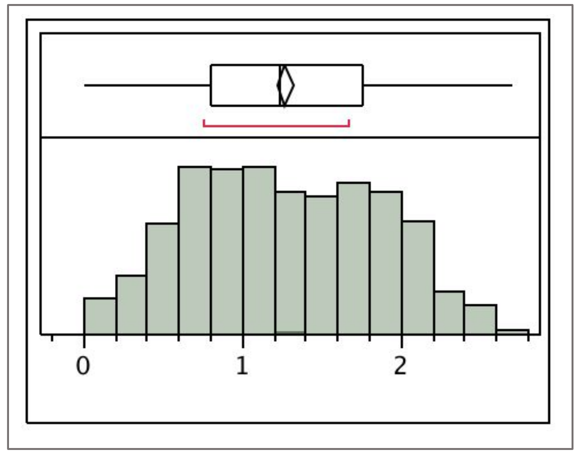


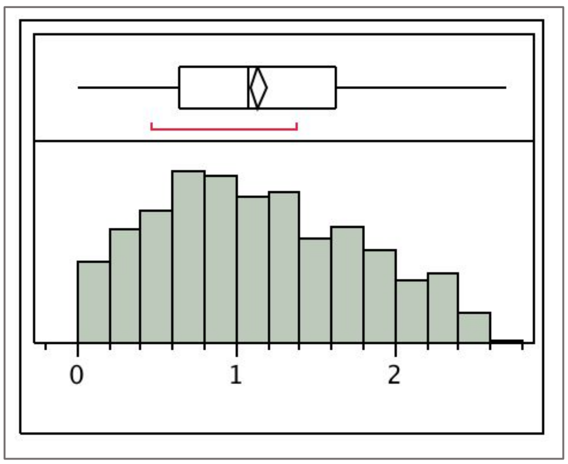
Figure 2.14. Female Holstein calves' body weight (BW, kg) at birth, 60, and 89 d of age, ± 3 d without consideration of the quartile level of individual feed intake.



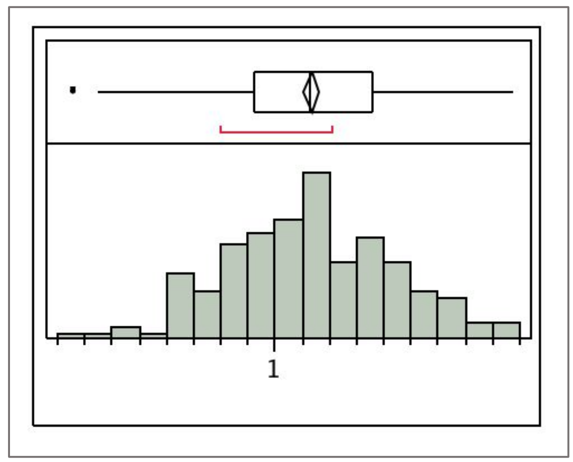
a) First period (n = 182 calves)



b) Second period (n = 183 calves)



c) Third period (n = 220 calves)



d) Fourth period (n = 170 calves)

Figure 2.15. Histograms of distribution of starter grain DMI, kg/d for female Holstein calves (n = 755) from 39 to 60 ± 3 d of age in four week periods of the study.

Calves starter intake was individually measured 4 d a week on the last 3 weeks in hutches. The calves were then classified as high (H), medium, and low (L) quartile levels of individual feed intake. High and low calves were randomly allocated to six treatments and their BW, ADG, DMI, feed efficiency (FE), and feeding behavior was analized.
Study treatments: HL = 10H + 10L; HHL = 15H + 5L; HLL = 10H + 10L; CTRL = 20 control; HH = 20H; LL = 20L. Medium calves were not used in the study.