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Swedish University of Agricultural Sciences
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How drinking behaviour in automatic milk feeders can be used as early disease detection

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Preface

This master thesis was performed in collaboration with the Swedish University of Agricultural Science and DeLaval. DeLaval has installed the ALPRO-management system at Lövsta Research Center in Uppsala where the trial was performed. I would like to thank Luis Miguel Alonso, Charlotte Hallén Sandgren and Henrik Rosenberg at DeLaval for their support and for giving me this opportunity to learn how the management system and the automatic milk feeder are working. Furthermore I will thank Gunnar Pettersson for all work laid down in order to extract the data collected by the ALPRO system and transform it into a form that could more easily be used in my calculations. I would also like to thank Ingemar Olsson and Bengt-Ove Rustas for feedback on the project. Finally I want to thank Axel Andersson for continuously supporting me in this writing process.

Abstract

Healthy calves are the foundation in order to run a profitable diary production. Being healthy as calf results in a better start in life and good growth is expected to follow. Within dairy production it becomes more common to rear calves in groups and feed them by an automatic milk feeder. The milk feeder enables for the calves in greater extent to ingest milk or milk replacer several times per day and they are also able to perform natural behaviors in greater extent.

Group rearing of calves puts higher demands on the animal keepers to localize individual calves in the group pen, showing signs of illness. In group pens it can be harder to detect which of the calves' suffering from disease compared to rearing calves in single pens. The aim with this master thesis is to detect calves with diarrhoea and compare their feeding behaviour in the automatic milk feeder with healthy calves. This also simplifies detection of upcoming illness at far level and simplifies the rearing of calves.

During the first 28 days in life faeces from 53 calves of Swedish Holstein (SH) and Swedish Red Breed (SRB) was examined. The faeces were scored at a four-graded scale (0-3) according to consistency and appearance. Grade 0 was considered as normal faeces (healthy calf) and scoring 1-3 included different grades of diarrhoea (diseased calf). The calves were weighed at the age of 1, 2, 4 and 8 weeks. In average the calves were moved from a single pen to a group pen, equipped with an automatic milk feeder, at the age of one week. When introduced in the group pen the calves had access to 8 liters of milk replacer, and after one week in the group box they had access to 10 liters of milk replacer.

From DeLaval's ALPRO system relevant data for the calves' consumption of milk replacer was obtained. Nearly all calves in the study were affected by different levels of diarrhoea. They were recorded with faeces score between 1 and 3 in average 3 of 4 test days. Because of the frequent occurrence of diarrhoea among the calves it was not possible in a greater extent to use data concerning milk consumption patterns to predict illness and health. Despite the high prevalence of diarrhoea, the growth of the calves was not affected.

Sammanfattning

Friska kalvar är grunden för att bedriva lönsam mjölkproduktion. Under uppfödningstiden läggs grunden till hur kon kommer att kunna producera under sin livstid som mjölkande ko. Att vara frisk som kalv ger en bättre start i livet, med god tillväxt som följd. Inom dagens mjölkproduktion är det alltmer vanligt att föda upp kalvarna i grupp där de utfodras genom en kalvamma. Kalvamman möjliggör för kalvarna att i större utsträckning kunna inta mjölk eller mjölkersättning under flertalet gånger per dygn, samt att de kan utföra ett mer naturligt dibeteende i amman.

Uppfödning av kalvar i grupp ställer högre krav på djurskötarna att se de individer som visar tecken på sjukdom. I gruppboxar kan det vara svårare att se vilken individ som är sjuk jämfört med kalvar som hålls i ensamboxar. Syftet med denna studie var därför att detektera kalvar med diarré och jämföra dem med deras drickbeteende i kalvamman och deras hälsostatus. Att enklare kunna finna vilken eller vilka kalvar i gruppen som är på väg att insjukna i diarré möjliggör förbättringar inom kalvuppfödningen.

Under de första 28 dagarna i livet undersöktes träcken från 53 kalvar av raserna Svensk Holstein (SH) och Svensk Röd Boskap (SRB). Träcken graderades enligt en fyra-gradig skala (0-3) med avseende på träckens konsistens och utseende. Gradering 0 ansågs som normal träck (frisk) och 1-3 inkluderade diarré i olika grad (sjuk). Kalvarna vägdes under levnadsvecka 1,2,4 och 8. Vid cirka sju dagars ålder förflyttades kalvarna till en gruppbox med tillgång till en drickstation kopplad till en kalvamma. Vid inflyttning var kalvarnas grundgiva åtta liter mjölkersättning och efter en vecka i kalvamman hade kalvarna tillgång till totalt tio liter mjölkersättning per dag.

Från DeLaval's ALPRO-system kunde relevant data för kalvarnas konsumtion erhållas. Kalvarna var under större delen av studien påverkade av olika grad av diarré, där de 3 av 4 testdagar registrerades med träckpoäng mellan 1 och 3. På grund av den frekventa förekomsten av diarréer bland kalvarna var det inte möjligt i större utsträckning att titta på förutsägelser av sjukdom och jämföra drickbeteendet med hälsan. Trots förekomst av diarréer, påverkades inte tillväxten på kalvarna.

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1. Introduction

In cattle production the calves are the future in the herd. When rearing calves it is important with good health to ensure good growth. Good health in the herd decreases the infection pressure on the animals. Good animal welfare leads to more efficient rearing with healthier animals. It is important that the calves are functioning well both physically and behaviorally in the rearing system to avoid increased costs and work for the farmer (Svensson & Hultgren, 2008).

In Swedish dairy production the number of animals per herd is increasing and the buildings of today are often designed to keep calves in groups. The calves may therefore practice natural behaviour to a greater extent, than if reared in single pens. The increased opportunity to perform natural behaviours prevents the animals from performing stereotypical behaviours in a greater extent (Jensen, 2006). At the same time group rearing may lead to increased infection pressure and it is often harder to detect sick individuals in large groups. Rearing calves in groups lowers the time spent per individual calf and also making it harder to detect sick calves (Lundborg, 2004).

Diseases in calves are an animal welfare problem. The importance in calf health and calf management to ensure healthy calves and good growth is well known. Due to the fact that the calves are the future in the herd puts high demands on their health, so that they in the future stays healthy and with increased longevity and can produce milk or meat. Decreased profitability in dairy production puts high demands on reduced production costs (Svensson & Hultgren, 2008). In dairy production successful rearing is often associated with higher yielding replacement heifers. The risk for morbidity during the rearing time is often increased if the calves have been affected by disease already early in life (Svensson et al., 2006). It has been shown that the effects from early diseases are seen even later in life with effects on the age at calving and longevity (Warnick et al., 1994; van der Fels-Klerx et al., 2002). Svensson & Hultgren (2008) concluded that calfhood health status and rearing factors could affect the milk production in first lactation.

Bigger herds increase the possibility to have efficient rearing systems of the calves. Different technical monitoring systems are developed and used in dairy production and some of these technics can also be used in calf rearing. A common system of today in cattle production is housing calves in groups with automatic feeders and possibilities to record intakes of both milk and concentrate for each calf. Automatic milk feeders provide information to the farmer on the calves' consumption of feeds. Goals with automatic feeding systems are to reduce labour and improve calf health which leads to reduced costs and improved production (Svensson, 2010). To maximize the utilization of the automatic feeder it is important to know what is registered in the feeder and how to use the information. It is also important that the information is both of high quality and trustworthy (James, 2005).

Bad hygiene or unsatisfactory environmental conditions can increase the risk for diarrhoea among calves. Likewise incorrect feeding or unregularly feeding, can cause disturbance in the intestine and therefore cause diarrhoea (Pettersson et al., 2001). In the automatic milk feeder it is possible to connect data on eating behaviour in the calves to diarrhoea and respiratory diseases. According to Svensson & Jensen (2007) the number of unrewarded visits is the most sensitive indicator for clinical disease in calves fed restricted milk volumes. Svensson (2010) could predict diseases 1-2 days before the disease outbreak according to changes in eating behaviour of the calf registered in the automatic milk feeder. An increased knowledge how the information recorded by the automatic feeder can be utilized to monitor the calves may provide a possibility to improve the calf health (Pettersson et al., 2001).

In the literature and among users and manufactures there are different names on the machine feeding milk or milk replacer to calves. In this report it is defined as automatic milk feeder.

1.2 Aim

The aim with this master thesis is to detect cases of diarrhoea in calves and compare feeding behaviour in the automatic milk feeder with the health status of the calf. By this investigation it can be possible to develop a system that alerts the disease status in groups of calves by using feeding behaviour as an indicator. This may simplify detection of upcoming illness among calves and make it easier to prevent calves from sickness or to treat calves in an earlier stage of disease.

1.3 Limitations

This master thesis focuses on diarrhoea combined with drinking behaviour in calves. This is mainly due to the fact that diarrhoea often is the first disease that the calves are suffering from and are first affected of after the birth (Olsson et al., 1993, Lundborg, 2004). It is often easier to examine if the calf care suffering from diarrhoea compared to respiratory diseases (Svensson et al., 2003). The automatic milk feeder used in the master thesis was CF 1000+ CS/CA Kombi (DeLaval, Sweden).

2. Literature review

2.1 Feeding and behaviour

Feeding behaviour has an important role in life of cattle and most part of the day is spent foraging and ruminating when kept freely at pasture (Hafez & Schein, 1962). If the animal is prevented from performing foraging behaviour there is a risk developing abnormal and stereotypic behaviour (Jensen, 2006). In a natural state the calf suckles the cow four to six times per day (Walker, 1950), during eight to ten minutes per occasion (Walker, 1962). When the calf is aging, it is suckling fewer times per day, but for longer time per occasion. At an age of eight to eleven months the calf is weaned gradually from the cow (Walker, 1962). As earlier mentioned group housing of calves gives the animals extended opportunities to practice natural behaviours. By using an automatic milk feeder there are extended possibilities to feed the calves several times per day (Jensen & Holm, 2003).

In dairy production it is common to separate calf from cow in a few days after birth and thus the calf has no natural nurturing from the cow (Lidfors, 1994; Lupoli et al., 2000). The calf's natural suckling behaviour is often limited by the feeding system and that the time for milk intake is often short. A suppressed suckling behaviour and the fact that animals are often reared in groups, can lead to problems such as abnormal sucking or cross-sucking (Lidfors, 1993) and intersucking (Lidfors, 2011). Abnormal sucking is often directed against interior objects like feeding-trough and gates. Cross-sucking is often directed against ears, genitals, mouth, tail and udder (Lidfors, 1993) whereas intersucking is weaned heifers suckling on the teat of another heifer or cow (Lidfors, 2011).

Milk intake lasts for longer time in calves suckling the cow than in those fed milk from an automatic milk feeder (Roth et al., 2009). By letting calves suckle milk during a longer time per feeding occasion in automatic milk feeder abnormal behaviour decrease (Haley et al., 1998, Jung & Lidfors, 2001). In a study 92% of participating calves developed abnormal sucking behaviour when fed milk from an automatic milk feeder. Roth et al. (2009) argue that it is unlikely that the automatic feeding systems meet the calf's natural need to suckle. A longer suckling time during feeding can be achieved through reduced milk flow in the automatic milk feeder. However if the milk flow is too low the calves are suckling during shorter times due to weary suckling muscles (Haley et al., 1998). de Passillé (2001) suggests that the milk flow needs to be reduced so that suckling time is extended to about 10 minutes, and that an artificial teat and hay should be offered after feeding to reduce the number of calves cross-sucking or performing abnormal suckling. Energy composition of the feed and suckling time before weaning has impact if heifers or cows are intersucking and the suckling behaviour can be triggered by an inadequate diet with short eating times (Keil and Langhans, 2001).

2.2 Immune defence; colostrum, immunoglobulin

The first milk after calving is called colostrum and differs from normal milk in many aspects. Colostrum is of great importance for the new-born calf, as a source of nutrients and immunoglobulins (Ig). Colostrum of high quality contains high amounts of Ig and needs to be provided to the calf soon after the birth. From the serum of the cow, immunoglobulins are concentrated into the colostrum around five weeks pre partum. There are different classes of immunoglobulins; IgA, IgG_1, IgG_2 and IgM, where IgG is in majority. Uptake of immunoglobulins to the blood occurs in the intestine of the calf and Ig from colostrum acts as passive circulating antibodies in the calf's blood. It also provides a local passive immunity in the gut lumen and for example protects calves from enterotoxigenic *E. coli* (ETEC) (Scott et al., 2004). It is well documented that calves that has received colostrum soon after birth decrease disease susceptibility and neonatal mortality. One of the most critical factors for new-born calves is the intake and uptake of sufficient amounts of immunoglobulins from the colostrum (Shearer et al., 1992). However, environmental and management factors are also of importance when uptake of immunoglobulins is considered (Scott et al., 2004). Colostrum can lower the risk of diarrhoea by acting as a local immunity mechanism in the intestine (Berge et al., 2009). According to Berge et al. (2009) diarrhoea seem to be associated with low-weight calves and low serum IgG levels.

Optimal absorption of immunoglobulins occurs before 4 hours after birth and is rapidly decreasing after 12 hours (Weaver et al., 2000). To ensure a sufficient absorption of immunoglobulins (100 mg), Weaver et al. (2000) suggest a minimum quantity of 4 litres colostrum to a calf of Holstein breed.

The routine to feed colostrum may affect the incidence of diarrhoea. In a study by Vasseur et al. (2010) most herds gave the calves their first meal 2-6 hours after birth or when the calf was found. When the calf is found after birth is truly affecting the time after birth when the calf gets its first meal of colostrum. Svensson et al. (2003) showed that calves fed colostrum by suckling had higher incidences of diarrhoea. This may indicate that the calves did not obtain enough colostrum and therefore had lower immune status, which made them more susceptible to by pathogens.

There is a need for controlling the colostrum when feeding newborn calves due to the fact that there are big differences in the colostrum quality between cows. To test the quality of the colostrum a colostrometer can be used to estimate the immunoglobulin concentration (Fleenor & Stott, 1980; Shearer et al., 1992). In a Canadian study none of the farms controlled the quality of the colostrum and 15.6% of the farms relied on the cow to provide colostrum to the calf (Vasseur et al., 2010). According to Gulliksen et al. (2008) it might be more of relevance to know the quality compared to a certain amount of colostrum given to the calf. A method to evaluate the passive transfer of immunity is to measure the immunoglobulin concentrations in the calves blood (Vasseur et al., 2010). Gulliksen et al. (2008) found that cows of the breed Norwegian Red Cattle, in their second parity, had the lowest IgG content in colostrum compared to Holstein breed. The median IgG content of the tested colostrum in the study were 45.0 g of IgG/L. According to Weaver et al. (2000) calves with measured TPP in blood plasma $\geq$55 g/L are considered to have sufficient uptake of antibodies from colostrum. Cows in their fourth parity or more had the highest content of IgG in the colostrum. Older cows have been exposed to antigens for a longer period than younger and hence older cows produce colostrum with higher content of IgG than younger cows. There were significantly lower IgG in colostrum produced from cows calving during the winter months compared to the rest of the year. This may be due to changed diets during indoor rearing, which may influence the IgG production (Gulliksen et al., 2008).

2.3 Calf health

The most important health problems in young calves are infectious diseases, with diarrhoea and respiratory syndromes being the most common (Simensen, 1982; Lundborg, 2004).

Group housing of calves makes it more difficult to notice the individuals that may be sick (James, 2005). A sick calf is often dull and unresponsive to other calves or to the animal keeper. The calf may also separate itself from the rest of the calves in the group. Other signs of illness are lack of luster in the coat, running nose or eyes, coughing or having diarrhoea. Calves with abdominal pain are often unwilling to move and may be bloated in the abdominal area. If the calf has respiratory problems due to disease, the calf will show signs of difficulty in breathing. Normal body temperature in the rectum is 38.5-39 ºC. According to Webster (1984) any temperature over 39 ºC should be considered as an indication of disease. Rectal temperature below 38 ºC can be a sign of a calf suffering from shock or dehydration.

To get a good start in the life it is important that the calves are born in a clean environment, where a calving pen is preferred. It is essential that the calf receives colostrum soon after birth to ensure a good support of immune globulins and therefore is given the best start to develop a high immune defense against infectious agents. A calf with lowered immune defense will easily be affected by pathogens and are at a higher risk of getting infected (Simensen, 1982; Scott et al., 2004). A sick calf is growing slower and rearing is therefore often prolonged. This increases rearing costs and includes extra costs for increased veterinary treatment and medicine, extra labor and feed. It is often also a risk that a calf that has been sick in early stages of life will have a lowered production in the future and also there is a risk for lowered longevity (Scott et al., 2004).

Lundborg (2004) found that diarrhoea (enteritis) was most common in calves during the first weeks after birth and that respiratory diseases were increasing slowly and was the most common disease after 4 weeks of age. After 7 weeks of age respiratory diseases were still more common compared to diarrhoea. According to Hepola (2003) it is more common with respiratory diseases than diarrhoea in systems with automatic milk feeding compared with bucket feeding. Lance et al. (1992) found that the major reasons for death in replacement heifers were diarrhoea and dehydration.

Diarrhoea

Diarrhoea is the first clinical sign of enteritis (Webster, 1984). Diarrhoea is caused by several factors including environment, health status of the calf, nutrition and infectious agents (Olsson et al., 1993; Lundborg, 2004; Radostits et al., 2000). Diarrhoea is a sign of imbalance between absorption and secretion of water and electrolytes (Scott et al., 2004). The disease can be defined as “an increase in faecal water loss due to increased faecal water content or to increased volume of faeces excreted or to a combination of both”. The consistency is looser than normal faeces and there is often changed in color and smell. Dehydration and acidosis are often seen among calves affected by diarrhoea due to the water loss (Radostits et al., 2000).

Diarrhoea is one of the most common diseases in calves less than 1 month of age and it is causing lowered welfare in the affected calves (Olsson et al., 1993; Radostits et al., 2000; Lundborg, 2004; Foster & Smith, 2009). Calves affected by diarrhoea are at an increased risk of developing respiratory diseases later (Svensson et al., 2006). According to Lundborg (2004) 7.8 % of the calves in southwest of Sweden developed diarrhoea (enteritis) during the first 90 days of life. Olsson et al. (1993) found similar numbers, where 7.2 % of the calves in a study suffered from diarrhoea during the first 90 days after birth. In a study with calves fed by automatic feeders, 75 % of the calves were diagnosed with diarrhoea and 20.5 % of those had more than one period of diarrhoea (Svensson & Jensen, 2007).

In a report by Simensen (1982) it was concluded that gastro-intestinal disorders were the most important cause of death in calves. Olsson et al. (1993) reported that the incidence of diarrhoea in young calves might be underestimated due to lower attention to mild symptoms. Hepola (2003) stated that diarrhoea is more common among group housed veal calves in automatic milk feeding system compared to individually reared calves with bucket feeding twice a day. Olsson et al. (1993) discussed the variance between different herds, meaning that there is room for improvement in herds with higher incidence of diarrhoea.

Because the complexity of the disease it is difficult to prevent all calves from diarrhoea, but to minimize the number of calves suffering and reduce the economic losses it is important to minimize the disease outbreaks (Radostits, 1974).

Clinical signs and identification of diarrheic calves

Group housing of calves may lead to increased difficulties to detect and identify calves affected by diarrhoea. It is easier to detect if the calf is suffering from diarrhoea in a single pen compared to a group pen. Higher mortality rates in larger herds are explained by less time spent per individual animal and in the same study it was found that major reasons for calf mortality were gastrointestinal disorders (Torsein et al., 2011).

When examining health status of a calf, with respect to the incidence of diarrhoea, the area around anus and faeces from the calf are inspected. Altered color or consistency of faeces or indication of mucus or blood can be a symptom of a nutritional disorder (Webster, 1984). Gulliksen et al. (2009) reported that not all calves affected by diarrhoea have impaired general condition at the time of faeces sampling and several of the diarrheic calves are short-term cases (Svensson et al. 2003).

A reaction to pathogenic bacteria or viruses, in the intestine of the new born calf is hyper secretion in combination with a lowered absorption resulting in loss of fluids, nutrients and electrolytes. Calves affected by diarrhoea do not consume normal quantities of milk and furthermore have decreased digestibility of nutrients. The calf suffering from diarrhoea is most likely dehydrated and is in energy deficiency. Therefore it is important to give both oral rehydration solution and milk (Radostits, 1974). This is to maintain the energy-, fluid- and electrolyte balance in the body. No treatment of the calf can be life threatening (Radostits et al., 2000). A prolonged period of diarrhoea causes a continuous loss in body weight (BW) (Radostits, 1974). In a study from 2007 very few cases of diarrhoea led to reduced general condition why Svensson & Jensen (2007) propose that the definition of diarrhoea can overestimate the actual cases of diarrhoea.

Risk factors

To control the disease and give right advice it is important to identify the agents and risk factors involved (Scott et al., 2004). To ensure a good start in life for the calf, the colostrum is essential. If the calf has been given high quality colostrum after the birth the risk of getting diarrhoea is lowered due to the improved immune status of the calf (Lundborg, 2004).

According to Svensson et al. (2003) and Lundborg (2004) risk factors for diarrhoea in calves are ingestion of the first colostrum by suckling the mother, calf pens placed along an outer wall, being of Swedish Red and White (SRB) breed, being born during the summer season and receiving colostrum from a young cow. In the study by Gulliksen et al. (2009) the prevalence of enteropathogens in diarrheic samples were low, indicating that there are other factors affecting the prevalence of diarrhoea in calves. Cause of diarrhoea can be triggered by rapid change in diet or malnutrition, pathogenic bacteria, virus or protozoa (Gulliksen et al., 2009). Rearing of susceptible calves in a highly contaminated calf barn is also a risk factor for diarrhoea (Radostits, 1974). Heavier calves are less likely to suffer from diarrhoea compared to low-weight calves. This may be due to low-weight calves being fed more milk in relation to body weight, when all calves received the same volume of milk replacer (Berge et al., 2009).

If the milk or milk replacer has not reached the suitable temperature (38-40 ºC), for milk to coagulate in the abomasum, there is a risk that it is not coagulating well, which can cause diarrhoea in the calf. Other types of feeding or feeding methods that can cause diarrhoea are feeding cold milk, bucket feeding, skim milk and high-fat diets. By using acidified milk or fermented colostrum, these feeding methods can alleviate diarrhoea (Scott et al., 2004). Also the teat in automatic milk feeders may be a source of growth of bacteria's and can spread diseases if not cleaned (Hepola, 2003).

In faeces from diarrheic calves example of infectious agents that can be found are Cryptosporidium (Silverlås et al., 2009), *E. coli* and rotavirus (de la Fuente et al., 1999; Gulliksen et al., 2009). Moreover coronavirus, enterotoxigenic *E. coli* (ETEC) and verocytotoxin *E. coli* (VTEC) can cause diarrhoea (Scott et al., 2004; Foster & Smith, 2009). Rotavirus, coronavirus and cryptosporidium are infectious agents that are common and can be seen on farms worldwide (Scott et al., 2004). According to Björkman et al. (2003) rotavirus is the major pathogen causing diarrhoea among calves in the age up to 90 days whereas coronavirus and *E. coli* is of less importance. Bartels et al. (2010) showed that *Clostridium perfringes* was the most and *E. coli* the least detected enteropathogen in faeces from calves in the age of 1 to 21 days. In a Norwegian study the most detected enteropathogens were rotavirus and cryptosporidium (Gulliksen et al., 2009). According to Hall et al. (1988) the most common combination of agents causing diarrhoea is rotavirus and cryptosporidia. Reasons for the agents causing greater outbreaks of diarrhoea together than when the agents are infecting alone is that they are infecting different parts of the intestine. A combination of the infecting agents is therefore causing a cumulative damage in the intestine (Hall et al., 1988). According to Scott et al. (2004) the mean age of calves infected by rotavirus is ten days. Though it has been showed that these agents can cause diarrhoea in calves it is not necessary that their presence in the intestinal tract directly lead to a disease outbreak (Scott et al., 2004). Outbreak of diarrhoea is more common when there are several agents present at the same time (Hoet et al., 2003; Scott et al., 2004).

Treatment

As diarrhetic calves become dehydrated fast, fluid therapy with electrolyte solutions are of great importance. In a Swedish farm survey, Svensson et al. (2003) reported that treatment with electrolyte solutions are initiated in 19 % of the detected diarrheic cases. Today the recommendation is to continue to give the calves milk and separately provide the calf electrolyte solution (Baumgartner, 2012). Also Heath et al. (1989) concluded that it is beneficial to continuously feed diarrhetic calves milk. There is a risk that use of antibiotic-treatment against diarrhoea continuously damage the intestinal mucosa, and making the calves more susceptible to pathogens, which delays the repair and may contribute to further diarrhoea. Antibiotics may also contribute to the resistance problem (Scott et al., 2004), why antibiotics are not recommended treatment in first place.

2.4 Automatic milk feeders

The use of computerized management systems are increasing in cattle production, leading to a more efficient overview of management and feeding in the herd. Registration of information and the availability of data for analysis are therefore improved. Nevertheless, the information delivered must be consistent and trustful (James, 2005).

Figure 1. Calf feeder CF 1000+ CS/CA Kombi, DeLaval, Sweden (DeLaval, 2011).

During the 1980's decade computer controlled milk feeding systems were developed (Svensson & Liberg, 2006). Automatic milk feeders enhance the prerequisites to feed calves milk replacer with right temperature and it is possible to feed the calves several times per day (Jensen & Holm, 2003). The calf is identified in the feeder by a transponder attached to a neckband. It is possible to feed calves different amounts of milk replacer, fresh milk and acidified milk. When an automatic feeder is used the need for space for eating equipment is lowered compared to if the calves were fed milk simultaneously in buckets. According to Kung et al. (1997) the investment costs for the automatic feeding system could be regained within two to three years by savings in labour and time needed to manage the calves.

Recordings of feed intake can be used as a tool to detect sick animals (Hepola, 2003). Lance et al. (1992) established that higher mortality rates in larger herds are explained by less time spent eating per individual animal (Lance et al., 1992). Most automatic feeders base alarm lists on milk consumption and there are some machines offering lists based on drinking rate. However, Svensson & Jensen (2007) could not find any significant association between milk consumption or drinking rate and disease among calves.

The automatic milk feeder prepares the rations for each calf, which leads to a fresh meal and serves it in a good position for the calf to suckle. It is important to regularly calibrate the feeder to ensure that right amount of milk or milk replacer, with right concentration, and at desired temperature, is given to the calf (Lundin et al., 2000).

Feeding behaviour in automatic milk feeder

Feeding behaviour of calves can be recorded in the automatic milk feeders. Rearing calves in groups with automatic milk feeding system provides them a possibility to practice social behaviour and suckle milk in a more natural way. Therefore cross-sucking is reduced due to a more natural way to suckle milk (Svensson et al., 2003). Alarm lists update the information on milk consumption, although this may not be the most sensitive measure (Svensson & Jensen, 2007). According to Lundin et al. (2000) calves spent three minutes per visits in the automatic milk feeder, and their motivation to suckle were not satisfied. In the study by Kung et al. (1997) calves were visiting the automatic milk feeder 23 times per day, feeding 4.5 kg milk replacer at maximum.

Milk allowance

Generous milk allowance may cause large variations in milk intake, why in this case milk consumption may not be a good health indicator (Svensson & Jensen, 2007). In a feeder with low milk flow and low milk allowance the calves were more often trying to compete to obtain milk in the automatic milk feeder (Jensen & Holm, 2003). Jensen & Holm (2003) suggest that a high milk allowance will reduce the time that the feeder is occupied; due to the fact that the calf is satisfied for a longer time when it has been suckling a bigger meal.

Unrewarded visits

Unrewarded visits in the automatic milk feeder are defined as visits when no milk is received (Hepola, 2003). Both numbers of unrewarded visits in the automatic milk feeder and duration of unrewarded visits can be reduced by high milk allowances (Jensen, & Holm, 2003; Jensen, 2006). When calves in group pens fed milk in automatic milk feeders, are reared close to calves in single pens, the unrewarded visits are increasing in the automatic milk feeder at the time when the calves in the single pens are fed milk (Hepola, 2003). Svensson & Jensen (2007) found that unrewarded visits were associated with disease. According to Svensson & Jensen (2007), a reduction in appetite during days with disease may be reflected by a lower level of unrewarded visits in the automatic milk feeder. By blocking the feeder while waiting for access to milk the unrewarded visits in the feeder may disturb the feeding for other calves (Jensen & Holm, 2003).

Learning period

There may be difficulties for newly introduced calves to drink from automatic milk feeders. This may lead to a decrease in growth why assistance is often necessary to help the calves to drink from the automatic milk feeder during the first weeks (Hepola, 2003). However Lundin et al. (2000) found that 83 % of the responding farmers in the study did not have any problems learning the calves to drink from the automatic milk feeder. There were more difficulties to learn the calves to drink if there were many new calves in the pen at the same time, if the calves were young (4-7 days) or if there were large age differences between calves in the group.

Complications of using automatic milk feeders

Hepola (2003) consider it to be of high importance for animal keepers to look after the animals and the milk feeding equipment to ensure a good calf rearing though automatic milk feeding systems have been installed.

Health problems have been one of the most common reasons to stop rearing calves in automatic milk feeding system. Typical for herds that have stopped using automatic feeding to calves was that they moved the calves to group pens before 14 days of age, they had also large age differences in the groups, and they fed milk replacer instead of whole milk and had fever cleanings of the automatic milk feeder (Lundin et al., 2000).

Growth

Hepola (2003) summarized that milk-replacer intake and growth rate were lower in an automatic feeding system compared to individual housing. In the report by Lundin et al. (2000) calves reared in a suckler cow system had higher daily growth compared to calves reared in an automatic milk feeding system. Regular calibration of the machine is necessary to ensure correct concentration of milk powder (Lundin et al., 2000). Growth in automatic feeding system may be affected by lowered palatability compared to in a twice a day feeding system. There is a risk that milk is left in the tubes from the automatic milk feeder, which may decrease the desire to eat if the milk has been cold (Hepola, 2003). There is a risk for the calf to get cold rinsing water before the portion of milk replacer is prepared. According to Kung et al. (1997) there are no differences in growth rate between feeding in automatic milk feeder or other systems.

Health

Automatic milk feeding may be positive to calf health and reduce the number of pathogens due to a lower abomasomal pH as a result of frequent, small meals (Webster, 1984). No difference in occurrence of diseases could be found when comparing automatic feeding to suckler cow system. Nevertheless the levels of IgG were lower in calves reared with suckler cow, probably due to a lowered infection pressure (Lundin et al., 2000).

2.5 Management

Good management routines are important to ensure a good growth, low morbidity and effective production. Providing the calf a good start in life increases the chances of effective rearing with fast growth and high production later in life as a dairy cow. It is important to have good management routines, especially in larger herds where there often are different animal keepers working with the calves (Svensk Mjölk, 2011). Most calves are dying before the time of weaning. Management practices not requiring high investment costs and are easily implemented are for example colostrum feeding and separation of diseased calves from healthy ones. More costly practice is if there is need of rebuilding the housing. In some cases, separate pens needs to be added for calves in different ages. Most management routines, which are providing better calf health, like colostrum feeding, separation of diseased calves and separation of calves in different ages are well known. Reasons why the farmers not always practice them may be due to low economic knowledge about calf diseases and low profitability in dairy production (Furichon et al., 1997).

2.6 Housing

In nature the calf can move freely and perform its natural behaviours, in different types of environments. Housing calves affects their social and natural behaviour as well as health status, why it is important that the type of housing must promote the optimal living situation. When rearing calves in small groups, at a limited area, a stimulating environment is important to keep the calves from develop stereotypical behaviours. Also it is important that the environment is draught free, light and have well adapted ventilation (Keil et al., 2000).

The systems in modern cattle rearing are more efficient, and less time is spent per individual calf. This leads to greater difficulties when trying to identify sick calves among the healthy ones (Radostits et al., 2000). Calves reared in a separate barn are often healthier than calves reared in the same barn as older calves or cows (Hepola, 2003). By mixing calves in different ages there is a risk that the older calves are spreading diseases to the younger calves (Kung et al., 1997).

The two most common systems for calf rearing are in single- or group pens. After birth the calves are often kept in a single pen. After the colostrum period the calf can be moved to a group pen or it is possible to continue the rearing in a single pen. According to Swedish law the calves should be kept in group pens after 8 weeks of age (SJVFS 2010:15).

Today it is possible to raise calves in groups and feed them milk or milk replacer with computerized systems. This may reduce labour and it is important to consider the incidence of disease and health management. Kung et al. (1997) found that working time for a calf housed in single pens amounted to approximately 10 minutes per day compared to a calf reared in a group pen where the working time was less than 1 minute per day. Still it is necessary to have a good management and frequent observations of calves, and not use the computerized systems as a substitute for good care of the calves (Kung et al., 1997).

Single pen

The single pen reduces the infection pressure for the newborn calf and the risk of spreading diseases is often lowered. Another aspect of rear the calf in single pens is to ensure that it is drinking enough colostrum, by manually feeding. It is easier to take care of the individual calf during this sensitive period in a single pen (Kung et al., 1997; Radostits et al., 2000). Calves kept in single pens are laying more, due to the fact that they are not able to move entirely freely compared to calves reared in group pens (de Wilt, 1985). Kung et al. (1997) showed a tendency for calves raised in single pens to consume more starter compared to those calves in group pens.

Group pen

Group housing of calves from the second week after birth is preferred due to the importance of social behaviour for the calves. When calves are kept in groups they are calmer, quieter and can socialize with each other. Calves reared in groups groom each other and have possibility to move around freely in the pen (Pettersson et al., 2001) and according to de Wilt (1985) calves in group pens are more active than calves in single pens. Rearing in groups with automatic milk-feeding system enable the calves to practice social behaviour and suckle milk (Svensson et al., 2003).

3. Material and methods

3.1 Animals and experimental design

Data collection was conducted at Lövsta Research Center in Uppsala between August and October 2012. The experimental procedure, including the animal handling was approved by the Ethical committee on Animal Experiments, Uppsala. The calves included in the study were treated according to established management routines at the farm. The experiment comprised all calves born in the herd from 2012-07-27 to 2012-09-09. Of the 53 calves 26 of them (15 female and 11 male) were of Swedish Red breed (SRB). The remaining 27 calves (14 female and 13 male) were of the Swedish Holstein breed (SH).

The health status of each calf was assessed once daily, by Caroline Eriksson, Monday to Friday until the calf was 4 weeks old. From about one week of age calves were reared in group pens where their drinking behaviour was registered by ALPRO herd management system, ALPRO Windows 7.00.

The quality of first colostrum given to each calf was assessed from its specific gravity measured by a commercial colostrometer (ColostrometerTM, Biogenic, Mapleton, OR, USA). Jugular blood was sampled from each calf once between day 3-7 after birth to examine total protein content in plasma (TPP). From measured values of colostrum density IgG values in colostrum could be estimated. TPP was determined by a refractometer (Master Refractometer, Atago, Tokyo, Japan).

The calves were weighed at birth and at the age of one, two, four weeks and eight weeks. The daily weight gain was calculated for every calf, during week 1-4, 4-8, 1-8.

3.2 Feeding

The first three days after birth the calves were fed two meals daily with 3 litres of colostrum from the dam. For the following two meals they were fed 50 % milk replacer + 50 % whole milk, and thereafter only milk replacer (ElitekalvXtra, Kvarnbyfoder, Sweden) continuously during eight weeks until weaning. According to the manufacturers declaration the milk replacer was based on whey and skim milk powder and contained 18.4 MJ per kg. After the transition to milk replacer the calves received 3 litres of milk replacer morning and evening until the calf was moved to a group pen and was fed by an automatic milk feeder (CF 1000+ CS/CA Kombi, DeLaval, Sweden). During the first 3 days in the group pen the calf received 8 litres of milk replacer in the automatic milk feeder, and then the amount of milk replacer was increased by 0.5 litres per day up to 10 litres. After seven days the maximum amount of milk replacer received was 10 litres. The calves were fed concentrate (Idol P, Lantmännen, Sweden) from an automatic concentrate feeder (DeLaval concentrate station, DeLaval, Sweden) in the group pen. The available amount of concentrate was 0.25 kg/day at start in the concentrate feeder and the allowance was gradually increased to a maximum of 2.5 kg/day. Hay and water were fed ad libitum but the intakes were not recorded.

Automatic milk feeder

The two automatic milk feeders used in the trial was of the model CF 1000+ CS/CA Kombi. The automatic milk feeder mixed heated water (40 C^{o}) and milk replacer. The total daily allowance of milk replacer was evenly distributed over 24 hours. The total amount of milk replacer available per visit depended on how much the calf was qualified for in relation to the time elapsed since last visit. The portion size in the mixer was 0.5 litres. To prevent calves from suckling to small amounts of milk replacer a minimum for access to the feed was set, in this trial, to the minimum saving of 1.0 liter (2 portions). If qualified the calf could receive maximum 2.5 litres (5 portions) per visit, which also prevented the calves from consuming to high amounts of milk replacer at each feeding occasion. When the maximum amount was ingested the access to a new meal was blocked for two hours, though saved amounts of milk replacer does not disappear. Calibration of the automatic milk feeder is necessary to mix the feed ingredients in right proportion and it was done twice a week during the trial. The intended proportion of milk replacer (powder) was 0.14 kg per litre water. The automatic milk feeder was cleaned twice a day by a rinsing program and the opening for milk powder dosage was cleaned daily according to recommended routines (DeLaval, 2011). Temperature settings in the automatic milk feeder were set temperature 42 ºC and minimum temperature 39 ºC. Residues of milk replacer in the mixer beaker were set to be emptied after 15 minutes to ensure hygienic milk replacer and the residues are emptied through a tube under the automatic milk feeder.

According to DeLaval's user information about the automatic milk feeders, each feeder in the basic version is equipped with one drinking nipple. This allows 35 rearing calves or 20 veal calves to be fed (DeLaval, 2011). The automatic milk feeders used in this trial had three drinking points per feeder but it is possible to have up to four drinking points per the automatic milk feeder. Calves can therefore be kept in smaller groups. The automatic milk feeders are allocating the milk replacer due to priority operation, and only one calf at a time can receive milk replacer. When the calf is suckling on the nipple the prepared feed is transported through the tubes to the nipple and is consumed by the calf. All tubes except one (pen 93) were insulated and heated to prevent temperature to drop during the transport from the automatic milk feeder to the nipple.

When preparing the portion to the calf, water was first portioned and then milk powder was mixed into the liquid. When the mixing beaker was empty, the automatic milk feeder is mixing a new portion to the identified calf, if it has access to it. If a calf stops drinking the portion in the beaker, the residues were released five minutes after it was prepared and any calf with access to a portion can drink it.

Data is summarized, updated and recalculated at Dayshift, a point on a 24-hour cycle. Dayshift in this trial occurred at eight minutes past midnight (00.08). The part of the daily ration not consumed by the calf could be transferred to and be available the following day. At dayshift the possible carry over was determined and 30 % of the not consumed ration was transferred to the next day for the calves. The transferred amount could never be greater than the minimum savings (1 liter). Indirectly the minimum saving decides the number of meals per day.

Obtained information from the automatic milk feeder

Data obtained from the automatic milk feeder per calf was time at start and end of each visit and the prepared and consumed amounts of milk replacer at each visit. Furthermore number of unrewarded visits and the maximum daily allowance of milk replacer per calf were registered. From the registered data the daily number of visits with or without intake of milk replacer, the duration of visits and the prepared and consumed amounts of milk replacer was calculated. The daily intake of milk replacer was also calculated in proportion (%) of the daily allowance.

3.3 Housing

From the first day after birth the newborn calves were reared in single pens (1.0×1.2 m^2). In the single pens the calves had straw bedding and were fed milk via teat buckets. At a mean age of 8 days they were moved to group pens with automatic milk feeding. One group pen was filled at a time, maximum 10 calves per pen. Two separate rooms were used in this trial with three groups and one automatic milk feeder in each room (figure 2). The single pens and group pens were in the same room. In each group pen there were one drinking station connected to the automatic milk feeder in the room. All pens were equipped with one concentrate feeder. The group pens measured 5.8*3.0 meters in total, where the straw bedding measured 3.9*3.0 meters. The remaining area in the pen was slatted floor.

1. Single pens
2. Concentrate feeder
3. Drinking station
4. Area with slatted floor
5. Area with straw bedding
6. Automatic milk feeder
7. Washing area (sink unit)

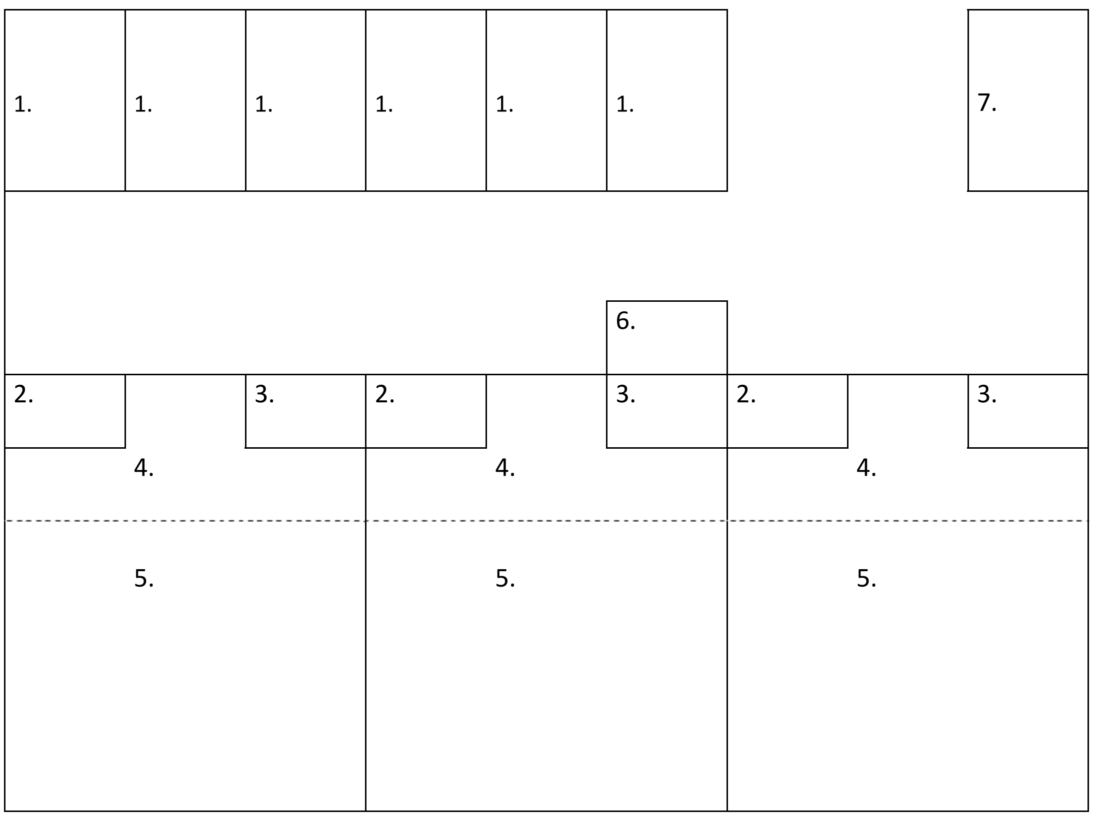

Figure 2. Schematic layout of a room for calf rearing in the experimental barn, in an approximate scale.

3.5 Examination of health and definition of diarrhoea

The health status of the calves was based on a categorization of the appearance of faeces according to a four-graded scale (Silverlås et al., 2010), as shown in Table 1. The appearance of faeces was examined and the rectal body temperature measured daily Monday to Friday on each calf, starting the second day after birth until the age of four weeks. A movable crate was used in the group pen for fixation of each calf during the examination.

Table 1. Definition of faecal scores in examined calves

Score	Definition
0	Normal faeces. Firm consistency. Brown colour. Clean and dry tail and perineum
1	Faeces with a paste-like consistency without shape. Yellow colour
2	Watery consistency
3	Watery consistency with blood

Perineum and/or tail was smeared with faeces at score 1 and 2 and 3. Runny to watery stools with blood were considered diarrheic. Grading 1-3 was per definition diarrhoea and grade 2 and 3 were considered as severe diarrhoea.

4 Results

In following chapter results from the study are presented.

4.1 Colostrum and immunoglobulin status

In figure 3 and 4 the colostrum density and the total protein content in blood plasma (TPP) for heifer and bull calves are shown. The mean value for colostrum density was 1044 g/L, measured by a colostrometer in the first colostrum fed to each newborn calf. The mean value for the measurements of TPP with refractometer was 57 g/L. There were missing values for colostrum density for calves 154, 156, 160, 180, 7154, 7156, 7161, 7167. The calves 154 and 156 also had missing values for measurements of TPP in blood plasma.

Calf number 166 had the highest value (1065 g/L) for colostrum density and calf number 7151 the lowest (1030 g/L). Calf number 170 has the highest value (78 g/L) for TPP in plasma and calf 165 the lowest (45 g/L). In Table 2 breeds and genders are compared according to colostrum density and TPP in plasma. In addition values for the content of IgG (γ-globuline) in colostrum calculated from density according to Fleenor & Stott (1980) are presented. SRB heifers have the highest mean density of colostrum and SH bull the lowest. SH heifers have the highest measured TPP values and bulls of both SRB and SH breed the lowest. The calculated mean value for IgG in colostrum for all calves was 46 g/L.

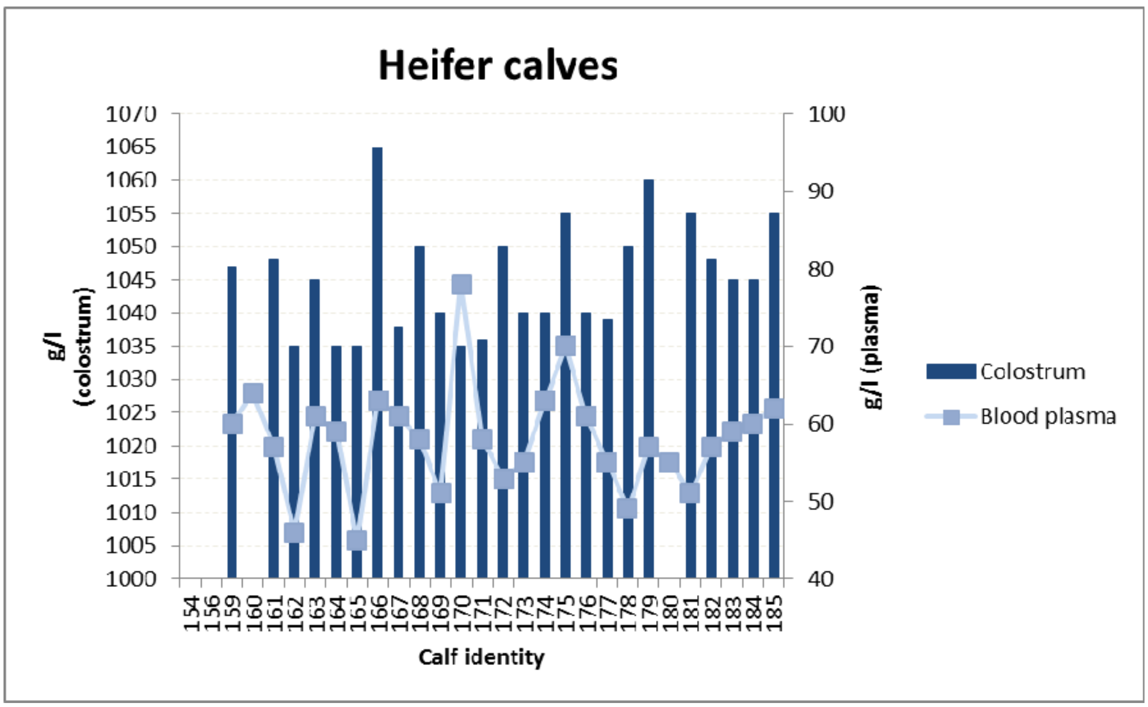

Figure 3. Colostrum density (g/L) and total protein in plasma from jugular blood TPP (g/L) sampled between 3 and 7 days of age in individual heifer calves.

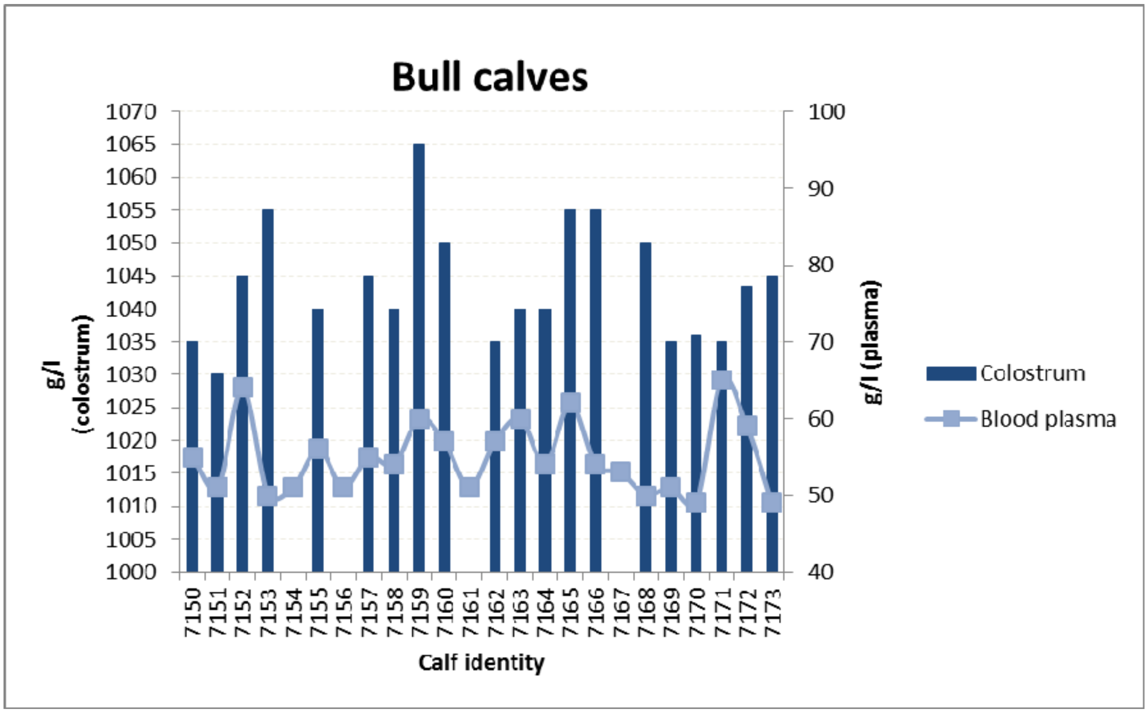

Figure 4. Colostrum density (g/L) and total protein in plasma from jugular blood TPP (g/L) sampled between 3 and 7 days of age in individual heifer calves.

Table 2. Maximum, minimum and mean values for colostrum density (g/L) and total protein in plasma (TPP,g/L) in calves of different breed and sex

	Mean	Maximum	Minimum
Colostrum density:			
SRB heifer	1047	1065	1035
SRB bull	1046	1065	1030
SH heifer	1044	1055	1035
SH bull	1042	1055	1035
Plasma (TPP):			
SRB heifer	58	70	46
SRB bull	55	64	50
SH heifer	59	78	45
SH bull	55	65	49

4.2 Consumption patterns in the automatic milk feeder

In Table 3, information from the automatic milk feeder is presented. Mean values are based on the total number of observations (n=1049) for all calves and all days registered in the automatic milk feeder.

The amount of prepared milk replacer, liters per day, was slightly higher than the consumed amount (Table 3). In average calves ingested 7.6 litres per day during the time in group pen with automatic milk feeder, which was considerably less than the mean amount available, 9.55 litres per day corresponding to only 79.3 % of the available amount. The variation in intake between calves and days was big and during 56.5 % of the days the calves ingested between 60 and 100 % of available milk replacer. During 22.7 % of the observation days, calves ingested less than 60 % of the available milk replacer and in 20.8 % of the observation days calves consumed more than the 100 % available milk replacer. The maximum amount of milk replacer consumed during one day by a single calf was 12.0 litres, though the maximum amount per calf was set to 10 liters per day. The calves that ingested the highest amounts of milk replacer obtained 125 % of the available amount of milk replacer. Possible carry over from the not consumed ration transferred to the next day was determined to 30 % of the not consumed ration. Minimum consumption of milk replacer was 2.9 % of the available amount. The lowest amount ingested milk replacer is 0.25 litres, which implies half a portion of milk replacer, occurred during 0.3 % of the observation days.

The average total time for a visit in automatic milk feeder per day was 23.62 minutes, the maximum time was 117.6 and the minimum was 2.0 minutes (Table 3). The mean time for visit per meal was 3.99 minutes. In total 27.9 % of the visits lasted for shorter periods than 3 minutes and 25.4 % of the visits in the automatic milk feeder continued for more than 5 minutes. The number of visits when milk replacer was consumed was in average 6.17 per day. The maximum number of visits per day was 21 and the minimum was 1 visit. The average number of unrewarded visits, that is visits when no milk consumption was recorded, was 0.45 per day. In 79.8 % of the observations the calves did not have any unrewarded visit in the automatic milk feeder. Expressed as percent of total visits per day the average percent of unrewarded visits was 4.4 % with a maximum of 65.2 % and a minimum of 0 %. The average total number of visits per day was 6.62 with maximum and minimum number of 23 and 1. In 59.6 % of the days the calves visits the automatic milk feeder 6 times or more.

Table 3. Consumption of milk replacer and drinking behaviour in the automatic milk feeder, mean ± standard deviation (where appropriate) values based on daily recordings per calf until 28 days of age during the period in automatic milk feeder (n=1049)

	Mean	Maximum	Minimum
Consumed milk replacer, litres per day	7.62±2.69	12.0	0.25
Prepared milk replacer, litres per day	7.77±2.62	12.0	0.5
Available milk replacer, litres per day	9.55±0.76	10.0	8.0
Total time for visits with consumption of milk replacer minutes per day	23.62±12.85	117.6	2.0
Mean time for visit per meal, minutes	3.99±1.56	14.8	1.2
Consumed milk replacer/available milk replacer, %	79.8	125	2.9
Number of visits with consumption of milk replacer per day	6.17	21.0	1.0
Number of unrewarded visits per day	0.45	15.0	1.0
Total number of visits per day	6.62	23.0	1.0
Unrewarded visits per day, % of total visits	4.4	65.2	0
Visits with consumption of milk replacer, % of total number	95.6	100	34.8

Despite a careful calibration of the automatic milk feeder twice a week and daily cleaning of the milk powder outlet, it was found that the automatic milk feeder delivered only 80-90 % of the expected amount of milk replacer at the following calibration due to milk powder adhering to the outlet. Based on this information it was estimated that the mean amount of milk powder delivered only became about 90 % of the expected amount. This means that the prepared liquid contained 126 g milk replacer per litre instead of 140 g corresponding to about 2.3 MJ ME per litre liquid.

In order to look for deviations from the normal consumption patterns the day before diarrhoea was observed in a calf, the scenario over three successive days "diarrhoea (today) - healthy (yesterday) - healthy (the day before yesterday)" was investigated. All such sequences were selected from the data base. Due to the high observed frequency of diarrhoea among the calves only 20 observations containing the sequence diarrhoea-healthy-healthy were found. A further important explanation to the low number of sequences found was that faeces consistency was only checked on weekdays which strongly reduced the number of possible three day sequences. It was found that if a calf has diarrhoea today, but was healthy yesterday and the day before yesterday, the consumption and number of visits decreased the day before it became diarrheic (Table 4). The mean values represent the difference between two days before disease and one day before disease. A negative number represents a reduction in visits or consumption compared to the day before. The day before the calves became diseased the number of daily visits in the automatic milk feeder decreased with 0.4 per calf. Time for visit in the automatic milk feeder in mean decreased with 3.86 minutes per day. The mean time for visit per meal decreased with 0.12 minutes the day before disease. There were no changes in eating behaviour among other variables recorded.

Table 4. Changes in number of visits per day or length of visit from two days before to one day before disease based on selected sequences diarrhoea-healthy-healthy (n=20)

	Mean
Number of visits in the automatic milk feeder	-0.4
Time for visit in automatic milk feeder per day, minutes	-3.86
Time for visit per meal, minutes	-0.12

4.3 Diarrhoea

There was a very high incidence of diarrhoea among the calves in the study, and all calves were noted for diarrhoea at least once until 28 days of age. In figure 5, an overview of all registered calves and days are presented. It shows that not many calves received faeces score 0 and that faeces score 1-3 are over-represented. Figure 6 shows the day in life when the first outbreak of diarrhoea was observed after birth. In average the first day with observed diarrhoea is already at day 3-4 after birth.

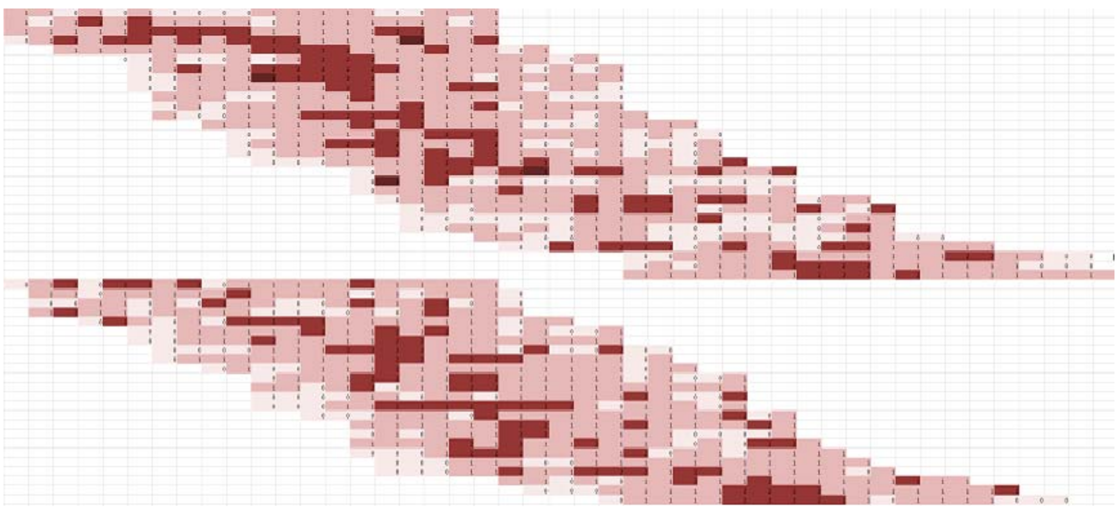

Figure 5. Overview of all faeces score registrations, for all calves. Heifer calves in the upper part and bull calves in the lower. The heifers start with calf nr 154, 156 and after calf 159 there are all id numbers up to 185. The bull calves has id number between 7150 up to 7173. Light pink areas shows faeces score 0, pink areas is score 2 and dark red areas shows faeces score 3.

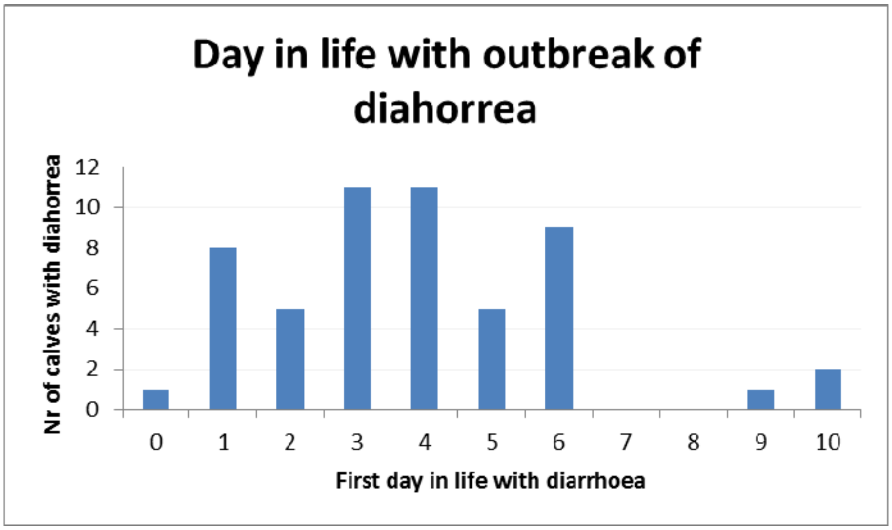

Figure 6. Age of calves when first day with diarrhoea (score 1-3) was observed.

Only four calves (179, 183, 7157, 7164) were not recorded for diarrhoea before entering the group pen and the automatic milk feeder. All of the other calves were suffering from diarrhoea at least once before they were introduced to the group pen and fed by the automatic milk feeder (figure 7).

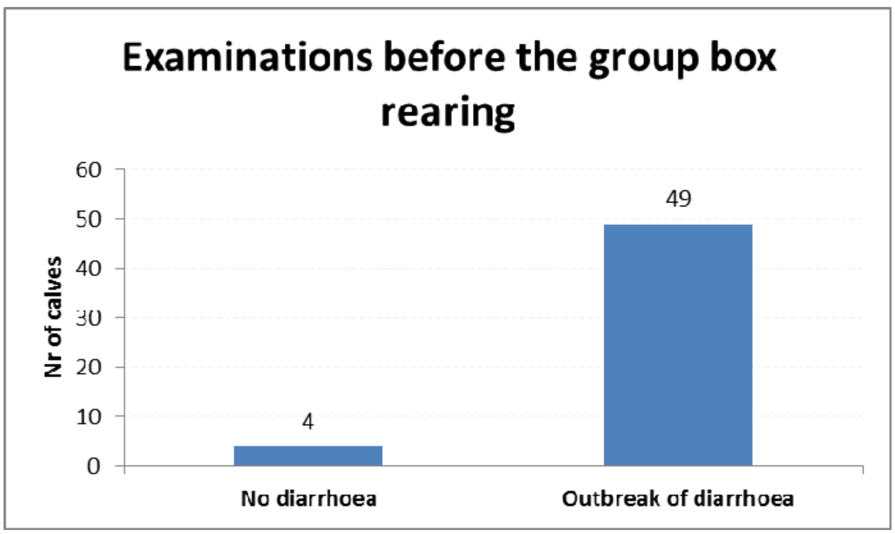

Figure 7. Number of calves with or without any incidence of diarrhoea before introduction to group pen and feeding by the automatic milk feeder.

In figure 8 it is shown that most calves has two to three days with registered diarrhoea before they are entering the group pen and are fed by the automatic milk feeder. In average the calves was reared in the single pens for 8 days. The calf with shortest rearing time in the single pen was calf number 7161, 3 days. The calf reared in single pen the longest period, 21 days, were calf number 156, due to severe diarrhoea that required prolonged treatment. The calves were moved to the group pen when the animal keepers thought that the calves were able to drink milk replacer and were healthy.

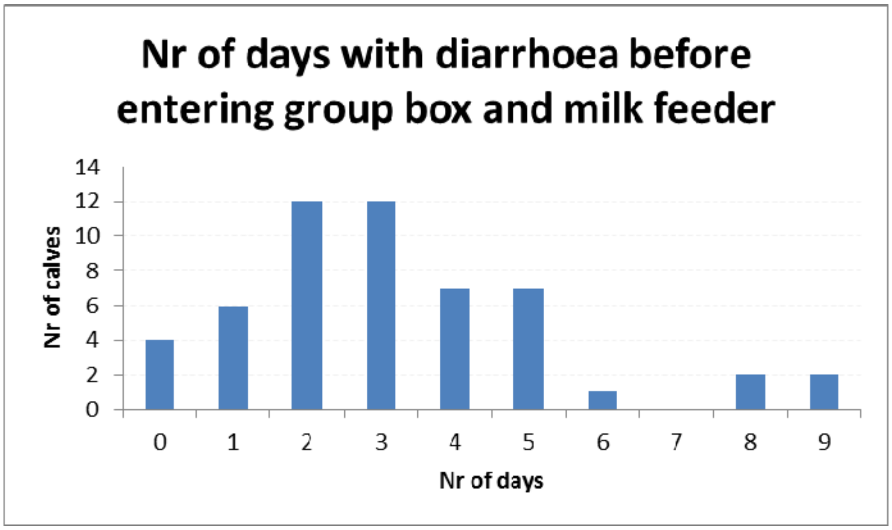

Figure 8. Number of days with diarrhoea (score 1-3) before the calves were introduced to the group pen and fed by the automatic milk feeder.

The total number of days from birth to 28 days of age when examined calves had a faecal score of 1 or higher is presented for different categories of calves in Table 5. There are high incidences of diarrhoea in general but small differences between categories including pens, automatic milk feeders, gender and breed. All differences are insignificant when tested by χ^2. Taking into account that calves were not examined for diarrhoea score on Saturdays and Sundays the number of days with observations was about 20 until the calves reached 28 days of age which means that diarrhoea in average was observed in approximately 3 days of 4. The severity of the observed diarrhoea can be judged by dividing the mean sum of faeces scores with the mean number of days with diarrhoea. The mean sum of faeces scores is about 1.25, with small differences between categories, indicating that in most cases the observed diarrhoea was judged as score 1.

Table 5. Mean number of days with registered diarrhoea and mean sum of faeces scores per calf during the trial, according to pen, automatic milk feeder, gender and breed

	Days with diarrhoea	Sum of faeces scores
Effect of pen:		
Pen 91	14.0	18.3
Pen 92	15.9	20.6
Pen 93	13.9	17.0
Pen 94	15.8	20.6
Pen 95	16.2	20.1
Pen 96	17.4	18.7
Effect of automatic milk feeder:		
Automatic milk feeder 1	14.5	18.5
Automatic milk feeder 2	16.6	19.7
Effect of gender:		
Heifer	15.0	19.0
Bull	15.6	19.2
Effect of breed:		
SRB	14.2	17.4
SH	16.2	20.2

In figure 9 and 10 the sum of faeces scores from day 1 after birth to 28 days of age are presented for heifer and bull calves. Each calf was examined 20 days and the highest possible score will thus be 60 (number of examination days × faeces score 3). Lowest possible score was 0, when no diarrhoea was observed during none of the test days. In total, calves with highest faeces score was 159, 160, 174, and the calves with lowest score was 175, 181, 179 and 180, all of them heifers.

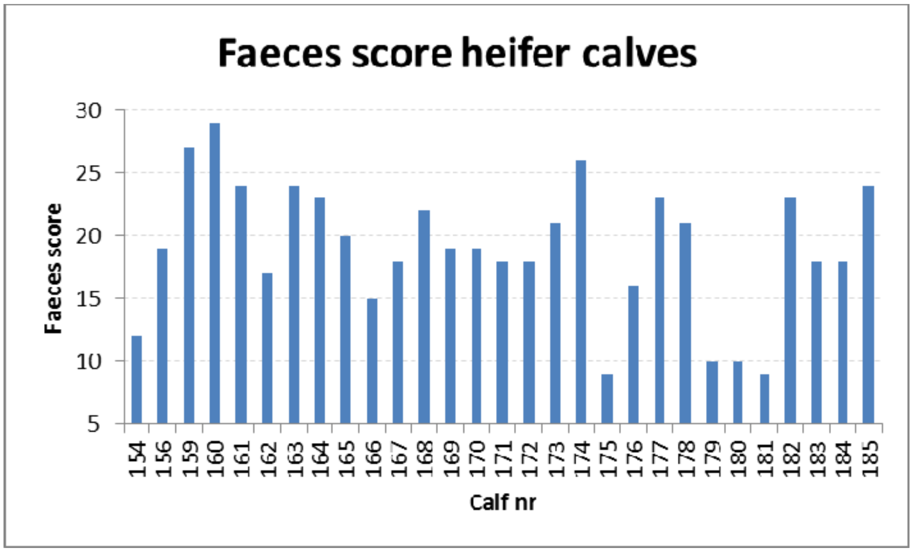

Figure 9. Sum of faeces scores for each heifer calf.

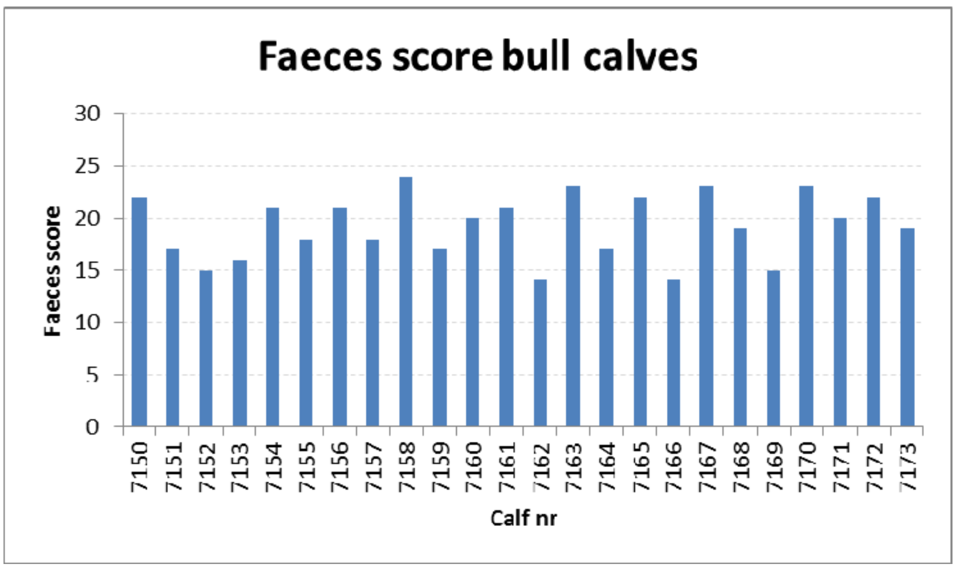

Figure 10. Sum of faeces scores for each bull calf.

Effect of TPP of frequency of diarrhoea

In figure 11 the regression of sum of faeces scores on TPP in blood plasma is presented. There was no effect of TPP in blood plasma on scoring of calves and the regression only explained 0.26 % of the variation.

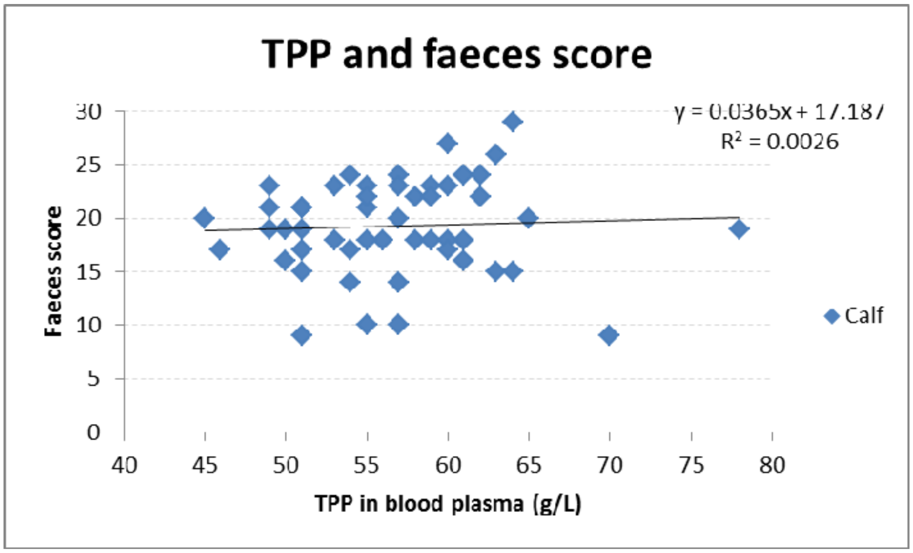

Figure 11. The regression of the sum of faeces scores from birth to four weeks of age on total protein in blood plasma (TPP).

4.5 Growth

The calves were weighed at birth and at the age of one, two, four and eight weeks of age. In Table 6 the mean weights at birth for the calves in different categories are shown. There were no significant differences within any of the categories. Heifers and bulls are similar in weights and like calves of the two breeds.

Mean growth rate in kg per day is shown in Table 6. Pen 91 and 95 has the highest growth rates during all periods while growth rates in general are lowest in pen 95. There were, however no significant differences between pens. The growth rate is similar between automatic milk feeder 1 and 2 and between the breeds. The bull has a significantly higher growth rate in all periods compared to the heifer calves.

Table 6. Weight at birth (kg) and growth rate (kg/day) according to pen, automatic milk feeder, gender and breed during week 0-4, 4-8 and 0-8. Least squares means ± standard error

	Birth weight	Week 0-4	Week 4-8	Week 0-8
Effect of pen:	p=0.41	p=0.075	p=0.69	p=0.10
Pen 91	38.8 ± 2.0	0.82 ± 0.06	0.72 ± 0.04	0.77 ± 0.04
Pen 92	43.1 ± 2.3	0.73 ± 0.07	0.69 ± 0.05	0.71 ± 0.05
Pen 93	39.0 ± 2.1	0.57 ± 0.06	0.66 ± 0.05	0.62 ± 0.04
Pen 94	38.7 ± 2.1	0.75 ± 0.06	0.71 ± 0.05	0.73 ± 0.04
Pen 95	41.3 ± 2.2	0.80 ± 0.07	0.73 ± 0.05	0.76 ± 0.05
Pen 96	36.9 ± 2.0	0.68 ± 0.06	0.64 ± 0.04	0.66 ± 0.04
Effect of automatic milk feeder:	p=0.47	p=0.59	p=0.94	p=0.68
Automatic milk feeder 1	40.0 ± 1.2	0.71 ± 0.04	0.69 ± 0.03	0.70 ± 0.03
Automatic milk feeder 2	38.8 ± 1.2	0.74 ± 0.04	0.69 ± 0.03	0.72 ± 0.03
Effect of gender:	p=0.28	p=0.0081	p=0.040	p=0.0026
Heifer	38.5 ± 1.1	0.66 ± 0.03	0.66 ± 0.02	0.66 ± 0.02
Bull	40.4 ± 1.3	0.80 ± 0.04	0.73 ± 0.03	0.77 ± 0.03
Effect of breed:	p=0.69	p=0.77	p=0.21	p=0.38
SRB	39.0 ± 1.2	0.72 ± 0.04	0.67 ± 0.03	0.69 ± 0.03
SH	39.7 ± 1.2	0.73 ± 0.04	0.72 ± 0.03	0.72 ± 0.03

As shown in figure 12 the sum of faecal scores did not affect the growth rate of the calves. The regression of growth rate on total faeces scores was not significant and it explained only 0.2 % of the variation.

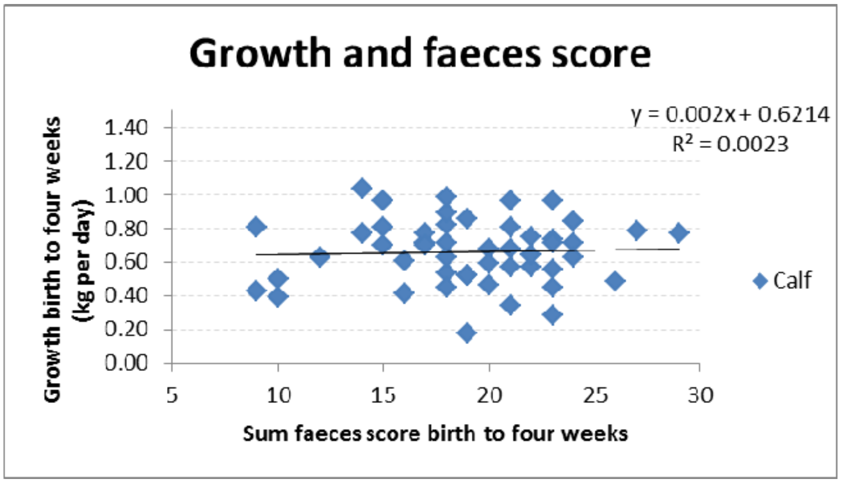

Figure 12. The regression of growth rate on sum of faeces scores from birth to four weeks of age.

5 Discussion

The aim of this master thesis was to investigate possibilities to predict and simplify detection of upcoming diseases by comparing drinking behaviour in automatic milk feeder with health status among dairy calves. Due to the fact that young calves often are affected by diarrhoea early in life, the study was limited to examine the incidence of diarrhoea in calves 0 to 28 days.

The importance of colostrum as a source of nutrients and immunoglobulins to the new-born calf is well known. It is well documented that the disease susceptibility and neonatal mortality decrease in calves that has received colostrum soon after birth. One of the most critical factors for new-born calves is the intake and uptake of sufficient immunoglobulins from the colostrum (Shearer et al., 1992, Weaver et al., 2000; Vasseur et al., 2010). Regarding feeding colostrum to newborn calves' routines and management factors at farm level can affect the calf's intake and therefore affect the uptake of antibodies (Scott et al., 2004). The local appearance of colostrum in the intestine can lower the risk of diarrhoea (Berge et al., 2009). Berge et al. (2009) means that diarrhoea is associated with low serum IgG levels. Gulliksen et al. (2008) found that the mean IgG content of the tested colostrum were 45.0 g of IgG per liter in first milked out colostrum from the cow. As a result of low density in colostrum and from TPP in plasma the calves with lowest values should have been the calves with highest incidence of diarrhoea, which could not be shown in this study (see figure 11). There were big variation between calves in colostrum density levels, TPP in plasma and the incidence of diarrhoea in this study. Despite the frequent observations of diarrhoea among calves there was low correlation between TPP in blood plasma and the sum of faeces scores. It cannot be concluded that failure in colostrum quality and the calves' uptake of antibodies was directly related to the increased risk of diarrhoea.

Among calves less than one month of age, diarrhoea is one of the most common diseases and it is causing lowered welfare in affected calves (Olsson et al., 1993; Radostits et al., 2000; Lundborg, 2004; Foster & Smith, 2009). In the present study all participating calves were suffering from diarrhoea during different number of days. Calves in pen 96 had most days with diarrhoea and calves in pen 93 fewest days. According to Lundborg (2004) 7.8 % of the calves in southwest of Sweden developed diarrhoea (enteritis) during the first 90 days of life. Olsson et al. (1993) found similar numbers, where 7.2 % of the calves in the study suffered from diarrhoea during the first 90 days after birth. In a study with calves fed by automatic feeders, 75 % of the calves were diagnosed with diarrhoea and 20.5 % of those had more than one period of diarrhoea (Svensson & Jensen, 2007). The diverse numbers of calves affected by diarrhoea in different studies may be a result of the definition of diarrhoea and the number of observed days. In this study the calves were examined for faeces consistency five days per week and the calf health in general was frequently recorded. Svensson et al. (2003) meant that several of the diarrhoea cases are short-term cases, why frequent registering of faeces is important when to investigate the frequency of diarrhoea among calves. Although Olsson et al. (1993) reported the incidence of diarrhoea in young calves could be underestimated due to low attention to mild symptoms. Though, Svensson & Jensen (2007) suggested that because few cases of diarrhoea leads to reduced general condition, the definition of diarrhoea could overestimate the actual cases of diarrhoea. Gulliksen et al. (2009) reported that not all calves affected by diarrhoea have impaired general condition. Calves examined in this study had in mean 3 of 4 examination days with diarrhoea, and in most cases the calves had score 1. Due to the fact that they were examined only during 20 days of 28, they were affected by diarrhoea during a majority of the time. The lack of differences between pens indicates that there were no changes in frequency of diarrhoea over time, since calves were allocated to one pen upon a time.

Several calves was observed with faecal score 2 already when moved into the group pen which indicates that the diarrhoea were not a result of feeding in the automatic milk feeder. The high frequency of diarrhoea among calves before entering the group pen could depend on hygienic deficiencies in the environment at birth, insufficient quality of colostrum or a delayed feeding of first colostrum, keeping new born calves in contact with older or sick calves, how the feeding of milk and milk replacer was performed, high disease pressure in the barn, etc. In this study the trend was that all calves, except four of them, were affected by diarrhoea before entering the group pen with automatic feeding.

Since diarrhoea is a complex disease it may be difficult to reduce the frequency entirely, but to lower the incidence can reduce economic losses and number of calves suffering from disease. According to Lance et al. (1992), diarrhoea and dehydration are the major reasons for death in replacement heifers. Calves that recover from diarrhoea are at an increased risk to develop respiratory diseases later in life (Svensson et al., 2006). It is necessary, both economically and according to animal welfare, to reduce the incidence of diarrhoea among calves. Olsson et al. (1993) meant that because there are differences in incidence of diarrhoea between herds there is a need and a potential for improvement in herds with diarrhoea problems.

Sick calves are growing slower and the rearing time is often prolonged which leads to increased rearing costs by extra labor and feed and often lowered production in the future (Scott et al., 2004). According to Radostits (1974) a prolonged period of diarrhoea leads to loss in body weight which was obviously not the case in this study. During this trial all calves continued to increase in weight and the mean growth rates per calf in different pens were between 0.68 and 0.82 kg per day (Table 6). There was a small variation in growth rate between pens, breeds, and automatic milk feeders. The correlation between sum of faeces scores and growth rate of individual calves (0-4 weeks) was very low ($r=0.048$). Consequently there was no indication in the present study that a high incidence of diarrhoea during the first weeks in life leads to lowered growth rate. For some reasons the calves in average only ingested 79.8 % of the available amount of milk replacer. The variation in ingested amounts varied a lot between calves and low intake of milk replacer may be one reason for lower growth among some of the calves. Reduced body weight gain may be due to the fact that calves with diarrhoea do not consume normal amounts of milk and have a decreased digestibility of nutrients (Radostits, 1974).

Automatic milk feeding of calves enables them to have several eating times per day (Jensen & Holm, 2003), which is more similar to a natural state where the calf is suckling the dam for several times per day (Walker, 1950). The mean time per drinking visit in the feeder was 3.99 minutes. This is less compared to the desired 10 min suggested by de Passillé (2001). In average the calves spent 23.62 minutes in the automatic milk feeder per day, which can be seen in Table 3.

After one week in the group pen the calves had access to 10 litres of milk replacer per day. Svensson & Jensen (2007) stated that generous daily milk allowance might cause large variations in milk intake, why in those cases milk consumption may not be a good health indicator. Jensen & Holm (2003) saw that if the calves were drinking from a feeder with low milk flow and low milk allowance per meal the calves were more often trying to compete to obtain milk in the automatic milk feeder. They meant that a high milk allowance per meal is preferred because the time that the feeder is occupied will be reduced and the calves will be satisfied for longer periods. In this trial the mean consumption of milk replacer in the automatic milk feeder was 7.62 litres per day, which corresponds to a mean percentage of 79.8 % of available milk replacer consumed per calf and day (Table 3). It can be discussed why the mean consumption of milk replacer in the automatic milk feeder was only 79.8 % of the available amount per day. Potential explanations could be that they were satisfied or that the calves did not wanted more milk replacer because of abdominal pain due to the diarrhoea.

According to Hepola (2003) recordings of feed intake can be used as a tool to detect sick animals. Alarm lists update information on milk consumption in automatic milk feeders, although according to Svensson (2007) this may not be the most sensitive measure and Svensson & Jensen (2007) could not find any significant association between milk consumption or drinking rate and disease among calves. When consumption patterns were studied in the present study according to the scenario over three days of "diarrhoea – healthy – healthy" few observations with this sequence could be selected, mainly due to frequent observations of calves with diarrhoea. This approach illustrates well the complexity of finding changes in patterns of drinking behaviour before calves develop diarrhoea. Mild diarrhoea, which was the cause in most of the calves, may not affect their general condition and their appetite in order to decrease milk consumption. There was though a difference in drinking behaviour on the few observations registered in this study, indicating a decrease in number of visits, time per visit and time in the automatic milk feeder per day (Table 4).

In the study by Kung et al. (1997) where the calves received a lower amount of milk replacer per day (4.5 kg milk replacer at maximum), calves were visiting the automatic milk feeder 23 times per day. In present study where the calves had in average access to 9.55 litres of milk replacer, the mean number of visits per day with milk was 6.62 and the calves were in 60 % of the observed days visiting the automatic milk feeder 6 times or more. In 80 % of the observed days the calves did not have any unrewarded visits to the automatic milk feeder. This can indicate that the calves were not hungry and that they did not want to visit the feeder more often despite they were qualified for milk. In 96 % of the visits the calves were consuming milk replacer (Table 3). A lower level of unrewarded visits in the automatic milk feeder can be an indication of disease due to a reduction in appetite during diseased days (Svensson & Jensen, 2007). There is a risk that calves in group pen with automatic milk feeding when reared in the same barn a calves in single pens with bucket feeding, are increasing the unrewarded visits in the automatic milk feeder when single penned calves are fed (Hepola, 2003). In present study it could not be seen that the number of unrewarded visits were altered the day before outbreak of diarrhoea.

To increase profitability in today's cattle production efficient rearing is of high importance. The significance of good management is increasing when herds are becoming larger. There are often different animal keepers at larger farms why the importance of good overview of the animals and their health are increasing (Svensk Mjölk, 2011). Though the extended possibilities to better monitor the calves with computerized systems it is still necessary to have good management and frequent observations of calves. There are often increased difficulties to detect sick calves in group housing systems. The more calves per group, the harder it is to detect the diarrheic calves compared to a calf housed in a single pen (Svensson et al., 2003). Important experiences during the trial were that different animal keepers had different opinions when deciding if calves were sick. They were in some cases missing the calves with highest incidence of diarrhoea, which were left in the group pen and with no specific treatment. This certainly shows the difficulty and complexity with disease detection in group pens, and consumption lists are not an effective method.

6 Conclusion

Diarrhoea in young calves is a common disease in cattle production and prevention from or prediction of disease outbreak is of high importance. From the DeLaval ALPRO-system relevant data was obtained and used in the study. As the calves were affected by diarrhoea during major parts of the trial it was not possible in greater extent to investigate drinking behaviour in automatic milk feeder in relation to health of young dairy calves. The frequency of diarrhoea did not appear to affect the growth of the calves.

7 References

Bartels, C.J.M., Holzhauer, M., Jorritsma, R., Swart, W.A.J.M, Lam, T.J.G.M. 2010. Prevalence, prediction and risk factors of enteropathogens in normal and non-normal faeces of young Dutch dairy calves. Preventive Veterinary Medicine 93:162-169.

Baumgartner, W. 2012. Diarrhoea in calves and young cattle. Lucrări Ştiinţifice - Seria Zootehnie 57:19-22.

Berge, A.C.B., Besser, T.E., Moore, D.A., Sischo, W.M. 2009. Evaluation of the effects of oral colostrum supplementation during the first fourteen days on the health and performance of preweaned calves. Journal of Dairy Science 92:286-295.

Björkman, C., Svensson, C., Christensson, B., de Verdier, K. 2003. Cryptosporidium parvum and *Giardia intestinalis* in calf diarrhoea in Sweden. Acta Veterinaria Scandinavica 44:145-152.

de la Fuente, R., LuzoÂn, M., Ruiz-Santa-Quiteria , J.A., GarcõÂa, A., Cid, D., Orden, J.A., GarcõÂa, S., Sanz, R., GoÂmez-Bautista, M. 1999. Cryptosporidium and concurrent infections with other major enteropathogens in 1 to 30-day-old diarrheic dairy calves in central Spain. Veterinary Parasitology 80:179-185.

DeLaval. 2011. Original bruksanvisning DeLaval kalvamma CF 1000 + CS/CA Kombi.

de Passillé, A.M. 2001. Sucking motivation and related problems in calves. Applied Animal Behaviour Science 72:175-187.

de Wilt, J.G. 1985. Behavior and welfare of veal calves in relation to husbandry systems. Thesis. Institute of Agriculture Engineering, Wageningen. 138.

Foster, D.M., Smith, G.W. 2009. Pathophysiology of diahorrea in calves. The Veterinary Clinics of North America, Food Animal Practice 25:13-36.

Furichon, C., Seegers, H., Beaudeau, F., Bareille, N. 1997. Newborn calf management, morbidity and mortality in French dairy herds. Epidémiologie et santé animale 31-32.

Gulliksen, S.M., Lie, K.I., Sølverød, L., Østerås, O. 2008. Risk factors associated with colostrum quality in Norwegian dairy cows. Journal of Dairy Science 91:704-712.

Gulliksen, S.M., Jor, E., Lie, K.I., Hamnes, I.S., Løken, T., Åkerstedt, J., Østerås, O. 2009. Enteropathogens and risk factors for diahorrea in Norwegian dairy calves. Journal of Dairy Science 92:5057-5066.

Fleenor, W.A., Stott, G.H. 1980. Hydrometer test for estimation of immunoglobulin concentration in bovine colostrum. Journal of Dairy Science 63:973-977.

Hall, G. A. Reynolds, D. J. Parsons, K. R. Bland, A. P. Morgan, J. H. 1988. Pathology of calves with diarrhoea in southern Britain. Research in Veterinary Science 45:240-250.

Hafez, E.S.E., Schein, M.W. 1962. The behaviour of cattle. In: The behaviour of domestic animals, (ed. Hafez, E.S.E.), 247-296. Bailliere, Tindall & Cox, Great Britain.

Haley, D.B., Rushen, J., Duncan, I.J.H., Widowski, T.M., de Passillé, A.M. 1998. Effects of resistance to milk flow and the provision of hay on nonnutritive sucking by dairy calves. Journal of Dairy Science 81:2165-2172.

Heath, S.E., Naylor, J.M., Guedo, B.L., Petrie, L., Rousseaux, C.G., Radostits, O.M. 1989. The effects of feeding milk to diarrheic calves supplemented with oral electrolytes. Canadian Journal of Veterinary Research 53:477-485.

Hepola, H. Milk feeding systems for dairy calves in groups: effect on feed intake, growth and health. Applied Animal Behaviour 80:233-243.

Hoet, A.E., Nielsen, P.R., Hasoksuz, M., Thomas, C., Wittum, T.E., Saif, L.J. 2003. Detection of bovine torovirus and other enteric pathogens in faeces from diahorrea cases in cattle. Journal of Veterinary Diagnostic Investigation 15:205-212.

James, A. 2005. The state of veterinary epidemiology and economics. Preventive Veterinary Medicine 67:91-99.

Jensen, P. 2006. Stress, beteendestörningar och välfärd. In: Djurens beteende och orsakerna till det, 83-91. Natur och Kultur, Stockholm.

Jensen, M.B., Holm, L. 2003. The effect of milk flow rate and milk allowance on feeding related behaviour in dairy calves fed by computer controlled milk feeders. Applied Animal Behaviour Science 82:87–100.

Jung, J., Lidfors, L. 2001. Effects of amount of milk, milk flow and access to a rubber teat on cross-sucking and non-nutritive sucking in dairy calves. Applied Animal Behavior Science 72:201-213.

Keil, N.M., Audigé, L., Langhans, W. 2000. Factors associated with intersucking in Swiss dairy heifers. Preventive Veterinary Medicine 45:305-323.

Keil, N.M., Langhans, W. 2001. The development of intersucking in dairy calves around weaning. Applied Animal Behaviour Science 72, 295-308.

Kung, L., Demarco, S., Siebenson, L.N., Joyner, E., Haenlein, G.F.W., Morris, R.M. 1997. An evaluation of two management systems for rearing calves fed milk replacer. Journal of Dairy Science 80:2529-2533.

Lance, S.E., Miller, G.Y., Hancock, D.D., Bartlett, P.C., Lawrence, E.H., Moeschberger, M.L. 1992. Effects of environment and management on mortality in preweaned dairy calves. Journal of the American Veterinary Medical Association 201:1197-1202.

Lidfors, L. 1993. Cross-sucking in group-housed dairy calves before and after weaning off milk. Applied Animal Behaviour Science 38:15-24.

Lidfors, L. (1994). Mother – young behaviour in cattle. Parturition, development of cow-calf attachment, suckling and effects of separation. Doctoral thesis. Faculty of Veterinary Medicine, Department of Animal Hygiene, Swedish University of Agricultural Sciences. Report 33.

Lidfors, L. Mars 2011. Personligt meddelande. Universitetslektor, Husdjurens miljö och hälsa, Sveriges Lantbruksuniversitet.

Lundborg, K. 2004. Housing, management and health in Swedish dairy calves. Department of Animal Environment and Health. Skara, Sweden. Doctoral thesis, Swedish University of Agricultural Sciences. Acta Universitatis Agriculturae Sueciae Veterinaria 168.

Lundin, K., Grank, B., Rørbech, N., Ventorp, M. 2000. Inhysnings- och skötselsystem för kalvar under mjölkperioden – inverkan på beteende, hälsa och tillväxt. Instutionen för jordbrukets biosystem och bioteknologi (JBT), Sveriges Lantbruksuniversitet, Alnarp. Rapport 123.

Lupoli, B., Johansson, B., Uvnäs-Moberg, K., Svennersten-Sjaunja, K. 2000. Effect of suckling on the release of oxytocin, prolactin, cortisol, gastrin, CCK, somatostatin and insulin in dairy cows and their calves. In: Johansson, B. (2000). Effect of milking and feeding routines on milk production, hormone release and behaviour in dairy cattle. Doctoral thesis. Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences. Acta Universitatis Agriculturae Sueciae, vol 2000:211.

Olsson, S.O., Viring, S., Emanuelsson, U., Jacobsson, S.O. 1993. Calf diseases and mortality in Swedish dairy herds. Acta Veterinaria Scandinavica 34:263-269.

Pettersson, K., Svensson, C., Liberg, P. 2001. Housing, feeding and management of calves and replacement heifers in Swedish dairy herds. Acta Veterinaria Scandinavica. 42:465-478.

Radostits, O.M. 1974. Treatment and control of neonatal diarrhea in calves. Journal of Dairy Science 58:464-470.

Radostits, O.M., Gay, C.C., Blood, D.C., Hinchcliff, K.W. 2000. Veterinary Medicine, W.B. Saunders., 60-75, 1115-1126, 1160-1168.

Roth, B.A., Barth, K., Gygax, L., Hillmann, E. 2009. Influence of artificial vs. mother-bonded rearing on sucking behaviour, health and weight gain in calves. Applied Animal Behaviour Science 119:143-150.

Scott, P.R., Hall., G.A., Jones, P.W., Morgan, J.H. 2004. Chapter 14, p. 185-212. In Bovine medicine diseases and husbandry of cattle. Edited by: Andrews, A.H., Blowey, R.W., Boyd, H., Eddy, R.G. Blackwell Science Ltd, Oxford, UK.

Shearer, J., Mohammed, H.O., Brenneman, J.S., Tran, T.Q. 1992. Factors associated with concentrations of immunoglobulins in colostrum at the first milking post-calving. Preventive Veterinary Medicine 14:143-154.

Silverlås, C., Emanuelsson, U., de Verdier, K., Björkman, C. 2009. Prevalence and associated management factors of Cryptosporidium shedding in 50 Swedish dairy herds. Preventive Veterinary Medicine 90:242-253.

Silverlås, C., Näslund, K., Björkman, C., Mattsson, J.G. 2010. Molecular characterization of *Cryptosporidium* isolates from Swedish dairy cattle in relation to age, diarrhoea and region. Veterinary Parasitology 169: 289-295.

Simensen, E. 1982. An epidemiological study of calf health and performance in Norwegian dairy herds. I. Mortality: Literature review, rates and characteristics. Acta Agriculturae Scandinavica 32:411-419.

SJVFS 2010:15. Statens jordbruksverks föreskrifter och allmänna råd om djurhållning inom lantbruket. ISSN 1102-0970. Saknr L100.

Svensk Mjölk. 2011. Kärnfullt nr 9, September 2011.

Svensson, C., Lundborg, K., Emanuelson, U., Olsson, S.O. 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. Preventive Veterinary Medicine 58: 179–197.

Svensson, C., Hultgren, J., Oltenacu, P.A. 2006. Morbidity in 3-7-month-old dairy calves in south-western Sweden and risk factors for diarrhea and respiratory disease. Preventive Veterinary Medicine 74:162–179.

Svensson, C., Liberg, P. 2006. The effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. Preventive Veterinary Medicine 73:43-53.

Svensson, C., Jensen, M.B. 2007. Short Communication: Identification of diseased calves by use of data from automatic milk feeders. Journal of Dairy Science 90:994-997.

Svensson, C. 2010. Automatiska registreringar som hjälpmedel för sjukdomsövervakning av kalvar. Slutrapport Stiftelsen Lantbruksforskning. Projektnummer V0730179 och V0830389.

Svensson, C., Hultgren, J. 2008. Associations between housing, management, and morbidity during rearing and subsequent first lactation milk production of dairy cows in southwest Sweden. Journal of Dairy Science 91:1510-1518.

Torsein, M., Lindberg, A., Hallén Sandgren, C., Persson Waller, K., Törnquist, M., Svensson, C. 2011. Risk factors for calf mortality in large Swedish dairy herds. Preventive Veterinary Medicine 99:136-147.

Walker, D.M. 1950. Observations on behaviour in young calves. Bulletin of Animal Behaviour 8:5-10.

Walker, D.E. 1962. Suckling and grazing behaviour of beef heifers and calves. New Zealand Journal of Agricultural Research 5:331-338.

van der Fels-Klerx, H.J., Saatkamp, H.W., Verhoff, J., Dijkhuizen, A.A. 2002. Effects of respiratory disease on the productivity of dairy heifers quantified by experts. Livestock Production Science 75:157–166.

Warnick, L.D., Erb, H.N., White, M.E. 1994. The association of calfhood morbidity with first-lactation calving age and dystocia in New York Holstein herds. The Kenya Veterinarian 18:177–179.

Vasseur, E., Borderas, F., Cue, R.I., Lefebvre, D., Pellerin, D., Rushen, J., Wade, K.M., de Passillé, A.M. 2010. A survey of dairy calf management practices in Canada that affect animal welfare. Journal of Dairy Science 93:1307-1315.

Weaver, D.M., Tyler, J.W., VanMetre, D.C., Hostetler, D. E., Barrington, G. M. 2000. Passive transfer of colostral immunoglobulins in calves. Journal of Veterinary International Medicine 14:569–577.

Webster, J. 1984. Calf husbandry, health and welfare. Granada technical books. Granada publishing Ltd. London.

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