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AN INVESTIGATION INTO THE SOCIAL INTERACTION AND DEMONSTRATION OF PREFERENCE FOR LOCATION OF COWS IN A COMMERCIAL DAIRY HERD.

Joanne Vincent

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Vincent, Joanne

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AN INVESTIGATION INTO THE SOCIAL INTERACTION AND DEMONSTRATION OF PREFERENCE FOR LOCATION OF COWS IN A COMMERCIAL DAIRY HERD.

by

JOANNE VINCENT

A thesis submitted to the University of Plymouth in partial fulfilment for the degree of

RESEARCH MASTERS

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Author's Declaration

At no time during the registration for the degree of Research Masters has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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Abstract

Joanne Vincent

AN INVESTIGATION INTO THE SOCIAL INTERACTION AND DEMONSTRATION OF PREFERENCE FOR LOCATION OF COWS IN A COMMERCIAL DAIRY HERD

Under free-ranging conditions cattle live in social groups because it is beneficial to them in terms of risk of predation, breeding synchronisation and collective intelligence, amongst others. However, current dairy cattle management practice is not geared toward management of the cow for her social wellbeing but rather for the ability to feed and manage appropriately and meet the cows' main needs that affect productivity and profitability. Domestic dairy cattle do not have free ranging opportunities. Heifers are managed in cohort groups from birth to calving and have little, if any, interaction with the adult herd until they calve. This study investigated the nearest neighbour preference and preference for location on a lactation group level in a commercial herd of 159 lactating dairy cows, during the winter housing period in the South Hams, Devon. CCTV cameras were used to record cow order at milking and cows were observed directly in the feeding and cubicle yards. This study determined that there were strong interactions within the lactation groups between younger animals in the herd. These findings suggest that cows in larger and younger cohort groups, have little need to form bonds outside of that group. Understanding the dynamic social nature of dairy cattle and their apparent preference for interaction with familiar animals, could lead to the development of management techniques that

focus on the group rather than individual animals, reducing stress and positively impacting on welfare and production.

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1.1 Introduction

The UK dairy industry produced 6,171 million litres of liquid milk in 2019 (AHDB, 2020), declining from 6,637 million litres in 2006. Liquid milk production has reduced, however, cheese and butter production have both increased by 16% and 38% respectively in the period 2006 to 2019 (AHDB, 2020) AHDB (2019) figures depict an overall decline in the number of cows in the UK dairy herd from two million two hundred and twenty nine thousand in 2001/2 to one million eight hundred and eighty one thousand in 2018/19, during the same period the average yield has increased from 6,449 litres per cow to 7,968 litres per cow. Cows are increasingly being managed in larger herds as the number of UK dairy farms has also declined, from 35,741 herds in 1995 to 12,752 herds in 2018 (AHDB, 2020a). The average number of cows in a herd has increased from 118 in 2000 to 205 in 2019 (Kingshay, 2019). The increase in herd size can have additional management considerations such as, repeated re-grouping (Bøe and Færevik, 2003) and changes in stocking rates (Winkler, Tucker and Weary, 2015) which can affect the animals' behaviour.

1.2 Domestication of cattle

Milk production in the UK occurs in a variety of management systems, ranging from: extensive grazing, low input – low output systems through to, intensive, zero grazing, high input – high output systems, with a variety of different methods in between. Whilst no two farms can be the same in terms of locality, topography, management system and environment, what is the same is the species of animal being utilised for milk production. *Bos taurus* were likely domesticated 10,500 years ago (Hirst, 2019). Archaeological and genetic research has shown that modern cattle are descendants of the wild auroch (*Bos primigenius*). (McTavish *et al,* 2013) There were many independent domestication events and todays cattle have emerged as two distinct species, *Bos taurus,* European cattle and *Bos indicus,* Asian cattle. Each selectively bred and consequently adapted to suit the climate and the needs of the humans that had domesticated them. The domestication of a species involves them becoming adapted to a particular environment that is in the main captive (Price, 1999)and has resulted in a "domestication phenotype" (Jensen, 2006). The domestication phenotype is important when considering suitability of animals for dairy production systems, in fact, selection criteria for dairy cattle includes temperament alongside longevity, type and health traits (Haskell, Simm and Turner, 2014). Consequently, selection of those with suitable temperaments for dairy production results in animals that would find it difficult to survive if returned to their non-domestic environment. Man provides food, water, accommodation, health and welfare benefits and protection from predation. In return dairy cattle provide increasing yields in larger herds and display a reduced sensitivity to changes in their environment (Price, 1999). Domestication and selection of animals for higher production, has led to responsibility to provide what the animal needs in terms of health, welfare and wellbeing.

1.3 Genetics and selective breeding

Selective breeding for dairy cattle has resulted in an animal more suited to frequent human and mechanical interaction (Byrne, 2016). Indeed, Freidrich *et al.* (2015) determine that, the selection for high milk yields has resulted in the selection for animals who have a lower reaction to novelty, due to the genomic and chromosomal association of the traits. Although the modern dairy cow has been selected to fit production and management systems, it can be proposed that management procedures can cause negative emotions that adversely affect animal welfare (Boissy *et al.,* 2005). Additionally, Adamczyk *et al.* (2013) state that behavioural traits positively correlate to production traits, also affecting longevity of cattle and can also be used to measure welfare. Sepúlveda-Varas *et al.* (2014) state that behaviour is an important tool for recognising illness in animals, using mastitis as an example, mastitis being the most frequent disease of dairy cows (Ruegg, 2017). Furthermore Siivonen *et al.* (2011) state that mastitis causes motivational conflict in cattle and behaviour markers can be used as an early detection tool for illness in cattle. Therefore, an understanding of behavioural markers, what motivates that animal and an ability to adapt management strategies to incorporate the animals' natural behavioural instincts, may produce positive results, in terms of both animal welfare and production.

1.4 Natural behaviour

Many species of animals live in social groups because it can be beneficial to them. There is a reduced risk of predation, reproduction can be synchronised and generations can learn from each other (Croft *et al*., 2012a) Wagner *et al.* (2012) state that rearing contact with the mother, even if limited can lead to enhanced social skills in dairy heifers, this is supported by the findings of Wagner *et al.* (2015) who state that rearing with access to the mother and herd results in increase sociality and Valníčková *et al.* (2015)found that maternal rearing and group housing improved performance and welfare of dairy calves. It has been determined that, in rangeland situations, domesticated cattle herds have complex social networks but are, in the main, composed of social subgroups (Sowell *et al.,* 1999). Lazo (1994, cited in Sowell *et al.,* 1999) stated that these social groups tend to be matrilineal. However, within these higher-level groups there are smaller, less stable, subgroups affected by environmental conditions, cows rarely join groups they were not born into but larger groups can form when unstable subgroups fuseThese groupings may form due to the gregariousness of the members, the preference for their own calves or human interaction and management, in addition to availability of resources in their preferred range (Sowell *et al.,* 1999). Conditions that allow these subgroupings on farm could be a positive influence on the welfare of dairy cattle, however, the removal of the calf from the mother at, or soon after birth may affect the maternal bonding that enables the matrilineal subgroups to develop. The ability to express natural behaviour is important for all farm animals and is one of the Five Freedoms (FAWC, 2012). Social interaction is a natural behaviour expressed by cattle and therefore, investigations into how cows interact are important. Understanding how behaviour affects their performance can inform management decisions, techniques can then be modified to improve cow welfare.

It is difficult to determine the natural behaviour of dairy cattle due to the artificial environment they are managed in. Cattle (*Bos taurus*), allowed to range free, are social animals (Sowell *et al.,* 1999) and, although this is their natural state (Hirst, 2019), in a domestic situation they are usually housed in groups (Beisner and McCowan, 2015) which could place limits on their social interactions, such as the ability to move away, matrilineal structure and seeking conspecifics. Husbandry techniques for domestic dairy cows commonly group cattle in homogenous groups determined by factors such as, age, milk yield, body condition scores (Bøe & Færevik, 2003), which is for ease of management and does not take into consideration the effects of social interaction and changes to management group have on dairy cattle performance. Modern dairy practices include several different methods of dam and neonate management, largely determined by the management system and preferences of the herd manager (von Keyserlingk and Weary, 2007 Wagner *et al.,* 2012, Johnsen *et al.*, 2015, Valníčková *et al. 2015*). Such practices may include, but are not limited to: snatch calving (NMR, 2020) (usually only carried out to the reduce the risk of disease transfer, such as Johnes), removing the calf once the cow has cleaned it and administering colostrum artificially, leaving the calf with the dam to receive colostrum for 24 to48 hrs, restricted suckling, cow and calf systems and nurse cows (Fröberg 2008). These methods have been shown to have a sometimes positive, sometimes negative effect on the cognitive abilities of the calf and its ability to socially interact later in life. (Valnickova *et al.,* 2015; Costa, 2018). Management of dam and neonate in a dairy in a dairy production system differs significantly from other livestock production systems, examples of these include; suckled beef calf production, dams rear their calves until weaning at approximately six to eight months (RSPCA, 2020). Sheep production systems typically wean at approximately 12 weeks (James, 2018) and pigs are weaned between 14 and 28 days (Lord, 2017). While it is difficult to measure natural behaviour it is important, as explained earlier, to find ways.

1.5 Early experiences

It is important to understand how modern livestock husbandry techniques affect dairy cattle performance, especially within the context of the history of volatility within the UK milk market, the environment an animal is reared and managed in, and the resulting ability to socialise, may impact on welfare and production. It has been shown that calves will choose to interact with other calves that are familiar to it, in preference to calves that are unknown after regrouping (Færevik *et al*., 2007). In contrast to this, Stephenson and Bailey (2014) have demonstrated that cattle grazed on rangeland in the United States did not form strong bonds with "buddies". Directly contradicting the findings of Lazo (1994) and Reinhardt and Reinhardt (1981), (both cited in Sowell *et al.,* 1999) who stated that cattle form stable subgroups within a herd, often in matrilineal groups. It can be speculated that one of the reasons behind the cattle not forming strong bonds could be due to the sheer numbers of animals that are available to interact with.

Dairy production systems commonly practice separation of the calf and dam immediately after birth, this contrasts with suckled beef production systems where the calf is reared with its dam in a complex social environment. Isolated individual rearing of calves, within sight, and sound of other calves, up until weaning has been shown to have detrimental effects on behaviour and development, they have difficulties coping in novel situations, deficient social skills and have cognitive deficits (Costa, von Keyserlingk and Weary, 2016). In addition to this Costa (2018) suggests that, for calves to learn about their environment and develop cognitive abilities they must form social relationships with the dam and conspecifics in the first few weeks of life. Farmers may prefer individual pens for rearing calves until weaning, for ease of management and health benefits, but there has been criticism of this method due to welfare grounds, as it limits social behaviours, Gaillard *et al.* (2014) stated that social housing for dairy calves may result in animals that have greater flexibility in response to changes in management. Additionally, Bolt *et al.* (2017) state that calves reared in pairs have stress buffering effects on each other and encourage full social contact with other calves as early as possible. Group rearing, however, has some drawbacks in terms of competition, especially if feed is restricted, and disease risk, especially in larger groups with a high stocking density (Duve and Jensen, 2011; Curtis *et al.,* 2016;Sherwin *et al.,* 2016), it is also difficult to measure feed intakes

1.6 Cognitive ability

As previously mentioned, it can be argued that the way an animal is reared will have an effect on its cognitive abilities. Gaillard *et al.* (2014) found evidence to suggest that individual housing has a negative effect on dairy calves' cognitive abilities, reducing their response to novel objects and reversal learning. Lower response to novel situations could be beneficial in terms of lesser response to stressful stimuli, however, the animal is likely to be less adaptable to changes, for example regrouping at drying off and calving..A calf's social interactions also have an effect on growth rates, as described by Valnickova *et al.* (2015), calves who remained with the dam for four days following birth had a greater growth rate up to two weeks of age, only to be overtaken by the grouped calves at ten weeks of age. Increased preweaning growth rates have been shown to positively affect post-weaning performance (Bhatti *et al., 2012).* Greater pre weaning growth rates are an important consideration that have a significant effect on health (Sherwin *et al., 2016)*age at first calving (Soberon *et al.,* 2012; Sherwin *et al.,* 2016), subsequent milk production (Soberon and Van Amburgh, 2013) and, ultimately, the profitability of the herd. Additionally, Costa (2018) states that calves reared on the dam and who have the ability to socially interact with other calves, have a greater ability to transition into the dairy herd, showed greater maternal behaviour and were less neophobic of new feeds, suggesting that rearing calves in a complex social environment could be of great benefit. These findings support evidence that calves reared individually up until weaning had impaired social skills and a reduced ability to cope with novel situations and cognitive deficit (Costa, *et al.*, 2016).

1.7 Cow performance

There are numerous factors that affect the performance of dairy cows, of which social interaction is a very important one. When cows are moved from one group to another, they display more aggressive behaviour as they re-establish hierarchy, (Bøe and Færevik, 2003) which in turn can stress animals and have an adverse effect on food and water intake, therefore reducing production performance (Lainez and Hsia, 2004). Improving social interaction with herd mates can improve welfare and increase performance of a cow..

1.7 Animal Welfare

Public perception of what constitutes good dairy cow welfare includes, appropriate feeding, good stockmanship, plenty of space, freedom to roam and environmental cleanliness (Ellis *et al.,* 2009). Participants in Ellis *et al. (2009)* survey felt that keeping dairy cows inside permanently was unacceptable and that they should be inside in the winter and outside in the summer, unaware that this is frequently the normal husbandry practice. Although it is becoming more common to keep cattle inside all year round, especially in high yielding herds (Meul *et al*. 2012). It could be argued that the welfare needs of the cows are being met if they are proficiently managed when continuously housed. Abeni and Bertoni (2009)summarise the main causes of poor welfare in intensively reared dairy cows in their review, they list the following as acceptable or good welfare conditions: attention to genetic background that meets farm conditions; buildings and equipment that meet the needs of the animal; maintenance and management of buildings and equipment; feed that meets nutritional requirements at all stages of production; social interaction that is gentle and/or enjoyable, including that with humans; good health conditions and it was interesting that public perception of good cow welfare did not include mention of social interaction. The public did however acknowledge a level of sentience within farm animals (Ellis *et al.,* 2009). The link was not made between sentience and the need for social interaction.

Social interactions typically consist of affiliative and agonistic behaviours, thought to establish a social network within the herd (Foris *et al*., 2019). Energy is expended during these agonistic interactions, and cows change their social competition strategies frequently when entering a new group and if they have a diseases such as metritis (Foris *et al.,* 2020) therefore it would be prudent for an animal that has evolved as a prey species to preserve that energy by not engaging in unnecessary social interactions

The negative impacts of poor animal health and welfare include reduced milk yield, poor reproductive performance, the main factors that challenge health are lameness, mastitis and infertility (Lotthammer and Wittkowski, 1994 cited in Marley *et al.,* 2010).

1.8 Group size and stocking density

Group size and stocking density are important factors that can affect overall performance, in terms of milk yield, growth rates, reproduction and welfare (Croney and Newberry, 2007, Færevik *et al.,* 2007, Rodenburg and Koene 2007, Talebi *et al,* 2014). Although it is recognised that group size and stocking density have an effect on production, welfare and health, however, little is known about the effect on social dynamics (Estevez *et al*., 2007) and consequently what effect social dynamics has on performance levels. A pilot study into the social interaction of post partum (pp) dairy cows (Burow *et al*., 2009) discovered that smaller groups of cows experience less agonistic behaviours than those introduced to the herd, on an individual basis following calving. Burrow *et al.*

(2009), hypothesise that this may increase resting times, due to fewer introduction events, and overall cow welfare, this in turn could contribute to increased performance due to more time spent ruminating and resting. Lameness also has a significant effect on lying times, cow activity time budgets and oestrus expression and therefore cow welfare, and milk yield (Walker *et al.,* 2008; Pavlenko *et al.,* 2011)

1.9 Feeding behaviour

Lobeck-Luchterhand *et al.* (2014) report the effect of prepartum grouping strategy on displacements from the feed passage and feeding behaviour of dairy cows. They found that an all in all out (AIAO) system of grouping of transition cows, resulted in fewer displacements from the feed bunk than a traditional (TRD) system (weekly entrance of new cows to the group to maintain pen density). The resulting conclusion was that AIAO strategy reduced negative social behaviours, this may be because the cows were familiar with each other. It did however reduce overall daily feeding times for the AIAO group, which could affect overall performance of the cattle during their lactation due to a reduction in intakes. Feeding time is directly linked to performance, although this is also determined by genetic factors and stage of lactation (Manzanilla Pech *et al,.* 2014) and, as previously noted, an increase in dry matter (DM) consumption does not automatically correlate with an increase in milk production (Hart *et al*., 2013). Dry matter intakes (DMIs) decreased gradually in the AIAO system as would be expected when all the cows are at the same stage of gestation, whereas the DMIs in the TRD system had no pattern, which was acknowledged by the authors as something that could have distorted the results and warranted further research.

The amount and quality of the feed available available to the dairy cow has a direct effect on milk production and milk constituents Chamberlain and Wilkinson, 1996). Recommendations are available for minimum feeding face allocation from various sources, ranging from 200 mm to 750 mm (The Dairy Site, 2011, RSPCA, 2018, AHDB, 2020a) although a meta-analysis of pasture allowance and the effect on dairy cows reports that intake, milk production and milk solid production increase at a declining rate as the pasture allocation increases, due to the voluntary feed intake of cattle and the cow’s capacity for forage (Perez-Prieto and Delagarde, 2012, Perez-Prieto and Delagarde, 2013). It could be concluded from this that increasing allocation of feed space far beyond the statutory recommendation, although serving to reduce aggressiveness at the feed barrier may not correspond with markedly increased dry matter intakes, group treatment of cattle will need to take into account the extra space requirement for feeding and lying. However, a reduction in feed space allowance from 56 to 20 cm per animal had no adverse effects on milk yield or feed intakes (O’Connell *et al*., 2010) although it was noted that a reduction in feed space allowance with individual head spaces did increase the amount of aggression within the study animals, which could have a detrimental effect on the animals were it to continue for a prolonged length of time. A further study into competition between cows for mixed rations describes less competition and consequently less aggression within groups of cows when given an increasing amount of feed space (Arachchige *et al*., 2014) allowing subordinate cows a greater access to feed, although they had less frequent feeding times. Understanding when cows are most likely to feed and what motivates them can help in designing new management systems.. Providing feed after milking was shown to increase cow traffic through the pre-milking yard and also reduced time spent lying in the yard(Scott *et al*., 2014). These are both important factors when improving animal health as they have less exposure to mastitis causing pathogens, from laying, that can be prevalent in collecting yards.

1.10Aims and objectives

The literature identifies that in commercial dairy production systems the social behaviour of a cow can be either beneficially or adversely affected by management system(Price, 1999, Jensen, 2006, McTavish *et al,* 2012, Adamczyk *et al.,* 2013 andBoyland *et al,* 2015). It is evident that the social environment influences dairy cow welfare and production. However, little is known about the social interactions of dairy cattle in a commercial setting. Investigating social interactions within a dairy herd, through direct observation is a valuable way of exploring this element. The aim of this study was to assess the social behaviour of dairy cattle using commercial, dairy production animals, reared in a familiar and consistent group, for two years prior to calving, to determine if they remain socially active predominantly within the same lactation group. Once they enter the main herd and the animals' social network expands, the study looked at whether their social interactions are random, or if they retained a preference for a distinct lactation group. If cows do not make social bonds with their herd mates, it could reasonably be supposed that their interactions would occur randomly and that they would demonstrate no preference for who their nearest neighbour was, therefore each cow would have had the same number of interactions with all other cows in the herd This study will also investigate if the cows demonstrate a preference for areas on the farm that they have access to.

H_o the observed interactions distribution can be described by the expected distribution.

H_a the actual observed interactions distribution differs from the expected distribution

2.0 Materials and methods

This study was based on the observation of animals, carried out in the milking parlour, the farm and cubicle yard to which the cows had free access . The observations in the yard were carried out by the author who also relief milked the cattle and, was therefore known and familiar to them. The observations in the parlour were carried out remotely by means of CCTV, Swann Pro 960 H, SWVAK-834254A (manufactured by Swann in the UK), which was played back at a later date. The CCTV cameras were installed one month prior to the study commencing, to allow the cows to become accustomed to the cameras before the study was undertaken, so that they would have minimal impact on cow behaviour according to MacKay *et al.* (2014).

2.1 Location

The observations were completed at Porsham Farm, Tamerton Foliot, Plymouth, PL5 4LJ grid reference SX 48672 62089 elevation 107 metres above sea level (Figure 2.1.1.)

Figure 2.1.1Aerial view of Porsham Farm (Google Maps 2017)

The cows were offered grass and maize silage and round-bale forage rape in the yard, using a combination of round bale feeders and feed trailers. Cows were offered a flat rate 16% protein dairy concentrate at 6kg per head in the parlour. The cows also had access to the silage pit from which to self-feed, there was an electric fence placed in front of the silage face to prevent cows walking into the silage and damaging the face of the pit. Silage was distributed to the cows using a Merlot telehandler fitted with a shear grab. Silage was placed in the round-bale feeders and feed trailers as milking was being carried out so that cows had immediate access to the silage as they exited the parlour. (Figure 2.1.2) In the aerial view of the yard and cubicle areas to which the cows had access.

Figure 2.1.2 aerial view of farmyard area (Google Maps 2017)

2.2 Animals

This study was completed in 2016, the animals were part of a commercial dairy herd comprising of 159 cows, all cows in the herd were observed as part of this study. The cows were, 64 Holstein Friesian, 56 Holstein Friesian cross Swedish

Red, nine Holstein Friesian cross Jersey and 30 three-way cross back to New Zealand Friesian.. The animals were identified by freeze brand number and corresponding numbered ear tags. Cows were grouped by lactation number (Table 2.3.1) groups were labelled lactation one (L1), lactation 2 (L2), lactation 3 (L3) and lactation four plus (L4+). The management of the herd has changed over time from calving all year round in 2006 when the oldest cow in the study, cow number 492, was born (06/01/06) to one single autumn calving block. Groups L1, L2 and L3 were born after the management change to one single autumn calving block,,no changes to management of the herd were made during the course of this study.

Table 2.3.1 Original cohort group size and cohort group size at time of study (groups are determined by date of birth)

Group Number	Original Group size	Maximum Group size during observations	Start date of birth	End date of birth
L4+ All year round calving	182	64	06/01/06	31/03/11
L3 Block Calving	37	29	17/08/11	24/09/11
L2Block Calving	30	27	18/08/12	18/09/12
L1 Block Calving	41	39	27/07/13	22/09/13
Total animals	290	159		

The difference between original cohort size and maximum cohort size during the observation is because there would naturally be cows culled from the herd as part of herd management. L4+ reduced by 118 animals, L3 by 12 animals, L2 by three animals and L1 by two animals. The sample size for each of the groups L1, L2, L3 and L4+ are good (Faber and Fonesca 2014), hence this study was possible.

2.3 Animal housing

The cattle were housed in two cubicle houses referred to as old cubicles (OC) and new cubicles (NC), labelled in Figure 2.1.2.

OC dimensions: External 1300 cm x 3000 cm containing 96 cow kennels 220 cm x 116 cm

NC dimensions: External 1650 cm x 3000 cm containing 96 cubicles 225 cm x 115 cm

There were 192 cubicles available resulting in 1.2 cubicles per cow, this exceeds the current recommendations of 1 cubicle per cow, rising to 15% spare for vulnerable animals, for example fresh cows (NADIS 2020).

Cattle had free choice of which cubicle house they used and had access to external yard/loafing areas (Y) containing two ring feeders of 208 cm in external diameter and four trailed feeders 610 cm x 267 cm external dimensions, cattle were also able to self-feed from the silage pit (SP), width 1250 cm (Figure 2.2.1). Cows had access to approximately 540 mm, current recommendations state that cattle weighing 500-599 kg should have 240 mm per head when fed *ad lib.* (Red Tractor, 2017).

Figure 2.2.1 aerial view of cubicle houses and yard area (Google Maps 2017)

Figure 2.2.2 aerial view of collecting yard and covered yard area (Google Maps 2017)

The milking parlour (P) was a Westfalia (manufactured in Germany) 8:16 herringbone (installed 2nd hand in 1987) with a small internal collecting area (ICA) 485cm x 483cm leading in from the collecting yard (CY) 1400cm x 900cm and covered yard area (CoY) 1400cm x 1100cm, (a 500cm x 400cm workshop is contained in the undercover yard) (Figure 4), resulting in 1.8 m^2 per cow at the start of each milkingThe cows had free choice in the order they entered the parlour. The parlour dimensions comprise of a 75cm entrance to each side 250cm from wall to pit with a 31cm trough attached to the wall, the pit is 64cm wide. Each milking took approximately 2hrs, approximately 6 minutes per side. Behaviour was measured in two contexts, in the parlour and outside in the feeding yard and cubicle housing. In both contexts the nearest neighbour of each cow was recorded, the nearest neighbour distance was also recorded in the feeding yard and cubicle areas. Each milking took approximately two hours, whilst waiting cows had free choice to move within the collection yards and therefore order of entry to the parlour. The outside observations were completed two hours after milking was completed so that the nearest neighbour observations were not re-sampling the parlour exit order.

2.4 Observation methods in the parlour

The cattle were recorded using two Swann 960H CCTV cameras in the milking parlour, which were installed 1 month before the study commenced to allow the cows to become familiar with them, so as not to affect their behaviour. It was considered important to allow a period of adjustment according to Kilgour, Melville and Greenwood (2006) where they postulate that cattle become less inclined to startle once novel objects become familiar, due to habituation.. The cameras were positioned, on the ironwork of the parlour, one on each side, where it was possible to record the freeze brand number of the cows as they exited the parlour. The side, left or right, of the parlour the cows were standing in, the side rank number from one to twenty and the order they exited the parlour was recorded for each observed milking. The side of the parlour corresponds to where the cows are standing in relation to the pit, where the milking operative works. A note was also made of whether milking took place in the morning or afternoon. Data was recorded for two hours in four replicated blocks between 8th January and 5th February 2016. Not all freeze brands were clearly visible during each milking, and as such it was not always possible to record all cow numbers observed. The decision was made to record the position, nearest neighbour, side and rank, where they stood in each side of eight, of all cows whose freeze brands were visible in the recordings. Nearest neighbour was recorded as the cow standing immediately behind the focal cow whilst being milked and recorded as they exited the parlour.

The recording equipment was set up to automatically capture each milking by setting a timer for each day, and data was used from the same days as the observations were carried out in the yard and cubicles. The data were recorded as inside or outside depending on where the observation was carried out. Data collected in the parlour was labelled as inside and data outside and in the cubicle yards was related as outside.

2.5 Observation method in yard and cubicles

Observations were completed by the same person (Author) at the same time of day and the same day of the week. The observer was known to the animals due to having previously worked on the farm as a relief milker, therefore limiting the effects of a novel person on the behaviour of the cattle (Kilgour, Melville and Greenwood, 2006). For each animal the nearest neighbour (NN) and nearest neighbour distance (NND) estimated in metres were recorded (Table 2.5.1 for descriptive terms used) nearest neighbour being the cow that the focal cow was closest to in terms of distance, which could be from touching each other when feeding, lying in a cubicle next to another cubicle up to being several metres away from the next cow. The nearest neighbour distance was estimated by eye, by the observer using known size indicators as point of reference, such as the width of the cubicle, scrape passage or cow length. Each cow was recorded as a focal cow when first sighted by the observer whilst walking through the yard. If there were more than one cow in view the observer noted the closest cow first. A record was made of the focus cows NN and their distance (NND), each cow could therefore, only be a focus cow on one occasion but, due to the length of the observation, any cow could be a NN on more than one occasion in each observation. Records were also made of the location of the animal, either yard , old cubicles or new cubicles . Observations continued until each cow in the herd was recorded, taking two hours. An initial observation was carried out on 11th December 2015 to determine the length of time required for the observations am and pm, due to it taking two hours to ensure all cows in the herd were observed during the observations the decision was made to observe the cows once during the day after milking and morning feeding so that disruption to the cow interaction due to routine handling, feeding and yard work was minimised, this also limited the disturbace of the animals by the observer (Lendvai *et a,l* 2015). The difference in number of expected NN observations of cows in each cohort, inside and outside can be explained because of the different observation methods; inside the cows have one chance to be observed, outside cows can be the NN on more than one occasion.

Data was recorded on the following dates: 8/01/2016, 22/01/2016, 31/01/2016, 5/02/2016 when the observer was released from work at Duchy College to be able complete the observations. In total eight hours of observation were carried out. Observations were carried out during the day due to there being no lighting in the outside area and cubicle yard.

Table 2.5.1 Table of descriptive terms used when recording positional and proximal locations of study cows.

Term used	Description
Nearest Neighbour (NN)	Cow observed as nearest neighbour to focal cow
Nearest Neighbour Distance (NND)	Estimated distance between focal cow and NN in metres
Old Cubicles (OC)	Original cow kennel design wooden, closed sided cubicle building
New Cubicles (NC)	Recently built steel framed open sided cubicle building
Yard (Y)	Feeding and loafing area to which cows had free access

2.6 Research timing

Lobeck-Luchterhand *et al*. (2014) made the importance of the timing of research clear due to the effect the transition period has on the overall performance of the cow in the following lactation. This indicates that it is important to determine the timing of research studies so that factors that may confound the results, such as stage of lactation, age and pregnancy are avoided or at the very least accounted for. It is also important to maintain a regular daily routine whilst conducting research as studies have discovered that supplementation of grazing cows at different times in the day altered grazing behaviour (Sheahan *et al*., 2013). Recording of behaviour needs to take account of milking times and feeding times and it has been suggested that results at these times should be excluded from analysis as it is not a true representation of the cow’s behaviour (Mattachini *et al*., 2011). This is not accurate as it is a true representation of their behaviour at milking and feeding times, what it does not represent is their behaviour during the rest of the day and night. Although, if the behaviour being recorded is feed bunk displacements as in the study conducted by Lobeck-Luchterhand *et al*. (2014) milking and feeding times will be important to include in the results.

2.6 Data recording

Individual cow data, (Date of birth and Dam) were extracted from handwritten farm records. Observation data was recorded manually for both parlour and outside yard and cubicle yard observations. The video recordings of each milking on the observation dates was watched and the order of cows exiting the parlour written down, note was also taken of which side the cows were in as milking progressed, this was then transferred to spreadsheets (Microsoft excel). The outside observations were recorded on a table that was prepopulated with cow numbers so that all animals were observed, an example of the table can be seen in Table 2.6.1. the date and time of observation were also recorded on the table, this information was transferred to Microsoft excel (2010).

Table 2.6.1 Example of the table used to record Nearest Neighbour Identification (NNID), Nearest Neighbour Distance (NNDist), location and notes for observations taking place outside.

Cow ID	NNID	NNDist	Location	Notes
492				
570				
591				

2.7 Data processing

If cows do not make social bonds with their herd mates, it could reasonably be supposed that their interactions would occur randomly and that they would demonstrate no preference for who their NN is, therefore each cow would have the same number of interactions with all other cows in the herd. If the interactions are random then each cow at Porsham Farm had on average a 1 in 158 chance to interact with other cows.

A tally chart of NN inside (Parlour) and outside (yard and cubicles) was produced using Microsoft excel so that the number of cow-to-cow interactions could be clearly identified. . The information was then collated into lactation groups and the total number of interactions between lactation groups was determined.

2.8 Data handling and analysis

The statistical analyses were completed using Minitab V19.2 (2019). The cohort interaction counts were analysed with a Chi-Square goodness of fit test, to determine if the distribution of observed NN interactions, within the parlour and in the yard and cubicle area, between groups were consistent with the hypothesised distribution.

Each group differed in size; to ensure each group accounted for an equal weighting for analysis the following data transformation was performed:

- Total interactions per group were recorded and divided by the number of groups to determine the expected number of interactions with the other groups if interactions were random (expected interactions).
- Interactions per group were then divided by the group size and added to give a total for figure for the whole herd.

- The adjusted interactions figure was then divided by the total for the group to determine the proportion of interactions between one group and all groups.
- The resulting figure was then multiplied by the total number of interactions for the whole group.
- This is shown in the equation below.

$((O/N)/It)*Ot = Z$

O = Observed interactions

N = group size

I = interactions adjusted for group size

It = total interactions adjusted for group size

P = Proportion of interactions adjusted for group size

Ot = Total interactions for group

Z = Interaction coefficient

2.8.1 Analysis of expected distribution of interactions

In order to determine if the frequency of interactions between lactation groups was significantly different to the expected, a chi-square goodness of fit test was carried out. The hypotheses tested using the chi-square goodness of fit test were.

H_o the observed interactions distribution can be described by the expected distribution.

H_a the actual observed interactions distribution differs from the expected distribution.

The same hypothesis was tested for each of the cohort groups observed interactions both inside and outside.

2.8.4 Observed differences in location preference of the herd

When observations were made a note of the location of the focus cow was also made. These data were collated to show the number of cows in each location. A chi-square test for association was carried out to determine if the variables, cohort id and location had a statistically significant association.

3.0 Results

3.1 Observations carried out by CCTV in the milking parlour

The analysis of the observations of NN between each lactation group as a focal cow group and all lactation groups (Figure 3.1) showed that the interactions of groups L1 (Chi-square = 22.0, 3 d.f, P<0.001) and L4+ (Chi-square= 9.16, 3 d.f, P=0.027) differed from the expectation, while groups L2 (Chi-square = 1.01 3 d.f, P=0.0782) and L3 (Chi-square = 6.7, 3 d.f, P=0.082) did not.

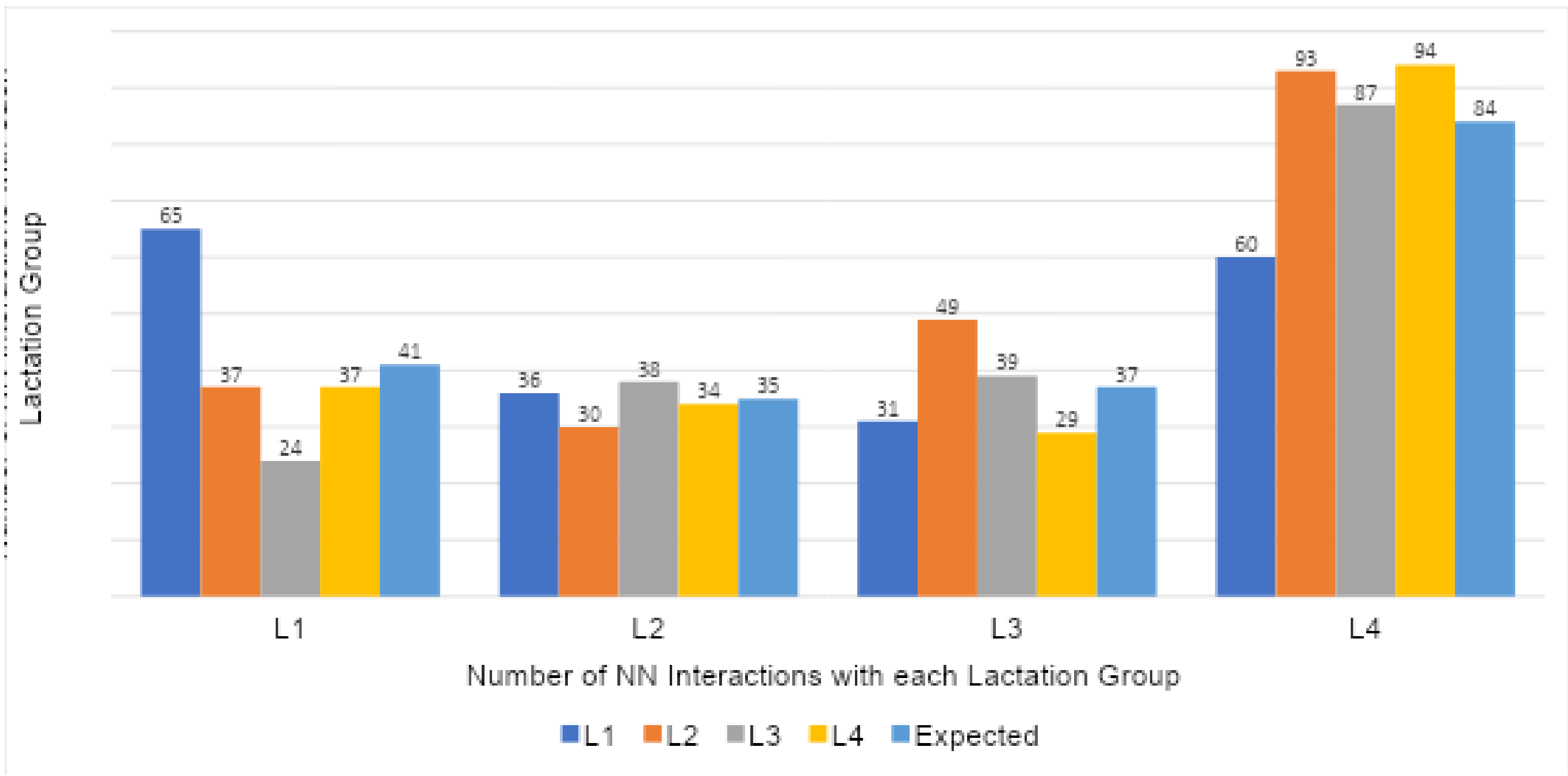

Figure 3.1 Observed interactions of each lactation group as focal cows with all lactation groups as NN with expected value for comparison

3.2 Direct observations carried out in the yard, new cubicles and old cubicles

The analysis of the observations of NN between each lactation group as a focal cow group and all lactation groups (Figure 3.2) showed that the interactions of groups L1 (Chi-square = 11.99, 3 d.f, P=0.007), L3 (Chi-square = 617.02, 3 d.f, P=0.001) and L4+ (Chi-square= 8.43, 3 d.f, P=0.038) differed from the expectation, while group L2 (Chi-square = 2.67 3 d.f, P=0.445) did not.

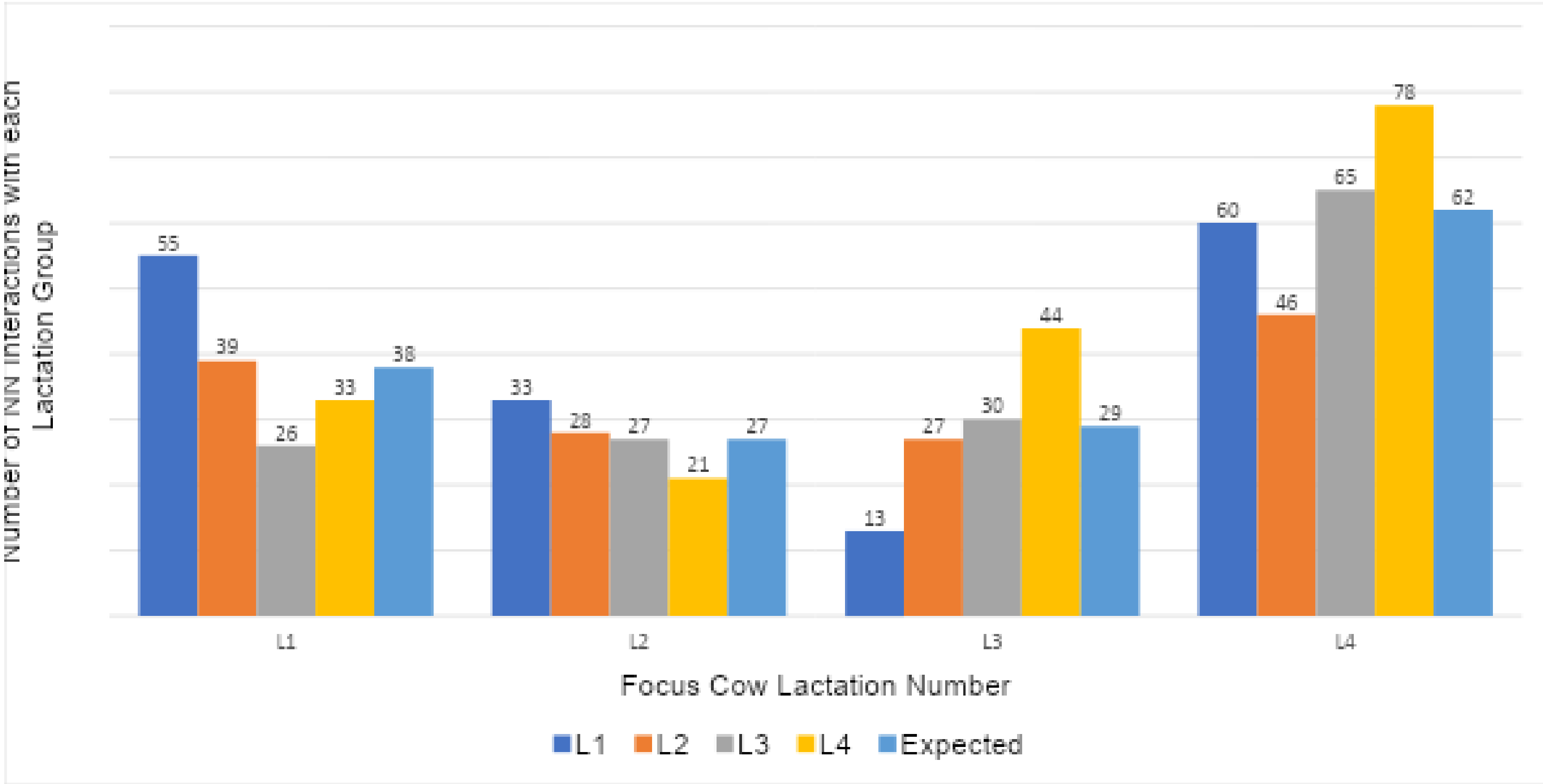

Figure 3.2 Observed interactions of each lactation group as focal cows with all lactation groups as NN with expected value for comparison.

3.3 Location preference

A chi-square test for association between location choice and cohort (Pearson chi-square = 46.177. 6 d.f, $P<0.001$, likelihood chi-square = 45.683, 6 d.f, $P<0.001$) showed that all lactation groups preferred the new cubicles to the old cubicles (figure 3.3). Of the four lactation groups L1 were more frequently observed in the new cubicles, L2, L3 and L4+ were more frequently observed in the yard areas (figure 3.3).

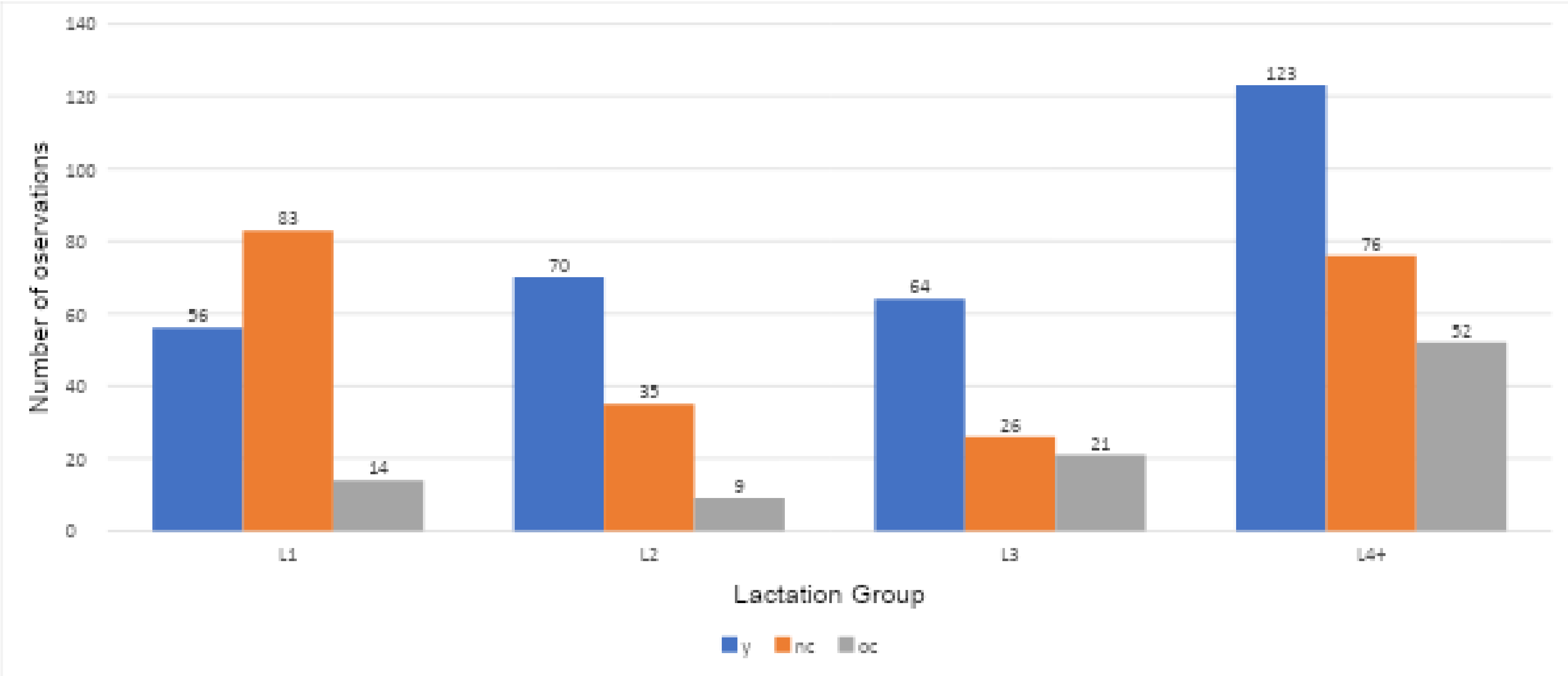

Figure 3.3 Location preference group L1 to L4+

4.0 Discussion

The objective of this study was to assess the social interactions, specifically the preference for nearest neighbour, of a commercial, lactating dairy herd . The intention was to investigate what, if any, preference the cows demonstrated towards their herd mates. This study also examined the possibility of cows demonstrating a preference for location in the yard and cubicle areas. A great deal of research has been conducted into how to improve cow welfare and therefore how do they produce more milk and ultimately improve profitability. Studies have been carried out in numerous areas including; accommodation and group size for dairy cattle (Croney and Newberry, 2006, Faervik *et al.,* 2007, Neisen, Wechsler and Gygax, 2009, Talebi *et al.,* 2014), health (Kramer *et al.*, 2009, Pavlenko *et al.,* 2011), improving lying times (Mattachini, Riva and Provolo, 2011, Watters *et al.,* 2013, Ito, 2014), feed intake and grazing (Perez-Prieto and Delgarde, 2013, , *Hart et al.*, 2014 Thanner *et al.,* 2014), milking frequency (Hart *et al.* 2013) and response to environment,(Arnold *et al.*,2007, Kusnirova *et al.,* 2012, Mackay *et al.,* 2014, Rajapaksha and Tucker, 2014 Yun *et al.,* 2015) all in an effort to increase yield and reduce health and welfare issues and increase productivity. Cow comfort has received a great deal of press and there are cow signals training companies endeavouring to educate stockmen in how to assess a cow's wellbeing and improve it. The assessments focus on the physical environment and the evaluation of the physical wellbeing of the herd and individual animal, they do not address the cows need for social interaction with herd-mates she is familiar with. Little is known about the psychological effects on cows when changing groups and the effect this has on production. Research has been conducted into the social dynamic of the dairy herd and the effects of how these animals interact (McClelland, 2013, Boyland *et al.* 2016, Foris *et al.,* 2019, de Freslon *et al.,* 2019) although there is little strong evidence to show that there are indeed strong bonds between individual animals this study has demonstrated that cows do show a preference for the animals that they are more familiar with and have been reared with as a heifer.

4.1 Observations of behaviour of cows inside the parlour

4.1.1 Nearest neighbour preference within the parlour

The analyses of data obtained from observations conducted within the parlour, revealed that dairy cows demonstrate a preference for their nearest neighbour from their own lactation group, most strongly demonstrated in L1. Indicating that, although there was little evidence to support the theory that cows have conspecifics that they prefer as nearest neighbours, there is evidence that shows they demonstrate a preference for their own lactation group within the herd. The youngest group, L1, showed the strongest relationship within their own group and had fewer nn encounters with L4+ than any other lactation group. It is common practice on the study farm to use older cows (L4+) at the end of milking to introduce heifers (L1) in the milking parlour prior to first calving, this managed association did not carry through to after calving. The effects of using training with cattle has been investigated with varying degrees of success, Loerch and Fluharty (2000) stated inconsistent results when using cull cows to train newly weaned calves entering beef feedlots, where there was success, there were improved weight gains and health status reported in the calves. Training heifers in the milking parlour prior to first calving was shown to have little effect by Sutherland and Huddart (2012), their experiment showed that by day four or five of lactation heifers showed less signs of distress regardless of their training, therefore, training might have limited value in preparing heifers for entering the herd and being milked, this study supports those findings. Timing of introduction to the herd, however, could have beneficial effects. Boyle, Ferris and O’Connell (2012) found that timing of introduction to the herd is important, introduction of heifers to the herd after p.m. milking was shown to reduce incidences of received aggression and could have beneficial effects on milk production, weight and condition loss.

4.1.2 Familiarity of cohorts within cohort and with other cohort groups.

. Gibbons, Lawrence and Haskell (2009) found that first lactation heifers were recipients of significantly more aggressive interactions than multiparous cows and actively avoided aggressive interactions whilst feeding. In this study the older cows in small cohorts, that have lost many members of their original cohort groups, might display fewer agonistic behaviours as they are habituated to the need to socially interact with animals that may be less familiar to them. The reduction in numbers of group L4+ has led them to seek out social interaction with others in the herd and these older cows may be ones with health issues, such as lameness (Pavlenco *et al.,* 2011) and mastitis (Sepúlveda-Varas *et al,*

2016) and therefore display fewer aggressive behaviours than the younger, healthier cohorts. L4+ showed a consistent number of interactions with L2 and L3, however, L1 are nn on fewer occasions, Haskell, Bell and Gibbons (2012) demonstrated that, as cows age they become more at ease and are more approachable, these changes progress to the middle of the first lactation, in this study the cattle in their first lactation had not yet reached this stage of lactation, this could explain why the L1 group preferred nn from their own lactation group. In this study L4+ was preferred nn

for groups L3 and L4+.

In this study L1 were the youngest group of cows within the herd, they had spent the first two years of their lives in a heifer group, consisting solely of animals born within one month of each other and was a large group, with few having been culled since entry into the herd, this would indicate that there has been little effect of culling on the social structure. The social needs of each member of this group could well be met within their own group, with strong relationships between this cohort resulting from them not forming relationships with the rest of the herd, this idea is supported by Færevick *et al.* (2007) who found that calves reared in batches were more likely to positively interact with calves they were familiar with after regrouping. L1 have been exposed to fewer regroupings than L2, L3 and L4+, Böe and Færevick (2003)state that repeated regrouping seems to accustom the animals to the procedure, in this study heifers entering the herd, the L1 group, appeared to be less confident to interact with the rest of the herd and therefore prefer nearest neighbours they are most familiar with, whereas L2, L3 and L4+ were observed as nn of each other on more occasions. However, in this study no record was made of the type of interaction between animals to determine if they were positive or negative interactions, which was due to the large size of the study group.

4.1.3 The effect of novel stimuli on expressed behaviour

It is known that novel situations and stimuli can affect a fear response in animals' behaviour (MacKay *et al., 2014)*. The process of mechanical milking of cows is not something that could be described as natural for the animal (Arnold *et al.,* 2007,Polikarpus *et al.,* 2014). To enable humans to be able to successfully milk cows in a milking parlour requires thousands of years of taming and domestication (, Price, 1999, Jensen, 2006 Adamczyk *et al.,* 2013 and McTavish *et al.,* 2013). This taming can reduce the negative effect mechanical milking may have on dairy cattle, this can be acquired through habituation or positive associative conditioning (Price, 1999). Dairy cattle have been selectively bred for temperament as well as production traits (Haskell, Simm and Turner, 2014, Lürzel *et al.,* 2016), but they do not arrive freshly calved in the parlour ready to be milked and need to become accustomed to the process, as previously mentioned, cows became more at ease and less nervous with age (Haskell *et al.* 2012) and Boivin *et al.* (2003) state that the benefits of habituating animals to humans include reduced fear, improved docility, reduced working time and a reduction in risk of injury to animals and the stockperson. Additionally, Lurzell *et al.* (2016) state that dairy heifers are susceptible to positive interactions, which provide opportunities to improve their quality of life, it was observed in this study that the freshly calved cows in L1often wait until the end of milking to enter the parlour, when there is no other choice, however they became accustomed to the milking process and began to enter the parlour earlier, long waiting times for milking can have a detrimental effect on cows as it places a strain on their time budget giving them less time to lie and eat (Gomez and Cook, 2010). Cows that are last to be milked do not have as frequent opportunities to express normal behaviour, their period of confinement is longer each day and this can lead to them spending more time in a stressful environment (Gomez and Cook, 2010; Dijkstra *et al.,* 2012). There are positive results from entering the parlour as the cows are fed, Ceballos and Weary (2002) stated that feeding had a positive effect on entry to the parlour, milking also relieves the pressure on the udder. However, in-parlour feeding does not win over an animal immediately, Haskell, Bell and Gibbons (2012) showed that the fear response dairy cattle display toward humans decreased over time and that cows were more at ease with humans as they grew older. In this study the larger number of animals from L1 remaining in the collecting yard at the end of milking and therefore, in the last milking sides, could be because they had not yet become habituated to the milking process and the stockperson (Breuer *et al.,* 2000; Hannah *et al.,* 2006; Kilgour *et al.*, 2006).

4.1.4 The stockperson effect

Observations of cow nn choice in the parlour were subjective because there were the effect of the stockperson to consider, (Breuer *et al.,* 2000; Hannah *et al.,* 2006; Kilgour *et al.*, 2006). It had been previously observed by the relief milker and farmer that the cows would enter the parlour in a different order depending on which person was milking,the stockperson's behaviour has been shown by Breuer *et al.* (2000) and Hannah *et al.* (2006) to influence yield and behaviour in the parlour. In addition to this, Kilgour *et al.* (2006) demonstrated that the heart rate of steers and heifers increased when the animals were in proximity of humans, and very few animals chose to interact with humans in the 4m test area. Although *Kilgour et al.* (2006) conducted their study on beef animals that are not selectively bred for mechanical milking, it can be argued that L1 are similar to the study animals in that they had very little human interaction before entering the herd at calving and therefore had not become habituated to human presence and interaction. This could be a factor causing them to delay and resist entering the parlour, where they are in close proximity to humans. Conversely, Sutherland and Huddart (2012) determined that although parlour training heifers before calving reduced distress in the first week following calving, heifers' response after that was determined largely by their temperament, largely supported by the findings of Kutzer *et al.* (2015) who showed that training heifers to the milking parlour had little effect on heart rate during milking or milk yield. Additionally, it has been shown that cows that do demonstrate a preference for side during milking are more dominant when competing for resources (Prelle *et al.* 2004). Animals that were judged to have a high fear response maintained that throughout Sutherland and Huddart's (2012) study, despite the inherent habituation to humans that results from continued milking throughout the lactation and life of a dairy cow (Haskell, Bell and Gibbons, 2012). Breuer *et al.* (2000) found that there was a 19% variation in milk yields where cows demonstrated a reluctance to approach an individual human. Additionally Coleman, Rice and Hemsworth (2012) stated that the way stockpersons handle an animal can cause increased levels of fear and stress and a reduction in animal productivity.. It has been shown that habituating animals to humans and improving stockmanship through training can improve animal health, productivity, welfare and product (meat) quality (Boivin *et al.,* 2003). Additionally, Ivemeyer *et al.* (2018) found that positive human-animal relationships were important in improving udder health. Indeed, as herd sizes become increasingly larger within the industry, so stockmanship becomes even more important and strict welfare standards adhered to that ensure freedom of the animals from fear and distress. (Marley *et al.,* 2010*).*

4.1.5 Expression of behaviour in the youngest cohort group

There is little opportunity for the dairy heifer in the collecting yard to express a preference for nearest neighbour because of the close proximity of all animals to each other, but what they can do is allow the other cows to enter the parlour first, Berry and McCarthy (2012) showed that higher milk yield was positively correlated with entrance to the parlour and Polikarpus *et al.* (2015) linked later entrance to the parlour to a rise in somatic cell count (scc). In this study L1 showed a greater frequency of itself as nn, this could be purely because they made up a larger proportion of the cows left at the end of milking, limiting the possibilities of them being observed with a nearest neighbour outside of their own lactation group. This could also affect the rest of the groups, reducing the likelihood of them being observed with L1 as a nearest neighbour.

A further explanation could be that, first calving heifers (L1 group) can reasonably be expected that those animals would be smaller than their herd mates in the other groups, because calving at 24 months means that the heifer is approximately 90% of her mature body weight at calving (CAFRE, 2020). In this study L1 could therefore, be demonstrating an ability to assess the body size of herd mates to determine dominance (Croney and Newberry, 2007) and as a result be less inclined to have their nn from a group consisting of animals that are older and larger, thus avoiding conflict and agonistic interactions. Sarova *et al.* (2013) found that age had a greater influence on dominance within a herd and that younger, heavier cows were subservient to older lighter cows. Although, in this study, this is a different reason why L1 would not choose older groups more frequently as nn, it is another explanation regarding social dominance and the effect it can have on preference for nn. Additionally, Neisen *et al.* (2009) found that heifers, introduced to the herd following calving, provided each other with mutual security and support and the heifers' welfare was as less risk, the recommendation was to introduce heifers in pairs to the herd, supporting the theory that L1s preference for nn from L1 is due to mutual support.

Dairy cows are social animals and can distinguish characteristics of individual animals in the herd and heifers have been shown to be more attracted to images of familiar conspecifics than non-familiar (Coulon *et al.,* 2011, Hagen and Broom, 2003). Considering the short period of time that the heifers would have been in the herd, in this study, it is reasonable to suggest that they would be more attracted to familiar conspecifics as a choice for nearest neighbour. Moreover, Gutmann, Špinka and Winckler (2015) state that animals who have a long-term familiarity with each other will invest more time and energy in social interaction than those with recent shared experience. Management procedures that allow heifers to join the herd with conspecifics they are familiar with can alleviate the negative emotions that can adversely affect animal welfare, described by Boissey *et al.* (2005)

4.2 Outside

There were 629 individual cow observations, carried out using direct observation, recorded in the yard and cubicle areas during this study. Although other research conducted into cow behaviour has been carried out on a smaller sample size and/or on a limited number of occasions. For example, Hagen and Broom (2003) observed 14 animals, Coulon *et al.* (2010) 23 heifers in total over two experiments, Faerevik *et al.* (2007) observed on three days, and Winckler, Tucker and Weary (2015) observed 36 animals in four groups. Interestingly Gomez and Cook (2010) found that during their study cows could spend up to 8.1 hours per day feeding, a significant proportion of their time budget and a factor that should be considered when interpreting the results.

4.2.1 Nearest neighbour preference during observations in the yard and cubicles

In this study,the nn observations of cows outside of the parlour, in the yard and cubicle areas for L1, L3 and L4+ were significant and L1 and L4+ both had strongest relationships within their own lactation group. L3's preferred nn group was L4.

The reasons for L1's preference in this study for its own lactation group should have very little to do with stock person interaction, due to the observations taking place once the stock person had completed the routine feeding and stock tasks. Therefore, it is reasonable to suggest that their preference is related to alternative factors. L1 were the youngest members of the herd and, as such, they had yet to fully integrate and develop their place within the social hierarchy, they could have been intimidated by the older cows and felt more secure with nearest neighbours of their own cohort. Gutmann, Špinka and Winkler (2015) suggest that dairy cows prefer to interact with familiar animals. Those that have been reared together, rest together and those sharing a dry period are more frequently found engaging in allogrooming behaviours than herd mates that are unfamiliar with each other, suggesting that, in this study L1 had less need than the rest of the herd to interact with L2, L3 and L4+ because of the size of their cohort group. Studies have shown that larger and older cows in the herd have more dominant roles in the social hierarchy. Šárová *et al.* (2013) suggest that age is superior to body size when asserting dominance over other cows in a beef herd, going on to say that the subordinate role will be respected for life. In addition to this, Patison *et al.* (2010) found that unfamiliar animals display avoidance behaviours until they become familiar with each other, this would explain why L1 would avoid interaction with other cohorts that are older.

It is not clear from the data recorded if the nn interactions were positive, such as allogrooming, which is an important part of social bonding in dairy cows (Sato, Tarmizu and Hatae, 1993). Neither does the data show if the interactions were agonistic, such as head butting which is an aggressive action (Rousing and Wemesfelder, 2006). It could be proposed that the older cows have a calming effect on the heifer group and as they are used to ‘train’ heifers in the parlour that they already have started to make some sort of social bond with each other that continues outside the parlour.

4.2.2 Location preference

This study showed that cows demonstrated a preference for the new cubicle building over the old cubicle building. it has been shown that cow comfort has a significant effect on cows lying time and therefore lameness and milk production (Dairy Global, 2018). However, a more recent study has found a weak negative correlation between lying times and yields (Pineiro *et al.,* 2019). Lying times are important for cows and is a higher priority for them than eating and social contact, should these activities be restricted (Munksgaard *et al.,* 2005, cited in Mattachini, Riva and Provolo, 2011) The cubicle beds in both cubicle buildings were the same type with compacted soil and straw bedding. of the same dimensions, the only difference was the absence of lunge space in the old cubicles, lunging room could be a factor affecting the choice of cubicle demonstrated by the cows. AHDB (2020) state that Holstein Friesian cows require 0.6m of lunge room at the front of the cubicle to allow them to lunge forward when rising, this will allow them to lie straighter in the cubicles and limit soiling of beds. It could be proposed that another factor that affects the cows' preference for the new cubicles is ventilation, which is extremely important for cow comfort (Lobeck *et al.,* 2011). The new cubicles had no walls, airflow in this building is unrestricted, unlike the airflow in the old cubicles, which are cow kennel design (Wareingbuildings, 2020) and have limited airflow. Limited airflow can lead to increases in moisture levels and concentration of micro-organisms and therefore higher risk of health issues such as mastitis (AHDB, 2012) and the cows in this study could have been demonstrating their preference for fresher air that was available to them.

The observations in the yard and cubicle areas were conducted at least two hours after the end of milking, this was to avoid resampling parlour exit, allowing the cows the opportunity to demonstrate a preference for location. L1 showed the strongest preference for the new cubicles (figure 3.3) this could be due to primiparous animals consuming smaller meals as described by Hart *et al*. (2014) who also showed that primiparous cows spent more time lying than multiparous cows, supporting the findings of this study. Furthermore, Ungerfield *et al. (2014)* stated that feeding activity is affected by social influences, which may explain why, in this study, the L1 group spent less time feeding and more time lying than the rest of the cows.

5.0 Conclusions

This study has shown that cows demonstrate a preference for their nearest neighbour. The cows in this study that demonstrated the strongest preference were those in lactation group 1. L1 demonstrated a strong preference for their own lactation group, both in the milking parlour and when in the feeding and cubicle yards. L4+ showed least preference for L1 as nn in the milking parlour and little difference between the L2, L3 and their own lactation group. The cows in this study also demonstrated a preference for location, again L1 showed the strongest preference for the new cubicles with the whole herd demonstrating a preference for them over the old cubicles, however the strongest preference for location in groups L2, L3 and L4+ was the yard. Further work is required to determine if these results would be replicated across a range of commercial dairy production systems, especially as this study was conducted on an atypical farm that had more cubicle and yard space available to the cows than many commercial dairy production systems.

6.0 Limitations of the current study

This section will investigate improvements that can be made to the methods used whilst undertaking this study. It will also make recommendations for further research.

6.1 Number and frequency of observations

The footage of eight milkings were watched and data recorded. The CCTV cameras were in place during the whole of the study period. The decision was made, due to time constraints and difficulties in identifying all of the cows, to use the data from the days that the direct observations outside of the parlour, in the yard and cubicle areas took place. To improve the ability to identify the cows, the cows could be marked with their numbers on their backs to make them much more easily identifiable when watching the footage and making it simpler to record.

6.2 Proximity loggers

The use of proximity loggers, a biotelemetry device used to non-invasively quantify animal to animal interactions (Watson-Haigh, O'Neill and Kadarmideen, 2012) would greatly enhance the ability of the study to determine which animals has spent time with others and for how long a period they spend interacting this would then give the observer and opportunity to determine whether those interactions were agonistic or mutually beneficial interactions. Many studies employ the use of proximity loggers, (Böhm *et al.,* 2009, Guttridge *et al.,* 2010Boyland *et al.,* 2013, O'Neill *et al.* 2014, Bolt *et al.* 2017, ,) enabling them to determine with accuracy how often and for how long animals are in proximity of one another.

It would be interesting to study the animals when grazing to see if the companions that they chose whilst grazing were the same as those they chose in the parlour and in the yard and cubicle areas. Lobeck-Luchterhand *et al.,* (2015) found that stocking density has a small effect on the social interaction of dairy cattle, comparing the interactions at pasture and during housing could shed some more light on this topic. Ungerfield *et al.* (2014) suggest that the reason less dominant cows spend more time grazing is because their bite size and speed of grazing is less than a dominant cow, which could be due to the time they spend avoiding the dominant cows.

Due to the dynamic nature of the study herd the number of animals did change over time by a small number, due to animals calving in or being culled out of the herd, the maximum number of cows in the herd over the period of the study was 164. Whilst it is beneficial to use a commercially active dairy herd, which provides a true to life situation to investigate, there are areas of the study which cannot be replicated easily. To mitigate this a smaller sub-herd could be observed, in the vein of Boyland *et al.* (2016), comprising of a subset of each cohort group although this then would add complications to the management of the dairy herd and would not be a practical solution. It would also change the whole dynamic of the study. The observations were carried out on a commercial herd whose composition and structure would be different to what would be found in nature, calves would not be removed from their mothers for example. Changing the herd size may mean that the behaviour of the animals within that herd would also change. Difficulties also arise when removing cows from familiar cohorts when the interaction within and between cohorts is the primary focus of the study, there is no way to mitigate this when the study is conducted on a working commercial herd.

6.3 Other considerations that could influence behaviour

Several factors can have an effect on cow behaviour, these factors include, but are not limited to, the factors that are be the focus of this section. Lactation number and yields can affect a cow's behaviour. Individual yields could be recorded, to determine whether they had an effect on the interactions. Higher yielding cattle have a higher feed intake requirement (Baile, 1981), this would reduce the amount of time available for social bonding and could influence the cohort interactions, both within cohort and herd. Norring, Valros and Munksgaard (2012) recorded a reduced lying time in high yielding cows as they spent more time ruminating whilst standing. Stage of lactation is also linked to pregnancy, which would also have an effect on feed intakes (Chamberlain and Wilkinson, 1996), as the foetus gets bigger so feed intakes reduce and yields also reduce. Regrouping of cows was found to have little effect on milk production (Brakel and Leis, 1976) however this is an old study conducted on a small sample of 20 cows.

The data for animal health was not collected for the purposes of this study. However, health of the herd could also be investigated to determine if they have an effect on the behaviour of the cows in the study. Instances of mastitis, lameness and metabolic disorders such as acidosis, ketosis and milk fever for example, which would have an effect on the cows behaviour and therefore their interaction with the rest of the herd, could be recorded to see if there was an effect on the most socially active cows. Pavlenko *et al.* (2011) found that sole ulcers and digital dermatitis influence the behaviour of dairy cows causing them to spend less time lying down, these cows could have a negative effect on observations in that, it is their mobility and health that are having an effect on their behaviour, rather than their behaviour influencing their choice of neighbour. Montgomery *et al.* (2012) also describes negative effects claw lesions have on locomotion and therefore interactions. If it was found that there were instances of lameness during the study period there could be an effect on the overall result, however, due to the number of observations recorded, this effect is likely to be minimal.

Mobility scoring is a method that farmers and herd managers can use to determine the amount and severity of lameness within their herd (AHDB, 2013), regardless of experience (Garcia, 2015). Lameness and its severity has a definite effect on cows' behaviour (Miguel-Pacheo, 2016), it causes the animal pain and is a welfare issue. Palmer *et al.* (2012) found that lameness affected cows' feeding behaviour. Cows had reduced dry matter intake due to fewer times eating larger meals, this had an effect on productivity. It is reasonable to suggest that those cows with a high mobility score and needing treatment would not interact as freely as cows with a low mobility score, who did not require treatment. Further studies could investigate if there was an association between mobility score and frequency of interactions between individuals and cohorts.

It would be interesting to see if the interactions changed at the end of the housing period compared to the beginning. Reasons for this could be, the social dynamic of the herd changes over time as animals in Cohort ten for example mature and begin to interact more within the herd. The most socially active cows could develop health and/or mobility issues, which would affect their social behaviours for an indeterminate time, or the most socially active cows might be culled for management reasons, allowing less socially active cows to take their place.

Anecdotal evidence, arising from discussions with the herd owner, pointed toward cows within dairy herd maintaining family groups. When cattle are given the opportunity to rear their young, the behaviour exhibited is similar to wild ungulates. The cow and calf can bond and the cow provides for and protects the calf (von Keyserlingk and Weary, 2007). However, as commonly practiced within the dairy industry, calves are removed from the dam within 48 hours of calving on the study farm, therefore suggesting that there is little or no memory of the calf by the dam or the dam by the calf. Valníčková *et al.* (2015) found that brief maternal rearing improves early performance in dairy calves, furthermore Wagner *et al.* (2012) suggest that if a calf has contact with its mother during rearing, even if this contact is limited, it may lead to enhanced social skills when the heifers join the herd after calving. Enhanced social skills could result in fewer within cohort interactions in heifer groups, leading to more cross cohort interactions. Furthermore, Wagner *et al.* (2015) found that 2.5 year old cows who had permanent access to their mothers, through an access gate, demonstrated increased sociality and lower stress levels when isolated. Issues arise when yield is reduced in nursing cows and disease transmission is less easy to control (Johnsen, 2016) it would not be practical to rear the calves with their dams.

Following a heifer group from birth through to the entry into the herd and subsequent lactations would enable determination of whether the animals do form friendship bonds in early life which are then continued into adulthood and on through their life within the herd. Duve and Jensen (2011) found that calves that were housed together from birth showed stronger preference for its companion than those reared in individual pens. This supports the findings of Bøe and Færevik (2003) who found that previous social experiences can affect social integration and that these factors contribute through to heifer groups and within the herd. Social housing was also found to improve calves cognitive performance (Gaillard *et al.,* 2014) and social interaction (Babu *et al.,* 2004). Calves form strong bonds from birth and, these bonds are carried trough to adulthood (Bolt *et al.,* 2016). Current practice within dairy cow management constantly changes animal groupings to suit management strategy if it is determined that animals within the herd form strong bonds with cohort groups it may be prudent to look at management practices and how they affect these bonds and subsequently affect the health and welfare of the dairy cow. McClennan (2013) discovered that there were social bonds between dairy cattle and that regrouping of animals, which separated them from their preferred partners, elicited a negative response. Social familiarity also improves performance (Coulon *et al.,* 2009) disturbing the bonds would have a negative effect.

Inevitably there will be times when animals are culled from the herd due to production or health problems, in this situation animals must replace the close companions of the cows that are left behind, in these circumstances it is unclear how cows choose who they are going to replace their companions with. Further research is required to determine if they choose their companions through frequency of agonistic interactions or with the animals that are less confident within the herd such as the heifer groups.

References

Abeni, F. and Bertoni, G. (2009) ‘Main causes of poor welfare in intensively reared dairy cows’, *Italian Journal of Animal Science*, 8(1), 45-66.

Adamczyk, K., Pokorska, J., Makulska, J., Early, B., Mazurek, M. (2013) ‘Genetic analysis and evaluation of behavioural traits in cattle’. *Livestock Science*, 154, pp 1-12.

AHDB (2020) UK product production. Available at: https://ahdb.org.uk/dairy/uk-product-production (Accessed: 22 February 2020).

AHDB (2020a) Feeding Space Allowances. Available at: https://dairy.ahdb.org.uk/technical-information/animal-health-welfare/mastitis/working-arena-prevention-of-infection/housing/feeding-space-allowances/#.Xl_VNqj7TIU. (Accessed 4 March 2020).

AHDB (2019) UK milk yield. Available at: https://ahdb.org.uk/dairy/uk-milk-yield (Accessed: 23 February 2020).

AHDB (2020a) UK producer numbers. Available at: https://ahdb.org.uk/dairy/uk-producer-numbers (Accessed: 23 February 2020).

AHDB (2012) Dairy Housing – Ventialtion Available at: https://dairy.ahdb.org.uk/resources-library/technical-information/buildings/dairy-housing-chapter-13-ventilation/#.XiRRduRCflU (Accessed 19 January 2020).

AHDB (2020) Cubicle Dimensions Available at: https://dairy.ahdb.org.uk/technical-information/buildings/housing/cubicles/cubicle-dimensions/#.XiROXuRCflU (Accessed 19 January 2020).

AHDB (2013) MOBILITY SCORE INSTRUCTIONS LAMINATE. Available at: https//dairy.ahdb.org.uk/resources-library/technical-information/health-welfare/mobility-score-instructons/#.XmzjxKj7TlU (Accessed 14 March 2020)

Arachchige, A. D.H., Fisher, A.D., Wales, W.J., Auldist, M.J., Hannah, M.C. and Jongman. E.C. (2014). ‘Space allowance and barriers influence cow competition for mixed rations fed on a feed-pad between bouts of grazing’, *Journal of Dairy Science*, 97, pp.3578–3588.

Arnold, N.A., Ng, K.T., Jongman, E.C. and Hemsworth, P.H., (2007), ‘Responses of dairy heifers to the visual cliff formed by a herringbone milking pit: evidence of fear of heights in cows (*Bos taurus*)’, *Journal of Comparative Pschology*. 121(4), pp. 440-446.

Babu. L. K., Pandey, H. N. and Sahoo, A. (2004) ‘Effect of individual versus group rearing on ethological and physiological responses of crossbred calves’, *Applied Animal Behaviour Science,* 87, pp. 177-191.

Bate, A. (2016) UK Dairy Industry Statistics Available at http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN02721 (Accessed: 24 February 2018).

Baile, C. A. (1981) ‘Nature of hunger and satiety control systems in ruminants’, *Journal of Dairy Science,* 64, pp.1140-1152.

Bertenshaw, C., Rowlinson, P., Edge, H., Simon, D. and Shiel, R. (2008). ‘The effect of different degrees of “positive” human-animal interaction during rearing on the welfare and subsequent production of commercial dairy heifers’, *Applied Animal Behaviour Science*, 114, pp.65–75.

Beisner, B. A. and McCowan, B. (2015) 'Social Networks and Animal Welfare' in Krause, J., James, R., Franks, D. W. and Croft, D. P., (ed.) *Animal Social Networks,* Oxford: Oxford University Press, pp.112.

Berry, D.P., McCarthy, J. (2012) ‘Genetic and non-genetic factors associated with milking order in lactating dairy cows’ *Applied Animal Behaviour Science*, 136, pp.15-19.

Bhatti, S.A., Ali, A., Nawaz, H., McGill, D., Sarwar, M., Afzal, M., Khan, M.S., Ehsanullah, Amer, M.A., Bush, R., Wynn, P.C., and Warriach, H.M. (2012) ‘Effect of pre-weaning feeding regimens on post weaning growth performance of Sahiwal calves’, *Animal*, 6:8, pp. 121-1236.

Bøe, K.E. and Færevik, G. (2003). ‘Grouping and social preferences in calves, heifers and cows’, *Applied Animal Behaviour Science*, 80(3), pp.175–190.

Boissy, A., Fisher, A. D., Bouix, J., Hinch, G. N. and Le Neindre, P. (2005) ‘Genetics of fear in ruminant livestock’, *Livestock Production Science*, 93 pp. 23-32.

Boivin, X., Lensink, J., Tallet, C. and Veissier, I. (2003) ‘STOCKMANSHIP AND FARM ANIMAL WELFARE’, *Animal Welfare,* 12, pp. 479-492*.*

Bolt, S. L., Boyland, N. K., Mlynski, D. T., James, R. and Croft, D. (2017) ‘Pair Housing of Dairy Calves and Age at Pairing: ‘Effects on Weaning Stress, Health, Production and Social Networks’, *PLOS ONE,* DOI:10.1371/journal.pone.0166926.

Boyland, N, James, R, Mlynski, D, Madden, J, and Croft, D. (2013) 'Spatial proximity loggers for recording animal social networks: consequences of inter-logger variation in performance', *Behavioral Ecology & Sociobiology*, 67, 11, pp. 1877-1890.

Boyland, N.K., Mlynski, D.T., James, R., Brent, L.J.N., and Croft, D.P., (2016). ‘The social network structure of a dynamic group of dairy cows: From individual to group level patterns’, *Applied Animal Behaviour Science*, 174, pp. 1-10.

Boyle, A. R., Ferris, C. P., and O'Connell, N. E. (2012). 'Are there benefits in introducing dairy heifers to the main dairy herd in the evening rather than the morning?', *Journal of Dairy Science.* 95 pp. 3650-3661.

Brakel, W. J. and Leis, R. A. (1976) 'Impact of Social Disorganization on Behavior, Milk Yield and Body Weight of Dairy Cows', *Journal of Dairy Science*, 59(4), pp. 716-721.

Breuer K., Hemsworth P.H., Barnett J.L., Matthews L.R., and Coleman G.J., (2000). 'Behavioural response to humans and the productivity of commercial dairy cows', *Applied Animal Behaviour Science,* 66. pp. 273–288.

Burow, E. Nielsen, T., Rousing., Halekoh, U. and Knierim, U. (2009). 'Social interactions of dairy cows introduced postpartally to a separated barn section – pilot study', *Animal Science*, 59, pp.192–196.

Byrne, T. J., Santos, B. F. S., Amer, P. R., Martin-Collado, D., Pryce, J. E., Axford, M. (2016) 'New breeding objectives and selection indices for the Australian dairy industry', *Journal of Dairy Science,* 99, pp 8146-8167.

Cabrera, V.E., Solís, D. and del Corral, J., (2010). 'Determinants of technical efficiency among dairy farms in Wisconsin', *Journal of dairy science*, 93, pp.387–393.

CAFRE (2020). *Heifer Rearing*. Available at https://www.cafre.ac.uk/industry-support/knowledge-transfer/project/heifer-rearing/ (Accessed 15.1.2020).

Ceballos, A., Weary, D.M., (2002) ‘Feeding small quantities of grain in the parlour facilitates pre-milking handling of dairy cows: a note’. *Applied Animal Behaviour Science,* 77(4) pp 249-254

Chamberlain, A. T and Wilkinson J. M. (1996) *Feeding the Dairy Cow.* Welton : Chalcombe.

Coleman, G.J., Rice, M., Hemsworth, P.H., (2012) ‘Human-animal relationships at sheep and cattle abattoirs,’ *Animal Welfare*, 21(S2) pp 15-21

Costa, J. H. C., von Keyserlingk, M. A. G. and Weary, D. M. (2016). ‘*Invited Review*: Effects of group housing of dairy calves on behaviour, cognition, performance and health’, *Journal of Dairy Science*, 99 pp 2453-2467.

Costa, J. (2018) ‘Are we raising “normal” cows? Effects of early life diet, feeding plan, and housing on the natural behaviour of dairy cattle’, *Journal of Animal Science*, 96, Suppl. S3 pp 6-7.

Coulon, M., Baudoin, C., Heyman, Y., Deputte, B. L. (2011) ‘Cattle discriminate between familiar and unfamiliar conspecifics by using only head visual cues’, *Animal Cognition.,*14, pp. 279-290.

Coulon, M., Deputte, B. L., Heyman, Y. and Baudoin, C. (2009) ‘Individual Recognition in Domestic Cattle (*Bos Taurus*): Evidence from 2D-Images of Heads from Different Breeds’. PLoS ONE 4(2): e4441. https://doi.org/10.1371/journal.pone.0004441.

Croney, C. C. and Newberry, R.C., (2007) ‘Group size and cognitive processes’, *Applied Animal Behaviour Science*, 103, pp. 215-228.

Curtis, G.C., Argo, C.M., Jones, D., Grove-White, D.H. (2016) ‘Impact of feeding and housing systems on disease incidence in dairy calves.’ *Veterinary Record* 179, pp. 512

Dairy Global (2018). *Give The Cows Some Rest*. Dairy Global, Smart Farming. Available at: https://www.dairyglobal.net/Smart-farming/Articles/2018/11/Give-the-cows-some-rest-364362E/ (Accessed 19 January 2020).

DEFRA (2019) Structure of the UK agriculture industry in England and the UK at June (annual) available at https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june (accessed: 22 February 2020).

de Freslon, I., Martinez-Lopez, B., Belkhiria, J., Strappini, A. and Monti, G. (2019) ‘Use of social network analysis to improve the understanding of social behaviour in dairy cattle and its impact on disease transmission'. *Applied Animal Behaviour Science*, 213. pp. 47-54.

de Boyer des Roches, A., Lussert, A., Faure, M., Herry, V., Rainard, P., Durand, D., Wemelsfelder, F. and Foucras, G. (2018) 'Dairy cows under experimentally-induced *Escherichia coli* mastitis show negative emotional states assessed through Qualitative Behaviour Assessment', *Applied Animal Behaviour Science,* 206, pp. 1-11.

Dijkstra, C., Veermae, I., Praks, J., Poikalainen, V., and Arney, D. R. (2012). 'Dairy Cow Behaviour and Welfare Implications of Time Waiting Before Entry Into the Milking Parlor'. *Journal of Applied Animal Welfare Science,* 15(4), pp. 329-345.

Duve, L. R. and Jensen, M. B. (2011) 'The level of social contact affects social behaviour in pre-weaned dairy calves' *Applied Animal Behaviour Science*,135, pp. 34-43.

Ellis, K. A., Billington, K., McNeil, B. and McKeegan, D. E. F. (2009) 'Public opinion on UK milk marketing and dairy cow welfare', *Animal Welfare*. 18, pp. 267-282.

Estevez, I., Andersen, I.-L. and Nævdal, E. (2007). 'Group size, density and social dynamics in farm animals', *Applied Animal Behaviour Science*, 103(3-4), pp.185–204.

Faber, J., and Fonesca, L.M. (2014). ‘How sample size influences research outcomes.’ *Dental Press Journal of Orthodontics,* 19(4):pp. 27-29.

Færevik, G., Anderson, I.L., Jensen, M.B. and Boe, K.E. (2007). ‘Increased group size reduces conflicts and strengthens the preference for familiar group mates after regrouping of weaned dairy calves (*Bos taurus*)’, *Applied Animal Behaviour Science*, 108, pp.215–228.

FAWC (2012) *Five Freedoms* Available at: https://webarchive.nationalarchives.gov.uk/20121010012427/http://www.fawc.org.uk/freedoms.htm (Accessed: 1 March 2020).

Foris, B., Von Keyserlingk, M.A.G., Weary, D.M., (2020) ‘Competition Strategies of Metritic and healthy Transition Cows,’ *Animals*, 10(5), 854.

Foris, B., Zebunke, M., Langbein, J. and Melzer, N., (2019). ‘Comprehensive analysis of affiliative and agonistic social networks in lactating dairy cattle groups’, *Applied Animal Behaviour Science*. 210, pp 60-67.

Friedrich, J., Brand, B., Ponsuksili, S., Graunke, K. L., Langbein, J., Knaust, J., Khun, C. and Scwerin, M. (2015) ‘Detection of genetic variants affecting cattle behaviour and their impact on milk production: a genome-wide association study’, *Animal Genetics*. 47 pp 12-18.

Fröberg, S., (2008) '*Effects of Restricted and Free Suckling – In Cattle used in Milk Production Systems'* Available at: https:www.pub.epsilon.slu.se (Accessed 27 October 2020)

Gaillard, C. Meagher, R. K., von Keyserlingk, M. A. G. and Weary, D. (2014) 'Social Housing Improves Dairy Claves' Performance in Two Cognitive Tests' *PLOS ONE.* 9(2) e90205. Doi:10.1371/journal.pone.0090205.

Galindo, F., and Broom, D.M. (2002). 'The Effects of Lameness on Social and Individual Behaviour of Dairy Cows', *Journal of Applied Animal Welfare Science*. 5(3), pp. 193-201.

Garcia, E. Konig, K. Allesen-Holm, B. H., Klass, I. C., Amiga, J. M., Bro, R. and Enevoldsen, C. (2015) 'Experienced and inexperienced observers achieved relatively high within-observer agreement on video mobility scoring of dairy cows', *Journal of Dairy Science.* 98, pp. 4560-4571.

Gibbons, J.M., Lawrence, A.B. & Haskell, M.J. (2010) 'Measuring sociability in dairy cows', *Applied Animal Behaviour Science*, 122, pp.84–91.

Gibbons, J. M., Lawrence, A. B. and Haskell, M. J. (2009) 'Consistency of aggressive feeding behaviour in dairy cows'. *Applied Animal Behaviour Science.* 121, pp. 1-7.

Gomez, A. and Cook, N. B. (2010) ‘Time budgets of lactating dairy cattle in commercial freestall herds’, *Journal of Dairy Science.* 93, pp. 5772-5781.

Google Maps (2017) ‘*Porsham Farm*’. Available at https://www.google.co.uk/maps/@50.4387731,-4.1320225,132m/data=!3m1!1e3 (accessed 12 July 2017).

Grasso, F., Rosa, G., Napolitano, F., Di Francia, A. and Bordi, A. (2007) ‘Entrance order and side preference of dairy cows in the milking parlour’, *Italian Journal of Animal Science.* 6:2, pp. 187-194

Gutmann, A.K., Spinka, M., and Winckler, C. (2015). ‘Long-term familiarity creates preferred social partners in dairy cows’, *Applied Animal Behaviour Science*. 169, pp. 1-8.

Hagen, K. and Broom, D. M. (2003) ‘Cattle discriminate between individual and familiar herd members in a learning experiment’, *Applied Animal Behaviour Science*. 82, pp. 13-28.

Hanna, D., Sneddon I.A., Beattie, V.E. and Breuer, K. (2006) ‘Effects of the stockperson on dairy cow behaviour and milk yield’. *Animal Science*, 82, pp.791.

Hart, K.D., McBride, B.W., Duffield, T.F. and DeVries, T.J. (2013) ‘Effect of milking frequency on the behavior and productivity of lactating dairy cows’, *Journal of Dairy Science*, 96, pp.6973–85.

Hart, K.D., McBride, B.W., Duffield, T.F. and DeVries, T.J. (2014) ‘Effect of the frequency of feed delivery on the behaviour and productivity of lactating dairy cows’, *Journal of Dairy Science*, 97, Pp. 1713-1724.

Haskell M.J., Bell, D. J. and Gibbons, J.M. (2012) ‘Is the response to humans consistent over productive life in dairy cows?’, *Animal Welfare* 21(3), pp.319-324.

Haskell, M. J., Simm, G and Turner, S. P. (2014) ‘Genetic selection for temperament traits in dairy and beef cattle’, *Frontiers in Genetics*. Animal and Veterinary Sciences Group, Scotland’s Rural College, Edinburgh, UK

Hirst, K. K., (2019) ‘History of the Domestication of Cows and Yaks’. Available at: https://www.thoughtco.com/history-of-the-domestication-of-cows-170652 (Accessed: 1 March 2020).

Hopster, H., van der Werf, J. T. N. and Blokhuis, H. J. (1998) ‘Side preference of dairy cows in the milking parlour and its effects on behaviour and heart rate during milking’, *Applied Animal Behaviour Science*. 55, pp. 213-229.

Ito, K., Chapinal, N, Weary, D.M. and von Keyserlingk, M.A.G. (2014) ‘Associations between herd-level factors and lying behavior of freestall-housed dairy cows’, *Journal of dairy science*, 97, pp. 2081–9.

Ivemeyer, S., Simantke, C., Ebinghaus, A., Poulsen, P. H., Sorensen, J. T., Rousing, T., Palm, R. and Knierim, U. (2018) ‘Herd-level associatiosn between human-animals relationship, management, fecal cortisol metabolites, and udder health of organic dairy cows’, *Journal of Dairy Science.* 101, pp. 7361-7174.

Jensen, P. (2006) ‘Domestication - From behaviour to genes and back again’. *Applied Animal Behaviour Science*. 97, pp. 3-15.

Johnsen, J. F., Zipp, K. A., Kälber, T., de Passillé, A. M., Knierim, U., Barth, K. and Mejdell, C. M. (2016) ‘Is rearing calves with the dam a feasible option for dairy farms? – Current and future research’, *Applied Animal Behaviour Science.* 181, pp.1-11.

Kilgour, R, J., Melville, G, J. and Greenwood, P, L. (2006) ‘Individual differences in the reaction of beef cattle to situations involving social isolation, close proximity of humans, restraint and novelty’, *Applied Animal Behaviour Science*, 99, pp. 21-40.

King, M. T. M., LeBlanc, S. J., Pajor, E. A. and DeVries (2017) ‘Cow-level associations of lameness, behaviour and milk yield of cows in automated systems’, *Journal of Dairy Science,* 100, pp. 4818-4828.

Kingshay (2019) *Dairy Costings Focus Annual Report* 2019 Somerset: Kingshay.

Konig, S., Kohn, F., Kuwan., Simianer, H. and Gauly, M. (2006) 'Use of Repeated Measures Analysis for Evaluation of Genetic Background of Dairy Cattle Behaviour in Automatic Milking Systems', *Journal of Dairy Science*, 89 pp. 3636-3644.

Kramer, E., Cavero, D., Stamer, E. and Krieter, J. (2009) 'Mastitis and lameness detection in dairy cows by application of fuzzy logic', *Livestock Science*, 125(1), pp.92–96.

Kušnírová, E.Debrecini, O., Bordacova, V. and Petrak, J. (2012) 'The influence of floor quality on dairy cow behaviour and their body cleanliness vplyv kvality podlahy na správanie dojníc a ich č istotu povrchu tela abstrakt', 13(1), pp.34–43.

Kutzer, T., Steilen, M., Gygax, L., Wechsler, B. (2015) 'Habituation of dairy heifers to milking routine-Effects on human avoidance distance, behavior and cardiac activity during milking', *Journal of Dairy Science,* 98(8), pp. 5241-5251.

Lainez, M. M., and Hsia, L. C. (2004) 'Effects of Season, Housing and Physiological Stage on Drinking and Other Related Behavior of Dairy Cows (*Bos taurus*) Asian-Australas' *Journal of Animal Science*. 17(10), pp.1417-1429.

Lendvai, À.Z., Akçay, Ç., Ouyang, J.Q., Daskin, R., Domalik, A.D., St John, P.S., Stanback, M., Moore, I.T. and Bonier, F. (2015) 'Analysis of the Optimal Duration of Behavioural Observations Based on an Automated Continuous Monitoring System in Tree Swallows (*Tachycineta bicolour*): Is One Hour Good Enough?' *PLoS One.* 10(11). Published online 2015 Nov 11. Doi:10.1371/journal.pone.0141194

Lobeck-Luchterhand, K.M.,Silva, P.R.B., Chebel, R.C. and Endres, M.I. (2014) 'Effect of prepartum grouping strategy on displacements from the feed bunk and feeding behavior of dairy cows', *Journal of Dairy Science*, 97, pp.2800–2807.

Lobeck-Luchterhand, K. Silva, P. Chebel, R. and Endres, M 2015, 'Effect of stocking density on social, feeding, and lying behavior of prepartum dairy animals', *Journal of Dairy Science*, 98, 1, pp. 240-249.

Lobeck, K. M., Endres, M.I., Shane, E.M., Godden, S.M. and Fetrow, J. (2011) 'Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest', *Journal of Dairy Science*, 94(11), pp. 5469–5479.

Loerch, S. C. and Fluharty, F. L. (2000) 'Use of trainer animals to improve performance and health of newly arrived feedlot calves', *Journal of Animal Science.* 78, pp. 539-545.

Lürzel, S., Windschnurer, I., Futschik, A. and Wablinger, S. (2016) ‘Gentle interactions decrease the fear of humans in dairy heifers independently of early experience stroking’, *Applied Animal Behaviour Science.* 178, pp. 16-22.

Marley, C. L., Weller, R. F. Neale, M., Main, D. C. J., Roderick, S. and Keatinge, R. (2010) ‘Aligning health and welfare principles and practice in organic dairy systems: a review’, *Animal.* 4(2), pp. 259-271.

MacKay, R.D.J., Haskell, M.J., Deag, J.M. and van Reenen, K. (2014), ‘Fear responses to novelty in testing environments are related to day-to-day activity in the home environment in dairy cattle’, *Applied Animal Behaviour Science*. 152, pp. 7-16.

Manzanilla Pech, C.I.V., Veerkamp, R.F., Calus, M.P.L., Zom, R., van Knegsel, A., Pryce, J.E. and De Haas, Y. (2014). ‘Genetic parameters across lactation for feed intake, fat- and protein-corrected milk, and liveweight in first-parity Holstein cattle’. *Journal of Dairy Science*, 97, pp.5851–5862.

Mattachini, G., Riva, E. and Provolo, G., (2011) ‘The lying and standing activity indices of dairy cows in free-stall housing’, *Applied Animal Behaviour Science*, 129(1), pp.18–27.

McLennan, K. M. (2013) ‘Social bonds in dairy cattle: the effect of dynamic group systems on welfare and productivity’, Doctoral thesis. The University of Northampton.

McTavish, E. J., Decker, J. E., Schnabel, R. D., Taylor, J. F., Hillis, D. M. (2013) ‘New World cattle show ancestry from multiple independent domestication events’, PNAS. Available at: www.pnas.org/cgi/doi/10.1073/pnas.1303367110 (Accessed 4 March 2020)

Microsoft Corporation (2010) *Excel* (2010) [Computer program] Available at: https://www.microsoft.com/en-gb/p/excel/cfq7ttc0k7dx?=&OCID=AID2000750_SEM_torTd9SN&MarinID=torTd9SN%7c79371079151178%7cmicrosoft+excel%7cbe%7cc%7c%7c1269936258333145%7ckwd-79371225554834%3aloc-188&lnkd=Bing_O365SMB_App&msclkid=9dabc8ee3a05129e3dbb968dec87a0f6&ef_id=Wd49jwAAAHD-RVbn%3a20200307171447%3as&activetab=pivot%3aoverviewtab (Accessed 7 March 2020)

Minitab (2019) *Minitab* (19.2) [Computer programme] Available at https://www.minitab.com/en-us/products/minitab/?hsa_net=adwords&hsa_mt=e&hsa_ver=3&hsa_grp=1228154664602403&hsa_ad=&hsa_tgt=kwd-76759809480196:loc-188&hsa_cam=2063260456&hsa_acc=4841564033&hsa_src=o&hsa_kw=minitab&utm_source=bing&utm_medium=cpc&utm_campaign=BFO%20-%20Bing%20UK%20-%20EN%20-%20Branded&utm_term=minitab&utm_content=Minitab%2019%20Software (Accessed: 7 March 2020)

Montgomery, J. A., Forgan, K., Hayhurst, C., Rees, E., Duncan, J.S., Gossellein, J., Harding, C. and Murray, R.D. (2011) ‘Veterinary science development’, Veterinary Science Development. PagePress.

Meul, M., Van Passel, S., Fremaut, D., Haesaert, G. (2012) 'Higher sustainability performance of intensive grazing versus zero-grazing dairy systems'. *Agronomy for sustainable development* 32(3) pp. 629-638.

NADIS (2020) *DISEASE A-Z/LAMNESS CONTROL IN DAIRY HERDS/ Part 7 – Cubicle Comfort* Available at: https://www.nadis.org.uk (Accessed 18 October 2020)

Neisen, G., Wechsler, B. and Gygax, L. (2009), 'Effects of the introduction of single heifers or pairs of heifers into dairy cow herds on the temporal and spatial associations of heifers and cows'. *Applied Animal Behaviour Science*, 119. pp 127-136.

NMR 2020 *'Introduction to Johne's Disease.'* Available at https://www.checs.co.uk (Accessed 27 October 2020)

Norring, M, Valros, A, and Munksgaard, L (2012), 'Milk yield affects time budget of dairy cows in tie-stalls', *Journal of Dairy Science*, 95, 1, pp. 102-108.

O'Connell, N.E., Ferris, C.P., Patterson, D.C. and Mayne, C.S. (2010). 'Effect of feed barrier design and feed space allowance on performance and behavioural parameters in dairy cows', *Applied Animal Behaviour Science*, 127(1-2), pp.20–27.

Patison, P.K., Swain, D.L., Bishop-Hurley, G.J., Robins, G., Pattison, P. and Reid, D.J. (2010) ‘Changes in temporal and spatial associations between pairs of cattle during the process of familiarisation’, *Applied Animal Behaviour Science*, 128, pp. 10-17.

Pavlenko, A., Bergsten, C., Ekesbo, I., Kaart, T., Aland, A. and Lidfors, L. (2011) ‘Influence of digital dermatitis and sole ulcer on dairy cow behaviour and milk production’, *Animal*. Cambridge University Press, 5(8), pp. 1259–1269.

Perez-Prieto, L. A and Delagarde, R. (2012) ‘Meta-analysis of the effect of pregrazing pasture mass on pasture intake, milk production, and grazing behavior of dairy cows strip-grazing temperate grasslands’ *Journal of Dairy Science*, 95, pp.5317–5330.

Perez-Prieto, L. A. and Delagarde, R. (2013) ‘Meta-analysis of the effect of pasture allowance on pasture intake, milk production, and grazing behaviour of dairy cows grazing temperate grasslands’, *Journal of Dairy Science*. 96 pp 6671-6689.

Pineiro, J. M., Menichetti, B. T., Barragan, A. A., Relling, A. E., Weiss, W. P., Bas, S. and Schuenemann, G.M. (2019). ‘Associations of postpartum lying time with culling, milk yield, cyclicity, and reproductive peformance of lactating dairy cows’, *Journal of Dairy Science*. 102, pp. 3362-3375.

Polikarpus, A., Grasso, F., Pacelli, C., Napolitano, F. and De Rosa, G. (2014) ‘Milking behaviour of buffalo cows: entrance order and side preference in the milking parlour’, *Journal of Dairy Research*. 81, pp. 24-29.

Polikarpus, A., Kaart, T., Mootse, H., De Rosa, G., Arney, D. (2015) ‘Influences of various factors on cows’ entrance order into the milking parlour’, *Applied Animal Behaviour Science*. 166, pp. 20-24

Prelle, I., Phillips, C. J. C., Paranhos da Costa, M. J., Vandenberghe, N. C. and Broom, D. M. (2003) ‘Are cows that consistently enter the same side of a two sided milking parlour more fearful of novel situations or more competitive?’ *Applied Animal Behaviour Science*, 87, pp. 193-203.

Price, E.O., (1999). ‘Behavioural development in animals undergoing domestication’, *Applied Animal Behaviour Science*, 65, pp. 245-271.

Rajapaksha, E., Tucker, C.B., (2014) ‘How do cattle respond to sloped floors? An investigation using behaviour and electromyograms’. *Journal of Dairy Science*. 97, pp.2808-2815.

Red Tractor, (2017) *Certified Standards For Farms Dairy Scheme*, Available at: https//www.assurance.redtractor.org.uk/contentfiles/Farmers-6802.pdf (Accessed 28 October 2020)

Rodenburg, T.B. and Koene, P. (2007) ‘The impact of group size on damaging behaviours, aggression, fear and stress in farm animals’, *Applied Animal Behaviour Science*, 103(3-4), pp.205–214.

Rousing, T. and Wemelsfelder, F. (2006) ‘Qualitative assessment of social behaviour of dairy cows housed in loose housing systems’, *Applied Animal Behaviour Science*, 101, pp 40–53.

RSPCA (2018) RSPCA *Welfare Standards for Dairy Cattle.* RSPCA. West Sussex.

Ruegg, P.L. (2017) ‘A 100-year Review: Mastitis detection, management and prevention. *Journal of Dairy Science*, 100, pp 10381-10397

Sarova, R., Spinka,M., Stehulova, I., Ceacero, F., Simeckova, M. and Kotrba, R. (2013). ‘Pay respect to the elders: age, more than body mass, determines dominance in female beef cattle’, *Animal Behaviour* 86(6), pp. 1315-1323.

Sato, S., Tarmizu, K., and Hatae, K., (1993) ‘The influence of social factors on allogrooming in cows’, *Applied Animal Behaviour Science.* 38(3-4), pp 235-244.

Scott, V.E., Kerrisk, K.L., Thomson, P.C., Lyons, N.A. and Garcia, S.C. (2014) ‘Voluntary cow traffic and behaviour in the premilking yard of a pasture-based automatic milking system with a feed supplementation regime’, *Livestock Science*, 171, pp.52–63.

Sepúlveda-Varas, P., Proudfoot, K.L., Weary, D.M. and von Keyserlingk, M. A. G. (2016) ‘Changes in the behaviour of dairy cows with clinical mastitis’ *Applied Animal Behaviour Science*. 175, pp. 8-13.

Sheahan, A J., Gibbs, S.J. and Roche, J.R. (2013) ‘Timing of supplementation alters grazing behaviour and milk production response in dairy cows’, *Journal of Dairy Science*, 96, pp.477–83.

Sherwin, V., Hudson, C., Henderson, A. and Breen, J. (2016) ‘Measuring health and performance in preweaning dairy calves’. *In Practice*. 38 pp 113-122.

Siivonen, J,Taponen, S., Hovinen., Pastell, M., Lensink, B. J., Pyorala, S. and Hanninen, L. (2011) ‘Impact of acute clinical mastitis on cow behaviour’, *Applied Animal Behaviour Science*, 132(3-4), pp.101–106.

Soberon, F., Ryan, C.M., Nydam, D.V., Galton, D.M. and Overton,.T.R. (2011) ‘The effects of increased milking frequency during early lactation on milk yield and milk composition on commercial dairy farms’, *Journal of Dairy Science*, 94, pp.4398–4405.

Soberon, F., Raffrenato, E., Everett, R.W. and Van Amburgh, M. E. (2012) Preweaning milk replacer intake and effects on long-term productivity of dairy calves. *Journal of Dairy Science*, 95, pp. 783-793.

Soberon, F. and Van Amburgh, M.E., (2013) Lactation Biology Symposium: The effectof nutrient intake from milk or milk replacer of preweaned dairy calves on lactation milk yield as adults: a meta-analysis of current data. *Journal of Animal Science,* 91, pp. 706-712.

Sowell, B. F., Mosley, J. C. and Bowman, J. G. P. (1999) ‘Social behaviour of grazing beef cattle: Implications for management’, *Journal of Animal Science*, 77, pp. 1–6.

Sutherland, M. A. and Huddart, F. J. (2012) ‘The effect of training first lactation heifers to the milking parlor and behavioural responses to milking and productivity’. *Journal of Dairy Science.* 95, pp. 6983-6993.

Talebi, A., Von Keyserlingk, M.A.G., Telezhenko, E. and Weary, D.M. (2014) ‘Reduced stocking density mitigates the negative effects of regrouping in dairy cattle’, *Journal of Dairy Science*, 97, pp.1358–63.

Thanner, S., Schori, F. and Bruckmaier, R.M. (2014) ‘Grazing behaviour, physical activity and metabolic profile of two Holstein strains in an organic grazing system’, *Journal of Animal Physiology and Animal Nutrition*, 98, pp.1143–1153.

The Dairy Site (2011). *Does Feed Space Allowance Impact Performance*? Available at:

http://www.thedairysite.com/articles/2614/does-feed-space-allowance-impact-performance/ (Accessed 4 March 2020).

Ungerfeld, R., Cajarville, C., Rosas, M. I. and Repetto, J. L. (2014) ‘Time budget defferences of high- and low-social rank grazing dairy cows’, *New Zealand Journal of Agricultural Research.* 57(2), pp. 122-127.

Valníčková, B., Stěhulová, I., Šárová, R. and Špinka, M. (2015) ‘The effect of age at separation from the dam and presence of social companions on play behaviour and weight gain in dairy calves’, *Journal of Dairy Science.* 98, pp. 5545-5556.

Van Reenen, C.G., Cornelis, G., Van Der Werf, J.T.N., O'connell, N.E., Heutinck, L.F.M, Spoolder, H.A.M., Jones, R.B., Koolhaas, J.M. and Blokhuis, H.J. (2013) ‘Behavioural and physiological responses of heifer calves to acute stressors: Long-term consistency and relationship with adult reactivity to milking’, *Applied Animal Behaviour Science*, 147(1-2), pp.55–68.

von Keyserlingk, M. A. G. and Weary, D. M. (2007) ‘Maternal behaviour in cattle’ *Hormones and Behaviour*. 52, pp. 106-113.

Wagner, K., Barth, K., Palme, R., Futschik, A. and Waiblinger, S. (2012) ‘Integration into the dairy cow herd: Long-term effects of mother contact during the first twelve weeks of life’, *Applied Animal Behaviour Science*. 141, pp. 117-129

Wagner, K., Seitner, D., Barth, K., Palme, R., Futschik, A. and Waiblinger, S. (2015) 'Effects of mother versus artificial rearing during the first 12 weeks of life on challenge responses of dairy cows' *Applied Animal Behaviour Science,* 164, pp. 1-11.

Walker, S.L., Smith, R.F., Routly, J.E., Jones, D.N., Morris, M.J., Dobson, H., (2008) Lameness, Activity Time-Budgets, and Estrus Expression in Dairy Cattle Cattle, *Journal of Dairy Science* 91(12) pp. 4552-4559.

Wareingbuildings (2020) *Standard Cow Kennels*. Available at: http://www.wareingbuildings.co.uk/casestudies/agricultural/cowkennels-casestudy.html (Accessed 14 March 2020)

Wathes, D.C. Cheng, Z., Bourne, N., Taylor, V.J., Coffey, M.P. and Brotherstone, S, (2007) 'Differences between primiparous and multiparous dairy cows in the inter-relationships between metabolic traits, milk yield and body condition score in the periparturient period', *Domestic animal Endocrinology*, 33(2), pp.203–25.

Watson-Haigh, N. S., O'Neill, C. J. and Kadarmideen, H. N. (2012) 'Proximity Loggers: Data Handling and Classification for Quality Control', *IEEE Sensors Journal.* 12(5), pp. 1611-1617

Watters, M.E.A., Meijer, K.M.A., Barkema, H.W., Leslie, K.E., von Keyserlingk, M.A.G. and DeVries, T.J. (2013) 'Associations of herd- and cow-level factors, cow lying behavior, and risk of elevated somatic cell count in free-stall housed lactating dairy cows', *Preventive Veterinary Medicine*, 111(3-4), pp.245–255.

Yun, J., Swan,K.M., Oliviero, C., Peltoniemi, O. and Valros, A. (2015) 'Effects of prepartum housing environment on abnormal behaviour , the farrowing process , and interactions with circulating oxytocin in sows', *Applied Animal Behaviour Science*, 162, pp.20–25.