The effect of solid feed diet on the oral and cross-sucking behaviour of pre-weaned dairy calves

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Abstract

In the dairy industry calves are most frequently artificially reared in groups, which create a greater opportunity for solid feed consumption and non-nutritive oral behaviour. This study aimed to compare the effect of differing solid feed diets on the pre- and post- weaning feed intake, growth rate and oral behaviour of calves reared artificially in groups. This experiment was a randomised block design with the treatments diets allocated at random, in blocks. The research was completed at Massey University's dairy calf unit #4 and involved 108 Friesian and Jersey x Friesian dairy calves that were allocated to one of three treatment diets: lower forage (LF) alfalfa total mixed ration (TMR); a higher forage alfalfa (HF) TMR; and perennial ryegrass hay along with a pelleted starter (HPS). Calves were reared in 36 groups of three calves per group and monitored until 12 weeks of age. Calves fed HPS had the greatest dry matter intake (LF: 0.80 (0.012), HF: 0.95 (0.012), HPS: 1.70 (0.011) kg/DM/d), live weight at 40 d of age (LF: 60.3 (1.41), HF: 63.8 (1.41), HPS: 67.1 (1.38) kg) compared with TMRs. These calves also spent the most time eating (LF: 129.1 (0.14), HF: 163.7 (0.14), HPS: 154.1 (0.14) mins/d), and spent the least amount of time engaged in non-nutritive pen sucking (LF: 13.4 (0.16), HF: 11.2 (0.17), HPS: 10.3 (0.16) mins/d). It was concluded that, while cross-sucking was not entirely eliminated, providing perennial ryegrass hay along with a pelleted starter resulted in the least non-nutritive sucking behaviour, along with the greatest feed intake and growth rates compared with low and high forage alfalfa based total mixed rations.

Key words: Calves, Growth, Intake, Behaviour, Sucking

Glossary of frequently used abbreviations

ADF:	Acid detergent fibre
AR:	Artificially reared
CP:	Crude protein
BW:	Body weight
d:	day(s)
DE:	Digestible energy
DM:	Dry matter
DMI:	Dry matter intake
g:	gram
h (s):	hour (s)
hd:	head
HF:	High fibre
HW:	Hip width
kg:	kilogrammes
L:	Litre(s)
LF:	Low fibre
LWT:	Live weight
ME:	Metabolizable energy
Min (s):	Minute
MR:	Milk replacer
NDF:	Neutral detergent fibre

NZ:	New Zealand
PH+S:	Pasture hay and starter diet
TDN:	Total digestible nutrients
TMR:	Total mixed ration
WM:	Whole milk

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Chapter 1.0 Introduction

In New Zealand (NZ), the dairy industry makes up a large proportion of the agricultural industry, with a total of 11,798 dairy herds and 4,634,226 cattle recorded to be involved in dairy production within New Zealand (Dairy NZ and LIC statistics, 2012). This represents approx. 1.6 million hectares being employed in dairy farming, which produced approximately 19.1 billion litres of milk in the 2011/12 milk production season (Dairy NZ and LIC statistics, 2012). The amount of animals and land involved in dairy production has been steadily increasing over recent years leading to a wider range of management systems being employed and increased concern regarding animal welfare. The NZ Animal Welfare Act of 1999 follows the five freedoms of welfare: freedom of hunger and thirst; freedom from discomfort; freedom to express normal behaviour; freedom from fear and distress; and freedom from pain, injury and disease.

In NZ dairy systems, calves are separated from their dams within hours of birth and reared by artificially feeding milk typically through teats (Hammell et al., 1988; de Passillé, 2001; Chua et al., 2002; Veissier et al., 2002; Margerison et al., 2003; Roth et al., 2009), less commonly by drinking milk from buckets and pails (Lidfors, 1993; Appleby et al., 2001; Jensen, 2003) and increasingly automatic feeding machines (Wendl et al., 1997; Weber and Wechsler, 2001; Jensen, 2003; Roth et al., 2009, Froberg et al., 2011). The raising of any animal in an unnatural situation, leads to the behaviour and welfare of the animal being of greater public and management concern (Keil et al., 2000). In artificially reared calves, animal health (de Passillé, 2001; Rushen et al., 2010), the adequacy and appropriateness of nutrition (Coverdale et al., 2004) and the ability of the animal to perform natural behaviour (de Passillé, 2001; Rushen et al., 2010) are major concerns.

Neonatal calves have a natural innate motivation to suckle (de Passillé, 2001) and calves that are not allowed to suckle naturally, behaviour such as cross-sucking of other calves (de Passillé, 2001; Weber and Wechsler, 2001; Jensen, 2003; Margerison et al., 2003; Nielsen et al., 2008; Roth et al., 2008) and non-nutritive sucking of inanimate objects (Keil and Langhans, 2001; Margerison et al., 2003; Nielsen et al., 2008; Roth et al., 2008) have been found to be more prevalent. The continued cross-suckling following weaned from milk and in adult animals within the lactating dairy herd can be detrimental to the health and welfare of other animals and lead to negative effects such as; mastitis, teat damage, milk stealing and udder malformation (de Passillé, 2001; Keil and Langhans, 2001).

Farm surveys carried out in various studies have found that cross-sucking was observed in artificially reared (AR) dairy calves in between 93 % and 94.3 % of the farms observed (Keil et al., 2000; Keil et al., 2001; Lidfors and Isberg, 2003). Over 90 % of the calves in a study carried out by Keil and Langhans (2001) showed cross-sucking behaviour pre-weaning. It has been found that on average between 55 % (Keil et al., 2001) and 85 % (Roth et al., 2008) of calves on individual farms were observed cross-sucking at some stage. The majority of cross-sucking occurred pre-weaning, during the milk weaning phase, and throughout the first year of the animal's life (Lidfors and Isberg, 2003). Keil et al. (2000) carried out a farm questionnaire and found that 61.5 % of farms had heifers that were inter-sucking heifers, whereas a survey completed by Keil et al. (2001) found that 11.1 % of heifers performed inter-sucking, indicating variations between farms and the existence of factors that affect the amount of cross-sucking AR calves undertook. Keil et al. (2001) reported 26.3 % of farms had adult cows that inter-sucked, however only 1.6 % of the total number of cows observed cross-sucked. This data supports the theory that cross-sucking developed pre-weaning, could become habitual and was linked to inter-sucking in growing heifers post-weaning and in adult cows in the dairy herd.

Dairy cattle are herd animals and the development of social behaviour in calves is an important factor in the management of dairy heifers (Phillips, 2004; von Keyserlingk et al., 2004; Hepola et al., 2006; Jensen and Budde, 2006). Under commercial farm practice calves can be reared individually, in pairs or in groups for the first few weeks of life, however national welfare guidelines vary regarding tethering and individual housing, and many require individually reared calves to have sight, sound, and some contact with other calves (Keil et al., 2001; Chua et al., 2002; Jensen, 2003; Jensen and Budde, 2006; Rushen et al., 2010) and stipulate that older calves, from 12 weeks of age, should be housed in groups to facilitate social development (Keil et al., 2001; Jensen, 2003; Rushen et al., 2010). Housing calves individually can reduce cross-sucking and aggressive behaviour, however this will not allow calves to develop social behaviours and, depending on space allocation, provide the calf with sufficient space to exercise (Chua et al., 2002; Jensen and Budde, 2006; Rushen et al., 2010; de Paula Vieira et al., 2010).

The practice of group rearing and giving individually reared calves direct access to other calves allows calves the opportunity to suck on other calves and the area of the body sucked depends on the access provided and the preference of the calves involved. As a consequence, housing management practices are key factors involved in limiting the amount of access calves have to each other and thus cross-sucking that occurs in AR calves. Group housing of calves has become more common in commercial systems, due to benefits of lower labour requirements, more frequent use of mechanical feeders, and the need to allow social interaction between calves; however, cross-sucking is practical problem associated with rearing calves in groups. Whereas rearing calves individually, isolated from others with no contact with or sight of other calves impedes the social development of the calf, having indirect consequences in later life due to the social dominance cattle have (Bøe and Faerevik, 2003).

It is more efficacious to reduce the occurrence of cross-sucking in artificially reared calves (Lidfors, 1993; de Passillé, 2001; Laukkanen et al., 2010; de Passillé et al., 2011). Veissier et al. (1998) concluded that feeding conditions are more important than housing conditions in limiting non-nutritive behaviours. Once a cross-sucking relationship has become established, these can become habitual in a small proportion of animals (Lidfors and Isberg, 2003; Jensen and Budde, 2006; Roth et al., 2009; de Passillé et al., 2011;) and various methods that can be applied to prevent cross-sucking in calves include the following: feeding milk through a teat (Appleby et al., 2001; Loberg and Lidfors, 2001; Chua et al., 2002; Veissier et al., 2002; Margerison et al., 2003; Jensen and Budde, 2006), use of automatic milk feeders (Weber and Wechsler, 2001; Veissier et al., 2002; Roth et al., 2009), slower milk flow rate (Haley et al., 1998; de Passillé and Rushen, 2006), increasing the amount of milk provided (de Paula Vieira et al., 2008; Nielsen et al., 2008; de Passillé et al., 2010; de Passillé et al., 2011), providing the appropriate energy level in the diet (Roth et al., 2009; de Passillé et al., 2010), the provision of access to concentrate and forage directly following milk feeding (Lidfors and Isberg, 2003; Hepola et al., 2006; Roth et al., 2008), access to a dry teat after a milk meal (Veissier et al., 2002; de Paula Vieira et al., 2008; Ude et al., 2011;), environmental enrichment (Keil et al., 2000; Lidfors and Isberg, 2003; Ude et al., 2011) and gradual weaning (Nielsen et al., 2008; Roth et al., 2008; de Passillé et al., 2010). The correct feeding management during weaning, can greatly reduce the amount of cross-sucking that occurs and this detrimental behaviour can be reduced by increasing solid feed intake by providing access to a starter concentrate and forage source immediately after a milk meal and allowing free access to these feed continually (Haley et al., 1998; Hepola et al., 2006; Roth et al., 2008; Roth et al., 2009), however, comparing the effect of access to differing solid feeds on cross-sucking has not been carried out. Therefore, the aim of this research was to assess the effect of offering calves access to differing starter diets, from the first week of life, on the occurrence of cross-sucking behaviour in group reared dairy calves.

Chapter 2.0 Review of relevant literature

2.1 Natural suckling behaviour of calves

Suckling is essential for calf survival, health, growth and social bonding and as such, it is an innate behaviour (de Passillé, 2001; Roth et al., 2009), and its deprivation in AR calves can result in considerable frustration and have a negative impact on the welfare of these animals (de Passillé, 2001; Phillips, 2004; Nielsen et al., 2008). Calves reared on the dam, up to twelve weeks of age (Lidfors et al., 2010), suckle as many as ten times each day (Spinka and Illmann, 1992), with suckling bouts lasting from seven to twelve minutes each, resulting in suckling occupying approximately 72 minutes of the day (Spinka and Illmann, 1992; Jensen, 2003; Lidfors et al., 2010). The frequent consumption of milk throughout the day is known to have a positive impact on the digestive system, due to the stimulation of the ruminoreticular groove and metabolic hormones (Appleby et al., 2001) by the act of suckling.

Dairy calves suckled on the dam have shown three distinct suckling phases, starting with pre-suckling stimulation of the mammary gland, followed by suckling and finished with post-suckling stimulation of the mammary gland (Nielsen et al., 2008; Lidfors et al., 2010). The pre-stimulation of the mammary gland consists of butting and some short non-nutritive sucking bouts on the mammary gland, important for initiating milk let down; while suckling was a longer phase, made up of suckling and rhythmical, low occurrence butting used for increasing milk flow rate and milk ingestion rate (Jensen and Budde, 2006), and finally, post-suckling stimulation of the mammary gland consists of non-nutritive sucking bouts, in which a higher amount of butting occurs ensuring that milk was fully removed from the mammary gland in order to maximize milk production and reduce mastitis (de Passillé et al., 1997; de Passillé and Rushen, 2006a; Nielsen et al., 2008; Lidfors et al., 2010). This also ensuring the calf consumes milk of a higher fat concentration, resulting in the consumption of a greater amount of energy and higher growth rates (Margerison et al., 2003).

2.2 Suckling motivation and milk related factors affecting time spent suckling

Suckling motivation is thought to arise from tactile, auditory, gustatory and visual stimuli (Hammell et al., 1988, Margerison et al., 2003). However, the actual ingestion of milk, including the taste of milk, is responsible for the initiation and continuation of suckling behaviour (De Passillé et al., 1991) with relatively small amounts of milk or milk replacer (5 mL) being required to elicit suckling behaviour (De Passillé et al., 1997). The taste of milk, stimulation of the rumo-reticular reflex and a slight distension of the stomach, due to milk ingestion; lead to the positive feedback and reinforces the continuation of suckling behaviour (de Passillé et al., 1991; de Passillé and Rushen, 2006b). This positive feedback was thought to ensure that calves drink sufficient amounts of milk to effectively and fully remove milk from the mammary gland of the dam and encourage calves meet their nutritional requirements (de Passillé and Rushen, 2006a). In terms of meeting nutritional requirements, increasing the milk replacer (MR) concentration from 40, to 120 and 360 g/l of water (de Passillé et al., 1997) and doubling the lactose concentration (De Passillé and Rushen, 2006b) increase the time calves spend suckling. Furthermore, milk lactose was found to be the main factor eliciting suckling behaviour (Rushen and de Passillé, 1995; de Passillé, 2001; Veissier et al., 2002), whereas milk protein concentration had no effect on suckling behaviour (De Passillé et al., 1997).

The feeling of hunger enhances suckling motivation (Roth et al., 2008); and calves that missed one meal of milk spent a greater amount of time suckling at the following milk feed (Rushen and de Passillé, 1995). The ingestion of milk creates some satiation and elimination of hunger, but does not eliminate suckling per se; indicating factors other than hunger and milk ingestion are involved in suckling motivation (Hammell et al., 1988). In calves, digestive hormones, such as cholecystokinin (CCK), insulin and gastrin (Veissier et al., 2002) have been shown to be secreted following milk feeding and were stimulated by suckling (de Passillé et al., 1991; de Passillé et al., 1993) and sucking a dry teat (de Passillé et al., 1992; Lidfors, 1993; de Paula Vieira et al., 2008). These hormones act as a negative feedback and satiety mechanism, which decreases the desire to suckle (de Paula Vieira et al., 2008). Moreover, De Passillé et al. (1993) found a positive correlation between suckling duration and concentrations of CCK and insulin. In terms of time frame, suckling behaviour and motivation to suck has been shown to decline within ten to thirty minutes directly following milk ingestion (de Passillé, 2001; Lidfors, 1993) even for calves offered relatively small amounts of milk (Margerison et al., 2003), indicating a satiation of motivation by the act of suckling *per se*.

2.3 Non-nutritive sucking, cross-sucking and inter-sucking behaviour

Calves, particularly AR calves, exhibit cross-sucking, non-nutritive and inter-sucking behaviours (Table 2.1) which have been described by various authors (Lidfors, 1993; Keil and Langhans, 2001; Lidfors and Isberg, 2003; Nielsen et al., 2008), and were thought to stem from the redirection (Jensen, 2003) and the lack of satiation of natural suckling behaviour (Margerison et al., 2003).

Table 2.1 Description of sucking behaviours that occur in dairy herds

Behaviour	Description	Object
Non-nutritive	Animal touching any part of the pen with mouth and tongue, and attempting to suck	Pen or pail
Cross-sucking	Animal touching a body part of group member with its mouth and trying to take hold and suck. Usually followed by group member warding off the animal cross-sucking. A detrimental, abnormal behaviour carried out in calves group housed or individuals with close contact.	All body parts
Inter-sucking	Animal touching the inguinal area of a group member with its mouth and trying to take hold and suck.	Inguinal Area

Source: Lidfors, 1993; Keil and Langhans, 2001; Lidfors and Isberg, 2003; Nielsen et al., 2008

In cattle, cross-sucking refers to a calf sucking on a body part of another calf (Lidfors, 1993), and inter-sucking refers to a calf, heifer or adult cow that sucks on the inguinal region, navel and udder, of another animal (Keil and Langhans, 2001; Lidfors and Isberg, 2003). Whereas, non-nutritive oral behaviour includes licking and sucking on inanimate objects such as bars of the pen, pail and feeders (Keil and Langhans, 2001).

2.4 Effect of the amount and component concentration of milk on oral behaviour

2.4.1 Effect of ad-libitum milk feeding on suckling behaviour

Little cross-sucking has found in calves offered milk ad-libitum (Chua et al., 2002; de Passillé et al., 2010) as these animals spend more time performing milk feeding behaviour (Appleby et al., 2001). Calves fed milk ad-libitum drink almost twice as much milk (8.6 L) as calves fed restricted amounts of milk (4.6 L) (de Paula Vieira et al., 2008; Roth et al., 2009), however, calves fed restricted amounts of milk sucked on artificial teats for nearly twice as long as those fed milk ad-libitum (de Paula Vieira et al., 2008), supporting the hypothesis that feeding a restricted amount of milk was insufficient to satiate the suckling motivation (Rushen et al., 1995; de Passillé, 2001; Jensen, 2003; Margerison et al., 2003; de Passillé et al., 2006; Roth et al., 2009). Calves fed milk ad-libitum consumed the milk diet in five feeds each day, rather than the once and twice daily milk feeds that are more typical to AR restricted milk feeding practices (Appleby et al., 2001; de Paula Vieira et al., 2008). Calves fed milk ad-libitum have been found to spend greater amounts of time resting and have longer sucking bouts, during which they performed more butting, which potentially resulted in cholecystokinin (CCK) secretion taking place while the calves were feeding, whereas calves offered restricted amounts of milk would have finished the milk meal before CCK and the negative feedback mechanisms would have been able to have an effect (de Paula Vieira et al., 2008) of calf’s natural suckling behaviour.

2.4.2 Effect of feeding restricted amounts of milk on suckling behaviour

Young calves, from 33 to 96 d of age, that were fed restricted amounts of milk twice daily (8:20 and 15:35 h), were found to be inactive for between 30 and 70 % of the time between milk meals and spent 8 and 25 % of the day nibbling at and eating solid feeds (Veissier et al., 1998). The majority of cross-sucking was found to occur directly adjacent to milk meals, with 20 % of the cross-sucking prior to and 40 % following milk feeding (Veissier et al., 1998), which was similar to other research that found cross suckling most frequent directly following milk feeding (Margerison et al., 2003). As calves grew older, the time spent inactive declined and time spent eating solid feeds and in social encounters increased (Veissier et al., 1998). Calves offered restricted amounts of milk carried out twelve times more unrewarded visits to the feeder than calves offered milk ad-libitum, therefore performing greater amounts of non-nutritive sucking (de Paula Vieira et al., 2008). Rushen and de Passillé (1995) found that AR calves offered lower amounts of milk, (33 % and 75 % of regular feeding amount) 1.82 to 4.12 L/d compared to 5.5 L /d, spent longer sucking on a dry teat after the milk feeding. Conversely, Nielsen et al. (2008) and de Passillé et al. (2011) found that the amount of milk fed, between 4 to 6 L/d and 8 to 12 L/d, had no effect on cross-sucking.

2.4.3 Effect of type of diet and milk components

Calves are fed a variation of milks and formulations of MR to meet their nutritional requirements (Table 2.2). It has been found that relatively small amounts of milk (50 mL) are sufficient to elicit suckling motivation (Rushen and de Passillé, 1995; de Passillé et al., 1997). Increasing concentrations of the MR from 40 to 360 g per litre of water (de Passillé et al., 1997) and concentrations of milk lactose, increased the duration of non-nutritive sucking. Whereas omitting milk lactose and associated minerals from MR decreased non-nutritive sucking (de Passillé and Rushen, 2006 b). Altering the fat and protein concentration of MR; by double the amount of milk casein and removing the milk casein and whey protein, had no effect on the amount of non-nutritive sucking calves undertook on a dry teat (de Passillé et al., 1997).

Table 2.2 Composition of colostrum (days 1 to 3), whole milk and a milk replacer compared with calf requirements

Composition	Colostrum Day 1 pp	Colostrum Day 2 pp	Colostrum Day 3 pp	Whole milk	Calf Milk Replacer (Ancalf 20 kg bag, 600 g/ l water)	Calf requirement [1]
Total Solids, %	23.9	17.9	14.1	12.9		
Crude Protein, %	14.0	8.4	5.1	3.1		
Crude Protein, % of DM	58.6	46.9	36.2	24	26	18 to 26
Immunoglobin G, mg/ml	48.0	25.0	15.0	0.6		
Fat, %	6.7	5.4	3.9	3.7		
Fat, % of DM	28	30	27.7	28.7	20	16 to 18
Lactose, %	2.7	3.9	4.4	5.0		
Lactose, % of DM	11.3	21.8	31.2	38.8	43.5	
Iron, mg/kg	10			3		75 to 100
Copper, mg/kg	2.5			1		10
Vitamin A, iµ/kg	12,400			11,500		11,000
Vitamin D, iµ/kg	500			307		600
Vitamin E, iµ/kg	15			8		50

Source: Margerison and Downey, 2005; James, 2011b; www.horselands.co.nz

[1] - 45 kg pre-weaned calf from NRC, 2001

pp - postpartum

2.5 Cross-sucking behaviour of calves

2.5.1 Development of cross-sucking behaviour

The development of cross-sucking behaviour has been found to be affected by internal factors, such as age, breed, and individual coping mechanisms (Lidfors and Isberg, 2003), along with external factors which include; housing, management, feeding and nutrition practices (Keil et al., 2000; Lidfors and Isberg, 2003). Mammals are born with an innate urge to find and suckle a teat (Margerison et al., 2003) from which cross-sucking can develop mainly due to insufficient fulfilment oral behavioural needs as a result of AR practices, due to the restricted amount of milk being insufficient to satiate suckling, but being sufficient to increase the motivation for sucking (Spinka and Illmann, 1992; de Passillé, 2001; Weber and Wechsler, 2001). The initial ingestion of milk initiates the sucking behaviour resulting in the motivation for continuation of this behaviour (de Passillé et al., 1992) beyond what drinking the restricted amounts of milk offered from a pail or consuming solid feed by artificially reared calves provides. However, in calves reared in groups, the odds of cross-sucking were reduced by feeding milk to all of the animals at the same time (Keil et al., 2000).

Calves have a natural desire and motivation to be in social contact with others. Group housing allows for the expression of normal behaviour; such as play, social skills and self-maintenance behaviours; interaction between calves and reduces labour of cleaning, feeding and maintenance (Keil et al., 2000; von Keyserlingk et al., 2004; Jensen and Budde, 2006). Group or pair housing leads to the development of normal social behaviours, from the engagement of social play and are important later in life when heifers join the dairy herd (Chua et al., 2002; Rushen et al., 2010). Larger groups (20 to 30) are more common in commercial rearing systems with no significant relationship between group sizes and cross-sucking being found (Lidfors and Isberg, 2003); however, Jensen (2003) found larger groups (>8) have more competition and more cross-sucking occurring than smaller groups. Research completed by Chua et al. (2002) found that calves reared individually before milk weaning showed more agonistic behaviours following weaning. In contrast, von Keyserlingk et al. (2004) and Jensen and Budde (2006) clearly stated that in group reared calves there was an increased incidence and likelihood of cross-sucking occurring, along with a higher incidence of stress, disease and mortality (de Passillé, 2001, Rushen et al., 2010).

Some evidence exists supporting the observation that genetic factors; both breed and parent-offspring heritability, are involved in the occurrence of cross-sucking (Spinka, 1992). Keil et al. (2000) found that the breed of the animals, with dairy cattle breeds such as Holstein and Brown Swiss being higher than Simmental, was a contributory factor and cross-sucking was more prevalent in cross-bred than in pure breed animals (Lidfors and Isberg, 2003).

2.5.2 Occurrence of cross-sucking

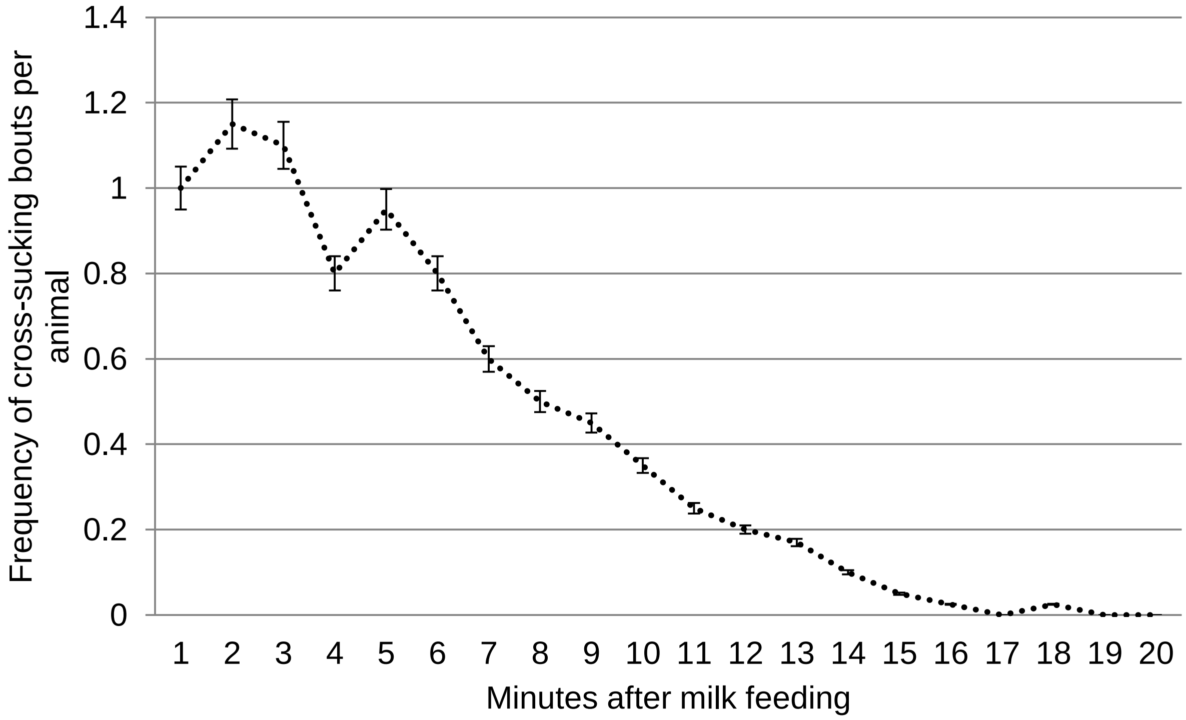

Figure 2.1 Frequencies of cross-sucking bouts per calf over time directly following milk feeding (Amended from: Lidfors, 1993)

Great variation in cross-sucking frequency have been found between individual calves, for a specific animal on differing days and between farms (de Passillé et al., 1992; Keil and Langhans, 2001; Lidfors and Isberg. 2003; Ishiwta et al., 2007; De Passillé et al., 2010; Laukkanen et al., 2010; de Passillé et al., 2011. Lidfors (1993) found that all calves showed cross-sucking behaviour, but there was a great variation in the frequency between individual animals. It has been shown that while the frequency of cross-sucking bouts varies between animal and between days, the mean total non-nutritive sucking time of 7.5 minutes per day was more predictable (Keil, 2001). While cross-sucking bout duration varied significantly, with over 95 % of the cross-sucking bouts lasting for two or less minutes (Keil et al., 2001) each, with an average bout duration of 69 seconds (Keil and Langhans, 2001).

The greatest amount of cross-sucking has been found to occur during the first 10 minutes directly following when milk feeding ceased and the peak, in frequency, taking place immediately after nutritive sucking (de Passillé et al., 1992; Lidfors, 1993; Rushen and de Passillé, 1995; Margerison et al., 2003) and this typically had subsided, in a linear decrease, by 15 minutes post-feeding (Figure 3, Lidfors, 1993), which was similar to the length of time calves take to drink from the dam. Hammell et al. (1988), Veissier et al. (1998) and Margerison et al. (2003) all found that cross-sucking behaviours occurred following milk feeding supporting the idea that milk ingestion elicits cross-sucking (de Passillé, 2001). When calves were presented with a dry teat forty minutes after milk consumption, little non-nutritive sucking occurred indicating that the suckling motivation had ceased supporting the observation that sucking motivation decreased over time (Rushen and de Passillé, 1995).

Calves that carried out cross-sucking were more likely to stand and allow another to cross-suck, known as mutual cross-sucking (Spinka, 1992; Keil and Langhans, 2001; Laukkanen et al., 2010; De Passillé et al., 2011), with a positive correlation being found (Keil and Langhans, 2001) between the number of times an animal cross-sucked and the number of times it was cross-sucked. Spinka (1992) found that mutual cross-sucking occurred as an opportunistic relationship between two calves and that the calves did not always choose the same calf to pair-bond with and cross-suck. Lidfors and Isberg (2003) supported this and suggest that social facilitation was the main potential cause of this behaviour. On the other hand, Keil and Langhans (2001) found that 17 out of 35 calves selected one specific calf to cross-suck more than 50 % of their total cross-sucking time.

2.5.3 Parts of the calf's body affected by cross-sucking

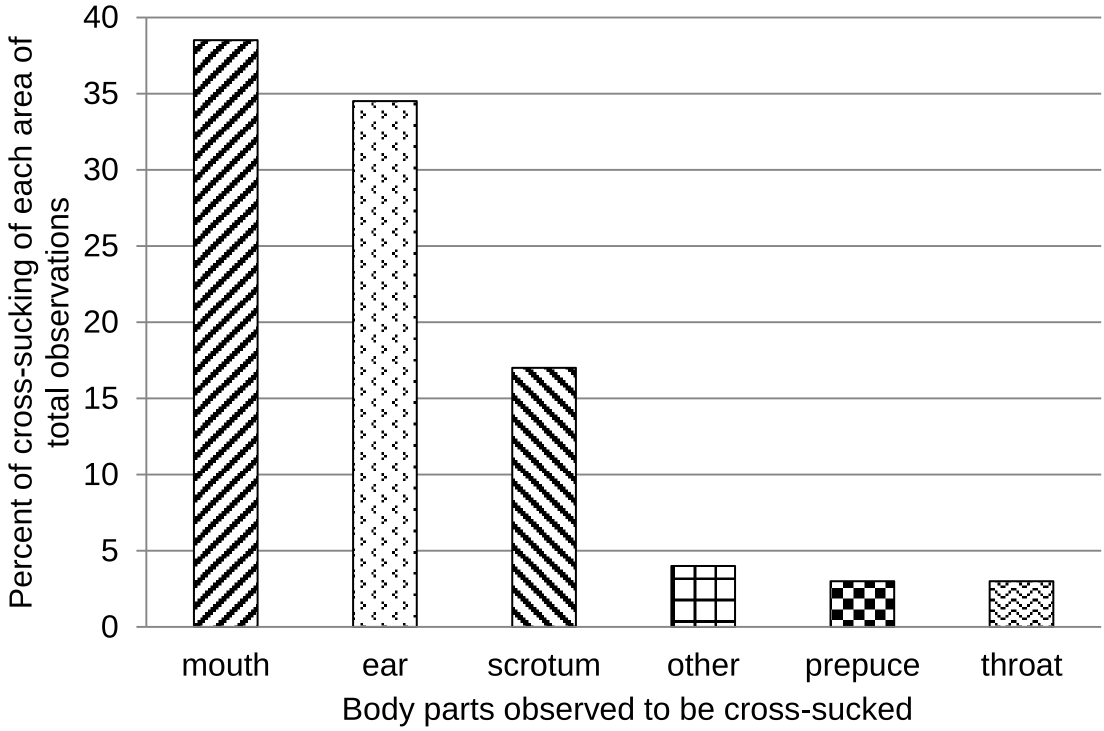

Figure 2.2: Body parts being cross-sucked shown as a percentage of total observations of cross-sucking (Amended from: Lidfors, 1993)

The parts of the body most often sucked included the; udder, navel and ears; whereas the legs, tail, mouth and neck were sucked less extensively (Haley et al., 1998, Margerison et al., 2003; Figure 2). Some research has reported that most cross-sucking was directed to the head and muzzle, with limited cross-sucking to other areas of the body (Lidfors, 1993; Jensen and Budde, 2006) but this was due to calves being individually reared in pens which limited access to these areas of neighbouring animals. Keil and Langhans (2001) reported that 30 out of 35 calves, which were reared in groups and had access, preferred to suck the udder for cross-sucking. Margerison et al. (2003) and Roth et al. (2006) found similar results with the majority (98 %) of cross-sucking bouts being directed towards the inguinal area, with the greatest concern being the development of habitual cross-sucking and subsequent suckling in lactating animals.

2.5.4 Establishment of cross-sucking as a habitual behaviour

Cross-sucking in dairy calves leads to future problems in the dairy heifer and cow herds known as inter-sucking and milk stealing (Keil, 2001). A link has been found between animals that cross-suck as calves, being more likely to inter-suck as heifers and adult cows (Keil et al., 2000; Lidfors and Isberg, 2003). In support of this, Keil at al. (2001) found that 69 % of the cows that inter-sucked as an adult were observed cross-sucking as a heifer. De Passillé et al. (2011) found the five heifers that spent the greatest amount of time cross-sucking had a high frequency of cross-sucking as calves and many sucked the same partner, supporting the idea that cross-sucking becomes habitual and is not always associated with milk intake as a stimulus. Weaning calves from milk was thought to decrease or eliminate cross-sucking because it is thought that milk ingestion stimulates suckling; however, the relationship was more complicated and by this stage, the behaviour may have become habitual (Lidfors, 1993, Keil and Langhans, 2001). While many of the older calves had stopped cross-sucking once moved to the heifer barn, due to ingesting more solid feed; not all calves had and these calves were thought to carry out this behaviour due to habituation (Roth et al., 2009; De Passillé et al., 2011).

2.5.5. Detrimental effects of cross-sucking

Cross-sucking of calves on the navel can lead to infection and hernia (Ude et al., 2011). Cross-sucking of other body areas can lead to hair loss, inflammation, irritation, and possibly wounding of that area being sucked (Jensen, 2003;

Laukkanen et al., 2010). It can also lead to poor growth among the calves doing the cross-sucking (Haley et al., 1998). In cattle, inter-sucking has been reported to occur in between one and eleven percent of dairy cattle in the herd, taking into account Simmental, Holstein, Ayrshire and Swiss cattle (Spinka, 1992; Keil et al., 2000). It can lead to multiple detrimental effects such as reduced milk yield, udder malformations and mastitis (Keil et al., 2000; de Passillé, 2001; Keil et al., 2001). Inter-sucking on teats allows bacteria to enter the mammary gland, leading to a significant relationship between inter-sucking and mastitis (Spinka, 1992; Lidfors and Isberg, 2003). Should animals cross-suck on pregnant dry cows, they may cause colostrum to be produced too early resulting in the new born calf receiving little to no colostrum and colostrum of poor quality (Weber and Wechsler, 2001; Lidfors and Isberg, 2003).

2.5.6 Methods of preventing cross-sucking once established

Multiple methods have been implemented to prevent cross-sucking; however, nothing has been found that completely eliminates this behaviour (Haley et al., 1998; de Passillé, 2001; Jensen, 2003). A farm questionnaire carried out by Keil et al. (2000), found that the commonly used countermeasures for cross-sucking on smaller sized farms included; restraining calves during milk feeding; feeding hay and starter directly following milk feeding; and the application of nose rings. While, Lidfors and Isberg (2003) reported bull nose rings, keeping calves in individual pens and regrouping of calves were the most commonly used methods. Moreover, it was stated that cross-sucking should be discouraged as early as possible, especially around milk weaning age, as this was more likely to reduce and potentially eliminate inter-sucking in the adult animal (Lidfors and Isberg, 2003). The most effective way to reduce cross-sucking was to provide a means for the calf to carry out its natural suckling motivation (de Passillé, 2001; Margerison et al., 2003).

2.6 Effect of artificial milk feeding methods on cross-sucking behaviour

2.6.1 Feeding milk through a teat compared to a pail

Offering milk through a teat provided the calf with the natural, positive behaviour of suckling, and increased the time period over which milk feeds were consumed (Hammell et al., 1988; de Passillé, 2001; Chua et al., 2002). This extended period of nutritive suckling has been shown to significantly decrease the amount of time calves spent cross-sucking, but it did not eliminate cross-sucking entirely (Haley et al., 1998; de Passillé, 2001; Loberg and Lidfors, 2001; Veissier et al., 2002; Jensen and Budde, 2006).

Table 2.3: Oral and Physiological behaviour of calves offered milk from teats and pails

	Milk offering systems	
	Teat	Pail
Oral	Provide natural sucking behaviour	More sucking of pen bars
	Longer drinking time	More time licking pens
	Decrease non-nutritive sucking	More time sucking dry teat
Physiological	Increased gain weight	Higher weight gain
	More frequent butting	
	Increase insulin and CCK [1] secretion	
	Lie down sooner	

Amended from: Hammell et al., 1988; de Passillé, 2001; Veissier et al., 2002

[1] Cholecystokinin

Feeding milk through a teat has been found to stimulate calves to rest sooner and for approximately twice the length than calves offered milk from a pail (Veissier et al., 2002), mainly due to a greater feeling of satiety associated with a longer feeding period and slower rate of milk ingestion. Hammell et al. (1988) found that calves fed milk through a teat spent significant less time sucking a dry teat (1 minute) compared with calves that drunk milk from a pail (13 minutes). Offering milk through a teat, rather than milk being drunk from a pail (Table 2.3), has been shown to have a positive effect on digestive processes, such as a more cuprous secretion of saliva, salivary lipase and gastric fluid (Hammell et al., 1988). Moreover, calves that suckle milk through a teat were more likely to form an effective rumo-reticular groove, which allows milk to bypass the rumen and enter directly into the abomasum; whereas, this formation was less effective in calves that drink milk from a pail, in which case some of the milk enters into the undeveloped rumen / reticulum (Appleby et al., 2001) reducing the efficiency with which the nutrients from milk can be digested and a subsequent reduction in the growth rate of the calf. Veissier et al. (2002) found no benefits with respect to calf growth rates and rate of feed conversion efficiency when using a teat system compared to feeding MR from pails.

2.6.2 Effect of feeding milk from mechanical calf feeders

Automatic feeders are being used more frequently for group rearing of calves, reducing labour required for the mundane task of offering calves milk. Weber and Wechsler (2001) compared a regular automatic teat feeder (RATF) with a modified automatic teat feeder (MATF), in which the calf was held in a stall after the meal to carry out non-nutritive sucking on a dry teat. Cross-sucking and other non-nutritive sucking observed the calves fed milk by the MATF was lower during the first 15 minutes following milk feeding than in the calves fed milk from the RATF (Wendl et al., 1997). MATF resulted in less cross-sucking overall (Wendl et al., 1997). All (100 %) calves fed milk by the RATF showed cross-sucking behaviour, compared with 50 % of the calves fed milk from MATF (Weber and Wechsler, 2001).

Veissier et al. (2002) found that group housed calves offered milk from an automated milk feeder performed more cross-sucking and nibbled and sucked on the bar of the pen than calves offered milk through a teat and from a pail. Whereas, Roth et al. (2009) found that thirteen out of fourteen calves showed cross-sucking when offered milk was fed from an automated milk feeder, while only one of fourteen calves offered milk by their dam cross-sucked. Calves offered access to their dam consumed milk for twice as long (12.51 ± 1.6 min/ 4 hours) compared to calves offered 8 L of milk from an automatic feeder (6.12 ± 0.9 min/ 4 hours), but ate less starter concentrate, with calves on their dam eating approximately 2.74 kg (±0.57) in total while artificially reared calves ate 21.78 kg (±3.25) total, than calves raised on automatic feeders (Roth et al., 2009).

2.6.3 Effect of milk flow rate from the artificial teat on cross-sucking

Decreasing the milk flow rate from 3 L /minute to 0.2 L /minute increased the length of milk feeding period, which allows time for the negative feedback mechanisms (CCK, insulin) to decrease sucking motivation and resulted in a decrease in cross-sucking and non-nutritive sucking (de Passillé, 2001; Jensen, 2003). Calves were able to alter the rate of MR ingestion (de Passillé and Rushen, 2006a). Haley et al. (1998) compared varying teat orifice diameters and found that the smallest orifice diameter (0.16 cm) had the lowest MR flow rate, and the longest MR consumption period and the least non-nutritive sucking (Haley et al., 1998). Whereas other orifice diameters (0.55 cm, 0.39 cm, 0.27cm) had no effect on MR flow and ingestion rate.

2.6.4 Effect of pacifiers and sucking of dry teats on cross-sucking

De Paula Vieira et al. (2008) and Ude et al. (2011) found that providing calves a dry teat resulted in less cross-sucking and non-nutritive sucking, supporting the idea that non-nutritive sucking *per se* has a satiety effect. De Passillé (2001) and de Paula Vieira et al. (2008) found that providing a dry rubber teat for the calves to suck on after the meal lead to a 75 % reduction in occurrence of cross-sucking. De Passillé et al. (1992) found that calves started sucking on a dry teat almost immediately following MR feeding, once the pail was removed and after a given time, the calves stopped sucking the teat and explored the pen, eventually lying down. In an experiment carried out by Veissier et al. (2002), dry teats attached to the bars of the pen of calves offered milk from a pail were for longer (0 to 11 minutes) than calves offered milk from a teat (0 to 1.5 minutes) (Veissier et al., 2002). It was also found that calves preferred to suck a dry teat compared with eating hay, concentrate starter and cross-sucking (de Paula Vieira et al., 2008; Ude et al., 2011). Dry teats are a useful tool in reducing cross-sucking.

2.6.5 Effect of environmental enrichment on cross-sucking

An enriched environment refers to a larger pen, which can include an exercise yard, post feeding area, larger than normal area and access to a rubber teat and other outlets for the natural suckling behaviour. Providing the calves with an enriched environment and pasture after milk feeding resulted in less cross-sucking (Keil et al., 2000; Lidfors and Isberg, 2003). Ude et al. (2011) found that calves provided with an enriched environment performed 32.5 to 38.1 % less non-nutritive sucking and bouts of nibbling on the pen than calves group housed commercially. The lower amount of cross-sucking, from 17.2% to 12.3 %, was seen in calves kept in an enriched environment over time compared with 58.6% to 73.7% in calves not offered environmental enrichment (Ude et al., 2011). The increase in cross-sucking seen with increasing age could be accounted for by greater hunger, due to calves having greater nutritional requirements. Offering a dry teat in the post feeding area reduced the amount of cross-sucking but increased the amount of non-nutritive sucking on the dry teat. In the enriched environment, calves increased their use of a dry teat in the post feeding area from 97.0 to 255.0 seconds per calf over time (Ude et al., 2011) coinciding with the increased cross-sucking in the non-enriched environment indicating the calves motivation to suck.

2.7 Effect of calf housing and re-grouping on cross-sucking

Re-grouping and moving animals between groups of; calves, heifers and adult cows can result in splitting up animals that mutually suck and lead to less cross-sucking occurring overall (Keil et al., 2001; Lidfors and Isberg, 2003). The separation of calves that suck other calves (suckers) could result in a significantly lower amount of cross-sucking (Lidfors and Isberg, 2003). Animals often associate sucking with a specific partner (suckee) and as such regrouping separates these animals so they are with unfamiliar animals (Keil et al., 2001; Lidfors and Isberg, 2003). Social facilitation has been shown to affect the amount of cross-sucking that occurs (Spinka, 1992). The housing of younger heifers with older cows may also reduce cross-sucking as the older cows are unlikely to tolerate this behaviour (Lidfors and Isberg, 2003). Finally, the animal responsible for the cross-sucking can be completely separated from the group of animals, so that this behaviour would be prevented.

2.8 Effect of weaning from milk on cross-sucking

2.8.1 Effect of gradual and abrupt weaning from milk on cross-sucking

Calves raised on the dam have been seen to be weaned by the mother gradually over a period of weeks and cross-sucking was not observed (Spinka, 1992; Nielsen et al., 2008; Roth et al., 2009; de Passillé et al., 2010). In early weaning systems, cross-sucking around weaning was significantly lower in calves weaned according to their average daily concentrate intake rather than age (Roth et al., 2008). De Passillé et al. (2010) compared abrupt and gradual weaning periods extended over: four, ten and twenty two days, and found that gradually weaning over twenty two days resulting in the most cross-sucking compared to all of the other shorter weaning periods. In contrast, Nielsen et al. (2008) found gradually weaned calves, over fourteen days, reduced cross-sucking compared with calves weaned abruptly. Calves weaned gradually ate more concentrate during the days of reduced milk intake and when calves were gradually weaned off milk, the starter concentrate consumption increased during this period leading to better rumen development allowing for a more efficient use of ingested food than calves weaned abruptly Spinka, 1992; Nielsen et al., 2008; Roth et al., 2009; de Passillé et al., 2010.

Greater cross-sucking bout length, seen in calves at weaning, occurs when the sucking motivation was no longer satisfied by milk ingestion when weaned calves were moved to the heifer barn (de Passillé et al., 2011) and even individual calves would be housed in groups. Calves that had shown the least and no cross-sucking activity before weaning were unlikely to exhibit this behaviour following weaning, whereas calves that showed a greater amounts of cross-sucking before weaning were more likely to continue to do so and show greater levels of cross sucking following weaning (Lidfors, 1993; Keil and Langhans, 2001). The number of these post-weaning cross-sucking and non-nutritive sucking bouts decreased over time, up until nine weeks following weaning, when no more were observed (Spinka, 1992; Lidfors, 1993; Keil and Langhans, 2001; Jensen and Budd, 2006).

2.8.2 Effect of weaning age on cross-sucking

After milk weaning, calves become more aversive to cross-sucking and the bouts become shorter. Calves in artificially reared systems have typically been weaned from milk at six to eight weeks of age; when weaned at six weeks of age a greater amount of cross-sucking occurred (Roth et al., 2009). The early weaning of 6 weeks could be causing more cross-sucking due to the calf's inability to digest and adapt to the solid diet which they were offered after milk weaning (Roth et al., 2009) however, these calves would be weaned according to starter feed intake (Margerison and Downey, 2005) and cross sucking is more likely due to hunger, indicated by the rapid increase in starter intake following weaning, and a lack of daily satiation of sucking due to the removal of milk feeding.

2.9 Effect of provision of solid feeds

2.9.1 Effect of the provision of solid feeds, concentrated starters and forages

Providing the calf with free access to concentrates and forages was thought to increasing solid feed intake and reduce cross-sucking behaviour. Wendl et al. (1997) and Haley et al. (1998) found that providing hay immediately following a milk meal reduced the amount of non-nutritive sucking; however, the results may vary due to the developmental stage of the rumen. Hepola et al. (2006) found that providing free access to hay and starter concentrates reduced cross-sucking during times other than directly after milk feeding. Greater concentrate feed intake at weaning would result in and be indicative of better development of the rumen, which in turn would better prepare the calf for weaning and enable them to handle the diet change (Roth et al., 2009) and removal of nutrients provided by milk. Roth et al. (2008) found that when calves were eating more hay, less cross-sucking occurred, and calves had greater weight gains. Offering hay on a limited basis directly following a milk meal may result in an increased motivation by the calf to eat roughages in order to aid rumen development. This concept was proposed by Veissier et al. (1998) who found that providing solid feeds in the form of concentrates and forage reduces non-nutritive sucking and was supported in more recent research by Keil and Langhans (2001) and Chua et al. (2002) who found that an increase in solid feed intake reduced cross-sucking.

In farm surveys Keil et al. (2001) found that less inter-sucking was seen in adult cows that had been offered large amounts of hay or silage as calves and farms that offered an enriched environment such as a pasture and extended space such as a barnyard. The main problems that led to cross-sucking by dairy heifers were associated with diet. The feeding a low concentrate to forage ratio (30:70 and lower) resulted in more cross-sucking (Lidfors and Isberg, 2003). As the calves aged, they spent more time eating hay and concentrates along with interacting to a greater extent with other calves (Veissier et al., 1998), and thus supplying the animal with the appropriate diet, access to forage and starter, around weaning has been shown to be important limiting the amount of inter-sucking that occurs following weaning; therefore, feeding management has a large impact on this behaviour after weaning.

Ishiwta et al. (2007) stated that the level of nutrition and the quality of the diet had the greatest effect on the amount of oral behaviour. Poor quality and unpalatable feeds, and diets that did not meet the nutritional requirements of the animal increased the occurrence of cross-sucking behaviour (Jensen, 2003; Roth et al., 2008). There have been few studies completed to assess the effect of the energy concentration of the diet on cross-sucking and oral behaviour of calves. de Passillé et al. (2010) found that when the digestible energy (DE) content of the diet was below 0.4 MJ/kg bodyweight, cross-sucking occurred more frequently. The number of cross-sucking bouts tended to be negatively correlated (*P*<0.01) to the energy density of the diet (Keil and Langhans, 2001) and Roth et al. (2009) agreed with these findings, showing that DE concentration of the diet and cross-sucking are negatively correlated; however, after milk weaning, they found that there was no longer any relationship.

2.9.2 Effect of group rearing on solid feed intake

Allelomimicry, which is social facilitation, has been found to be very important in the ability and speed with which young calves learn to consume solid feeds (Phillips, 2004), which was supported by the observation that young calves that were managed in groups had greater grass intake than calves housed individually (Phillips, 2004). A calf being able to see the intake of food into the mouth of another calf plays an important role in social facilitation of feeding. Veissier et al. (1998) found evidence to support the idea that social facilitation plays a role in the behaviour of calves housed in groups, especially when eating solid feeds. This social facilitation in group reared situations could account for the greater intake of hay and concentrated starter, rumination, and length of time spent eating occurring at a younger age in group reared than in individually reared calves (Chua et al., 2002; Hepola, 2003; Hepola et al., 2006). Moreover, Xicaato et al. (2001), found that group housing calves lead to greater final live weight due not only to feed intake but to better feed conversion efficiency, compared with individually reared calves. This later study may be indicative of better rumen development and or function, possibly due to a more appropriate diet containing a greater level of forage and more adequate energy intake.

2.9.3 Effect of the provision of forage and starter intake on oral behaviour of calves

Solid feed intake, forages and concentrates, are pivotal in the transition of calves from a pre-ruminant animal to a ruminant animal, through their vital role in the development of the rumen (Coverdale et al., 2004; Garnsworthy, 2005). This transition from the nutrient being provided mainly from milk fat and glucose moving gradually onto a solid feed diet producing short-chain fatty acids as primary energy substrates (Baldwin et al., 2004), with the required development of feed digestion in the rumen (Coverdale et al., 2004), are key requirement for weaning the calf off milk and the opportunity for the calf to grow at an adequate rate by utilizing increasing amounts of nutrients gained from more cost effective feeds such as starter concentrates and forages on which they can be fully fed following weaning from milk (Margerison and Downey, 2005). The provision of solids feeds, especially forages, are essential for the satiation of innate oral behaviour and preventing oral behaviour from being directed towards alternative objects in the environment, which include animate objects and other animals (Haley et al., 1998). The earlier and greater the amount of cereal (Guilloteau et al., 2009) and fibre (Porter et al., 2007) consumption have been shown to be beneficial to rumen development, initially due to cereals stimulating rumen papillae development, by stimulating rumen microbial proliferation and increased concentrations of butyric and propionic acid (Castells et al., 2012), followed by the provision of fibre from forages which assists in papillae function, by reducing parakeratosis, stimulating rumination and saliva flow, and improving the muscularity and health of the rumen wall (Coverdale et al., 2004; Suárez et al., 2007).

Calves that are weaned from milk with insufficient rumen development, to digest adequate amounts of nutrients from solid feeds, perform greater amounts of cross-sucking (de Passillé et al., 2010). Keil et al. (2000) showed the importance of the adequate rumen development in the calf before weaning, and found that more cross-sucking was performed by calves when they were offered higher volume of milk rations pre-weaning and when they were weaned at an early age. Interestingly, Appleby et al. (2001) observed that calves offered milk from a pail, consumed twice as much starter as those offered the same amount of milk from a teat (0.25 ± 0.02 vs. 0.11 ± 0.03), once sufficient solid feed started to be consumed (> 21 d of age). Suckling (Margerison et al., 2003, de Passillé and Rushen, 2006a), oral exploration (de Passillé et al., 1992) and solid feed consumption are innate survival behaviours, which were considered important for the uptake of forages and concentrates. Nibbling and licking behaviour was stated to be an important for calves to exhibit, as it led to grazing behaviour in cattle (Veissier et al., 1998). Calves have been seen spending time sniffing around the pen, which supports the idea that calves have an innate foraging behaviour (Veissier et al., 1998) and it has been indicated that while sucking, following milk feeding, can be directed towards a dry teat for a period of time, after that time the calf will direct more interest in the surrounding environment by licking and the manipulation of other objects (Hepola et al., 2006; Jensen and Budde, 2006) including solid feeds.

The longer calves spend eating hay and concentrate, the lower the amount of cross-sucking occurs (Table 2.4) with the motivation to suckle decreasing with the intake of forages (Phillips, 2004). This could be due to the calves' innate urge to perform oral activities such as sucking being met by eating forages. Group rearing has been shown to lead to greater amounts of hay and calf starter being consumed, due to social facilitation, and less cross-sucking occurring than in calves reared individually (Hepola et al., 2006), which are likely to have less opportunity for socialisation. When the calves are reared on the dam, they eat less hay and concentrate, but also perform less cross-sucking than calves reared artificially (Margerison et al., 2003; Roth et al., 2009). In terms of specific solid feed selection, when provided with ad-libitum hay, calves were observed to spend more time eating hay than concentrate (Table 2.4). In the past feeding forages during the milk-feeding phase was discouraged, based on some research that showed lower starter intake and weight gains in calves provided access to forage (Warner et al., 1956; Stobo et al., 1966). Whereas, more recent studies have shown that introducing forage during the milk-feeding period improved live weigh gain and total DMI (Khan et al., 2011). Furthermore, offering pasture hay has been reported to improve feed efficiency when feeding texturized starters (Coverdale et al., 2004; Khan et al., 2011) and pelleted starter feeds containing 18% NDF on a DM basis (Castells et al., 2012). The comparison of feeding starter feeds alone and in combination with forage has the potential underlying complication of differences in gut fill that would confound some of the growth and efficiency parameters of calves (Bach et al., 2007; Kertz, 2007; Khan et al., 2012), whereas measuring live weight and growth rate of animals offered the same diet over a more prolonged period following weaning would go some way to removing these potential issues.

Table 2.4 Calf rearing system effect on oral behaviour and solid feed intake by calves

System	Milk diet (/d)	Allo-groom	Solid feed intake (Kg DM/day) Hay	Starter	Total	Sucking duration (means ±SEM) Cross	Non-nutritive	Reference
Natural suckling	Ad-lib				1.7±0.51	0.00±0.0		Roth et al., 2009
Restricted suckling	15 mins				3.7±0.63	0.10±0.1		Roth et al., 2009
Artificial suckling [1]	8 L				21.7±3.25	2.04±0.7		Roth et al., 2009
Artificial suckling [2]	8 L				21.3±2.26	3.24±1.4		Roth et al., 2009
Restricted suckling	15 mins	3.1 [3]	348	61		0.14		Margerison et al., 2003
Artificial Rearing	4 L	2.3 [3]	348	59		1.80		Margerison et al., 2003
Pair housed	2 L	71 [4]				0.63±0.37	2.18±0.51	Jensen & Budde, 2006
Group Housed	6 L	56 [4]				0.97±0.43	1.38±0.38	Jensen & Budde, 2006
Individually reared	1 L	1.51±0.22 [5]	0.04±0.01	0.20±0.03	0.99±0.03	0.03±0.01	4.41±0.38	Hepola et al., 2006
Group reared	4 L	1.92±0.51 [5]	0.07±0.01	0.26±0.04	1.12±0.04	0.32±0.23	4.32±0.71	Hepola et al., 2006

† % of calves performing behaviour [1] - 2x/d [2] - 6x/d [3] - Events/d [4] - % of calves [5] - % (total obs.)

2.10 Practical implication of provision of milk and solid feeds for calves

2.10.1 Milk intake, calf growth and importance in diet

Recent research into dairy heifer nutrition has shown that feeding greater amounts of milk and feeding milk for longer periods of time increases the growth rate of calves and studies have shown that increasing energy and protein intake during the milk-feeding period increases calf growth rate and first lactation milk yield (Khan et al., 2011; Soberon et al., 2012; Bach, 2012; Margerison et al., 2013). These higher growth rates of dairy calves were typically, with the exception of Margerison et al. (2013), achieved by increasing MR (Bartlett et al., 2006; Davis Rincker et al, 2011; Soberon et al., 2012) or by increasing whole milk (WM) feeding levels from 10 % to 17.9 % (Jasper and Weary, 2002) and up to as much as 20 % of BW (Khan et al., 2007 a; Khan et al., 2011). However, increasing milk feeding volume was found to reduce starter intake at weaning to half that of calves offered milk at the equivalent to 10 % of BW (Jasper and Weary, 2002; Cowles et al., 2006; Raeth-Knight et al., 2009), which often results in BW loss and difficulty for the calf following weaning (Keil et al., 2000; Jensen, 2003) and more importantly increases calf rearing costs (Jasper and Weary, 2002).

Restricting WM and MR feeding levels has been found to increase starter feed intake (Jasper and Weary, 2002; Margerison and Downey, 2005) and increase the rate of rumen development and growth at weaning (Suarez-Mena et al., 2011). A relationship has been clearly demonstrated between milk feeding and starter intake (Terré et al., 2007; Raeth-Knight et al., 2009) and the intake of cereal based calf starter feeds was greater when milk feeding levels were restricted, typically to the equivalent of 10 % of BW (Margerison and Downey, 2005; Khan et al., 2007 a, b). Starter intake also shows a sharp increase when milk was withdrawn completely (Jasper and Weary, 2002). Moreover, dairy calves fed greater amounts of MR, from 562 up to 1,358 g/day (Cowles et al., 2006) and from 423 up to 704 g/d (Bascom et al., 2007), rather than greater volumes of milk diets have been found to have greater growth rates, especially when fed MR that had a greater crude protein concentration (up to 31 % of DM) and when less of the gross energy (4.9 to 5.2 kcal/g) in the MR was derived from fat (Fat: 15 to 21 % of DM) (Cowles et al., 2006; Bascom et al., 2007). These changes in MR composition have been found to achieve greater growth rates and energy retention, along with lower fat and greater lean tissue deposition (Diaz et al., 2001; Tikofsky et al., 2001) in MR fed calves. In these studies, maintaining the energy concentration of MR was achieved by the addition of lactose (from 42.9 to 43.4 % of DM) (Diaz et al., 2001; Tikofsky et al., 2001; Hill et al., 2010). In older calves, between 2 to 13 weeks of age, lactose can be replaced by cereals (Huber et al, 1968; Toullec, 1989; Margerison et al., 2013) as a non-fat energy source, due to the development of pancreatic function (Guilloteau et al., 2009).

2.10.2 Concentrated starter feed intake and importance in diet

Calves offered low milk allowance were observed to consume more concentrated feed, which could be important for stimulating early rumen development (Nielsen et al., 2008). Volatile fatty acids (VFA), particularly butyrate and propionate, are the most important substrates stimulating rumen papillae growth (Coverdale et al., 2004; Suárez et al., 2006; Castell et al., 2012). However, feeding only concentrated feed resources can lead to a reduction in rumen pH, hyperkeratinisation, and decreased ability to absorb nutrients (Castell et al., 2012).

Warner et al. (1956), showed rumen development in calves offered varying diets (Figure 1). Calves offered milk only (Photo 487) was not physiologically different from that of new born calves (Photo 504), due to nutrients bypassing the rumen through the rumo-reticular (oesophageal) groove and resulting in limited rumen development, whereas calves offered cereal grain and milk (Photo 483) had dense papillae population, longer papillae length and width, which were stimulated by VFA production, from cereal grain fermentation. Finally, when calves are offered milk and forage (Photo 490), the rumen had less well developed papillae and the rumen wall was thicker and more muscular, due to the physical structure of high fibre forages.

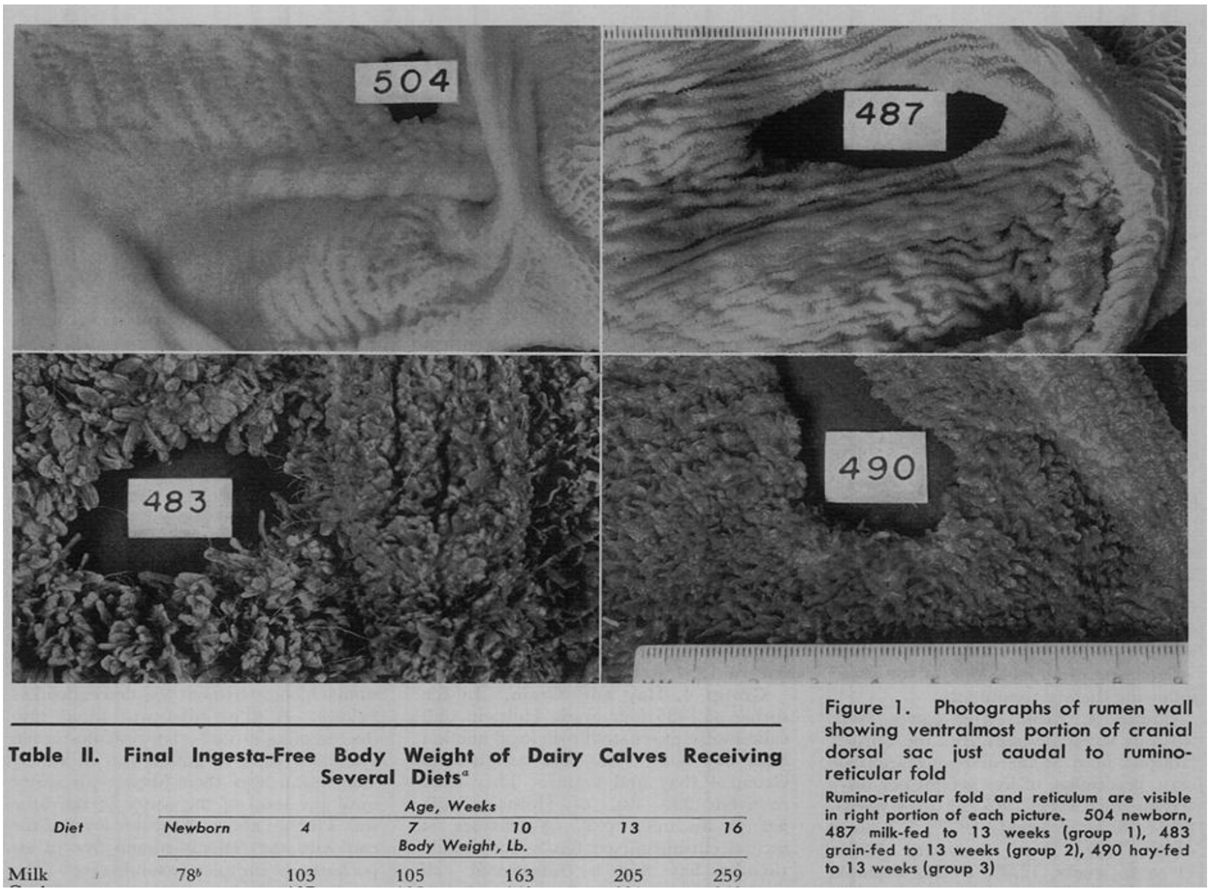

Figure 2.3: Photographic comparison of the inside of the rumen on different diets (Warner et al., 1956) * *photograph 504 is the rumen of a newborn calf; 487 is the rumen of a calf offered only milk for thirteen weeks; 483 is the rumen of a calf offered milk and ad-libitum grain for 13 weeks; 490 is the rumen of a calf offered milk and ad-libitum hay for 13 weeks

2.10.3 Forage sources and importance in diet

In European countries, at least 100 g/hd/d of a fibrous food must be available from two weeks of age, increasing to 250 g/hd/d at 20 weeks of age (Phillips, 2004). If the diet is pre-mixed ration, the forage in the diet should be between 10 to 25 % and the fibre source must be palatable and stimulate rumination (Castells et al., 2012). The feeding of forage to very young calves, before three weeks of age, has been associated with reduced concentrated feed intake, impaired rumen papillae development and poor forage digestion (Castells et al., 2012). Delaying feeding forages until after concentrates have been consumed can aid in rumen development

(Margerison and Downey, 2005). VFA’s stimulate the microbial population which in turn decreases the rumen pH level and increases the availability of VFA’s for absorption which in turn drives rumen epithelial growth (Heinrichs and Lesmeister, 2005). Feeding forages causes an increase in rumen pH which decreases VFA availability due to the increased fibre content and particle size (Heinrichs and Lesmeister, 2005).

Forages and fibrous feeds stimulate saliva production. Saliva contains urea and minerals, important for rumen pH, microbial growth and development, and rumination, which can result in a reduction in cross-sucking and non-nutritive sucking (Moran, 2002; Coverdale, 2004; Castells et al., 2012). Forages are especially important in the muscular development of the rumen wall (Coverdale, 2004; Castells et al., 2012) and aid in the growth and development of the rumen papillae, mainly due to the physical abrasion of the papillae and break down of the outer layer of keratinisation (Castells et al., 2012). High fibre diets and diets consisting of a mash have been found to result in the production of large amounts of butyric acid, which is important for rumen development. Forages, alone, are more likely to result in the production of acetate and insufficient butyrate for an adequate rate of papillae development and as such feeding cereal based concentrated starters that increase butyrate and propionate production should be fed feed alongside forages (Coverdale et al., 2004; Khan et al., 2011; Castells et al., 2012).

The importance of the diets fibre level and the physical form of the diet for calves in avoiding bloat and parakeratosis and instigating rumination (Porter et al., 2007). The feeding of high amounts of forages increased the length of time spent feeding, which resulted in the behavioural needs of the cattle being satisfied (Keil and Langhans, 2001) to a greater extent. Providing pasture, as forage for calves, greatly reduced the performance of oral behaviours, such as licking objects in the environment and grooming of others (Phillips, 2004). Whereas calves offered straw ate more forage and concentrated starter resulting in a greater growth rate (Phillips, 2004) and rumination time, compared to calves offered pasture hay.

Pelleting of feeds has been shown to have a positive impact on palatability of feed, but has a higher rate of passage due to decreased digestibility (Porter et al., 2007). The higher rate of passage through the rumen was explained by the smaller particle size and therefore the shorter digestion time which affects rumination (Porter et al., 2007).

2.11 Summary of Hypotheses

In this chapter the motivation for suckling and the underlying factors that contribute to cross-sucking has been reviewed along with current strategies used to reduce and try to eliminate this abnormal, unwanted behaviour. While the effects of MRs and starters on cross-sucking have been researched, little research has assessed the effect of solid feed diets on cross-sucking. Feeding forages and concentrates directly following milk meals has been found to reduce cross-sucking; however, comparisons between hay and starters and total mixed rations containing high CP concentrations have not been carried out. Different fibre sources will have varying palatability, intake, rumination and feeding lengths. The fibre sources would have different digestible fibre levels and varying amounts of lignin and pectin, which alter how the fibre is broken down. The more slowly digestible fibre requires more rumination and may result in a lower amount of cross-sucking. Palatability of differing diets may affect the amount of time calves spent eating differing diets. Whereas, higher fibre intakes and longer degradation rates may create rumen gut-fill from ingested fibre could lead to satiety levels. These factors could well affect cross-sucking.

The following Chapters contribute to a more thorough understanding of the effect of solid feeds and TMR on feed intake, growth rates and oral behaviour, specifically cross-sucking behaviour in group housed, artificially reared dairy heifers. The hypotheses of this study were would calves offered pasture hay with starter concentrate and TRMs of a higher and lower forage inclusion have differing:

1. Total solid feed intake and growth rates during the pre-weaning period

2. Amounts of time spent ruminating and consuming solid feeds during the pre-weaning period

3. Amounts of time spent cross-sucking and non-nutritive sucking behaviour, suck differing parts of the body and or environment during the pre-weaning period
4. Incidences and patterns of cross sucking directly following milk feeding during the pre-weaning period

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Chapter 3.0 Materials and Methods

3.1 Animals, housing and experimental design

3.1.1 Location and experimental design

The research was completed between 1st August and 21st December 2011, at Massey University No. 4 calf unit, located at Palmerston North, in accordance with the Universities animal ethics procedures and approval (MUAEC 10/71). A total of 108 heifer calves (Friesian, Jersey x Friesian) were selected at random from Massey University dairy units No. 1 and 4 and weighed at 48 h of life and allocated to one of three solid feed diets according to birth date, live weight and breeding worth such that each treatment group of calves were equal for these factors. Calves were housed in 36 pens (3.3 m × 2.0 m), with three calves in each pen that were bedded with a layer of sand that had sawdust applied to the surface daily.

3.1.2 Animal management and feeding

Newborn calves were collected from the calving paddock, twice daily, had the umbilicus treated with a 7 % iodine solution and were fed up to 4 L /d of first day milking colostrum, with a minimum of 50 g/L of IgG, within the first 6 to 12 h of birth (split over two feeds). Blood samples were collected from the jugular vein 24 h after the first feeding of colostrum and analyzed for total serum protein levels (determined using a Reichert AR 200 digital hand-held refract meter; Reichert, Inc., Depew, NY, USA) and IgG concentration (by radial immune diffusion; VMRD Inc., Pullman WA, USA). At 1 to 18 d of age calves were fed twice daily, at 0700 and 1500 hours, receiving up to 4 L/hd/d (equivalent to 10.5 % BW) of stored colostrum (6.1 ± 0.35 % protein; 5.42 ± 0.64 % fat, 6.2 ± 0.16 % lactose and SCC of 170 ± 44.6 × 10^3 per mL), with the addition of 50 g/d of probiotic (X-Factor™ formulations, Bell-Booth, Ltd, Palmerston North, NZ) and from 19 days of age calves were fed stored colostrum once daily, at 0700 hours, with the addition of 200 g /hd/d of the plant carbohydrates, with amino acids (Table 3.1) Queen of Calves™ formulations (Bell-Booth, Ltd, Palmerston North, NZ). Colostrum and milk was fed at approximately 28°C using plastic calf feeding containers (4 L capacity; Stallion Plastics Ltd, Palmerston North, NZ) fitted with rubber teats. Milk feeding equipment was rinsed with cold water, washed and disinfected with hot water plus a 5% hypochlorite solution following each feeding. Calves were given local anaesthetic before being dehorned at 5 ± 0.5 weeks of age using a gas powered hot disbudding iron, and vaccinated (Ultravac™, Zoetis, NZ Ltd, Auckland) for a range of clostridia infections.

3.1.3 Treatment diets

Table 3.1 Chemical composition (% DM) of low (30:70), high (70:30) of alfalfa and cereal total mixed rations, starter and pasture hay

	Total mixed rations			
	30:70	70:30	Starter	Hay
Dry matter, %	52.4 (0.16)	45.7 (0.21)	87.4 (0.63)	89.2 (0.52)
Nutrients				
CP, %	14.9 (0.05)	20.1 (0.15)	20.7 (0.35)	12.1 (0.18)
Fat, %	5.0 (0.04)	3.1 (0.04)	5.2 (0.03)	2.0 (0.02)
NDF, %	25.9 (0.61)	38.4 (0.40)	27.8 (0.23)	64.4 (0.43)
ADF, %	16.5 (0.31)	30.8 (0.47)	15.9 (0.98)	34.1 (0.36)
Ash, %	8.2 (0.06)	10.5 (0.09)	11.7 (0.11)	7.0 (0.10)
TDN, %	77.4	60.9	78.2	57.24
ME, Mcal/kg	2.8	2.2	2.8	2.1
ME, MJ/kg DM	11.7 (0.07)	9.3 (0.03)	11.8 (0.01)	8.7 (0.01)
Minerals				
Ca, g/kg DM	13.3 (0.47)	12.7 (0.35)	16.7 (1.16)	7.0 (0.21)
Mg, g/kg DM	3.4 (0.16)	2.3 (0.03)	3.0 (0.05)	2.5 (0.04)
K, g/kg DM	13.5 (0.25)	27.3 (0.13)	12.9 (0.14)	2.5 (0.03)
P, g/kg DM	6.2 (0.10)	2.6 (0.26)	4.3 (0.06)	3.5 (0.05)

TDN and ME calculated from ADF using NRC equation (2001)

All calves had ad-libitum access (with at least 10 % refusal) to clean fresh water and one of three diets resulting in 36 calves being fed milk with: a high forage (HF) to cereal (70:30) proportion total mixed ration (TMR): a low forage (LF) to cereal (30:70) proportion TMR; pasture hay with a calf starter (Table 3.1) (NRM Ltd, Auckland, NZ) (PH+S) up to 49 days of age. The TMR and starter were fed in individual feed troughs, while hay was offered from nets, all of which were suspended above ground level (0.2 m) inside each pen, and this was replenished twice daily. Calves were weaned from milk abruptly at 49 d of age and continued to be housed for a further seven days. At 56 days of age calves from all treatments were turned out to pasture and calves fed TMR were offered ad-libitum access to mixed forage TMR, whereas calves offered PH+S were fed ~ 2 kg DM /hd/d of starter meal (16 % CP, NRM Ltd, Auckland, NZ, Table 3.1) and ad-libitum access to pasture hay for a further four weeks (NRM Ltd, Auckland, NZ).

3.2 Measurements

Calves were observed twice daily for any sign of illness (nasal discharge, cough and diarrhoea), and faecal consistency was scored using a 5-point scale (0: poor runny to 5: very good / firm). Body weight, heart girth, wither height, hip height and hip width were measured weekly from birth until three weeks following turning out to pasture. The amount of fresh feed offered and remaining were weighed and the feed intake was calculated. Feed samples were collected daily, bulked into weekly composite samples, and sent to the Massey University Feed Analysis Laboratory (Palmerston North, New Zealand) for determination of DM, CP, ADF, calcium, phosphorus (AOAC International, 2000), and NDF (Van Soest et al., 1991) and the total digestible nutrients (TDN) were calculated using the NRC (2001) equations (Table 3.1).

3.2.1 Maintenance behaviour

The calves were observed on three separate occasions, over three 24 h periods, to obtain a reasonably accurate estimate of behaviour and eliminate the effects of day-to-day variation (Albright and Timmons, 1984). During each of three 24 h observation periods, the behaviour of all the animals was observed manually using scan sampling (Martin & Bateson, 2007) during which the behaviour of the calves were recorded every five minutes during daylight (06:00 to 21:00) and every fifteen minutes during darkness (21:00 to 06:00), to obtain an accurate representation of bovine standing, lying and feeding behaviour (O'Driscoll et al., 2008; O'Driscoll et al., 2009; Mitlohner et al., 2001). The recorded behaviours, defined in Table 3.2, were used are ethological indicators for the assessment and make statements about the effect of the diets fed on the needs and welfare of the animals.

Table 3.2 Ethogram of the behaviours observed during the experiments and the definitions of observations

Code and behaviour	Description
L = lying	Cow is lying down with her body on the ground
S = standing	Standing on four feet
Gr = grazing	Standing with the head closer than 20 cm from the ground
F = feeding	Taking silage into the mouth and jaw moving, or muzzle in contact with silage and moving
R = ruminating	Jaw moving, not taking feed into the mouth
Other activities	All other behaviours not mentioned above, for example walking, drinking, licking, social behaviour, aggression

These observations were facilitated by application of either numbers or letters of the alphabet, which applied to the body of the animal to identify each animal individually within each group. The observer recorded the following activities, for each animals; posture (lying on ground, lying on bed, standing while feeding, standing idle, standing fully on bed with all four feet, half standing on bed with only the front feet in a stall, or walking) and activity (feeding, grazing, ruminating, drinking, grooming, or aggression). A calf was recorded as eating when they had their head in the feed trough and was actually engaged in consuming food. A bout was defined as the time between lying down and rising, maximum bout length was defined as the longest episode of continuous bout recorded, and total lying was the sum of all bout lengths. The number of lying and standing bouts per day were determined as the mean number of times a cow stood up and lay down in a period of 24 h and when the calf was idling and doing nothing else, it was scored as standing.

3.2.2 Cross-sucking and non-nutritive sucking behaviour

A selection of twenty seven similar age and weight calves, taken equally from each of the three diet treatments, were observed continually over a 30 minute period directly following milk feeding to record the occurrence of cross-sucking behaviour. This observation was completed in the morning after the calves were on once-a-day feeding. The observations were carried out on one pen at a time, observing all three calves at the simultaneously allowing for mutual sucking to be identified using the methodology carried out by Lidfors in 1993. The start and end time of each cross-sucking and non-nutritive sucking bout were recorded using a stop watch, along with the article being sucked. Individual cross-sucking and non-nutritive suckling bouts were recorded from the time the calf had a body part of another calf's or object in its mouth and the sucking movement was first observed to the time the calf fully removed its mouth from the area of the calf or object. The cross-sucking areas identified included navel, mouth, ear, neck, udder, leg and other body parts, whereas non-nutritive sucking areas identified included bars of the pen, netting, bedding and other environmental objects.

3.3 Statistical Analysis

The time calves spent lying, standing, feeding, walking; the number of lying bouts and the average time spent lying per 24 h was calculated for each individual animal. These behaviours were analysed according to the length of time spent in a specific behaviours and the number of times that the behaviour was performed was assessed according to Haley et al. (2000). The growth rate and feed intake was found to be normally distributed and was analysed as repeated measures with the ANOVA General Linear Model (GLM) command in Minitab 16.0 (2012, Pennsylvania, USA), using diet and period as fixed effects and individual animal as a random effect. The behaviour data was found to be not normally distributed; according to the normality distribution plots, and was assessed using Kruskal Wallis non-parametric data analysis command in Minitab 16.0 (2012, Pennsylvania, USA), using diet as a fixed effect and individual calf as a random effect in the model. The data was transformed and where it was normally distributed analysed by GLM command in Minitab 16.0 (2012, Pennsylvania, USA) and presented as mean ± standard deviation and was used to assess the time animals spent performing differing behaviours in each observation period. The overall time animals spent cross-sucking and non-nutritive sucking when offered differing fibre levels was used to assess the existence of significant differences between differing diets, to compare the effect of diet on cross-sucking and non-nutritive sucking behaviours. The existence of significant differences between means were reported when the probability value (P) was P<0.05 and a tendency was reported when the P <0.10.

Chapter 4.0 Results

4.1 Live weight and feed intake

On allocation to diets, at 48 h of age, the live weight of calves did not differ significantly between calves offered differing starter diets: low fibre (LF) total mixed ration (TMR), high fibre (HF) TMR and Perennial ryegrass hay and pelleted starter (PH+S). At 20 d and at 40 d of age the calves offered PH+S had a significantly higher mean live weight compared with calves fed the LF TMR. Whereas the mean live weight of calves offered the HF TMR did not differ from calves offered LF TMR and PH+S (Table 4.1). The calves offered PH+S had a significantly higher mean daily DMI between 3 and 20 d and 21 and 40 d of age, compared to calves offered the LF and HF TMR's (Table 4.1). Whereas the mean daily DMI of calves offered LF and HF TMRs did not differ between 3 and 20 d of age, however between 21 and 40 d of age the daily DMI was significantly lower for calves offered the LF TMR compared with the HF TMR. There was a high and significant correlation relationship between calf daily mean live weigh and dry matter intake at 20 d (R^2=0.86; P<0.001) and 40 d (R^2=0.89; P<0.001) of age.

Table 4.1: Mean live weight and dry matter intake of calves offered a low forage (LF) total mixed ration (TMR), high forage (HF) TMR and Perennial rye grass hay with a pelleted starter (PH+S) during the pre-weaning period

	LF TMR	HF TMR	PH+S	*P* value
Live weight				
2 d of age, kg	38.3 (0.81)	40.0 (0.83)	39.0 (0.80)	0.4518
20 d of age, kg	50.1 (1.04) ^{b}	52.0 (1.01) ^{a,b}	53.1 (1.02) ^{a}	0.0197
40 d of age, kg	60.3 (1.41) ^{b}	63.8 (1.41) ^{a,b}	67.1 (1.38) ^{a}	0.0043
Dry matter intake				
2 to 20 d, kg/d	0.09 (0.029) ^{b}	0.11 (0.029) ^{b}	0.18 (0.029) ^{a}	0.0010
21 to 40 d, kg/d	0.80 (0.012) ^{c}	0.95 (0.012) ^{b}	1.70 (0.011) ^{a}	<0.0001

$^{a, b, c}$ Means in the same row followed by differing superscript letters differ significantly at *P*<0.05.

4.2 Time spent in maintenance behaviour and frequency of oral behaviour

Table 4.2: Mean incidence (No.) and time spent (min/d) performing differing behaviour by calves offered a low forage (LF) total mixed ration (TMR), high forage (HF) TMR and Perennial rye grass hay with a pelleted starter (PH+S) during the pre-weaning period

	LF TMR	HF TMR	PH+S	*P* value
Time spent, per 24 h				
Standing, min	251.4 (1.16)	238.9 (1.16)	264.9 (1.06)	0.6555
Lying down, min	926.6 (1.25)	953.5 (1.16)	985.4 (1.16)	0.4434
Sleeping, min	210.9 (2.12)	178.2 (1.93)	189.8 (2.13)	0.2323
Eating, min	129.1 (0.14) [b]	163.7 (0.14) [a]	154.1 (0.14) [a]	0.0354
Ruminating, min	386.2 (0.18)	394.9 (0.18)	406.5 (0.18)	0.7211
Other, min	51.1 (0.49) [b]	69.5 (0.67) [b]	0.10 (0.01) [a]	0.0344
Incidence, per 24 h				
Vocalising, No.	1.5 (0.10)	1.7 (0.10)	1.5 (0.10)	0.985
Allo-grooming, No.	4.01 (0.11) [b]	5.7 (0.11) [a]	5.1 (0.11) [a]	0.0312
Drinking water, No.	2.5 (0.10)	2.0 (0.10)	2.3 (0.10)	0.7891

[a, b] Means in the same row followed by differing superscript letters differ significantly at $P<0.05$.

Calves offered the HF TMR and PH+S spent significantly more time eating solid feed and performed significantly more incidents of allo-grooming, compared with calves offered the LF TMR (Table 4.2). The diet offered to the calves had no significant effect on the time calves spent standing, lying, sleeping or ruminating, and the daily incidents of vocalising and drinking water. Calves offered PH+S spent significantly less time engaged in other activities, than calves offered LF TMR and HF TMR which included walking, social encounters, aggression, inactivity, and licking. There was a significant correlation relationship between the time calves spent eating solid feeds (R^2=0.81; $P<0.05$), allo-grooming (R^2=0.85; $P<0.05$) and DMI (R^2=0.89; $P<0.001$), whereas there was no correlation with time spent standing, lying, sleeping, ruminating or the incidence of vocalising or drinking water.

4.3 Cross-sucking behaviour

Calves on the three diets did not vary significantly for the number of cross-sucking incidents, mean non-nutritive sucking bouts and mean total non-nutritive sucking lengths (Table 4.3). The number of incidents of sucking on the bars of the pen was not significant but has a tendency to be different between LF TMR, HF TMR and PH+S (R^2=0.81; *P*<0.05).

Table 4.3: Mean cross-sucking behaviour of calves offered a low forage (LF) total mixed ration (TMR), high forage (HF) TMR and Perennial rye grass hay with a pelleted starter (PH+S) during the pre-weaning period

	LF TMR	HF TMR	PH+S	*P* value
Cross-sucking, No.	4.8 (0.09)	3.9 (0.11)	4.0 (0.09)	0.242
Sucking pen, No.	13.4 (0.16)	11.2 (0.17)	10.3 (0.16)	0.0817
Non-nutritive sucking				
Bout, No.	13.2 (9.40)	11.9 (5.05)	10.1 (6.08)	0.368
Total bout length, Sec	328.9 (371.73)	192.9 (161.89)	93.1 (102.26)	0.368

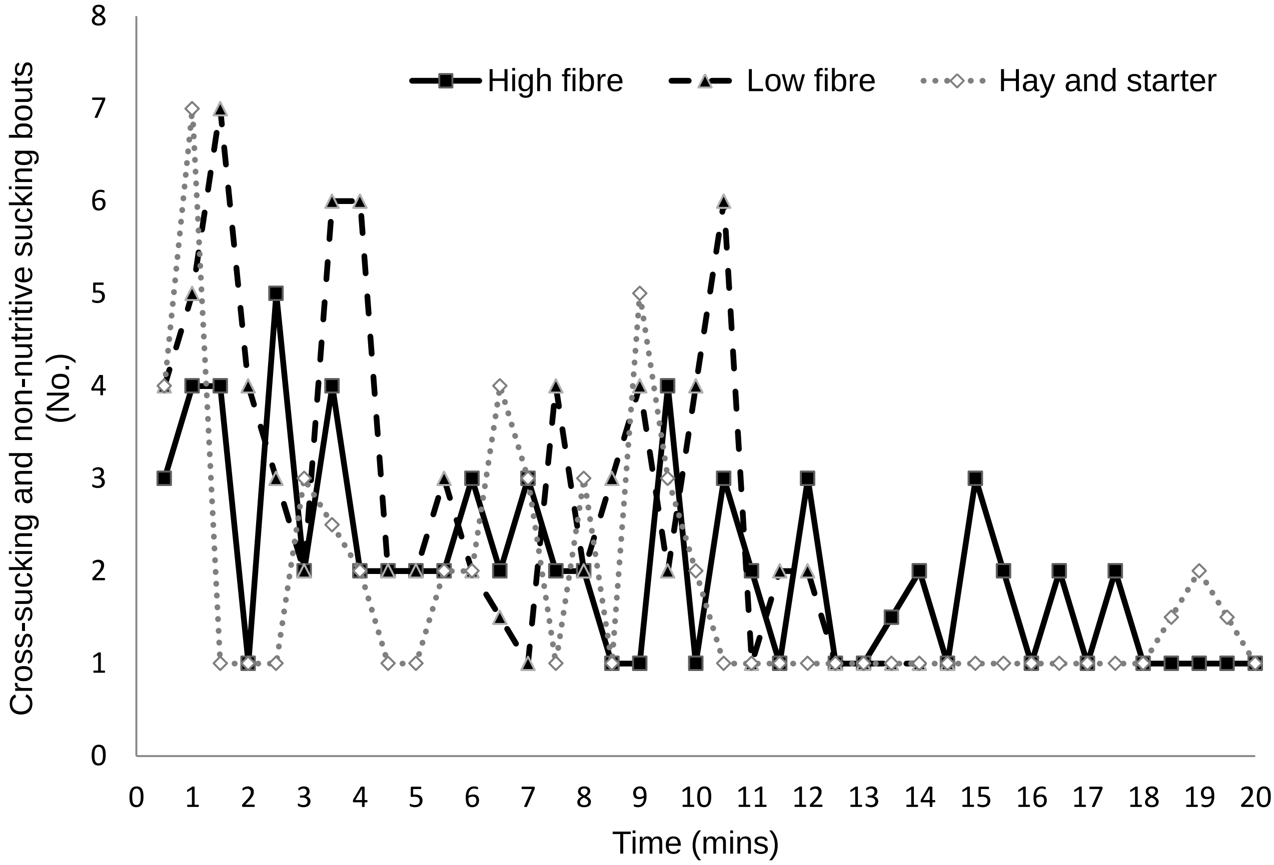

Figure 4.1: Incidence of cross-sucking, during the 20 min period directly following milk feeding, by calves offered a low fibre (LF) total mixed ration (TMR), high fibre (HF)TMR, and Perennial rye grass hay with a pelleted starter (PH+S)

There were three calves (2 on PH+S, 1 on HF TMR) that performed no cross-sucking or non-nutritive sucking, whereas two calves (1 on LF TMR, 1 on HF TMR) performed only one cross-sucking or non-nutritive sucking bout. The frequency of cross-sucking decreased significantly over the 30 minutes directly following milk feeding (Figure 4.1). The mean amount of cross-sucking in LF TMR declined more rapidly and sooner compared with calves fed PH+S and HF TMRs, whereas the median amount of cross-sucking in HF TMR calves continued to occurring at 20 minutes following milk feeding.

4.4 Area of the body sucked during cross-sucking behaviour

Calves offered HF TMR and PH+S sucked on the navel for a significantly shorter (*P*= 0.035) period of time than calves offered LF TMR. Calves offered HF TMR sucked the udder (*P*=0.039) for a significantly longer period than calves offered a LF TMR and PH+S. There was significantly lower number of sucking bouts directed towards the inguinal region (*P*=0.042) in calves fed a HF TMR and PH+S, compared with calves fed a LF TMR (Figure 4.2). The time calves spent and the number of sucking bouts directed towards the mouth, neck, leg and other body parts of other calves did not differ significantly among diets (Figure 4.2).

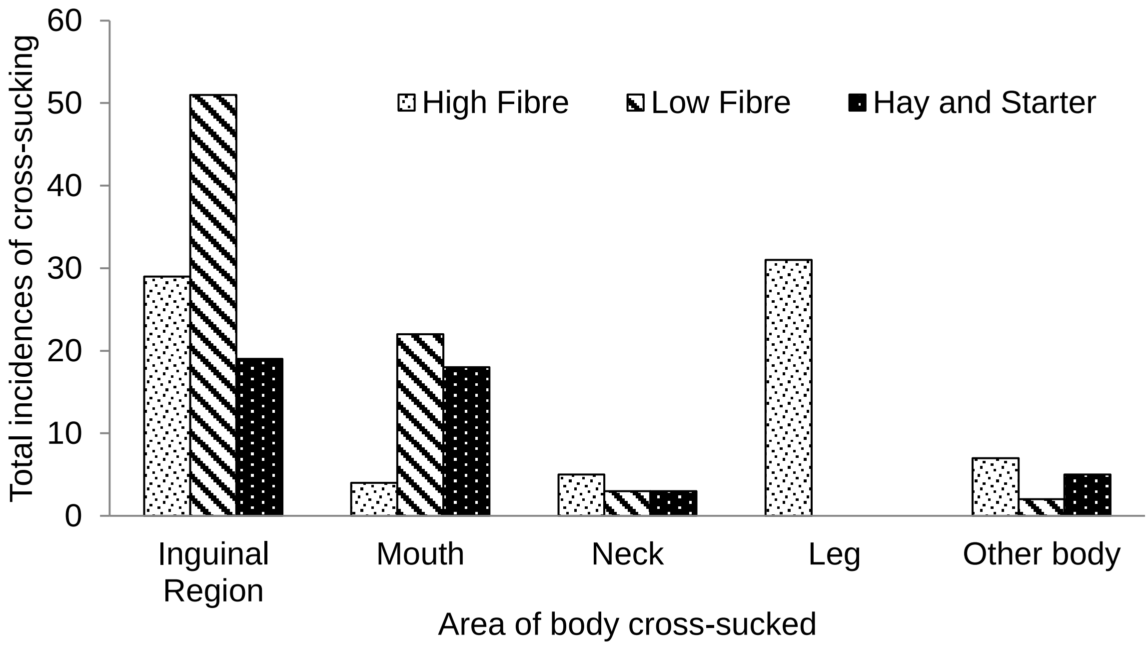

Figure 4.2: Total daily incidence of cross-sucking, according to body part, directly (30 mins) following milk feeding in calves offered a low fibre (LF) and high fibre (HF) total mixed ration (TMR) and Perennial rye grass hay and a pelleted starter (PH+S). Calves offered a HF TMR and PH+S spent significantly less time (*P*=0.041) and performed significantly (*P*=0.040) less bouts (Figure 4.3) of sucking on the bars of the pen than calves fed a LF TMR. Whereas the time spent and number of bouts of sucking directed towards the pen netting did not differ significantly between diets.

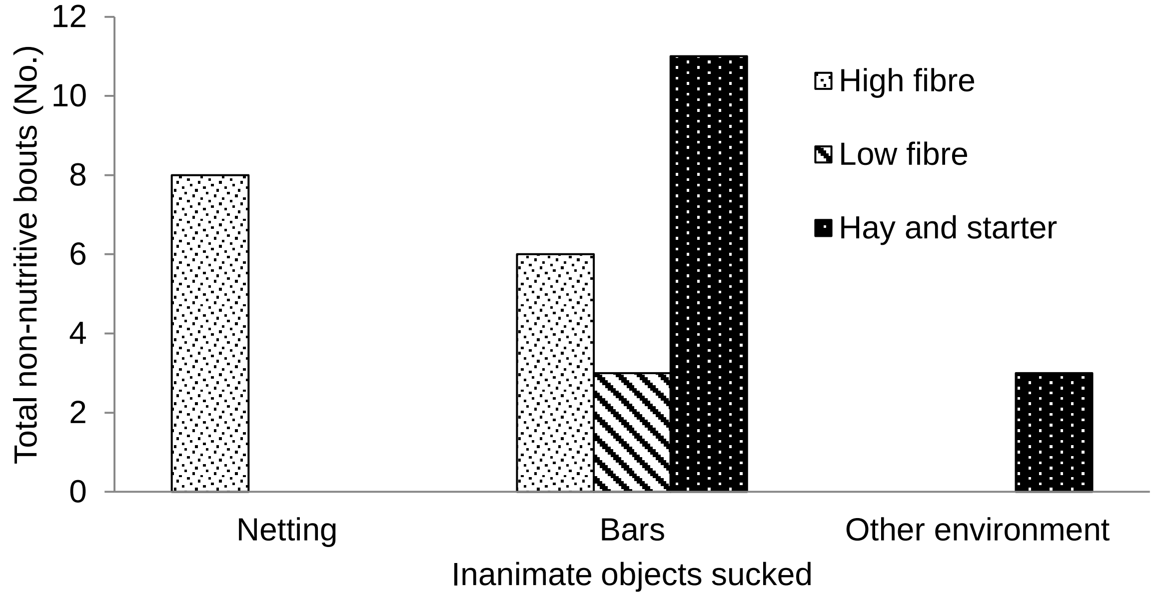

Figure 4.3: Total bouts (No.) of non-nutritive sucking, according to inanimate object sucked, by calves offered a low fibre (LF) total mixed ration (TMR), high fibre (HF) TMR and Perennial rye grass hay with a pelleted starter (PH+S)

Chapter 5.0 Discussion

5.1 Forage level impact on live weight and feed intake

Phillips (2004) found that calves fed pasture hay spent less time eating concentrate and more time ruminating than those not offered pasture hay, whereas calves offered cereal straw ate more forage and starter concentrate, grew faster and spent longer ruminating than those offered only hay, mainly because cereal straw cantinas more fibre than hay. Calves fed perennial ryegrass hay with a pelleted starter (PH+S) had a higher DMI and LWT gain (Table 4.1) over the study period than the low fibre (LF) total mixed ration (TMR) and high fibre (HF) TMR. The calves fed a HF TMR had a higher DMI and LWT gain than LF TMR between 21 and 40 d of age. The HF TMR and PH+S spent a significantly more time eating solid feeds, although the time spent ruminating each day did not vary between the three diets. These results could be due to the PH+S and HF TMR diets being more palatable than the LF TMR diet, and/or the LF TMR containing too little forage to provide similar rumen degradation.

Calves in this study ruminated less than calves in a study carried out by Margerison et al. (2003) (386 to 406 min/day versus 560 min/ day), which may also indicate a difference in solid feed fibre levels. Group housed calves eat hay at an earlier age than individually reared calves (Hepola et al., 2006) due to social facilitation. Amount of roughage, duration of feeding, ratio of concentrate to forage and rumination have all been suggested as factors that affect cross-sucking (Lidfors and Isberg, 2003). Castells et al. (2012) found that calves that spent the most time eating and ruminating, had the lowest non-nutritive sucking and vice versa.

5.2 Forage level impact on maintenance behaviour and frequency of oral behaviours

Phillips (2004) found that calves fed a low fiber diet, with no grass, spent more time licking the pen and had less self-grooming bouts than calves fed (grass) fibre in their diet. In this study, calves fed the LF TMR carried out less allo-grooming and spent longer time per day sucking on the pen than HF TMR and PH+S (Table 4.2). This could be due to the low forage proportion combined with the low intake of this diet. The calves fed LF TMR not having the need for oral behavioural met by this diet, hence they sucking on the pen. Grooming is assumed to represent a positive behaviour, indicating that the calf is satisfied and relaxed. Margerison et al. (2003) found artificially reared calves spent 17.3 events/ day of grooming themselves and others, which is significantly higher than the number of events of allo-grooming found in the current study. However, this study was completed in a tropical environment, which may have led to greater animal activity.

Phillips (2004) found calves drank similar amounts of water, time spent standing per day and time spent calling or vocalising. In the current study, there was no effect of solid feed diet on the time spent standing, lying, sleeping, vocalising and drinking water (Table 4.2). Calves on the PH+S diet had a lower amount of time spent in 'other' activities than HF TMR and LF TMR. The 'other' activity refers to activities such as licking (other than allo-grooming), nibbling, sniffing, urinating, defecating and inactivity. Veissier et al. (1998) also found that providing solid feeds with milk reduced the amount of time spent licking, nibbling and inactivity and Phillips (2004) found that by providing grass, that increased forage intake, reduced the frequency of licking the pen and grooming others. Time spent sniffing was reduced by the provision of solid foods showing innate behaviour to forage (Veissier et al., 1998) with behaviours developing over age to gradually become adult behaviours (MacFarland, 1990).

5.3 Forage level impact on cross-sucking behaviour

Roth et al. (2009) and Laukkanen et al. (2010) found mutual sucking was frequently observed and was linked with future cross-sucking in older animals. Calves that are most often sucked on become accustomed to this and are likely to let specific calves suck while others they chase away (Ude et al., 2011). Keil and Langhans (2001) support this finding with 17 calves performing more than 50 % of their sucking bouts at one specific calf. It's been found that situation and not pair bonding that elicits mutual sucking with a positive correlation between cross-sucking and being cross-sucked (Keil and Langhans, 2001; Laukkanen et al., 2010). It was observed, in this study, that mutual sucking occurred and that it was specific calves that repeated the behaviour and had relationships with other specific calves (Table 4.3).

Previous studies found 58.6 % (Ude et al., 2011), 85 % (Roth et al., 2008) and 92.1 % (Keil and Langhans, 2001) calves cross-sucked. In this study variation was seen between calves with some performing no cross-sucking (two from PH+S, one from HF TMR) and two calves performing only one cross-sucking bout (one calf from LF TMR, one calf from HF TMR); neither of which were diet dependent. de Passillé et al. (1992), Keil and Langhans (2001), Weber and Wechsler (2001), de Passillé et al. (2010), Laukkanen et al. (2010) and Ude et al. (2011) agree with this reporting large differences between individual animals but consistency per animal in cross-sucking frequency.

5.4 Forage level impact on area of the body sucked during cross-sucking

The mouth being an area frequently sucked can be explained by residual milk and the flavour being present. Lidfors (1993) and Jensen and Budde (2006) agree with this finding, reporting the muzzle being the main area of cross-sucking, while Margerison et al. (2003) and Lidfors and Isberg (2003) found the head area (ears, muzzle, and neck) was the second most cross-sucked area. Lidfors (1993) and Jensen and Budde (2006) found all calves were seen to cross-suck the inguinal area. The navel and mouth were most often cross-sucked areas on the calves in this study (Fig 4.2). The calves fed a HF TMR cross-sucked a greater amount of time directed towards the udder than the other two diets. Whereas the LF TMR had a significantly higher amount and number of bouts of cross-sucking directed towards the navel than HF TMR and PH+S. The navel being the area most frequently cross-sucked is due to it being in the inguinal region and calves have an innate behaviour to suckle milk from this area (Spinka, 1992; Keil and Langhans, 2001). Research carried out by Keil and Langhans (2001) Lidfors and Isberg (2003), Margerison et al.

(2003) and Roth et al. (2008) agrees with these findings in that the inguinal area, including the navel, udder and prepuce, was the area, that had the majority 60.1 to-98 % of cross-sucking bouts directed towards it. The bars of the pen were the most non-nutritive sucked inanimate object in the environment. Calves fed a LF TMR tended to have a greater number of non-nutritive sucking bouts on the bars of the pen and suck the environment for longer periods than calves fed a HF TMR and PH+S.

5.5 Overall trend of cross-sucking behaviour

The frequency of cross-sucking showed a general linear decrease over the 30 minutes directly following milk feeding. Lidfors (1993), Jensen (2003) and Margerison et al. (2003) found that in artificially reared calves, all cross-sucking instances were in the first twenty minutes directly following milk feeding, declining linearly. The data shows there were more bouts at the start of the observation period but were for fairly short periods and once they settle down a bit the cross-sucking bouts were longer with fewer bouts occurring. This could be due to the calf being more excited and the urge to suckle was higher as the positive feedback system causing suckling motivation was high but the negative feedback system starts to take effect over time with Lidfors (1993), Veissier et al. (1998) and de Passillé (2001) supporting these findings and de Passillé et al. (1992) reported non-nutritive sucking to start within ten seconds after milk feeding. The HF TMR and PH+S the sucking behaviour that occurred after twenty minutes was directed towards objects in the environment with LF TMR finishing non-nutritive sucking before twenty minutes post milk feeding. This behaviour could be considered to be curiosity and foraging behaviour in order to meet other nutritional needs more than non-nutritional sucking. De Passillé et al. (1992) found similar results and stated that calves sucked the teat, then manipulated it, then explored the pen and licked parts of it, then lay down.

Offering different feeds could alter cross-sucking behaviour with more palatable feeds having a higher intake, which in theory should decrease cross-sucking behaviour. Feeds higher in fibre should also decrease cross-sucking behaviour due to more rumination and eating time required to consume these feed sources and oral behavioural needs being satisfied. Haley et al. (1998), Keil et al. (2001) and Roth et al. (2008) found non-nutritive sucking and cross-sucking was reduced when hay was offered by provided a limited amount of roughage following milk meal, this could influence a higher roughage intake and may result in less non-nutritive sucking and help initiate rumen development; providing a grain or concentrate can have similar results. Veissier et al. (1998) found calves fed concentrate and chopped straw had a reduced non-nutritive nibbling. The effects on cross-sucking when fed solid feeds along with milk only had an effect at times not around milk feeding period (Veissier et al, 1998). Keil and Langhans (2001) found calves fed high maize silage and small amounts of starter concentrates inter-sucked most often. A negative correlation has been found between cross-sucking and DE intake (Roth et al., 2009; de Passillé et al., 2010) indicating that great feed palatability and intake, of diets with an adequate forage content are the most likely to favour lower amounts of cross sucking. In this study, the pasture hay and concentrate starter diet fitted this criteria more closely resulting in greater dry matter intakes, lower amounts of cross sucking and higher growth rates.

5.6 Conclusions

In conclusion the diet that had the best overall results was Perennial ryegrass hay with a pelleted starter (PH+S). No positive difference was observed by feeding a higher fibre diet; however, feeding a lower fibre diet had significant negative results. When on a low fiber (LF) total mixed ration (TMR) diet, less allo-grooming, more cross-sucking incidents per day, high cross-sucking on the navel and more time sucking on bars of the pen both throughout the entire day and directly following milk feeding were observed. This supports the idea that these calves were not receiving appropriate dietary needs and their innate oral behavioural needs were not being satisfied. Calves fed on the PH+S diet had a higher DMI, LWT gain, time spent eating, lower ‘other’ activity and lower non-nutritive oral behaviours by having a higher solid feed intake could explain the lower non-nutritive oral behaviours and ‘other’ behaviours by their nutritional and oral behavioural needs being met. In agreement with previous studies, the navel and mouth were the most desirable body parts to be sucked on. Also, cross-sucking bouts started directly following milk feeding and decreased linearly over 20 minutes after which calves were seen to show foraging or exploration behaviour. Mutual sucking was observed but great variation was found between individual calves although per calf cross-sucking was fairly consistent. Cross-sucking and non-nutritive oral behaviours were not eliminated.

Future research

In future research, a comparison of calves fed a fibre source directly after a meal and calves not fed a fibre source directly after a meal could be compared. This will help support other studies which have found feeding hay directly after milk feeding results in a lower amount of inter-sucking. It may also help encourage calves to eat fibre sooner leading to an earlier rumen development. This study helps show the importance of management and feeding in the reduction of the detrimental cross-sucking behaviour.

Chapter 6.0 References

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Appendix A: Ethogram Recording Table

Date:

Pen: Diet:

Cross-sucking in calves 30 minutes after feeding

Calf Number	Start sucking	Stop sucking	Area sucked	Total Length sucking (seconds)	Total Cross-sucking bouts

Notes/ observations: