DAIRY PRODUCER VIEWS ON CALF REARING

by

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Abstract

Calf rearing practices vary greatly among farms, including feeding and weaning methods. This variation may relate to differences in how dairy producers view these practices and evaluate their own success, but no previous research has examined these views. The aim of this study was to investigate perspectives of dairy producers on calf rearing, focusing on calf weaning and how they characterized weaning success. We interviewed 18 dairy producers from Western Canada: British Columbia (n = 13), Manitoba (n = 2), and Alberta (n = 3). Participants were asked to describe their calf weaning and rearing practices, and what they viewed as successes and challenges in weaning and rearing calves. Interviews were recorded, transcribed, and subjected to qualitative analysis from which we identified four major themes: (1) reliance on calf-based indicators (e.g., health, growth, and behaviour), (2) management factors and personal experiences (e.g., ease, consistency, and habit), (3) environmental influences (e.g., facilities and equipment), and (4) integration of external support (e.g., advice and educational opportunities). These results provide insight into how dairy producers view calf weaning and rearing and may help inform the design of future research and knowledge transfer projects aimed at improving management practices on dairy farms.

Lay Summary

Considerable research has focused on feeding and weaning practices for dairy calves, but none has focused how dairy producers view these practices. We interviewed dairy producers, asking them to describe their views on calf rearing, including weaning. Calf rearing practices varied widely on commercial farms, likely reflecting differences in views among producers. Producers also described a reliance on calf-based measurements to assess the success of their rearing methods. In addition, management and personal experiences, environmental factors and external farm support were all described as important influences on their calf rearing program.

Preface

E.R. Russell, D.M Weary, and M.A.G. von Keyserlingk designed this study. E.R. Russell conducted interviews and analyzed the data. Graduate student K. Mills assisted with inter-coder agreement. E.R. Russell wrote the manuscript. D.M. Weary and M.A.G von Keyserlingk supervised and provided feedback on the manuscript.

A version of Chapter 2 is in preparation for publication: Russell, E.R, M.A.G. von Keyserlingk., D.M. Weary. Dairy producer views on calf rearing. The research described in this chapter was approved by the University of British Columbia's Behavioural Research Ethics Board (#H19-01195).

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List of Abbreviations

ADG: average daily gain

AMF: automated milk feeding systems

BW: body weight

FPT: failure of passive transfer

Ig: immunoglobulin

IgG: immunoglobulin G

SOP: standard operating procedure

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To my friends and colleagues at the UBC Dairy, I give you all the gratitude. The majority of my master's program was spent under lockdown in the COVID-19 pandemic. During this time many of you became my family. To Kathryn, my officemate, roommate, and continuous cheerleader, I appreciate your friendship and guidance. To Rapha and Bianca, my Brazilian buddies who were always available for deep philosophical discussions and words of wisdom. To Allison, Emeline, Rodrigo, and so many others at the farm, you made my experience memorable and for that I'm extremely grateful. Many thanks to the wonderful UBC Dairy Farm Staff: Nelson, Mary-Ann, Audrey, Brad, Bill, Barry, Madison, Megan, and Jo for continuously supporting the students' (sometimes wild) ideas. I thank you.

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Dedication

In memory of my great-grandparents, Ronald and Ellen Russell.

Prologue

As I get older, I try to take more time to reflect on who I was in the past, who I am in the present, and who I achieve to be in the future. I have learned from my mentors in qualitative methods that it is important to practice reflexivity and be aware of your positionality when conducting research. Reflexivity plays a role in positionality as it is the active self-recognition of a researcher's positionality and how it may affect research outcomes (Berger, 2015). Before beginning the introduction to this thesis, it is important to recognize my own positionality (Holmes, 2020).

I was not born into an agricultural family, but I was raised in an agricultural community, a community that supported my upbringing and continues to be supportive of my educational career to this day. Before attending UBC, I had experience in the dairy industry but no research background. I have worked with farmers as they navigate the day-in-day-out routine of caring for their animals. I have worked alongside migrant farm workers in the hot sun treating sick calf after sick calf with IV fluids. I understand the hard work, grit, and spirit that embodies those who farm. I also have felt the bond between human and animals by growing up with cats, showing dairy cows, and, in the present, training my horse. I am a second-generation college graduate who has had the opportunity to live and study at multiple higher institutions outside my hometown. It is a combination of these experiences that have built me into the person I am today.

Chapter 1: **Introduction**

1.1 Dairy calf management and welfare

Rearing calves is a crucial component to dairy farming as most dairy farms rely on their own young stock to provide replacement heifers and future milk cows. On North American dairy farms, it is common to remove calves from their mother soon after birth to be reared by humans. This means that calves are often subjected to experiences that vary from the natural setting where cow and calf remain together even after weaning (Reinhardt and Reinhardt, 1981). The development of science-based practices for calf care can assist in guiding dairy producers to promote animal welfare. In Canada, the Code of Practice for the Care and Handling of Dairy Cattle (National Farm Animal Care Council (NFACC), 2009) provides producers with requirements and recommendations for common calf care practices such as colostrum management, milk feeding allowances, housing design, and weaning methods. These recommendations are intended to promote calves' health, growth, and wellbeing.

In this chapter I will summarize some of the literature that provides a base for understanding the current recommended practices for calf rearing. Furthermore, I will provide an introduction to research that has investigated alternative approaches to calf rearing. This thesis uses the animal welfare framework provided by Fraser et al. (1997), recognizing welfare as three constructs; biological functioning (health), natural living (the ability to perform natural behaviours), and affective states (feelings and emotion).

1.2 Dairy industry in Western Canada

My thesis research focuses on farmers within Western Canada, which consists of Manitoba, Saskatchewan, Alberta, and British Columbia. Canada is home to nearly 1 million dairy cattle with roughly 23% residing in these western providences (CDIC, 2021). The UBC Animal Welfare program has a history of supporting the Western Canadian dairy industry, especially through the UBC Dairy Education and Research Centre situated in the Fraser Valley of British Columbia. This history has resulted in relationships between the university, researchers, industry professionals, and dairy producers from across the region, and this rapport allowed my thesis research to be possible.

1.3 Conceptual background

1.3.1 Approaching dairy calf literature

Most of the research on calf rearing utilizes common indicators of 'success' including feed intake, body growth, health measures and behavioural indicators of welfare. These have been used in numerous quantitative studies on calf rearing (milk allowances, Jasper and Weary, 2002; Miller-Cushon et al., 2013; Rosenberger et al., 2017; weaning, Benetton et al., 2019; milk allowances and weaning, Mirzaei et al., 2018). Below I provide an overview of some of this work, and I will discuss the alternative ways being used to research dairy management practices.

1.3.2 Newborn calf care

Calves are born without an acquired immunity and depend on maternal immunoglobulins from colostrum to protect from disease (Weaver et al., 2000). To ensure calves are provided the

proper immunoglobulins to build a strong immunity, an adequate amount of high-quality colostrum should be provided within the first few hours of life. It is recommended that a newborn calf receive 4 L of high-quality colostrum within the first 12 h of life, as the optimal immunoglobulin absorption occurs at 4 h (Weaver et al., 2000). The failure to do so can result in failure of passive transfer of immunity (FPT) (Stott et al., 1979; Bush and Staley, 1980). FPT can be classified as a blood serum Immunoglobulin G (IgG) concentration of less than 10mg/mL (5.2-5.5 g/dl total protein) (Tyler et al., 1996; Jaster, 2005). Calves with higher serum Ig concentrations tend to higher average daily gains and body growth (Points et al., 1988).

The importance of maternal colostrum on neonatal immunity has been known for over one hundred years (Famulener, 1912). Colostrum management, including the quality, feeding, and preservation, has been significantly investigated since the 1970's (reviewed by Kertz et al., 2017). Despite this wealth of information on feeding quality colostrum to calves, a little over half (53.3%) of surveyed dairy operations in the United States monitor colostrum quality and 45% rely on visual appearance as a quality indicator (USDA, 2016).

1.3.3 Milk feeding

Historically, dairy calves have been fed restricted milk allowances (10-12% of BW, average <6L/d) across an average of two meals per day (Vasseur et al., 2010; USDA, 2016). While more recent research suggests that farmers are adopting higher milk feeding practices, 25-30% of calves in Canada are still being offered <6L/d of milk or milk replacer (Medrano-Galarza et al., 2017; Winder et al., 2018). Feeding restricted milk allowances across minimal meals is far from what would occur if the calf was reared with its dam. While there is little literature on conventional dairy breeds (e.g., Holstein-Friesian and Jersey), observation of beef cattle (Bos

taurus) and Zebu (Bos indicus) in natural settings show that calves reared with their dam consume more frequent meals of milk, roughly 4-5 meals per day (Lidfors and Jensen, 1988; Paranhos da Costa et al., 2006), learn how to eat solid feed, and are alongside the dam until weaning around 7-10 months of age (Reinhardt and Reinhardt, 1981). Calves have the ability to consume more milk than what is conventionally offered; calves offered ad libitum milk consume 89% more milk then calves fed conventional restricted diets (10-12% of BW) (Jasper and Weary, 2002). Calves fed higher milk allowances (20% of BW/d, Khan et al., 2011) have larger average daily gains (ADG) pre and post weaning than calves fed restrictive amounts (Rosenberger et al., 2017). In addition, higher nutrient intake in the pre-weaning period promotes growth and is correlated to first lactation milk yield (Soberon et al., 2012).

The method in which milk is consumed is also important. Calves fed via artificial teats perform less non-nutritive sucking and drink more milk, slower than calves fed by bucket (Hammell et al., 1988; Appleby et al., 2001). Drinking from a teat allows for the proper contraction of the esophageal groove which allows milk to pass the forestomach (rumen and reticulum) and into the abomasum (Wise and Anderson, 1939). Failure to do so can introduce milk to the rumen and cause fermentation which has been linked to ruminal bloat in calves (reviewed by Burgstaller et al., 2017). Furthermore, feeding speed can play an important role in milk digestion which has been linked to higher average daily gains (McInnes et al., 2015). However, milk feeding methods remain variable across farms. In one survey of Canadian dairy producers, 92% were reported to feed milk via bucket (Vasseur et al., 2010). More recent survey work by Medrano-Galarza et al. (2017) reported that 36% of their participants fed calves from buckets, and 53% fed from teats. To allow more natural milk feeding, dairy calves should be fed higher milk allowances, more frequently and via teat.

1.3.4 Housing of young calves

It is common practice for dairy calves to be housed individually during the milk feeding period (Canada, Vasseur et al., 2010; Europe, Staněk et al. 2014, United States, USDA, 2016). The use of social housing, with calves paired or grouped, is far less common. Calves are housed individually because of perceived benefits in disease prevention and reduced cross-suckling behaviour (Hötzel et al., 2014). Calf-to-calf contact can promote the spread of disease (Callan and Garry, 2002), but pen hygiene practices (e.g., removing manure, disinfection, and bedding quality and quantity) (Klein-Jöbstl et al., 2014; Heinemann et al., 2021) and group size (Svensson et al., 2003) are recognized as the main risk factors for calf disease in social housing systems. Non-nutritive suckling, including cross sucking, occurs close to the ingestion of milk, is usually performed 10-15min after consumption of milk (Lidfors, 1993), and is often seen in calves that are bucket fed limited milk allowances (Jensen and Budde, 2006; Pempek et al., 2016). However, research on the influence of milk allowances on cross-sucking is inconsistent. For example, some studies report milk allotment and nutritional state as influencing cross sucking behaviours (Jung and Lidfors, 2001; Roth et al., 2009), but others report no effect of milk allowance on cross-sucking (Nielsen et al., 2008), suggesting that cross-sucking may also be influenced by individual susceptibility to perform stereotypic behaviours (De Passillé et al., 2011a). The benefits to social housing include improved solid feed intake (De Paula Vieira et al., 2010), growth (Miller-Cushon and DeVries, 2016), and social development (reviewed by Costa et al., 2016). In addition to benefits for the calf, recent evidence shows that the public prefers social housing, as it is perceived to allow calves more space to perform social behaviours (Perttu et al., 2020).

1.3.5 Calf weaning and solid feed intake

All mammals eventually transition from milk to solid feed, a process known as weaning. Under 'natural' conditions, where calves are reared with the dam, weaning is gradual as the calf spends more time away from the dam (Reinhardt and Reinhardt, 1981) and occurs around 10 months of age (Reinhardt et al., 1986). In modern dairy production, calves are often weaned around 7-9 wk of age (e.g. Vasseur et al., 2010; USDA, 2016). Weaning is a critical time in a calf's life and is often coupled with not only a diet change, but exposure to routine painful procedures (Winder et al., 2016) and housing changes (Pettersson et al., 2001). A successful transition from milk to solid feed is influenced by multiple factors, including milk allowance, age at weaning and weaning method (e.g., gradual, or abrupt).

1.3.5.1 Influence of milk allowances and age at weaning

Calves fed restricted milk allowances tend to consume more solid feed (i.e., concentrates such as grain or calf starter) pre-weaning compared to calves fed higher milk allowances (Khan et al., 2007). Calves with lower milk allowances may consume more calf starter before weaning to try to compensate for the lower nutrition received from consumption of milk (Khan et al., 2011). However, even with decreased solid feed intake pre-weaning, calves fed higher milk allowances tend to have higher body growth (Khan et al., 2007; Rosenberger et al., 2017). To promote the increase of solid feed intake in calves fed higher milk allowances prior to weaning, different weaning strategies such as weaning by individual starter intake can be implemented (Benetton et al., 2019).

1.3.5.2 Methods of weaning

Age is a common criterion for calves to be weaned (Canada, Vasseur et al., 2010; Europe, Staněk et al., 2014; Australia, Phipps et al., 2018). Weaning by age may limit some calves the opportunity to transition from high milk allowances to solid feed (De Passillé et al., 2011b; Eckert et al., 2015), but weaning calves by intake is another option (Benetton et al., 2019). In addition to weaning criteria (i.e., age or intake), there are two commonly discussed techniques to weaning calves, abrupt and gradual. Weaning can be considered to be "abrupt" when calves are weaned by a sudden complete stop of milk feeding and "gradual" when milk allotments are reduced over a period of time (Jasper et al., 2008). Gradual weaning is recommended to promote calf starter intake (Sweeney et al., 2010) and post-weaning growth (Steele et al., 2017). According to survey data collected in Canada, gradual weaning was utilized by 89.6% of dairy producers surveyed (Vasseur et al., 2010). However, it is important to note that the practice (e.g., age weaned, weaning duration and milk reduction) of gradual weaning seems to vary considerably even in the scientific literature (summarized in Table 1.1).

Table 1.1 A summary of research utilizing gradual weaning techniques, showing weaning criteria and description of weaning age, weaning duration, and milk reduction. References selected from cited studies on calf weaning reviewed in section 1.3.5.1 and 1.3.5.2.

Reference	Criteria[1]	Technique	Age weaned[2]	Weaning duration[3]	Milk reduction
Khan et al., 2007	Age	Gradual and "Step-down"	d 50	d 46- d 50	(Conventional) Diluted milk by 10% water each feeding for 5-d. (STEP) d 26-30 diluted with water 10% volume each feeding until milk feeding rate of 10% BW. Held at 10% BW for 15-d. Then reduced following conventional methods.
Jasper et al., 2008)	Age	Gradual	≈ d 75	5 d	Diluted milk by 10% water each feeding for 5 d.
Sweeney et al., 2010	Age	Gradual	d 41	22 d 10 d 4 d	.55 kg/d (22-d) 1.20 kg/d (10-d) 3.00 kg/d (4-d)
De Passillé et al., 2011b	Age	Gradual	d 47 d 80	d 39 - d 47 80 - d 89	Not described
Eckert et al., 2015	Age	Gradual "Step down"	d 43 d 57	d 36 - d 43 d 50 - d 57	4 L/ d for 7-d
Rosenberger et al., 2017	Age	Undefined	d 55	d 50 - d 55	Reduction 50% allowance at d-42 20% allowance/d from d-50
Steele et al., 2017	Age	Gradual "Step-down"	d 48	d 36 - d 48	50% reduction of milk at d-26
Benetton et al., 2019[4]	Intake and Age	Gradual	(Age) d 70 (Successful Intake) d 52 $\pm$ 6.1 (Intake Early) d 54.4 $\pm$ 5.3 (Intake Late) d 71.3 $\pm$ 7.0	(Age) 7 d (Successful Intake) 11.8 $\pm$ 4.3 d (Intake Early) 12.6 $\pm$ 4.1 d (Intake Late) 10.2 $\pm$ 5.5 d	(Age) 1.2 L/d from d 30-35. Then .86L/d over 7 d (Intake) 25% reduction of individual's average milk intake at each target starter intake (225, 675, 1300 g/d.)

[1] Criterion to begin milk reduction.
[2] Age completely removed from milk.
[3] Length of time milk reductions occurred from peak milk allowance to no milk.
[4] Two experiments were conducted. Age weaned and duration of weaning is summarized as treatment (i.e., Age, Successful Intake, Early and Late weaning) average for weaning age and duration.

1.3.6 Weaned calves

After weaning and prior to first calving, female calves are commonly referred to as heifers. However, some producers continue to identify animals as 'heifers', more specifically 'first lactation heifers', until second calving and the definition of the heifer rearing period may be variable amongst farms. In this thesis heifers are defined as female calves after weaning and before first calving. Research on heifers over the years has provided evidence to generate significant improvements in feeding management and reproductive performance of replacement heifers (reviewed by Heinrichs et al., 2017). Success of rearing practices are often assessed using reproductive outcomes including age of puberty, age at first breeding, and age at first calving. Onset of puberty in Holsteins is around 12 months of age (Wathes et al., 2014), and to maximize economic returns and improve lifetime productivity it is recommended that age at first calving be around 22-24 months of age (Heinrichs et al., 2017). It is believed that nutrition and feeding practices can affect these outcomes. For example, Bruinjé and colleagues (2020) found that calves and heifers fed higher plans of nutrition before and after weaning had physiological responses (e.g., circulating leptin concentrations) associated with earlier onset of puberty. In addition, Davis Rincker et al. (2011) also investigated the effect of feeding higher planes of nutrition on long-term outcomes and found that calves fed higher energy and protein intake had lower age at first calving than calves fed less intensive diets. Similar results were found by Raeth-Knight et al. (2009), supporting the importance of nutrition both pre-weaning and post-weaning on reproductive performance.

After weaning, it is common for calves to be moved to different housing (Pettersson et al., 2001). Open dry lots with barns or sheds and group pens inside a barn are the most common forms of heifer housing in the US (USDA, 2016). In Canada little is known about how heifers

are housed after being weaned. Understanding how heifers are housed on farm and the housing transitions they undergo may assist in generating solutions on how to minimize housing transition stress. Minimizing regrouping may be beneficial, as recent research indicates that heifers regrouped with unfamiliar conspecifics show signs of anhedonia immediately after regrouping (Lecorps et al., 2020). In addition, housing changes can alter feeding and lying behaviour in heifers (von Keyserlingk et al., 2011).

There is little research evaluating the long-term impact of transitions (e.g., housing and diet) that occur following weaning. Furthermore, much remains unknown regarding heifer management on farm (e.g., housing, feeding and observation). One study from the UK identified large variability in heifer growth across farms, suggesting a need for improvement in long-term heifer management (Bazeley et al., 2016).

1.4 Human aspects of animal welfare

The care of farm animals is dependent upon human caretakers (Waiblinger et al., 2006). Several studies have found that interactions with humans influence animals. For example, negative interactions with humans are associated with reduced milk production in dairy cows (Hemsworth et al., 2000; Waiblinger et al., 2002). Ellingsen and colleagues (2014) used qualitative behaviour assessment (QBA) on dairy calves and found effects of stockperson handling.

As discussed in previous sections of this chapter, numerous studies have explored the effect of management practices on various animal outcomes. But animal care outcomes are also influenced by values and behaviours of human caregivers. To better understand these human factors, Lund et al. (2006) recommends the integration of social sciences with natural sciences.

Several studies have used social science methodologies to assess issues relevant to farm animal welfare. For example, there have been a variety of different approaches applied to understanding the effect of stockperson attitudes on dairy cattle welfare (reviewed by Adler et al., 2019). Survey work has looked at public attitudes towards calf rearing practices such as housing (Perttu et al., 2020) and cow-calf separation (Busch et al., 2017). In addition, the use of focus groups and interviews can provide detailed insight into understanding a phenomena (Gill et al., 2008). For example, Sumner and von Keyserlingk (2018) used focus groups to understand veterinarian perspectives to calf welfare and Vaarst and Sørensen (2009) interviewed dairy producers to explore farmer attitudes and perceptions of calf mortality on farm. In-depth interviews can provide a detailed view into the behaviour and practices of producers as seen in the treatment of lame dairy cattle (Horseman et al., 2014). Understanding producer views and perceptions towards calf rearing can provide insight into why specific practices are implemented on farm.

1.5 Thesis objectives

Despite the abundance of science-based evidence relating to calf rearing practices, there remains considerable variability in farm practices. Weaning is a critical period in a calf's life and there are multiple factors that contribute to science-based weaning "success", but no research to date has investigated the perspectives of dairy producers. Identifying what dairy producers' find to be key components that contribute to "success" on farm can provide information to direct future research and extension opportunities. Therefore, the aims of my research were to understand the views of Western Canadian dairy producers towards calf and heifer rearing in general and, more specifically how they characterize weaning success.

Chapter 2: **Dairy producer views on calf rearing**

2.1 Introduction

Milk feeding of dairy calves and the transition from milk to solid feed at weaning are two challenging phases to manage. Despite evidence that calves can consume approximately 10 L/d of milk (Appleby et al., 2001; Rosenberger et al., 2017), calves are often only offered 10 to 12% of their BW (4 to 6 L/d) in milk or milk replacer (e.g., Vasseur et al., 2010). Feeding restricted milk allowances is associated with prolonged hunger, as evidenced by the high number of unrewarded visits to automatic feeders (Jensen and Holm, 2003; Jensen, 2006; De Paula Vieira et al., 2008) and lower locomotor play behaviour (Jensen et al., 2015). An advantage to feeding higher milk allowances (e.g., approximately 20% of BW) is increased ADG in pre-weaned calves and higher overall body growth (Khan et al., 2007; Jafari et al., 2020). Increased growth in pre-weaned calves has been associated with increased first-lactation milk yield (Heinrichs and Heinrichs, 2011; Soberon et al., 2012; Van De Stroet et al., 2016) and lower age at first calving (Moallem et al., 2010).

Calves are often weaned from milk at approximately 8 wk of age (Vasseur et al., 2010; USDA, 2016), a process that is performed earlier and more abruptly than what would occur in nature (Weary et al., 2008). Distress during the weaning period has been evaluated using behavioural indicators, including increased vocalizations (De Passillé et al., 2010; Fröberg et al., 2011), increased unrewarded visits to the automatic feeder (Jensen, 2006) and decreased play behaviour (Krachun et al., 2010). Solid feed intake before weaning has been used as an indicator of a calf's ability to transition to solid feed, with starter intake often used as an indicator by producers (Vasseur et al., 2010; Le Cozler et al., 2012; Phipps et al., 2018). A suggested calf

starter intake of roughly 1.5 kg/d for 3 consecutive days is a commonly used industry recommendation (Bovine Alliance on Management & Nutrition, 2017). Calves fed higher milk allowances tend to consume less starter before weaning (Khan et al., 2007), but gradually weaning calves from high milk allowances using individual intake targets can help reduce weaning age and maintain BW after weaning (Benetton et al., 2019). In addition, calves on a step-down (gradual) weaning protocol consume more feed and have greater BW compared to calves weaned abruptly (Khan et al., 2007). Gradually weaning calves from high milk allowances can also reduce cross-suckling (Nielsen et al., 2008).

Despite this research-based evidence, little is known about the practices that dairy producers use to wean their calves. Work to date on calf rearing practices (Canada: Vasseur et al., 2010; Brazil: Hötzel et al., 2014; Czech Republic: Staněk et al., 2014; United States: USDA, 2016; Germany: Hayer et al., 2021) indicates considerable variation in feeding and management of calves among and within regions. Survey-based research can show 'what' producers do but does not explain 'why' they do what they do. There has been an increase in work evaluating farmer attitudes, motivations and perceptions towards calf rearing practices, such as disease control (calf illness and mortality; Vaarst and Sørensen, 2009), painful procedures (dehorning; Cardoso et al., 2016), and farm management (identification of young stock management hazards; Boersema et al., 2013). One recent study evaluated the perceptions of English dairy producers and advisors on the adoption of different milk feeding protocols (Palczynski et al., 2020); this study found that some producers fed restricted milk allowances and used inconsistent weaning protocols, a result the authors attributed to poor guidance from advisors, reflecting historical rather than science-based practices. To our knowledge, no research has focused on understanding how producers characterize weaning success. The aim of this study was to investigate producer

views toward heifer rearing, with a focus on calf weaning. We sought to understand why producers rear calves the way they do, and what practices they view as successful or challenging. We adopted a qualitive approach to explore participant experiences and perspectives (DiCicco-Bloom and Crabtree, 2006; Gill et al., 2008) for better understanding of the reasoning behind different rearing practices with a view to inform future research and extension efforts.

2.2 Materials and Methods

This study was approved by The University of British Columbia's Behavioural Research Ethics Board (H19-01195), and all participants gave verbal consent to participate. Data were collected from July to September 2020.

2.2.1 Recruitment

We recruited a convenience sample (Robinson, 2014) of dairy cattle producers in Western Canada. Participants were recruited via industry contacts (e.g., feed manufacturing companies), media outlets (e.g., breed associated publications and provincial milk organization newsletters), and by word of mouth. 20 dairy producers were recruited, due to scheduling conflicts 2 producers were unable to arrange a time to be interviewed and did not participate in the study. The number of participants was not predetermined; interviews continued until data saturation, described as when no new ideas were apparent in additional interviews (Guest et al., 2006). Recruitment material included a single page document outlining the research objectives, participant requirements, description of how the study was to be conducted, and researcher contact information. Dairy producers were encouraged to contact the first author (E.R.) via phone or email if they were interested in participating in the study. Potential participants were

then provided additional information regarding consent and a time was scheduled for the interview to take place.

2.2.2 Participants

A total of 18 individuals (10 male and 8 female) were interviewed from 16 different dairy farms in Western Canada: British Columbia (*n* = 12), Manitoba (*n* = 2), and Alberta (*n* = 2). Participants were identified as being the farm manager or owner (n=15) or calf caretaker/manager (*n* = 3). Herd size ranged from 75 to 540 lactating cows (Table 1). Calf housing, feeding, and weaning practices varied by farm (Table 2). To be included in the study participants had to: 1) be actively dairy farming in Western Canada, 2) have a minimum 10 dairy heifers being reared on the farm at the time of the interview, and 3) be responsible for making decisions regarding calf management (i.e., they were the farm owner, manager, calf feeder, and/or calf manager). All interviews were with a single participant, except for 2 interviews where 2 participants represented a single farm.

To protect confidentiality, participants were randomly assigned participant (P) identification numbers (ID), represented as P_ID (e.g., P_10) for the quotes presented in the text. Some of the quotes provided in the text were modified with ellipses for missing text, and include square brackets (i.e., […]) to represent text that was modified to improve clarity.

2.2.3 Interviews

Due to restrictions associated with the COVID-19 pandemic all interviews took place via a video (*n* = 13) or phone call (*n* = 3), depending on the participant's preference. The semi-structured interviews were audio recorded and lasted between 30 and 70 min (mean ± SD; 47

±11 min). Interviews began with an introduction of the researcher (E.R.), study objectives and warm-up questions (e.g., questions about the participant(s), farm demographics, and other small talk) with the intention of building rapport between the participant and interviewer (Dilley, 2000). Participants were then asked a series of questions to better understand how they raise calves, specifically heifers from newborn to first breeding, what they view as being challenging and successful practices, how they define a successful weaning, and their view of the future of calf and heifer rearing. In addition to these primary questions, the interviewer followed up with secondary questions to explore some points in greater detail. Participants were also given the opportunity to ask the interviewer questions throughout the interview. Before starting the study, 2 pilot interviews were conducted to ensure that questions were phrased in such ways that the research objectives were met. Pilot interviews were not included in the final data analysis. All interviews were carried out by E.R. using a critical realist perspective (Archer et al., 1998). E.R. is a female and was a MSc student who came into the study with a background in dairy science and experience working on dairy farms in the United States and Canada.

2.2.4 Method of analysis

Audio recordings were listened to by E.R. to ensure the quality of recording and to remove any identifying information. Fieldnotes were taken during the interviews by E.R. but were not included in data analysis. Recordings were then uploaded to a transcription service and transcribed verbatim into a text file. E.R. reviewed the transcriptions with the audio recording to ensure the accuracy of the transcribed file. Transcripts were then sent to each participant for review and corrections; 1 participant provided additional updated information that was added to their interview and no corrections were requested. Transcriptions were then subjected to thematic

analysis by E.R. using NVivo 12 (QSR International, 2021). Thematic content analysis was selected because of its ability to provide a rich description of data (Braun and Clarke, 2006; Bard et al., 2019). An inductive approach was taken with the creation of the codebook, where the development of codes was driven by the data (Braun and Clarke, 2012). Meaningful pieces of texts (line-by-line) that were related to research questions, were manually sorted into codes, which developed into an initial codebook (Miles et al., 2014). The initial codebook was then sent to a second researcher trained in qualitative methods, along with two transcripts to review for intercoder reliability. The codebook, codes and themes were discussed between the 2 researchers. The generation of the codebook was an iterative process and upon reflection and revisions the codebook was finalized and used to code all interviews by E.R.

2.3 Results and Discussion

Participants discussed what they considered to be factors that contributed to challenges and successes of calf rearing, including weaning success. From the analysis of these interviews 4 main themes emerged: 1) reliance on calf-based indicators; 2) management and personal experiences; 3) environmental influences; and 4) integration of external farm support.

2.3.1 Reliance on calf-based indicators

When describing their views regarding successes in calf rearing, participants relied heavily on calf-based indicators, including behaviour, growth, and health. Reliance on calf-based indicators is consistent with a long history of research on dairy calf rearing that has focused on measures such as feed intake, growth, and more recently, behaviour (reviewed by Kertz et al., 2017).

2.3.1.1 Behaviour

Participants understood the importance of feeding high milk allowances, reflecting research showing the benefits to feeding calves more milk (Soberon et al., 2012; Miller-Cushon et al., 2013). Some participants viewed feeding high milk allowances early in life as the key to success; for instance, one participant said, "we've just found the key to the whole thing is a good start, just getting a lot of milk solids into them at the beginning" (P_12) and "…some of my babies are drinking …. 12 to 16 litres of milk a day. And that seems to help a lot…" (P_70). One participant (P_18) recognized that calves have the ability to consume high quantities of milk, "…we really pound the milk into them early, which they drink voluntarily… lots of them are just drinking 11-12 litres." P_72 credited feeding higher milk allowances to increased growth and smoother transitions at weaning, "… since I started feeding the calves more milk, I see the calves, the growth, [they're] way 'growthier'. They just do better, they transition better."

One participant (P_38), however, was cautious about feeding higher milk allowances and expressed concerns about solid feed intake, "I guess the challenge for us at that time is the program [Automated milk feeder (AMF)] allowed [calves] to consume up to 10 litres of milk a day. And the grain consumption was really hard to get going at that time." This illustrates the importance that some participants saw in using solid feed intake as an indicator of weaning success, a point echoed by P_43 who stated: "Successfully weaned is you know; they're going strong in the sense that they're consuming that grain when you put it in front of them you know, and they lap it all up [and] they're eating hay…" Solid feed intake has been used as an indicator of a calf's ability to transition from milk to solid feed by producers (Le Cozler et al., 2012). Furthermore, as observed by P_38, calves fed high milk allowances can have reduced starter

intakes before weaning compared to calves fed restricted allowances (Dennis et al., 2018; Jafari et al., 2020), although gradually weaning calves from milk, especially when feeding high milk allowances, can promote solid feed intake with minimal growth check (e.g., Khan et al., 2007).

Participants emphasized the social behaviour of calves, including observations of play. Play was seen as an indicator of a successful calf rearing program by P_16, "I just want to see them up and jumping around a little bit." Participants also mentioned calf vocalizations when asked to describe indicators of successful calf weaning. "…I guess we've done a good job if you can't hear them once we've weaned them when they go to the group pens" said P_12. Similarly, P_16 commented, "I basically don't want to hear them freaking out too much about a change in their situation. So, like, if they're really freaking out, I feel like I did it [weaning] too fast." Vocalizations are thought to be indicative of hunger (Thomas et al., 2001; Manteuffel et al., 2004), and vocalizations around feeding may be directed to the human caregiver responsible for milk feeding (Watts and Stookey, 2000; De Paula Vieira et al., 2008). However, others like P_10 saw vocalizations as normal and not a basis for concern, "So… they whine and bitch for about five or six days, and moan and groan, and then they get over it… And it's a bit loud, but hey, yeah, no one's ever starved to death on this farm".

Producers have been known to focus more on measures associated with basic health and functioning rather than on affective states or natural living criteria aspects of animal welfare (e.g., Tuyttens et al., 2010; Albernaz-Gonçalves et al., 2021). That said, some participants did discuss the affective states of calves, for example using the word "happy" to describe calves during weaning and housing transitions; P_44, who reared calves on a nurse cow, said it was challenging to keep calves and cows "happy" during weaning: "Well that's the tricky part because they, neither the cow nor the calf, is very happy then [at weaning]." Other participants

recognized housing transitions (e.g., from individual hutches to group pens) as being a source of "stress" for calves; P_83 discussed the transition from individual housing in hutches to group housing as "a huge stressor for them to go from something that they've been in, you know, for such a long period of time." P_18 wondered if there was a way to mitigate calf stress during housing transitions with the use of pharmaceuticals, "I don't know if we gave them like some sort of a painkiller when they move... I don't know if that would help just limit some of the stress that they have." This recognition of affective states is consistent with previous work showing that producers recognize that cattle experience emotions (Bertenshaw and Rowlinson, 2009).

2.3.1.2 Calf growth

Calf growth was described as an indicator of a successful calf rearing program. Continued BW gains after weaning were viewed as important, as mentioned by P_16, "…I want to see them continuing to gain weight; don't want to see them going backwards... that [is the] challenge - to keep them moving forward." Some participants monitored weight gains to gauge success. For example, P_18 stated: "So I think everything's going to get based off those weaning weights. I think it's such a vital number, and I think my unique success will be purely based on average daily gain." Doubling birth weight was seen as a way to gauge success of the pre-weaning rearing programs and was used by some to decide when to start weaning; P_74 saw their ability to double calf birth weight in the first 50 days as a way to reduce the amount of milk fed to calves, "I mean by 50 days, they're double their birth weight. Why bother feeding them an expensive product when they can move off..." Participant awareness of feed costs in relation to growth does not come as a surprise as feed costs are the largest expense in rearing replacement heifers (Heinrichs et al., 2013).

Rapid BW gains before and after weaning allows breeding at younger ages, and breeding age was used as an indicator of a successful rearing program - “we are breeding our heifers now at 12 or 13 months, if I wasn't doing that, I would maybe go back and revisit what are we doing wrong. But we're breeding them early. They're calving out early. So, I'm imagining that we must be successful in what we're doing” (P_10). Another participant (P_74) also used reproductive age as an indicator of rearing success, “The fact that I can have an animal ready to breed at 12 months, but some of them at 11 months already. Like they're already cycling at 10-11 months...” Participant recognition of growth and reproductive outcomes align with literature on rearing replacement heifers, where these outcome measures are often used to monitor calf and heifer management and coincide well with feeding practices (reviewed by Heinrichs et al., 2017).

2.3.1.3 Calf morbidity and mortality

Maintaining calf health was viewed as a challenge in calf rearing; as stated by P_12: “There's nothing more depressing than having a calf barn full of sick calves.” Health challenges varied depending on calf age. Diarrhea was considered a challenge within the first 2 weeks of life: “…scours is probably our biggest challenge at times” (P_38). For older calves, participants cited additional health concerns, such as pneumonia and parasitic infections including coccidiosis and cryptosporidiosis. P_16 mentioned their struggle with pneumonia, “probably less than half ... get a bit of pneumonia at some point along the way… So that's another thing I say we struggle with a little bit is some pneumonia in the calves”. P_61 referred to coccidiosis as being “…kind of a big thing.” Participant P_16 noted an issue with cryptosporidiosis that was “very hard to get reduced.” Diarrhea in young calves, poor growth during the milk feeding phase, and parasitic infections in weaned calves were also identified as concerns of Dutch dairy

producers (Boersema et al., 2013). US reports show mortality at roughly 6.4% and 1.9% for pre-weaned and weaned heifers respectively; diarrhea is responsible for more than half the deaths pre-weaning and respiratory illness is the leading cause of mortality in weaned calves (USDA, 2018).

In addition to concerns about disease and parasites in calves, participants viewed a low mortality rate as a key indicator of a successful rearing program. Low mortality was a source of pride: "I think we have a very low mortality rate. You know, it's really got to be about 2% of calves that end up in the calf barn that leave without walking out. So, we're proud of that" (P_24) and "… [My brother has] the same amount of quota, same number of robots and stuff like that. And every fall, we do our inventory and I've got about 15 to 20% more heifers all the time. And it's just a simple mortality rate difference" (P_12). "…that's why we have so many replacement stock…it's because of that [low mortality rate], you know, we just don't lose animals here" said P_43, highlighting the desired outcome of achieving a low mortality. Increased calf mortality can be an indicator of poor management (e.g., poor colostrum feeding, milk feeding and weaning practices), negative welfare (Mellor and Stafford, 2004; Zucali et al., 2013), and results in economic losses (Boulton et al., 2017). Sumner et al. (2018a) also found that British Columbian dairy producers perceived low mortality as an indicator of success. Future work would benefit from collecting data on calf mortality and using this context to better understand participants' views; previous work suggests that producers sometimes underestimate calf mortality on their farms, reducing motivation to change practices (Vaarst and Sørensen, 2009; Vasseur et al., 2012).

2.3.2 Management and personal experiences

Participants viewed their personal experiences in managing calves as critical to the successes of the calf rearing program. Consistency and ease of practices, managing conflicts on the farm, capacity for observation, and experiences were all considered important.

2.3.2.1 Employees

Management practices on farm play a critical role in calf health and mortality (Seppä-Lassila et al., 2016; Abuelo et al., 2019). Having designated employees responsible for calf care was considered beneficial by participants. On 2 farms, the interviews included both the owner and the primary calf-caregiver. In both cases the owners credited the calf-caregiver with a portion of the success: “I know I don't have to worry about the newborn to weaning because [the calf-caregiver has] got that covered” (P_61 owner) and “I don't have to take care of it. [the calf-caregiver] does such a good job” (P_38 owner). Recent work (Hayer et al., 2021) found that farms that had hired a calf rearing employee were more likely to complete crucial management practices properly (e.g., feed colostrum early, disbud calves within the first 2 wk of life, and maintain hygienic practices, such as pen cleaning and navel disinfection).

The quantity and classification (e.g., family or not) of employees was seen as contributing to success. P_24 acknowledged that having designated employees for calf care was limited by farm size: “The success is that on some of these large farms they have one or a team of people dedicated to one component of the farm.” Many of the participating farms had both family and non-family employees. Most participants worked with family members on the farm, which follows the typical structure of dairy farming in Canada (Statistics Canada, 2016). In the U.S, smaller operations (>250 cows) are also likely to rely on family labor (Schewe and White,

2017). P_12 mentioned that having only family employees made calf weaning time variable and sometimes dependent on family functions, "… being a family run thing, [a] two week [weaning period] is a little bit variable. Sometimes it depends on what baseball [game] we're going to and who remembers and who doesn't remember." In contrast, P_10 mentioned problems in observing and treating calf illness when working with inexperienced non-family employees; "Not throwing anybody under the bus, but [employee name] still has challenges in that early recognition [of calf illness]."

2.3.2.2 Consistency and ease of practices for producers

Consistency of milk feeding practices is often considered a high priority (Hill et al., 2009). Our participants believed that consistency was important in calf rearing, especially during the milk feeding phase; "I know personally that consistency with all of the steps of calf feeding, feeding the milk, the same way each day, the same temperature if you can, as much as possible" said P_16. One participant (P_28) cited their choice to feed milk replacer as a way to maintain consistency, "…they get milk replacer…hundred percent milk replacer…that way, it's always consistent." A few participants felt that consistency was challenged by variable staffing schedules. For example, P_61_1 said, "…you really have to pay attention and kind of know what's going on in the barn. And if you have too many people, I think, then they don't know the calves. They don't notice little inconsistencies or things that will change." P_12 advocated for the use of standard operating procedures (SOPs) to maintain this consistency, "Big perspective view, I would say just move to protocols, SOPs. That was a game changer for us. It just made it so much easier to tell the next person what we do." SOPs are increasingly requested in animal care assessments (e.g., Dairy farmers of Canada ProAction; the US based National Milk Producers

Federation FARM, 2020) and can be useful in ensuring practices remain consistent (De Treville et al., 2010) and for training (Barbé et al., 2016). While our study did not focus on the use of SOPs, the challenge of working with inexperienced employees suggests some value to adopting this approach; recent work has shown that the uptake of SOPs varies among farms (Mills et al., 2020a), suggesting the need for extension efforts focused on this topic.

Participants saw importance in the "ease" of a task, "If it's easy, it gets done" (P_10). More specifically, "easiness" of milk feeding practices and weaning programs were thought to be important, a result also seen with English dairy producers (Palczynski et al., 2020). For example, P_44 raised calves on a nurse cow and described their method of rearing calves as "…a poor man's version of an automated calf feeder. Without the headache of cleaning and mechanical maintenance." In another case (P_12), the decision to wean calves was dependent upon when it was "convenient for the [calf] feeder…"

2.3.2.3 Constraints and conflicts

Time availability was seen a limitation in successful calf rearing. For example, P_61 considered the lack of time as a constraint in keeping facilities clean: "We do try to clean their pens as much as possible, as much as we can and as much as time allows us to." Time has also been reported by dairy producers as being a limiting factor for reducing lameness on farm (Leach et al., 2010a).

Interpersonal conflict was mentioned as a challenge. P_83, who worked on the family farm, said "… I do receive pressure from you know, the man above me. [They] will say 'you are taking too long to wean these calves'." P_74 mentioned differences among family members in recognizing problems on the farm; "I realized that calf barn ventilation is just a matter of I can

smell the ammonia my husband can't. So, I will tell him it needs to be cleaned out and he's going 'nope, doesn't stink', I said, 'yes, it does, so do it.'"

2.3.2.4 Experience and habit

Participants cited personal experiences to justify rearing practices, "Just sort of the way we've always done it" said P_28. Similarly, Wilson et al. (2021) reported that dairy producers developed calf care practices primarily from personal experiences. Weaning procedures were often based upon personal experience and what participants believed worked well on their farm. "I've been taking care of calves on this farm since I was in like elementary school. So, I've really watched them, I've learned what seems to make them [the calves] happy, what works" (P_16). Likewise, P_24 reflected on the role of experience, but also recognized that they had become complacent, "I've been doing this all my life, but it's a mix of things I've learned over the years and maybe [I am] set in my ways, I don't know." A person's previous experience contributes to decision making and willingness to change and has been highlighted in previous studies on producer adoption of biosecurity measures (Ritter et al., 2017). Previous experience with negative situations (e.g., disease outbreak) is likely to motivate producers to implement new management (e.g., biosecurity measures) in the future (Moya et al., 2019). Producers may feel as though they have an understanding of best practices, but this often comes from experience rather than specific training (Garforth et al., 2013). Habit and tradition were identified as influencing rearing practices. P_43 recognized that, "there's probably best practices [for weaning] that are better… but I'm just telling you how we do it right now…because that's traditionally what we've done...". Producer and employee habit, experience, and personal routine can be a barrier to the implementing practices, as seen with milking practices (Belage et al., 2019). Furthermore, farm

tradition can affect implementation of new rearing practices. For instance, Brazilian dairy producers reported farm tradition as justification for continuing calf rearing practices harmful for calf welfare (e.g., limit milk feeding, painful procedures, etc.; Hötzel et al., 2014).

2.3.2.5 Calf and heifer observations

Careful observation of calves was believed to be important. P_24 emphasized the need for regular daily observations of calves and the importance of having an experienced observer, "I do a walk through [the calf barn] a couple extra times a day. I think an experienced eye is part of our success." However, observations declined as calves aged and began to be perceived as more mature heifers. Participants felt that once calves were weaned and moved to different pens, observations were not necessarily needed: everything "at that stage [post-weaning] is straight forward" said (P_77) and "Postweaning really, we don't look at them other than issues" (P_74). One participant (P_83) noted that the observation and care of calves after weaning was insufficient; "I do think that like, from weaning till first breeding, our heifers are very neglected. Very neglected. Which happens quite often on farms, right?" This shift in focus may reflect the common practice of moving calves to different facilities after weaning, often with reduced observation (Heinrichs et al., 1986; Pettersson et al., 2001). Previous work has evaluated preweaning treatments and the effects on outcomes such as age at calving, milk yield, and growth (Moallem et al., 2010; Davis Rincker et al., 2011). While these studies followed calves from newborn to first lactation, they also typically focused on the preweaning period with little information on calves after weaning. The lack of focus on heifers from weaning to breeding is consistent with the limited number of studies on the effects of management practices during this period. Decreased observations of older calves likely also relates to the participants' priorities,

with older calves considered to be a lower priority than younger calves. Lai et al. (2019) found that U.S. dairy producers ranked calf and heifer management as the second most important management area (behind milk production management). However, Lai et al. (2019) lumped together calf and heifer rearing in one category; we suggest that producers interviewed in this study may have placed more weight on calves than heifers, and thus, we encourage future work to explore whether this is representative of most dairy producers.

In addition, clarification of the definition of 'heifer' may be necessary as usage varied amongst participants. Some participants defined "heifer" as a specific age range, "If I was to take a stab at it, I would probably say six months of age for me, okay." (P_43). Whereas some participants gave definitions based on when calves transitioned to a new pen, "yeah, it's really just when it [the calf/heifer] gets moved to a specific barn for us…It's not really an age thing." (P_77). A few participants also defined heifers immediately upon birth: "They are classified here…as a replacement heifer for us within the first 24 hours." (P_74) and "I call them 'heifer calves' right from the get-go." (P_61). Interestingly, variability in terminology was identified as an issue when dairy producers and veterinarians appeared to use the term 'transition period' differently (Mills et al., 2020b), acting as a potential barrier to improving management practices

2.3.3 Environmental influences

Participants perceived and discussed several environmental influences on calf weaning and rearing outcomes, including the effects of facilities and equipment.

2.3.3.1 Facilities and equipment

Participants perceived environmental influences on calf weaning and rearing outcomes, including the effects of facilities and equipment. Farm facilities were thought to have an important influence. Space limitations were mentioned with emphasis on keeping calves moving through the rearing system. P_18 said, “We're trying to cycle as many calves through the facilities that we have, without losing body weight or conditioning...” P_61 noted that while not ideal for calves, moving calves to different pens often was necessary due to space limitations, “We do move them quite a bit, which is not always ideal, but it is what it is, because it's what we have for facilities.” Some producers felt that modifications to barns could help calves transition, “…when we changed the barn, one of the goals was to make the transition from the calf, baby calf stage, to the heifer barn more smooth” (P_79). Ventilation was recognized as crucial to calf health, with poor ventilation perceived as a risk for respiratory illness. Participants who had improved ventilation reported decreased pneumonia: “We did have quite a bit of pneumonia in our calf barn prior to putting a positive pressure tube in” (P_70) and “[We] went to a positive pressure air tube about a year ago. And that's probably been one of the biggest improvements on our calf rearing, minimizing pneumonia” (P_38). The presence of respiratory disease has been reported to be influenced by ventilation and housing style, along with other management factors (e.g., colostrum management, nutrition, and weaning strategies) (Lago et al., 2006; Gorden and Plummer, 2010). Calf housing style (e.g., individual, group, pair, or nurse cow) and cleanliness were also viewed as contributing to rearing success, but views varied regarding preferred housing systems. Some participants preferred to rear calves individually citing perceived health benefits and ease of monitoring; “…with the hutches. I can definitely see how much they eat. And I feel like that's a huge thing for me” (P_83). However, other participants felt that group

housing improved a calf's ability to transition at weaning and increased play behaviour: "…we used to find when we took our calves out of hutches, they had never experienced anything but being in a hutch. So now they're in pairs. And then in groups…So our transition is very smooth." (P_79) and "They're kicking up their heels and bellering and you just see they're having fun; they're playing with each other. So, I [would have] a really hard time putting calves back in a hutch when I see how well they do in a group setting" (P_44). Reduced fear responses and increased play are known benefits of social rearing for calves (Costa et al., 2016).

Increased milk allowances are associated with the method of milk delivery; producers who utilize AMF tend to feed higher milk allowances than those who use manual milk feeding systems (Medrano-Galarza et al., 2017). The use of AMF and milk pasteurizers were viewed as having value to participants who utilized these. Participants with AMF commented on their ability to manage milk allowances for sustained growth: "So basically, a success in our barn is the milk feeder and utilizing proper feeding at a young age" (P_74). Participants who had AMF believed weaning calves using a computerized system was easy: "The computer feeders are really good for that because they really can just slow down the milk consumption and the calves slowly drink more water and [eat] more feed" (P_18) and "…that's the part I love about the milk feeder. I mean don't have to sit and think about, 'okay, you're being weaned…' the program does it for me." (P_74).

2.3.4 Integration of external farm support

Participants discussed how external farm support affected calf rearing, including relationships with veterinarians and peers, and educational opportunities.

2.3.4.1 External advice

It is important that farm support comes from those who are known to the producers and understand what occurs on farm (Croyle et al., 2019). Participants considered veterinarians as trusted advisors to calf rearing; a finding that is similar to that reported by Sumner et al. (2018b). A few of the participants were enrolled in calf programs with their veterinary clinic, which included testing immunoglobulin G levels, weighing calves, administering vaccinations, and disbudding. Those enrolled in these programs conveyed that their veterinarian was a resource for monitoring calf health and growth. Similarly, previous work has identified veterinarians as trusted advisors for animal health and management (Chase et al., 2006; Pothmann et al., 2014). Overall, participants found it important to have a good relationship with their veterinarian. One participant found value in their veterinarian's background as a dairy farmer, "…our vet[erinarian] always says our calves look great. And [the veterinarian's] a dairy farmer, or he's from a dairy farming family, so he gets the whole thing about calves" said P_72. Fostering a good relationship with the veterinarian helped build trust, an essential component of the farmer-veterinarian relationship, facilitating changes on farm (Bard et al., 2019; Svensson et al., 2019).

Not all farms and participants had access to calf monitoring programs. One participant (P_43) reflected on their struggle accessing this service, "…my vet[erinarian] has some strengths, but he has some weaknesses too. And I don't really see him as that detail guy who wants...to set up a program. Let's say it's on young calf health, and really monitor all those things, it's not really in his wheelhouse..."

In addition to veterinarians, advice from peers was described as valuable. Peers were identified as other dairy producers and those involved with the dairy industry. Participants

looked to peers for advice on feeding and weaning, equipment, and methods of observing calf growth and health. Access to a network of peers can be important to producers as a form of information sharing (Galdino Martínez-García et al., 2014) and has been regarded by veterinarians as an opportunity for learning and a motivator for change (Roche et al., 2019). Moreover, producers identified as proactive, defined as those who are well informed and interested in new developments, find advice from peers especially helpful (Jansen et al., 2010). The use of benchmarking, which compares performance among peers with the intent to improve performance of specific indicators, can be an effective way of motivating behavioural change in dairy producers (Chapinal et al., 2014; Sumner et al., 2018a). Furthermore, the curation of benchmarking with guidance from veterinarians can strengthen producers' perceptions of the veterinarian as an advisor in calf management (Sumner et al., 2020). Previous work on colostrum management found that the majority of participants made at least one change to their colostrum management program after receiving benchmark reports, suggesting that having identifiable measurements can assist in achieving change (Atkinson et al., 2017). Future research should examine the effect of benchmarking calf performance around weaning on improving management practices during this period.

2.3.4.2 Educational opportunities

Participants viewed seminars, conferences, and industry publications as useful resources in developing calf rearing practices, as was reported by Wilson et al. (2021). P_61 described how information at a conference prompted the development of the milk feeding and weaning program they used, "When I first came in with my husband… they didn't really have a weaning practice. My father-in-law went to a conference, and they talked about going up and then taking the milk

down… So, then he started that [weaning program].” The use of conferences to make informed decisions shows the need for extension opportunities. The expansion of learning opportunities to producers through extension should be considered as extension training has been shown to have a positive impact on farmer adoption of practices (Baumgart-Getz et al., 2012). One participant (P_16) made the decision to pair house calves based upon an article they read in an industry publication, “I read an article in the Progressive Dairyman that basically went over all of the calf raising and pair raising benefits…I said, ‘Okay, I definitely need to keep on this [group housing]. I can't revert back. I want to keep it up’, because I felt that those things were important benefits for the calves.”

2.4 General discussion and conclusion

The findings from this study provide insights into producer views on calf rearing, focusing on the weaning period. However, there are limitations to this study. Data collection took place during the COVID-19 pandemic and participant recruitment was limited to producers who were willing to be interviewed over video or telephone call. In addition, the pandemic brought uncertainty for some participants that may have affected calf management. The results from this study are not intended to be generalizable. Participants in this study were Western Canadian dairy producers who reared replacement stock on farm, many of whom were familiar with the University of British Columbia’s Animal Welfare Program and Dairy Education and Research Centre. Results may be different for other participants, including those who dairy farm in different regions of the world.

We found that producers characterized weaning and rearing success using multiple factors. Firstly, participants relied on calf-based indicators such as calf growth, health, and

behaviour, to determine weaning and rearing success. Secondly, management practices such as employee management, and personal experience were regarded as important influences on how calves were weaned and reared and represented as both successes and challenges. Finally, the rearing environment, equipment, and external advice were also viewed as contributing to overall rearing success.

Table 2.1 Farm demographics

Participant ID	Number of employees[1]	Number of milk cows	Breed
P_10	5	160	Holstein
P_12	7	105	Holstein
P_16	7	150	Holstein
P_18	14	535-540	Holstein
P_24	3	75	Holstein
P_28	5	120	Holstein
P_38	4	260-270	Holstein
P_38_1	-	-	-
P_43	Not stated	120	Holstein
P_44	4	75-80	Holstein
P_61	Not stated	460	Mixed[2]
P_61_1	-	-	-
P_70	5	140-150	Mixed[2]
P_72	7	105-115	Holstein
P_74	7	78-90	Mixed[2]
P_77	3	103	Holstein
P_79	5	200	Holstein
P_83	7	180-200	Mixed[2]

[1]Number includes participant(s) and family labor.

[2]Mixed includes Holsteins and one or more of Jersey, Fleckvieh-Montbéliarde, and/or Brown Swiss breeds.

Table 2.2 Calf rearing practices as presented by dairy producers who participated in an interview-based study

	Milk feeding			Weaning	
ID	Method	Type	Amount per day	Age	Method
P10	Bucket with nipple	WM	8L/d	2-3.5 mo	"batch" wean, some "cold turkey"
P12	Bottle	WM	6L/d[1]	9 wk	3L/d[2] (wk 7-9)
P16	Bottle	WM	8L/d	3 mo	Step down over 3 wk
P18	Bottle & AMF	WM	2-5L/d (wk 1-2), 2.5L/2hr (wk 2-3), 8L/d (5-7 wk)	57 d	Step down
P24	Bucket	WM	4L/d	4 mo	Abrupt
P28	Bottle & bucket	MR	4L/d (wk 1-2), 6L/d (wk 4-5), 8L/d (wk 5-7.5)	≈ 8 wk	4L/d for 10 d. Abrupt to 0L/d at 8 wk
P38 & P38_1	Bottle & bucket	MR	8L/d	8 wk	Gradual from wk 6-8
P43	Bottle	WM	4.96L/d	90 d	Abrupt
P44	Nurse cow	WM	Unknown	2-2.5 mo	Gradual removal from cow
P61 & P61_1	Bottle & bucket	WM	4L/d (wk 1-2), 5L/d (wk 3), 6L/d (wk 4-6)	2 mo	.5L/wk reduction over 2.5 wk
P70	Bottle	WM	12-16L/d[1] (1-8wk)	9-13 wk	.5L/d over 6-7 d
P72	Bottle	WM	6-9L/d	≈ 2-3 mo	Step down. 6L/d (1 wk), 4L/d (1 wk), water (1 wk)
P74	Bottle & AMF	MR	6L/d (wk 1), 2L/hr (1-5wk)	59 d	9L/d from d 35-45, 2L/d reduction to d 56-59
P77	Bottle & AMF	MR	12L/d (d ≈ 5-43), 6L/d (d 43- 83)	90 d	Milk reduced over 1 wk
P79	Bottle & group milk bar	WM	8L/d (summer) and 12L/d (winter)	Youngest calf 60 d	Step down over 7-10 d.
P83	Bottle	MR	6L/d	3-4 mo	3L/d (5-7 d)

Abbreviations: Whole milk (WM), Milk replacer (MR). [1]Additional is milk variable, [2] Milk reduction is variable.

Chapter 3: **General discussion and conclusion**

3.1 Thesis Summary

In Chapter 1, I reviewed literature on calf and heifer rearing, including colostrum feeding, milk feeding, housing, and weaning. I also discussed literature that has used qualitative methods to investigate the attitudes of stakeholders that can affect animal care outcomes. On farm calf weaning and rearing practices vary greatly despite a wealth of science-based evidence that indicates that certain practices should be favoured (Vasseur et al., 2010; USDA, 2016). Some recent research has begun to focus on producer attitudes, views, and perceptions toward specific management practices (dehorning, Cardoso et al., 2016; cull cow management, Roche et al., 2020; male dairy calf care, Wilson et al., 2021; pasture and outdoor access, Smid et al., 2021), but little work to date has investigated how dairy producers view calf and heifer rearing.

In Chapter 2, I described the views of Western Canadian dairy producers on calf and heifer rearing, focusing on the weaning period, with the aim to understand how producers characterize weaning success. I took a qualitative approach and interviewed individuals who were directly responsible for calf care on dairy farms. My research identified four major themes associated with calf and heifer rearing and characterization of weaning success: 1) reliance on calf-based indicators, 2) management and personal experiences, 3) environmental influences, 4) integration of external farm support.

Calf-based indicators included growth, vocalizations, health, and behaviour. Weaning success was characterized by the continuation of calf growth before and after weaning, the ability to consume solid feed before weaning, and the behavioural reaction of the calf at weaning (e.g., indicators of stress including vocalizations). These factors also played a role in how participants viewed overall rearing success. For example, participants identified calf affective

states (e.g., reduced stress and signs of happiness) throughout the milk-fed phase and at weaning as indicators that a rearing program was working well.

Management and personal experiences also played an important role in the how participants viewed calf rearing. Certain management practices (e.g., hired employees for calf care) were viewed as helpful in ensuring rearing success. However, some participants attributed the challenges they faced to time and employee management. One surprising finding was the difference in observation and care of milk-fed versus weaned calves. The observation and care of young calves was of high importance for many of the participants, but after weaning this appeared to wane. Participants stated that they were not too concerned about the performance of weaned calves when they moved onto the next phase of rearing. Previous work has also indicated that calf management is ranked as being more important to producers than heifer management (Bauman et al., 2016). As mentioned in previous chapters, there is evidence showing how the milk-feeding phase is important for long-term outcomes (Davis Rincker et al., 2011; Heinrichs and Heinrichs, 2011; Van De Stroet et al., 2016), but little is known about the importance of management factors after weaning and before first breeding. Future research should assess how farmer attitudes towards this age class of animal affect aspects of their care. Other work may be required to better understand the economic impact of different management practices for heifers, as producer interest can be affected by perceived economic outcomes (e.g., Leach et al., 2010).

Housing was perceived by participants as playing a role in how calves were weaned and reared. More specifically, facilities such as barns and housing style (e.g., individual, and social housing) were perceived as important influences on calf-based outcomes such as calf growth, feed consumption, and weaning success. The use of equipment such as AMF was seen to provide opportunities to feed calves more milk, and wean calves in methods that contributed to weaning

success, similarly seen by Medrano-Galarza et al. (2017). On this basis, I would expect that milk feeding and weaning practices will change with increased adoption (reviewed by Costa et al., 2019) of automated calf feeding systems (i.e., AMF and concentrate feeders).

Finally, external farm support was viewed as important in the implementation of practices that contribute to a successful rearing program. Relationships with veterinarians, including enrollment in calf monitoring programs through vet clinics, were viewed as helpful in monitoring and ensuring rearing success. The influence of peers and access to research via conferences and industry publications was also viewed as important to the adoption of practices that contributed rearing success. Participants' method of acquiring information from research highlights the need for additional extension. Historically extension efforts have been based on top-down transfer of information, where scientists relayed information to extension agents, who then communicated directly to farmers (Black, 2000). However, a bottom-up approach which takes into account producer (participant) involvement may increase farmer understanding of 'best practices' (reviewed by Knook et al., 2018) and better influence producer behaviour (Johne's disease control, Roche et al., 2015). Future research should consider how producers receive information that is used to adopt practices, and what producers find to be helpful in the translation and applicability of research on farm.

3.2 Strength and Limitations

This thesis adds to the body of literature on rearing dairy calves and heifers and serves as a steppingstone for future investigations into calf rearing on farms. In the following section I will discuss the strengths and limitations of this thesis and provide suggestions for future research.

3.2.1 Strengths

The use of qualitative methods can be viewed as a strength of this thesis as it provides a unique view into calf and heifer rearing on farm. Lund et al. (2006) suggests approaching animal welfare from multidisciplinary approach, combining natural sciences with social sciences, with the understanding that animal welfare is a complex working of social and ethical factors. Existing literature on calf and heifer rearing provides science-based options on how to rear calves in ways that can satisfy animal welfare. For example, feeding calves more milk via teat and weaning gradually has been shown to reduce non-nutritive sucking, improve weight gains and decrease signs of hunger (De Passillé and Rushen, 1997; De Paula Vieira et al., 2008; De Passillé et al., 2011b; Rosenberger et al., 2017). Producers have the direct ability to implement these practices. Belage et al. (2019) investigated the barriers to the adoption of milking practices for the prevention of mastitis and found that adoption was limited by both intrinsic (e.g., change of habits, perception of the issue, and misconceptions around the issue) and physical (e.g., employees, finances, and infrastructure) barriers. Similarly, in Chapter 2, I found that participants recognized what Belage et al. (2019) noted as "intrinsic" and "physical" factors affecting calf weaning and rearing. For example, habit and personal experience, as well as facilities and housing style were recognized as barriers and opportunities in implementing new practices. Understanding what producers see as important factors in calf rearing can be useful in addressing why practices occur on farm and how to best assist producers with the adoption of new practices. The work from this thesis provides an introductory understanding of producer views towards calf rearing, with a focus on weaning, and can help inform future research and extension opportunities.

3.2.2 Limitations

My qualitative approach provided novel insight into calf and heifer rearing on farm, but there are several limitations with my approach. Firstly, I used a convenience sample from industry contacts, this was due to time constraints and the impossibility of in person recruitment because of the COVID-19 pandemic. This convenience sample limits my ability to generalize conclusions; my results should be seen as reflective of the specific individuals who participated (Robinson, 2014).

Secondly, I also recognize that some producers may be more comfortable participating in research studies than others. Participants in my research may have been more willing to participate as many were familiar with the UBC Animal Welfare Program (e.g., through previous participation in studies, personal contacts, engagement at conferences) and were actively engaged in the dairy community (e.g., through breed associations and nutrition companies). Future research should consider the different types of participants targeted for recruitment and strive to include producers who may be considered harder to reach. However, it should be noted that "hard to reach" producers are not one unified group and different communication strategies may be necessary (Jansen et al., 2010)

Thirdly, the study described in Chapter 2 was designed and conducted during the COVID-19 pandemic, while health and travel restrictions were in place. This meant that interviews took place over either video or phone calls, based on participant preference. Internet-based research is not a new concept and participant perceptions of video-based interviewing have been reported to be positive (Archibald et al., 2019). However, there are limitations to using this method. One limitation is the availability of access to a stable internet connection, which can be sometimes difficult in rural locations. Another limitation to conducting interviews over video

call is the recognition of non-verbal cues (Iacono et al., 2016). Over video call facial expressions are visible, but overall body language can be difficult to read (Seitz, 2016). For an interviewer, being able to read participant body language can provide information on how to proceed with interview questions with respect to participants' comfortability (Price, 2002). Despite these limitations, I consider the phone or video calls as valid methods of data collection (Krouwel et al., 2019; Saarijärvi and Bratt, 2021).

3.3 Future directions

3.3.1 Understanding farm-to-farm variation in rearing practices

In Chapter 2, I found that calf housing, feeding, and weaning practices varied by farm (Table 2.1). More specifically the duration of "gradual" weaning methods varied from 10 d to 3 wk with milk reductions ranging from 0.5 L/wk to 2L/d, and some milk reductions were left unspecified. Variation in calf weaning practices suggests that clarification of what is considered 'gradual', and what is the most optimal weaning duration, may be necessary. My review of the literature on gradual weaning also showed considerable variation in the approaches adopted, suggesting a lack of scientific consensus. Calf age at the start of weaning should be considered, as calves weaned at older ages from higher milk allowances have improved pre-weaning weight gains relative to calves weaned early from restricted milk allowances (Eckert et al., 2015; Mirzaei et al., 2018). Work by Khan and colleagues (2007) suggests weaning with a step-down method. This method has been adapted by other researchers to incorporate individualized weaning based on solid feed intake (Benetton et al., 2019) However, this method is most suitable using AMF and automated grain feeders, technology that is not always accessible to dairy producers.

3.3.2 Measuring success

Based on the findings from Chapter 2, producers viewed calf-based measurements (e.g., growth, health, and behaviour) as indicators of weaning success and overall, how well their rearing program was working. Management, environmental influences, and farm support were also considered important components to calf and heifer rearing success. To the best of my knowledge, no study has investigated the combination of practices that contribute to calf rearing success on commercial dairy farms. Future research could investigate weaning procedures used on farms with consideration of weaning age, milk allowances and other rearing factors (e.g., housing and milk delivery method). For example, increasing adoption of social housing and technologies like automated feeding systems may allow farmers to implement more individualized weaning programs. However, additional research is needed on individualized weaning procedures to determine what techniques are beneficial for calves and practical for producers.

One way to further investigate the effects of different calf weaning practices on farm would be to conduct a benchmarking study. Benchmarking performance measures (e.g., growth and feed intakes), and comparing this to peer performance, can promote engagement and improvements in practices (Bhutta and Huq, 1999). Benchmarking has been used to evaluate dairy farm practices (cow comfort, von Keyserlingk et al., 2012; lameness, Chapinal et al., 2013). Benchmarking has also been used to evaluate producer behavioural change in regards to colostrum management (Atkinson et al., 2017; Sumner et al., 2018). Sumner and colleagues (2018) used the theory of planned behaviour to identify producer motivations to improve calf management and concluded that benchmarking can help change producers' behaviour. To the

best of my knowledge, no one has conducted a benchmarking study that measures calf outcomes before and after weaning. This would provide a better understanding as to what practices are successful, and how to promote the adoption of successful practices on farm.

In addition, participatory methods could be incorporated to engage participants with the design of an on-farm calf rearing study. The design of the study described in Chapter 2 was crafted by a review of the literature on calf and heifer rearing, and my interest in weaning. Future research may benefit from adopting methods that allow for participant involvement in the development of the study design, objectives, and data collection. While not widely utilized in dairy cattle research, participatory research is thought to promote engagement from participants, providing a sense of ownership (Jones et al., 2016). Participatory research can build trust between producers and researchers through involvement in research activities and fosters an environment for collective learning of new strategies (Aare et al., 2021). Recent work by Mills et al. (2020) investigated the role of advisors on the development and adherence of SOPs by incorporating participatory methods in the development of farm specific SOPs for newborn calf care. I suggest that futures studies ask participants (i.e., producers) to assist in identifying research questions and data collection (e.g., calf weight, feed intake, and health measurements).

3.4 Conclusion

I investigated calf and heifer rearing from a qualitative approach by interviewing dairy producers from Western Canada. I found that dairy producers rely on calf-based measures for characterizing weaning and rearing success. However, there is recognition that other factors play important roles including management and personal experience of the producer, environmental influences, and external farm support. The use of qualitative methods provided a detailed

description of producer views. Future work may benefit from applying both qualitative (e.g., stakeholder views, attitudes, perceptions, and motivations) and quantitative methods (e.g., calf and heifer-based measurements) to measure rearing success on farm.

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Appendices

Appendix A Semi-structured Interview Guide- Calf Weaning Study

A.1 Introduction

Hello (participants name/ID) thank you for meeting with me and agreeing to participate in this interview. I'm very appreciative of your time and I look forward to hearing your thoughts.

A.2 Introduction to UBC & Interviewer

My name is (interviewer name) and I'm a master's student at UBC with the Animal Welfare Program. For my masters project I will be interviewing dairy farmers to better understand how they define weaning success and the perceived challenges to raising calves (including weaning) successfully. This interview will consist of a series of questions that I would like to hear your thoughts on. I expect the whole interview will take about one hour.

A.3 Inform interviewee of confidentiality, anonymity, and rights to not answer and stop the interview

The research team will respect your confidentiality and any information that discloses your identity will not be released without your consent unless required by law. Participants and farms will not be identified by name in any report or publicly available material, and we will not use quotes that enable the reader to identify study (i.e., through personal information or manner of speaking). You do not have to answer any questions if you do not want to and can terminate the interview at any time.

A.4 Consent (oral) to participate and for audio recording

With your permission I would like to audio record our discussion to ensure that I'm getting an accurate record of your thoughts.
Oral Consent:

1. Do you give your permission for me to interview you?
2. Do you give me your permission for me to audio record our interview?
3. Do you give me your permission for me to video record our interview?
4. Do you give your permission for me to re-contact you to clarify information?
5. Are you happy to take part in the study?

Ask if the participant has any questions

A.5 Conversation starter/demographics

1.) Where do you live?

2.) How long as the dairy been operating?

3.) What role do you play on the farm?

   a. Do you have family involved?

   b. Do you have employees?

      i. How many employees do you have?

4.) Do you mind if I ask how old you are?

5.) Do you hold any degrees or certificates?

6.) How many cattle do you have on the farm?

A.6 Qualitative Questions

1.) Could you briefly describe to me how you raise a calf from newborn to 1st breeding?
   a. Operational details (may be covered from above or questionnaire)
   Prompts:

      i. How do you feed your milk-fed calves?
      ii. How do you wean your calves?
      iii. Do you monitor intake?
      iv. Do you monitor body growth?

2.) At what point does a calf become defined as a "heifer"?
   Prompts:

   a. *After leaving the calf barn/raising area*
   b. *At weaning*
   c. *At a certain age (i.e., breeding age)*

3.) Why do you use these (insert the type) weaning practices?

4.) What are the key challenges that you face when raising calves from newborn calf to first breeding on your farm?

5.) What are the key challenges that you face when weaning calves on your farm?

6.) What are the practices you see as being successful for your farm when it comes to raising calves from newborn to first breeding?

7.) What do you see as being successful practices when it comes to weaning calves on your farm?

8.) Can you describe to me how you would define a successful weaning?

9.) What are you most proud of regarding your weaning program? What would you like to change the most?

10.) What are the barriers to implementing these changes?

11.) Relative to all other priorities for your farm, how important is calf care and rearing?

12.) If you were to pass your farm down to the next generation, say 30-50 years from now, what is your vision for the farm regarding calf and heifer raising?

Prompts:

a. *What are the challenges you see to achieving the vision you have?*
b. *What or who do you think will drive the changes?*

13.) Do you have any last thoughts on calf weaning and heifer rearing?

A.7 Conclusion

This concludes the interview. Thank you for your participation. I encourage you to reach out if you have any questions or want to follow up.