Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Sciences

Individual drinking water intake of dairy cows in an AMS barn

Individuellt dricksvattenintag hos mjölkkor i ett AMS-stall

Caroline Axegärd

Department of Animal Nutrition and Management, nr 595
Degree project 30 credits
Uppsala 2016

Individual drinking water intake of dairy cows in an AMS barn

Individuellt dricksvattenintag hos mjölkkor i ett AMS-stall

Caroline Axegärd

Supervisor: Torsten Eriksson, Bengt-Ove Rustas och Lena Lidfors
Department: SLU, Department of Animal Nutrition and Management

Examiner: Kerstin Svennersten Sjaunja
Department: SLU, Department of Animal Nutrition and Management

Credits: 30 credits
Level: A2E
Course title: Degree project in Animal Science
Course code: EX0551
Programme: Agricultural Science Programme - Animal Science

Place of publication: Uppsala
Year of publication: 2017
Cover picture: Caroline Axegärd
Title of series / Number of part of series: Examensarbete / Sveriges lantbruksuniversitet, Institutionen för husdjurens utfodring och vård, nr 595

Online publication: http://stud.epsilon.slu.se

Keywords: Dairy cows, automatic water bowl, water intake, milking production, feed and social factors, behavior.

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Sciences
Department of Animal Nutrition and Management

Abstract

Today's dairy cows have high requirements of nutrients and water to give a large milk production. Factors that under normal circumstances affect drinking behaviour are cow's eating pattern, the temperature of the water, whether the water is supplied in a water bowl or a trough, the cows' dominance order and if the water bowl is shared with other cows. There are several factors that are positively related to water intake such as temperature, humidity, dry matter intake, milk production, ration dry matter content, lactation day, body weight and also sodium and potassium intakes. The aim of this study was to investigate which factors that could best explain different levels of water intake in dairy cows and how social rank was related to diurnal pattern of water intake. A further aim was to evaluate a system for automated recording of drinking water intake with the help of observations of the drinking behaviours and social rank order. The study was performed in a barn with automatic milking system (AMS), and took place at The Swedish Livestock Research Centre, Swedish University of Agriculture Sciences, Uppsala, with dairy cows kept in a loose housing system. The number of cows in the barn section where the study took place was 60-65 cows. The dairy cows in the study were of the breeds Swedish Red and Swedish Holstein. The feed ration contained grass/clover silage and concentrate. The seven water bowls that were used in the barn had equipment which could identify the cow and measure the water flow for recording water consumption**.** From the 92 cows that was in the observation period there were 37 cows that were left when the other cows were removed because of reasons such as wrong registration, had been in the VMS group too short time and cows that splashed or licked out water. Data were compiled in Microsoft Excel 2013 and the built-in functions were used for calculating arithmetic means and making graphs. Statistical evaluation was done with procedures of SAS 9.3 (SAS Institute Inc., Cary, N.C**.).** Thirty-seven cows (42%) were correctly identified during the observation period. Cow identification with the necklace transponders did not show optimal results with the original placement of the antenna. The individual drinking water intake had a range between 23.9 and 130.4 kg/day and the total water intake (including feed water) were between 55.9 and 203.5 kg/day for the 37 cows. Drinking water intake was positively correlated to most of the factors including milk yield, dry matter intake, total water intake, potassium intake, sodium intake and nitrogen intake in the feed. The 37 cows in this study drank 56.0 % of their total daily intake between 8:00 to 20:00. Heavy cows, Swedish Holstein cows, lower ranked cows and parity 3 cows were cow categories that drank numerically most water/hour during a day. There was a main difference among cows regarding both the number of registrations/day and the duration/registration.

Sammanfattning

Dagens mjölkkor har höga krav på näringsförsörjning och ett stort vattenbehov för att kunna ge en hög mjölkproduktion. Faktorer som under normala omständigheter påverkar drickbeteendet är ätmönstret, temperaturen i vattnet, om vattnet dricks ur en vattenkopp eller ett tråg, kornas dominansordning och om vattenkoppen delas med andra kor. Det finns flera faktorer som är positivt relaterade till vattenintag såsom temperatur, luftfuktighet, torrsubstansintag, mjölkproduktion, foderstatens torrsubstanshalt, laktationsdag, kroppsvikt och även natrium- och kaliumintag. Syftet med denna studie var att undersöka vilka faktorer som bäst kunde förklara olika vattenintag för mjölkkor och hur social rang relaterar till dygnsmönstret för vattenintag. Ett ytterligare syfte var att utvärdera ett system för automatisk registrering av dricksvattenintag med hjälp av observationer av drickbeteende och social rangordning. Studien genomfördes i ett AMS-stall vid Sveriges Lantbruksuniversitet i Uppsala med mjölkkor i ett lösdriftssystem. Det var 60-65 kor i stallet av raserna Svensk röd och vit boskap (SRB) och Svensk Holstein (SH). Foderstaten bestod av gräs-/klöverensilage och koncentrat. De sju vattenkopparna som användes i stallet hade utrustning som kunde identifiera kon och mäta vattenflödet för registrering av vattenförbrukningen. Från de 92 korna som var med i observationsperioden var det 37 kor som var kvar när kor tagits bort på grund av felregistrering, att de varit i VMS-gruppen för kort tid eller att de stänkte eller slickade ut vattnet. Data samlades i Microsoft Excel 2013 och de inbyggda funktionerna användes för att beräkna aritmetiska medelvärden och göra grafer. Statistisk utvärdering gjordes i SAS 9.3 (SAS Institute Inc., Cary, NC). 41 kor (47 %) var korrekt identifierade under observationsperioden. Identifikation av kon med hjälp av transpondern visade inte optimala resultat med den ursprungliga placeringen av antennen. Det individuella dricksvattenintaget var mellan 23.9 och 130.4 kg/dag och det totala vattenintaget (inklusive fodervatten) var mellan 55.9 och 203.5 kg/dag för de 37 korna. Dricksvattenintaget var positivt korrelerat till ett flertal faktorer, bland annat mjölkavkastning, torrsubstansintag, totalt vattenintag, kaliumintag, natriumintag och kväveintag. De 37 korna i denna studie drack 56.0% av sitt totala dagliga intag mellan 8:00 till 20:00. Tunga kor, Svensk Holsteinkor, lägre rankade kor och kor i laktation 3 var de kategorier som drack numeriskt mest vatten/timme under en dag. Det fanns en stor skillnad mellan korna i antalet registreringar/dag och varaktigheten/registrering.

Table of contents

1 Background……………………………………………………………….……………5

2 Literature review…………………………………………………………..………...6

2.1 The cow's physiology……………………………………………………………..…………..……6

2.2 Restricted water intake……………………………………………………………..………………6

3 Behaviours……………………………………...…………………………………..6

3.1 Drinking behaviours…………………………………………………………………………………6

3.2 Drinking and eating pattern……………………………………………………………………….7

3.3 Water temperature…………………………………………………………………………………..7

3.4 Water bowl or trough………………………………………………………………………………..7

3.5 Dominance order/Water bowl shared with other cows………………………………….7

3.6 Drinking time……………………………………………………………………………………………8

4 Social behaviour of cows ………………………………………………………..8

4.1 Rank order……………………………………………………………………………………..………8

4.2 The agonistic and cohesive behaviour …………………………………..………………….9

5 Factors affecting water intake ……………………………………..……..……..9

5.1 Ambient temperature……………………………………………………………………………….9

5.2 The losses of water due to temperature …………………………………………………..9

5.3 Intake and dry matter content of feed…………………………………………..…….…10

5.4 The relationship between water consumption and milk yield…………….…….…10

5.5 Lactation day……………………………………………………………………………………….11

5.6 Body weight and body water…………………………………………………..…………….11

5.7 Sodium and potassium……………………………………………………………………………11

5.8 Ration mineral intake ……………………………………………………………………………11

5.9 Water quality…………………………………………………………………………………………12

6 Aims……………………………………………..…………………...……………….12

7 Materials…………………………………………………………...………………….12

7.1 Housing………………………………………………………………………………………………..12

7.2 Animals……………………………………………………………………………………………..………………12

7.3 Feeding……………………………………………………………………………………………….……………13

7.3.1 Roughage and concentrate…………………………………………………………………..………….13

7.3.2 Feeding area…………………………………………………………………………………………..………13

7.3.3 Water bowls………………………………………………………………………………………..…………13

7.3.4 Milking …….14

7.4 Observation…………………………………………………………………………………………..…….…..14

7.4.1 Pre observation to identify behaviours…………………………………………………….……..14

7.4.2 Recording of behaviour………………………………………………………………….…..………..14

7.4.3 Observation of rank order…………………………………………………………………….………15

7.5 Collection of silage and concentrate samples and analyses…………….………………15

7.6 The 92 cows………………………………………………………………..………………………………16

7.7 Statistics……………………………………………….…….……………………………………………16

8 Results and Discussion…………………………………………………………………18

8.1 The prototype system for drinking water registration……………………….……………18

8.2 Water intake relationship to feed and animal factors……………………….……………21

8.3 Effect of social rank on daily water…………………………………………………….………24

8.4 Drinking behaviour and whether water accessibility was limiting water intake…27

9 Conclusion……………………………………………………………...………….32

10 References…………………………………………………………...………………..34

11 Appendix ……………………………………………..…………………………38

Abbreviations

DM –Dry matter
DMI- Dry matter intake
ME- Metabolism energy
CP-Crude protein
K-Potassium
NA- Sodium
N-Nitrogen

1 Background

Today's dairy farms include more cows producing more milk than they did a few years ago. This has led to a much higher requirement for the cow in terms of nutrient and water supply and also regarding the cow's environment. High producing cows demand a large amount of energy, water, protein and minerals to give large milk yield (Kume et al., 2010).

Water is an essential and important nutritional source for dairy cows and they must consume much more compared to other animals (Murphy, 1992). A lactating cow require around 24-136 litres/day depending on where she is in the lactation period. However, a dry cow requires around 15-61 litres/day (Holter & Urban 1992). A lactating beef cow with calf requires around 43-67 litres/day, and a dry beef cow requires 22-54 litres water/day (NRC, 2000). Moreover, the cow take in water from three sources, the free water intake or drinking water consumption by the animal, the water in the feed and the water produced by the body's metabolism of nutrients through metabolic oxidation. To maintain water balance all the sources are required for the cow (Morris & Winchester 1956; NRC, 2001). The cow's losses are water in the milk, faeces, urine and evaporation (Murphy, 1992).

There are several factors that can affect free water consumption and drinking behaviours. Among them are water quality, feed dry matter, dry matter intake, protein and sodium intake, distance from feed to water, weather conditions, social factors and milk production (Meyer et al., 2004; Pinheiro Machado Filho et al., 2004).

According to Meyer et al., (2004) cows allowed to drink 90% or 50% of their previously determined free water intake decreased their milk yield with 3% and 26%, respectively. A cow that does not drink enough water will not eat enough and because of not eating she will lose weight. Loss of appetite, lack of gut fill, and firm, dry manure will also occur. Some cows can even be dehydrated. Also, if the inside of the smaller stomachs become too dried up the feed will not move and the digestive tract will be blocked which can lead to the cow's death (Pinheiro Machado Filho et al., 2004; Smith Thomas, 2009). The cow can usually lose all the body fat and one-half of the body protein and survive, however loss of one-tenth of the water from the body can lead to death for the cow (Sykes, 1995). Decreased water intake occurs usually when the cow has fever (Linn et al., 2008).

2 Literature review

2.1 The cow's physiology

For all the different organs in the body to function correctly, the fluid surrounding the cells need to have a stable composition without changes in the volume of body fluids. Such a change has an effect on arterial blood pressure. Also, around 65% of the body water is transcellular in cattle, for example in the lumen of the digestive tract, the reproductive tract and the urinary tract (Sjaastad et al., 2010).

Antidiuretic hormone (ADH) is formed in the nerve cells in hypothalamus, but is excreted from the pituitary gland. The hormone promotes reabsorption of water in the kidneys where the ADH is secreted. During periods with low water intake, the osmolarity of the extracellular fluid increase and this leads to increased secretion of ADH, which cause reduced water excretion. When the osmolarity of the extracellular fluid has reached a certain level, the thirst mechanism is triggered (Sjaastad, et al., 2010).

Milk is synthesized in the alveolus epithelium cells in the udder. Different components from the blood will be synthesized to milk protein, lactose and milk fat. The vitamins and minerals are transported via epithelium cells into the alveolus lumen from the blood. Protein synthesis starts with transport of protein in vesicles to the Golgi apparatus where it is packed in new vesicles which transport them to the apical membrane and via exocytose to alveoli lumen. Glucose from the blood is utilized in the glycerol synthesis and lactose synthesis. Lactose is synthesised with help from enzymes in Golgi apparatus membrane and exocytose on the same way as protein. On the way out to the lumen water goes into the vesicles through osmosis. (Sjaastad et al., 2010).

2.2 Restricted water intake

Restricted water intake has been shown to decrease feed intake in animals (Little et al., 1976). According to Burgos et al. (2001) lactating cows are able to cope with a sustained 50% restriction of drinking water intake and a 44% restriction of the total water intake. The cows in the experiment of Burgos et al. (2001) had access to water from 06:00 in the morning when the feed was first presented until the allowed quantity of drinking water was consumed for each cow. The cows drank 38 litres of water during the first hour of access and it was the same amount that was consumed when they had no restriction. The first meal of the day was the biggest meal during the restriction. Moreover, a 50% restriction of ad libitum water intake decreased the milk production from 18.7 to 13.6 kg/day. However, the milk composition did not change, except for urea and lactose content which were higher under water restriction (Burgos et al., 2001).

3 Behaviours

3.1 Drinking behaviours

A cow's natural drinking behaviour from an open surface starts with her lowering the muzzle 3-4 cm into the water at an angle of 60 degrees (Hafez, 1969). Then the cow sucks the water into the mouth at a rate of 20 l/min (Hafez, 1969). The water is swallowed without the head being raised and the cow's nostrils are nearly never under water during the water intake (Hafez, 1969).

Factors that under normal circumstances affect drinking behaviour are cow's eating pattern, the temperature of the water, whether the water is supplied in a water bowl or a trough, the cows' dominance order and if the water bowl is shared with other cows (Murphy, 1992).

3.2 Eating and drinking pattern

There is a large effect of the housing system on the drinking pattern of cows. Cows on pasture spend 4-14 hours grazing/day and 9-12 hours lying down with 1-4 drinking bouts/day (Stricklin, 1976). In a study with tie-stall cows (Dado & Allen, 1994), the cows had 14 drinking bouts/day with 6.4 litres each and 11 eating bouts of 2.2 kg DM each. The cows spend 18.5 min/day drinking, 301 min/day eating and 457 min/day ruminating with a total chewing time of 758 min/day (Dado & Allen, 1994). Additionally, cows in a free stall barn system studied by Cardot et al., (2008) visited the water station 7.6 ± 3.4 times/day, although 0.3 ± 1.1 visits/day were without drinking.

3.3 Water temperature

In a study by Andersson (1985), the cows were housed in a tied- up system with their own water bowl and the water temperatures 3, 10, 17 and 24 °C were tested during each of four periods. The study showed a decrease in water intake when the water temperature increased (24 °C) compared to water at lower temperatures. This contrasts to a study by Lanham et al. (1986), where nine lactating Holstein cows had access to drinking water with temperatures of 7.2, 15.6 and 23.9^{o} C, three cows/each temperature. The result was that the cows drank more water as water temperature increased. Cows that consumed water with 7.2^{o} C had higher milk production and this occurred when both ambient temperature and humidity were high. Different experimental conditions could probably explain the differences between the studies regarding drinking water response to water temperature.

3.4 Water bowl or trough

Castle & Thomas (1975) found in a study comprising several farms that cows drank less frequently from water troughs than from water bowls. Araujo Dias Coimbra et al. (2012) found that the social behaviour did not influence drinking behaviour if the water trough was placed on an open area, such as in a paddock. However, if the water trough was placed in an alley, more time was spent drinking and the number of drinking bouts were higher for higher ranked cows compared to lower ranked cows. According to Pinheiro Machado Filho et al. (2004), cows prefer high and large troughs. In the study the animals, which were lactating cows, non-lactating cows and heifers on pasture, showed clearly that they favoured high and large water troughs by longer drinking time, increased number of sips and increased intake. When the cows walked into the paddock they went first to the higher trough instead of the small trough.

The number of cows/water bowl in a loose housing system could not be too large if all cows should have access to all drinking water they desire. Castle & Thomas (1975) recommended that water bowls should be spread out in the loose housing system with 10 cows/water bowl when fed low dry matter feed and 6 cows/water bowl when fed high dry matter feed (Castle & Thomas, 1975). As a comparison, current Swedish legislation states in 2 cap.34 § L100 that there should be no more than 10 cows/drinking place for cows kept for milking and that watering and feeding system should be dimensioned, designed, and positioned so that the animals naturally and calm can drink and eat (SJVFS 2010:15).

3.5 Dominance order/ Water bowl shared with other cows

Andersson and Lindgren (1984) studied tied up cows that shared the same water bowl and observed that dominant cows drank 7% more water/day than low ranked cows. Before the water bowls were opened, the cows were fed with concentrates and all the cows ate. When the cows got access to the water bowls the dominant cows drank first before the low ranked cows. However, when the second concentrate meal was fed the submissive cows drank water and the dominant cows were eating.

3.6 Drinking time

Some studies show that most of the daily free water intake was achieved under the working hours (Cardot et al., 2008; Nocek & Braund, 1985; Osborne et al., 2002). Cardot, et al., (2008) with 41 cows housed in a free stall barn and Osborne et al. (2002) with 24 cows housed in tie-stalls with an individual water bowl, could see a structure in the drinking behaviour during daylight hours. There was no structure in water drinking behaviours from 19:00 at night to 05:59 in the morning in their studies. In Castle & Thomas (1975) study there was 14 herds with different housing systems. The cows drank 33.9% of their total daily intake from 09:00 to 15:00 hours, 40.0% from 15:00 to 21:00 hours and 26.1% from 21:00 to 09:00 hours.

Although 75% of all the cows drank within 2 hours after the evening milking, only 27% of the daily free water intake was consumed during that time interval (Cardot, et al., 2008). Additionally, a large number of cows visited the water station within 1 hour after leaving the milking parlour, indicating a rush to the water bowl. Cardot et al. (2008) had 18 cows/water bowl, although the recommendation is 10 cows/water bowl (SJVFS 2010:15), suggesting an effect of overstocking of cows in the experiment. However, there are different animal welfare regulations in different countries.

4 Social behaviour of cows

4.1 Rank order

Cows are social animals, forming a dominance hierarchy. Though the dominance hierarchy has evolutionary advantages, competitive advantages for dairy cows under modern herd situations are doubtful (Friend & Polan, 1974). However, in a group with cows with different ranks, the cows can have different responsibilities such as, a dominant cow might not only be dominant to other cows, she might also be a leader under travelling movements or be directly responsible for group protection (Lindberg, 2001). An example of a social behaviour is when a cow on pasture stops grazing and starts to walk to the water and often the other cows follow her (Schein & Fohrman, 1955). Also feeding behaviours when cows are housed are usually affected by social rank (Schein & Fohrman, 1955).

When two animals are in the same area, the behaviours will be modified with respect to the other animal. The factors which can determine the social rank are age, weight and lactation number (primiparous and multiparous) (Barr et al., 1970). Older cows are often higher ranked than younger cows (Lindberg, 2001). A cow in oestrus is often higher in social rank than when she is not in oestrus (Schein & Fohrman, 1955).

During *ad libitum* feeding the dominant cows eat more according to Schein & Fohrman (1955). Schein & Fohrman (1955) studied when the herdsman took in the cows to the barn and gave them roughage. The cows lined up at the manger, however, the higher ranked cows usually chased the lower ranked cows away from what looked like a load of roughage, and during the same time the lowest ranked cows searched for an opening whereby they could get to the feed. Miller & Wood-Gush (2010) reported somewhat similarly that the highest amount of aggressive interactions between dairy cows in loose-housing is in the feeding area. The size of the feeding area, the number of feeding places and also the amount and type of feed will influence the motivation for competition (Metz 1983). Low ranked cows prefer to eat separate from higher ranked cows (Appleby & Manson, 1990). A significant correlation between high rank and weight gain in cows was found by Andersson (1987) and one explanation was that the cows with higher rank could consume more of the feed than the low ranked cows.

4.2 The agonistic and cohesive behaviour

The agonistic behaviours which are behaviours associated with aggressive interaction between dairy cows can be divided into the following categories: the cows make contact head to head, butting with the head at some body part of another cow, threatening behaviour which involves purposeful advance towards another cow, using the shoulder to pass and passive dominance which mean that the cow only need to show herself to a lower ranked cow and she will move, the cows usually do not meet each other (Collis, 1976).

On the other hand, cohesive behaviour is when the animals do things together, such as grazing and licking each other (Reinhardt & Reinhardt, 1981). Grooming each other can occur when the animal lick the head or the neck of the other animal (Broom et al., 1997). According to Koichi et al. (1993) there were more frequent grooming performed from low ranked cows to high ranked cows.

5 Factors affecting water intake

There are several factors that are positively related to water intake such as, temperature, humidity, dry matter intake, milk production, ration dry matter content, lactation day, body weight and also sodium and potassium intakes (Meyer, et al., 2004).

5.1 Ambient temperature

During periods of cold climate the dry matter intake increase and daily water intake decrease and during the summer the opposite occurs. Solar radiation and temperature humidity index are the most important environmental factors affecting the daily water intake (Arias & Mader, 2011). Moreover, the environmental temperature interacts both with the needs of water of the dairy cows and also with their behaviours (Meyer et al., 2004). The comfort temperature for the cow is from -5 to 21 C^{o} (Muller & Botha, 1994). If the cow is subjected to lower or higher temperatures, it can lead to stress related behaviours and also decreased feed intake. An increase of one degree Celsius in temperature leads to an increased water intake with 1.52 kg/day (Meyer et al., 2004). However, there are studies that did not show any correlation between water intake and ambient temperature (Castle & Thomas, 1975; Little & Shaw, 1978).

5.2 The losses of water due to temperature

The five ways to lose water from the body are body surface, the digestive tract, the milk production, the airways and the urinary tract. Also, in lactating animals water will be lost through milk (Sjaastad et al., 2010).

Water losses through the skin and the epithelial surface of the airways are continuous and are known as insensible water losses because they cannot be sensed by the individual (Sjaastad et al., 2010). This kind of losses varies with environmental temperature and humidity, air movement and increases during sweating and respiration. The large body mass of cows is an advantage at high temperatures compared to smaller animals. Moreover, cows lose body water considerably faster than sheep and goats at high ambient temperature because a larger loss of water in the faeces, less ability to concentrate urine and less developed fur coat (Sjaastad et al., 2010).

5.3 Intake and dry matter content of feed

The metabolic oxidation from the feed forms 0.41, 1.07 and 0.6 g of water from 1 g of protein, lipid and carbohydrate correspondingly (Martin, 1985; Sykes, 1995). However, the total quantity of metabolic water is rather small in relation to that ingested by drinking or consuming food.

There is a positive correlation between free drinking water and dietary dry matter concentration and dry matter intake regardless of ration (Kume et al., 2010; Meyer et al., 2004; Strand., 1997). However, there was a weak correlation between total water intake and dietary dry matter in a study by Kume et al. (2010). In a study by Strand (1997) the dairy cows drank less when the feed had more water in it, but the relationship between drinking water intake and feed water concentration was not linear. An explanation why it was not linear could be that the effects of varying dry matter concentration between hay and silage were confounded with effects from the acid in the silage. Strand (1997) observed that dairy cows drank most of their water intake after feeding. Also, dairy cows that only were fed once a day consumed less water and dry matter compared to cows that were fed eight times/ day and the peak for water intake was coupled with the peak of DM intake (Nocek & Braund, 1985).

5.4 The relationship between water consumption and milk yield

A wide range of free water intake is reported in literature (Table 1). The difference could be explained with that some studies had both lactating cows and dry cows. Also, some of the studies had loose house and others tied up stalls.

There is a positive correlation between free drinking water and milk yield regardless of ration (Kume et al., 2010; Meyer et al., 2004; Strand., 1997). The water for the milk production needs to be ingested in addition to the water for the physiological requirement (Morris & Winchester, 1956). In three different studies the regression coefficients for milk production were similar, the regressions coefficient were 0.73, 0.87 and 0.90 kg drinking water/kg of milk (Little et al., 1976; Morris & Winchester, 1956; Murphy et al., 1983). Meyer, et al., (2004) showed that each kg of milk led to additional intake of 1.30 kg drinking water for cows milking from 5.6 to 59.2 kg/day.

Table 1. Dry matter intake, free water intake and milk yield, free water intake/kg milk and total water intake/kg milk from seven different studies with observation of water intake.

Reference	Dry matter intake kg/day	Free water intake kg/day	Milk yield kg/day	Free water intake/kg of milk prod.	Total water intake/kg of milk prod.
Holter & Urban, 1992	9.7-26.3	24.8-136.8	16.2-52.0	2.0	2.6
Murphy, et al., 1983	5.2-27.2	17.4-153.6	3.5-51.0		
Khelil-Arfa et al., 2012	4.7-27.5	2.3-140.0	5.5-42.2	2.1	2.6
Kume et al., 2010	17.2-24.1	57.0-110.3	21.9-35.3		
Dado & Allen, 1994	22.8	77.6	33.1	2.3	3.0
Meyer et al., 2004	*1.8-36.8	14.2-171.4	5.6-59.2		
Castle & Thomas, 1975	10.0-21.7	20.1-87.1	11.4-25.4		

* The DM intake 1.8 kg/day was caused by down in feed intake because of health problems or oestrus (Meyer et al., 2004)

5.5 Lactation day

The water intake increases after calving to meet the milk production (Davis, et al., 1984). The water intake for a newly calved cow increased with 67% from the week before partum to the week after partum with a further increase of 27% from the week after partum to the third week of lactation (Osborne et al., 2002). Kramer et al. (2009) adapted lactation curve functions to water intake data. Water intake was then approximately 55 kg/d around calving, then the water intake increased to approximately 70 kg around day 60. After that, the water intake decreased around day 120-180 days.

5.6 Body weight and body water

Meyer at al. (2004) observed increased water intake with increasing body weight. There are also indications that body water proportion may affect water requirement of dairy cows. Cows in later lactations have less body weight that consists of water, 62.4% compared to cows in early lactations that have a body water proportion of 69.0% (Andrew et al., 1995). This can imply that cows with different body weight have various water requirements per kg body weight (Andrew et al., 1995). Older cows also have lower body water content than younger cows (Murphy, 1992).

5.7 Sodium and potassium

Lack of sodium in the diet for dairy cows will result in intensive licking and biting of the interior in the barn (NRC, 2001). A high intake of sodium causes a decrease in milk yield and an increase in water intake (NRC, 2001).

Sodium is an extracellular cation and together with potassium and chloride, it affects several physiological functions in the body, such as the heart function and nerve impulse transmission. A correct function is depending on the right balance between sodium and potassium. The need for maintenance is based on the losses of sodium in the faeces and urine, lactation stage and temperature (NRC, 2001).

Lack of potassium in the diet for dairy cows will result in decreased water and feed intake, weight loss, a decrease in milk production and a lower potassium concentration in the blood plasma and in the milk (NRC, 2001). Moreover, when the lack of potassium is severe the cow will turn weak and lay down with muscle weakness and bad intestine functions (NRC, 2001).

Potassium is involved in the body's osmotic pressure (intracellular), water balance, acid-base regulation, nerve impulse transmission, oxidation and carbon dioxide transport, muscle contraction, and several enzyme reactions (NRC, 2001). Potassium is required in the feed due to little storage in the body. The potassium need for maintenance is based on the endogenous losses in the urine and faeces. The dairy cow require more potassium during lactation due to that potassium has an important role to help the microorganisms in the rumen to function and when the feed intake increase during lactation, it needs more potassium to keep the rumen's dynamical process working and also acids and base balance needs more potassium during high feed intake (NRC, 2001).

5.8 Ration mineral intake

There has been varying response in drinking water intake to increased daily sodium intake, with 54 g water/g Na (Murphy et al., 1983), 146 g water/g Na (Spek et al., 2012) and 400 g water/g Na (Meyer et al., 2004). There is also a positive relation between sodium and urine production, where one extra gram of sodium intake produced 136 g of urine (Spek et al., 2012).

In a study by Fisher et al., (1994) the water intake increased when the cows were fed medium and high potassium concentrations in the total mixed rations compared with cows fed lower potassium concentrations in total mixed rations. Additionally, a higher potassium level in the diet will increase urine output and drinking water intake (Fisher et al., 1994).

5.9 Water quality

Water quality is important for cattle to maintain the water intake (NRC, 1996). A dairy cow can detect unpleasant smell and taste and also the colour of the water has importance (Beede, 2006). If the water resource is unpalatable or has an odour, the cow will not drink adequate amount of water to meet the production demands (Beede, 2006). Bad taste or odour could be caused by the presence of bacteria or metabolic by products (Beede, 2006).

6 AIMS

The aim of this study was to investigate which factors that could best explain different levels of water intake in dairy cows kept in a loose house system, and how social rank was related to diurnal pattern of water intake.

The specific aims of the study conducted in this project were:

- To relate water intake to feed and animal factors such as dry matter intake, mineral intake, milk yield and body weight.
- To document when the water intake occurs with respect to the cow's social rank.
- To investigate if drinking behaviour of the cows suggests that water accessibility is limiting water intake.

Before the study began the expectation was to see if the water bowl worked correctly and how the cow functioned with the water bowl, if all the cows drank as much and little as the registration showed. The expectation from earlier studies was that most of our cows worked with the water bowl. The assumption was that the drinking cow stood right so that she always was correctly identified.

7 Material

7.1 Housing

The study took place at The Swedish Livestock Research Centre, Swedish University of Agriculture Sciences, Uppsala, with dairy cows in a loose housing system (Figure 1).The number of cows in the barn section where the study took place were 50-70 cows. The barn section included a resting area, two feeding areas and a milking robot (DeLaval VMS, Tumba, Sweden). The resting area had a total of 62 free stalls bedded with sawdust on rubber mats. In the feeding area, opposite the forage bins, there were 2 rotating cow brushes (Delaval AB, Tumba, Sweden) for grooming. From the feeding area where the cows ate silage, the cows were either directed to the milking robot or the feeding stations, where the cows ate concentrate, and the bedding area through a selection gate. The milking area consisted of a VMS robot and the waiting area. From the VMS, the cow could only enter the feeding area and then from there choose to go to the different areas. The alleys consisted of solid concrete floors sloping towards a central drain.

7.2 Animals

There were between 50-70 cows in the VMS area and a total of 400 animals. The dairy cows were in the first up to the seventh lactation and between 3 and 178 days in milk. The cows in the stall milked around 10 120 kg ECM/year. Every week newly calved cows were taken into the group and cows that had been in the group for a maximum of two months were transferred to a different barn section. Ninety-two dairy cows were observed in the study, however only 37 cows were used in the final calculations. The dairy cows in the study were of the breeds Swedish red (SR) and Swedish Holstein (SH).

7.3 Feeding

7.3.1 Roughage and concentrate

The feed ration contained grass/clover silage with (per kg DM) 11.2-11.9 ME and 163-177g CP due to that different silos were used during the observation period. The average intake of silage was 12.5 kg DM/day. The silage contained extra minerals and salt that was added in the mixer before feed out (Table 7). Two different concentrates were fed, Solid 620 (Lantmännen, Stockholm) at 11.4 kg/day (as fed) and Unik 82 (Lantmännen, Stockholm) at 1.5 kg/day (as fed). The cows in the study also participated in other studies and were therefore in some cases assigned to lower concentrate amounts than the standard feeding for the herd.

7.3.2 Feeding area

There were 20 feeding stations for silage (Bio-control A/S, Rakkestad, Norway). The feeding station’s front bar was lowered when the cow entered the silage trough. The logging system recorded cow identity, weight of the consumed feed, exit time and duration of the visit. The front bar rose when the cow left the feed station. There was a second feeding area with four concentrate stations (Delaval AB). The gate behind the cow in the concentrate station closed when she entered the station and was identified. Every time a cow entered the concentrate feeding station, the logging system recorded cow identity, total feeding time, time of entrance and consumption on a volume basis (Figure 1). Data from concentrate feeding stations, roughage feeding stations, water bowls, milking unit and control gate were transferred to a database at Lövsta for storage and analysis. The silage feeding troughs were filled a few times every day, often the cows had silage to eat when they wanted. However, it was observed that the roughage feeding stations could be empty for periods of the day.

7.3.3 Water bowls

The seven water bowls that were used in the barn had equipment which could identify the cow and measure the water flow for recording water consumption (Bio-control A/S Rakkestad, Norway). When a cow visited a water bowl the system recorded cow identity, time for the visit, total drinking time and amount of water consumed (Bio-control A/S Rakkestad, Norway). The water bowls in the barn were numbered 50-56 (Figure 1). Two water bowls were placed outside the milking robot where the cow exited the robot, four water bowls were in the feeding area opposite to the feeding troughs and the last one was placed in the waiting area.

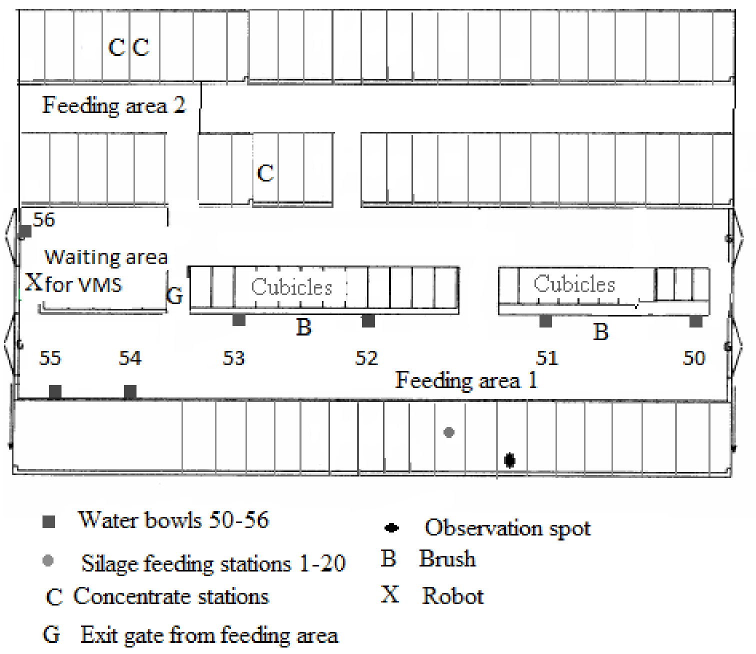

Figure 1. Part of the VMS barn section where the study took place, displaying location of water bowls.

7.3.4 Milking

All the cows in the observation study were milked in the milking robot (VMS, DeLaval Tumba) 1-4 times every day. If a cow not had milking permission, she walked through the milking unit to the feeding stations or to the resting areas (Figure 1). The cows' individual average milk yield for the observation period was 24.0-55.3 kg/day.

7.4 Observation

7.4.1 Pre-observation to identify behaviours

Behavioural observations were first carried out at the floor level to note at close-up what happened at the seven water bowls when the cows were drinking. The observations helped to identify different kinds of behaviours in order to be able to recognize them from above, where the major part of the observation was performed. The first observations were made at water bowls 54 and 55 which were located at the exit point of the milking robot (VMS) (Figure 1). The second observations were made at water bowls 50, 51, 52 and 53 which were behind the feeding table (Figure 1). Last observation was made of water bowl 56 which was placed in the waiting area for the cows before the robot milking. The observations were made during two days and comprised a total of 129 visits to the water bowls. The observations helped to evaluate the recording plans and to see if something needed to be changed or added.

7.4.2 Recording of behaviour

Observations of the dairy cows and when they were drinking took place from a central platform placed 5 meters above the yard during mornings and in the afternoons for four days a week for 8 weeks. Each observation session lasted 1- 2.5 hours. The cows were identified by large dyed numbers painted on the body. The observation protocol included cow identity, water bowl placement, and start and termination time of drinking. It was defined as drinking when the cow dipped her muzzle 3-4 cm into the water and sucked the water into her mouth and the water was swallowed without the head being raised. Likewise, it was defined as drinking if the cow licked the water with the tongue, if the cow touched the water with the muzzle and did not push forward water but drank the water. It was also recorded if there was a cow next to the cow which was drinking. All the different behaviours were documented in the observation protocol, for later comparison with the registrations from the logging system.

7.4.3 Observation of rank order

Separate behavioural observations took place at the same spot as the observation of when the cow drank, from a central platform 5 meter above the yard. Rank assessment was made with help from the following criteria:

- If a cow pushed away another cow which was drinking with the head on some part of her body.
- If a cow saw another cow walking towards her when she was drinking, causing the cow to stop drinking and walking away from the water bowl.

From these observations four groups were made, a group with high ranked cows (group 1), low rank (group 3), subdominant cows (group 2) and a group that could not be given any rank due to lack of recordings (group 4).

7.5 Collection of silage and concentrate samples and analyses

The silage and concentrates were sampled every day when the observations were made. The silage samples were weighed and then dried at 60 ºC in a force-dried oven for 24 hours. After drying, the dry silage samples were weighed and then mixed within sampling periods based upon when different silage (a new silo or changed proportions of two silos) was taken into use. The first period was from September 16 to the October 5, second period was from 6 October to 3 November, the third was from 4 November to 9 November and the last period was from 10 November to 16 November. The concentrate samples were mixed within corresponding periods and then the whole sample was weighed before oven drying. After drying, equilibration with ambient air and weighing, the samples of both silage and concentrates were ground on a hammer mill through a 1.0 mm screen. The samples were analyzed at the Department of Animal Nutrition and Management for dry matter by drying for 16 h at 103 ºC, for ash by combustion at 550 ºC for 3 h and for Kjeldahl N. The samples were also analyzed by inductively coupled plasma-atomic emission spectroscopy at Agri-Lab, Uppsala for the concentration of sodium, calcium, sulphur, potassium, phosphorus and magnesium.

Dry matter intake as well as intake of different nutrients including minerals were intended to be calculated from feed analysis and consumed amounts according to the logging systems. However, feed analysis showed that the sodium content in silage was very high, 7-20 g Na/kg DM as averages for the different sampling periods. This was explained by unexpected changes in the herd’s ration planning and an extensive addition of minerals and feed salt to the silage before feeding the cows. Because mineral and salt addition was irregular, a new calculation based upon harvest analysis and logged addition from the feed mixer and forage conveyor systems was made to find an approximation of the mineral content in the silage for each day (Table 7).

Barn temperature was recorded on observation days. Silage and concentrates were sampled each observation day. The samples were pooled and analyzed for dry matter, ash, nitrogen and minerals. The observations were compared with registrations from the logging system.

7.6 The 92 cows

All the 92 cows were used for evaluating if cows were correctly identified and registered when drinking. Due to the doubtful identification of cows from the water bowls, data for analyses involving total drinking water consumption were initially screened for what could be considered values outside the physiologically probable water intake. For that purpose, the equation of Dalhborn, et al., (1998) with daily milk yield and dietary DM % was used (Figure 2).

From a total of 92 cows, 4 were removed because they had been also in the AMR barn section during the observation period. Of the 88 cows that were left, 38 cows were considered outliers and removed from the dataset because the cows should have higher water intake according to Dalhborn, et al. (1998) equation. The cows that were taken out consumed between 5.0 to 52.9 kg less water compared to Dalhborn, et al. (1998) equation. From the 50 cows that were left, 8 cows that splashed or licked out water according to behavioural observations were removed. Finally, the cows that had been in the group for only a couple of days (3-14 days) were taken out and also the cows that did not have any rank, leaving 37 cows that could be used. One of these cows was dry and had to be excluded from calculations involving milk yield. The 37 cows were classified into different categorize according to their lactation number, weight class and rank order (Table 2).

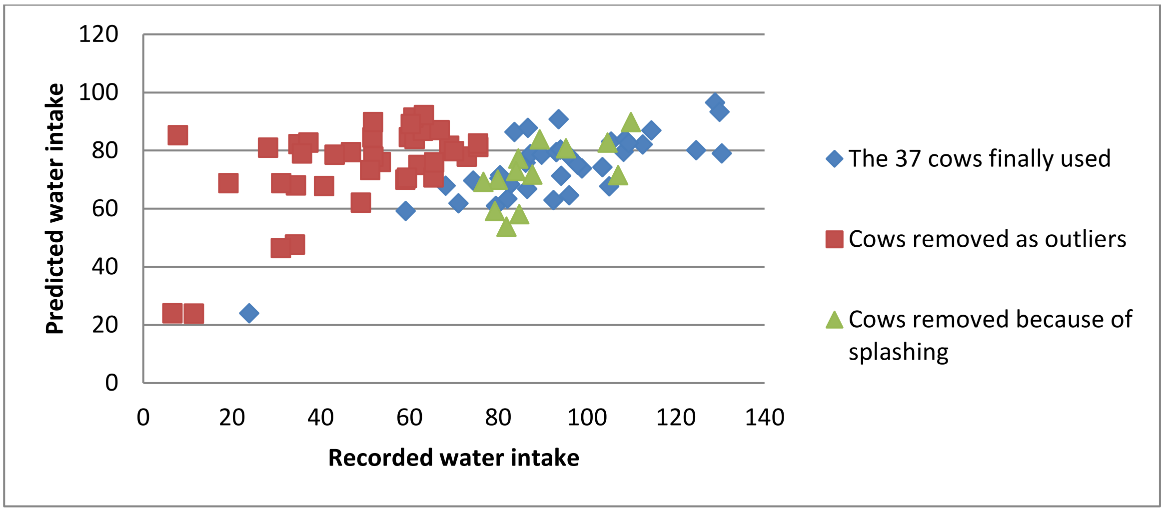

Figure 2. Recorded water intake and estimated water intake for all the 88 cows according to the equation 14.3+1.24*Milk (kg/day) +0.32*dietary DM % (Dalhborn, et al., 1998).

7.7 Statistics

Data were compiled in Microsoft Excel 2013 and the built-in functions were used for calculating arithmetic means and making graphs. Average water intake/hour was compared between breeds SR and SH, between heavy (657-806 kg) and light (534-652 kg) cows and between cows of high, low and sub dominant rank (Table 2). The heavy and the light cows were split in the middle of the list so there was almost the same numbers of cows in the groups. From a compilation with all the drinking events including amount and time stamp, graphs were made describing how drinking water consumption was distributed over time and among the seven water bowls.

Statistical evaluation was done with procedures of SAS 9.3 (SAS Institute Inc., Cary, N.C.). Arithmetic means for each cow from the entire observation period (63 days) were used for examining the relationship between drinking water intake and animal and feed factors. Measures of drinking pattern (mean and maximum water consumption/registration, water registrations/day and maximum duration of a drinking registration) were in the same manner evaluated based upon a single value per cow. Correlations were obtained with PROC CORR. A Stepwise regression model in PROC REG was used to obtain a multiple regression that explained drinking water intake. The explanatory variables allowed to enter the Stepwise model if $P < 0.15$ were milk yield, body weight, ration DM concentration and the intakes of dry matter, Ca, K, Mg, Na and N. Variables were likewise retained in the model if $P < 0.15$. Significance of the class variables rank, parity, breed and weight was evaluated with a model in PROC GLM where those variables were entered without interactions. Non-significant ($P > 0.05$) variables were then deleted from the model one at a time, starting with the variable with largest P, where after the model was rerun. This was repeated until only significant variables remained.

Table 2. The two breeds of cows (SR=Swedish Red, SH=Swedish Holstein) used for analyzes split up into different lactation numbers, weight class (light= 534-652 kg, heavy= 657-806 kg) and rank order (1=high, 2=subdominant, 3=low) (n=37)

	SR	SH	Total
Lact 1	3	6	9
Lact 2	9	5	14
Lact 3	4	4	8
Lact 4	4	1	5
Lact 6	1		1
Light	11	7	18
Heavy	10	9	19
Rank 1	8	2	10
Rank 2	7	6	13
Rank 3	6	8	14

8 Results and Discussion

8.1 The prototype system for drinking water registration

Of all the 88 cows, 37 cows (42%) were correctly identified during the observation period. There was a difference between the water bowls in the proportion of cows that were correctly identified. Water bowl 51 identified 33 cows correctly and had most correct cows and 19 cows wrong identified. The water bowl 56 in the robot area identified 13 cows correctly and 76 cows not observed when drinking. Water bowl 55 had 27 cows correctly identified and 16 cows wrong identified. The rest were cows that were not observed and cows that were sometimes incorrectly identified (Figure 3). The internal clock in water bowls 55 and 53 was wrong from the beginning to the end of the period and drinking events were logged with erroneous time.

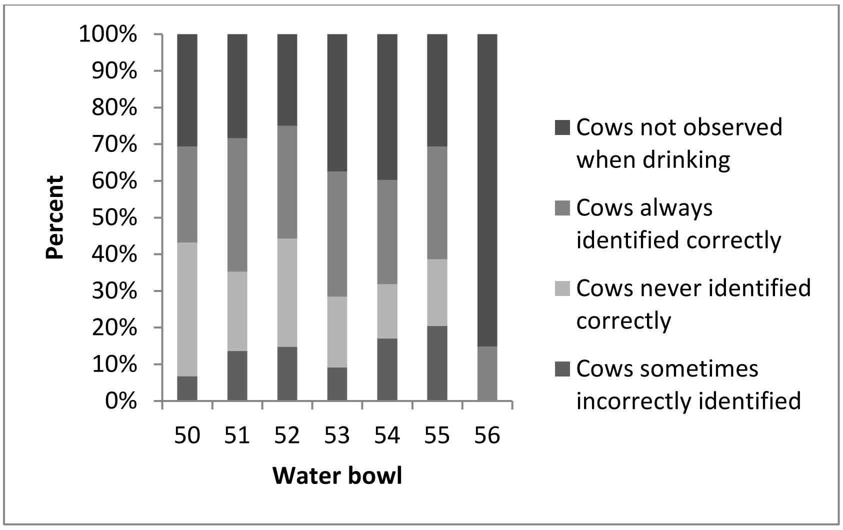

Figure 3. Proportion of cows correctly or incorrectly identified by the transponder system at different water bowls when compared to manual observations of the same drinking occasions. This is based upon 3845 registrations with 53-83 cows drinking from each bowl. Drinking occasions not observed mainly occurred at night.

Cow identification with the necklace transponders did not show optimal results with the original placement of the antenna (Figure 4). It worked better with some of the cows than with others. The main reason why it did not work was probably because the antenna had difficulties to make accurate readings due to the positions of the transponder. The cow often stood with the head turned away into the water bowl and because of that the cow could not be registered. An explanation why the cow did not stand right for water bowls 50-53 could be that the silage feeding stations were opposite to the water bowls and when the cow drank she did not want to be close to for example a high ranked cow which ate, and then only turned the head to reach the water bowl while the body was more or less parallel with the wall where the water bowl was mounted. Due to that, the transponder had wrong position in relation to the antenna.

Figure 4. Cow drinking water from water bowl 54.

Water bowl 50, 51 and 55 were most often used by low ranked cows (Figure 5). When the cows drank from water bowl 50, they stood with the transponder in a position not giving optimal contact with the antenna, especially the low ranked cows. An alley was next to the water bowl and the forage bins/troughs were at the other side. When there was a high ranked cow in the alley or at the forage bins, the low ranked cow stood almost always wrong with the transponder. Araujo Dias Coimbra, et al., (2012) saw that if the water trough was placed in the alley, more time was spent drinking and the number of drinking bouts was higher for higher ranked cows compared to lower ranked cows.

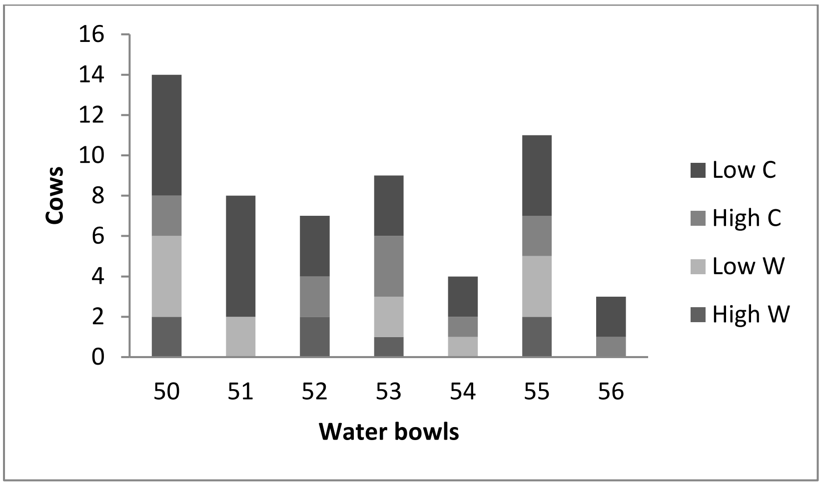

Figure 5. Number of the 37 cows that could be classified as always wrongly (W) and always correctly (C) registered in low and high rank groups at the different water bowls according to the observations.

The max water intake/registration for the 37 cows were between 8 and 31.8 kg/registration (Figure 6). There were 7 low ranked cows that had a max water intake/registration over 25 litres/registration. An explanation could be that they needed to drink when the high ranked cows were not there and when they drank they drank a higher amount. However, there was one low ranked cow that had a max water intake/registration of 8 litres. There were also 7 high ranked cows that drank over 25 litres/registration and an explanation could be that they stood and watch over the water bowl or the cows were low ranked instead for high ranked cows. It could also be that they were high producing cows or had been milked and drank a high amount of water after they had been in the robot.

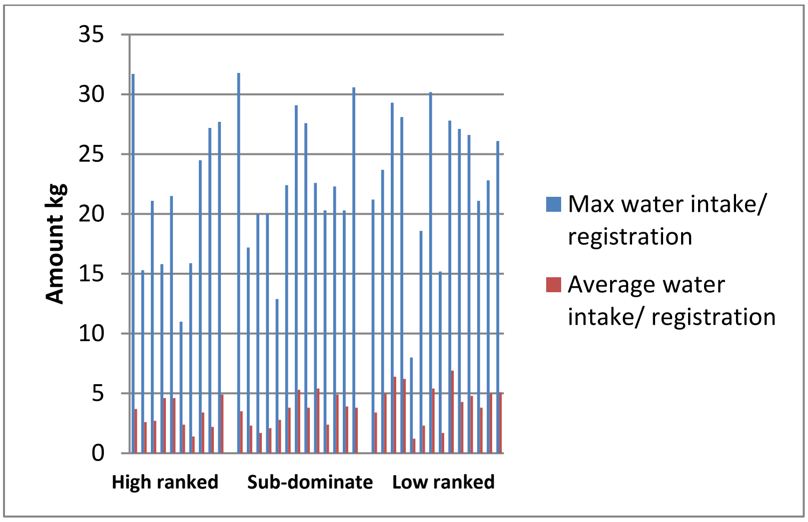

Figure 6. Maximum and average water intake of each registration for the 37 cows in the three rank groups used in the final evaluation.

In figure 5, there is a comparison between not correctly registered cows in high and low ranked groups of the 37 cows. There were both wrong and correctly registered low ranked cows at water bowl 50, but most of the low ranked cows were registered correctly. Also at water bowl 51 most low ranked cows were correctly registered. An explanation could be to avoid the high ranked cows, the low ranked cows drank standing in an awry position. There was a span between the cow that consumed less and the cow that consumed most. It could be explained with that some of the cows could stand and drink and other cows could only drink little before they were chased away (Figure 4).Water bowl 54 and 55 were placed close to where the cows came out from the milking robot and the gate from the resting area. There were not many low ranked cows at those water bowls, and an explanation could be that the cows needed to stand with the back against the gate and therefore did not want to drink from the bowls (Figure 5). From the observation many of the cows had aggressive interactions with each other. According to Miller & Wood-Gush, (2010), the highest amount of aggressive interactions between dairy cows in loose-housing is in the feeding area. Low ranked cows prefer to eat separated from higher ranked cows (Appleby & Manson, 1990).

After modification of the water bowls, where the antenna was moved to improve cow identification, some of the cows changed their registered water intake. In figure 7 with the cows that were correctly identified in the observational study, there are 2 cows that are special, numbers 10 and 1563. Cow 10 consumed 40 kg/d before water bowl renewal and 118 kg/d after the change and cow 1563 consumed 98 kg/d before water bowl renewal and 150 kg/d after the change. However, according to Dahlborn's equation that had been used for screening for outliers they consumed more than they should have done and were by then classified as being correctly registered. It was probably wrong to only look at Dahlborn's equation and base the number of cows of the right or wrong water intake, however the equation had good parameters to look on and compare with our study. For the next study it probably will be a good idea to compare the log with the observation earlier in the observation period to earlier find errors.

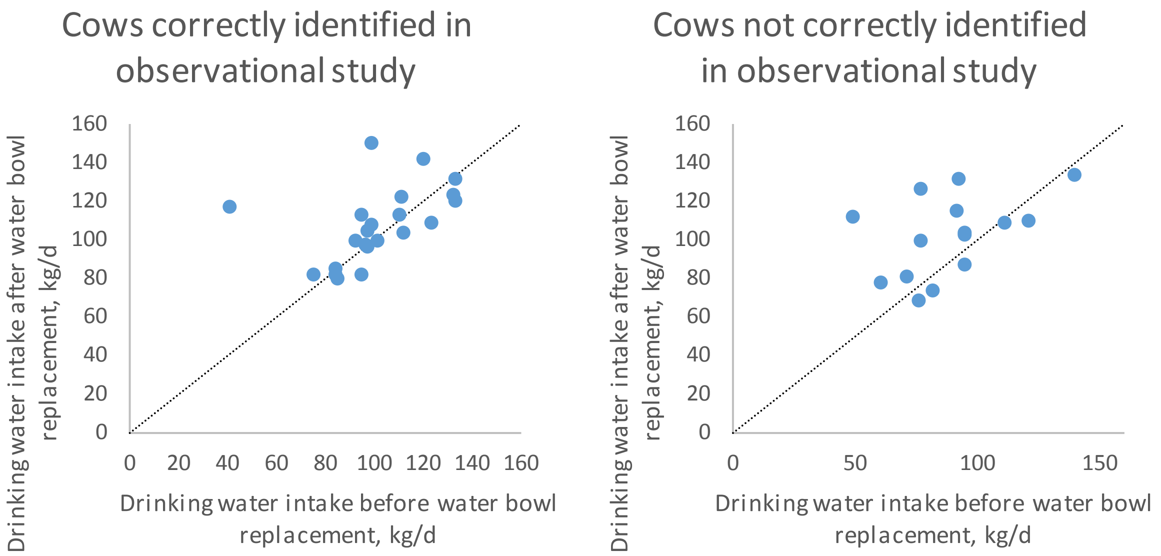

Figure 7. Weekly average of water intake immediately before and after renewal of water bowls in December 2014 (antenna was then moved for improved cow identification). Dashed line displays y = x. Left panel: Cows that were identified and recorded correctly by the system as confirmed by observational study in September-October 2014. Right panel: Cows that were not identified and recorded correctly according to the same observational study.

After reconstruction of the water bowl equipment, the registration antenna was higher up on the water bowls and more far out. Because cows usually were moved from this barn section after two months, there were only a few cows left from the observational study when the rebuilding took place so that their drinking behaviour before and after rebuilding could be compared. There was a difference in water intake after rebuilding the water bowl, such as 21 of 37 cows increased their water intake. From the observation the cows did not stand straight with the body from none of the water bowls.

Water licking behaviour is a factor that was noted during the observation. Of the 92 cows there were 8 cows that drank and at the same time licked so much that much of the water poured down to the walking lane. Those cows that had a lick and splash behaviour were taken out from the study. However, if such equipment should be used on a commercial farm, there would be a need to know which cows that can drink correctly and do not splash or play with the water. To use this equipment on water trough instead could probably help in some ways, such as when they lick and splash less water will pour down to the walking lane. However, there will be technical problems due to that more than one cow can drink at the same time. In the future, it probably will be possible to measure the water intake in other ways, such as with acoustic sensors or rumen temperature loggers.

8.2 Water intake relationship to feed and animal factors

There was a considerable range for most of the animal and feed factors (Table 3). The individual drinking water intake had a range between 23.9 and 130.4 kg/day and the total water intake (including feed water) were between 55.9 and 203.5 kg/day for the 37 cows. Other studies of drinking water intake have found daily intakes between 2.3 to 171.4 kg/day

(Castle & Thomas, 1975; Dado & Allen, 1994; Holter & Urban, 1992; Khelil-Arfa et al., 2012; Kume et al., 2010; Meyer et al., 2004; Murphy et al., 1983). Moreover, it is hard to believe that a cow can live on only 2.3-17.4 kg water/day especially when they produce milk. However, in the Khelil-Arfa, et al., (2012) study there were dry cows and lactating cows fed freshly cut pasture with probably high water content. In our study there were cows that had a water intake below 10 kg/day that were considered outliers and taken out of the study.

Table 3. Live weight, milk yield and intake of water, dry matter and feed constituents for the 37 cows used in the final evaluation (36 cows with milk yield)

Item	Mean	Standard deviation	Range
Live weight, kg	649	48.5	534 - 806
Milk yield, kg/d	38.3	7.4	24.0 - 55.3
Dry matter intake, kg/d	23.6	4.4	9.7 - 31.9
Free water intake, kg/d	93.5	20.7	23.9 - 130.4
Total water intake, kg/d	123.8	24.4	46.2 - 171.7
Free water/ kg milk	2.5	0.4	1.8 - 3.4
Tot water/kg milk	3.3	0.5	2.4 - 4.5
K intake, g/d	525	91.3	330 - 727
Na intake, g/d	133	26.4	63 - 182
N intake, g/d	713	137	282- 952

Drinking water intake was positively correlated to most of the factors (Table 4) including milk yield, DMI, total water intake, potassium (K) intake, sodium (Na) intake and nitrogen (N) intake in the feed. However, ration DM concentration was not correlated to drinking water intake and the total water intake was not correlated with ration DM concentration. The correlation between DMI and total water intake was considerably larger than the 0.65 reported by Kume et al., (2010). A feed with high DM the more water will the cow drink and a feed with low DM the cow will drink less (Strand, 1997). In Strand, (1997) the DM was much higher than in this study and gave a correlation between DM and water intake. In this study there were no correlation between DM and water intake and it can be explained by the low DM content in the silage.

Table 4. Correlations between animal factors, water intake and feed factors (intake of DMI, K, Na, N) for the 37 cows used in the final evaluation (36 cows with milk yield) [1]

	Body weight	Milk	Free water	DMI	DM%	Feed water	Total water	K	Na
Milk	0.56 ***								
Free water	0.41 *	0.69 ***							
DMI	0.56 ***	0.73 ***	0.75 ***						
DM%	0.02 ns	0.15 ns	0.26 ns	0.41 *					
Feed water	0.48 **	0.43 **	0.51 **	0.60 ***	-0.45 **				
Total water	0.47 **	0.70 ***	0.98 ***	0.79 ***	0.10 ns	0.68 ***			
K	0.57 ***	0.60 ***	0.67 ***	0.87 ***	-0.09 ns	0.92 ***	0.80 ***		
Na	0.54 ***	0.54 ***	0.66 ***	0.73 ***	-0.13 ns	0.85 ***	0.77 ***	0.87 ***	
N	0.55 ***	0.72 ***	0.75 ***	1.00 ***	0.48 **	0.54 ***	0.77 ***	0.82 ***	0.68 ***

[1] ns, P > 0.05; *, P < 0.05; **, P < 0.01; ***, P < 0.001

The 37 cows in the study ate between 6.7-18.1 kg DM silage/day and 3.6-18.7 kg concentrate /day. In other studies the cows ate between 1.8 to 36.8 kg DM/day (Castle & Thomas, 1975; Dado & Allen, 1994; Holter & Urban, 1992; Khelil-Arfa, et al., 2012; Kume, et al., 2010; Meyer, et al., 2004; Murphy, et al., 1983;). Figure 8 displays the regression of total water intake against dry matter intake.

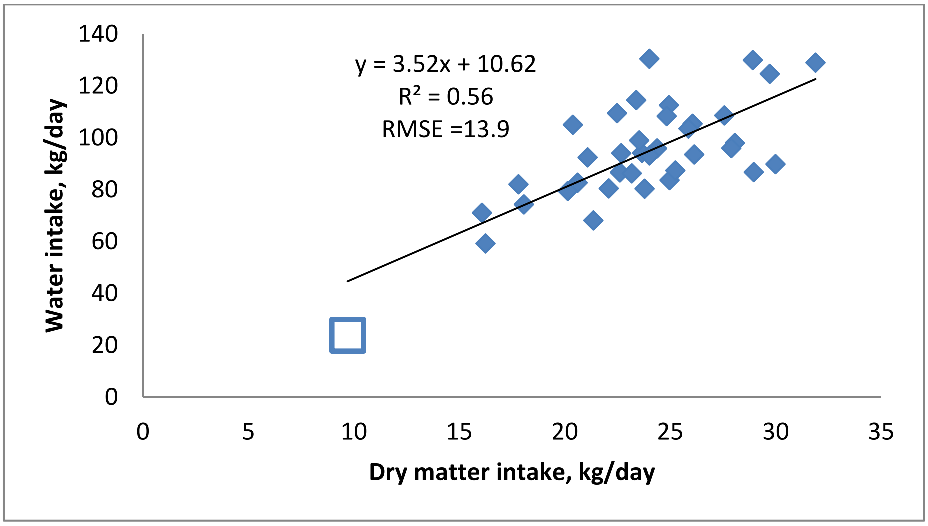

Figure 8. Regression for drinking water intake against dry matter intake for the 37 cows used for the final evaluation. Removing dry cow (open square) as an outlier gives the solution y = 2.92 x + 25.3; R^2 = 0.41; RMSE =13.5.

When several factors were entered into a Stepwise regression model (Table 5), only milk yield and K intake became significant.

The milk yield was between 24.0-55.3 kg/day and is within the range of other studies on water intake, where the milk yield was between 3.5 to 59.2 kg/d (Castle & Thomas, 1975; Dado & Allen, 1994; Holter & Urban, 1992; Khelil-Arfa et al., 2012; Kume et al., 2010 Meyer et al., 2004; Murphy et al., 1983). There was a positive correlation between water intake and milk production (Table 4) and each kg of milk gave an additional intake of 1.20 kg drinking water for the cows (Table 5). This is close to the findings of Meyer, et al., (2004), where each kg of milk led to an additional intake of 1.30 kg drinking water for cows milking from 5.6 to 59.2 kg/day.

Mineral intake was much higher than expected because of the extra addition to the silage. This most likely had an impact on the water intake. If there is free access to water, a high sodium intake would not be a problem for the cow (NRC, 2001).

Table 5. Stepwise regression model for drinking water intake from 36 cows (dry cow removed because milk yield included in regression). Independent variables allowed entering the model if P < 0.15 were milk yield, body weight, ration DM concentration and the intakes of dry matter, Ca, K, Mg, Na and N.

	β	SE	*P*	R^2 cumulative
Intercept	18.2	13.4	0.18	-
Kg milk/d	1.20	0.35	0.002	0.48
K intake, g/d	0.059	0.030	0.06	0.53

8.3 Effect of social rank on daily water intake

The dairy cows drank most of their daily water intake from water bowl 55 which is the water bowl placed in the corner where the cows came out from the milking robot. The cows drank least from water bowl 56 which is in the milking area where they wait for milking (Figure 9). During the observation period, there were not many cows that could be observed to drink in the milking area. According to Cardot et al., (2008) the cows usually walk to the water system after milking. An explanation might be dehydration due to milk yield (Cardot et al., 2008). This can be an explanation why the cows drank most of the water from water bowl 55.

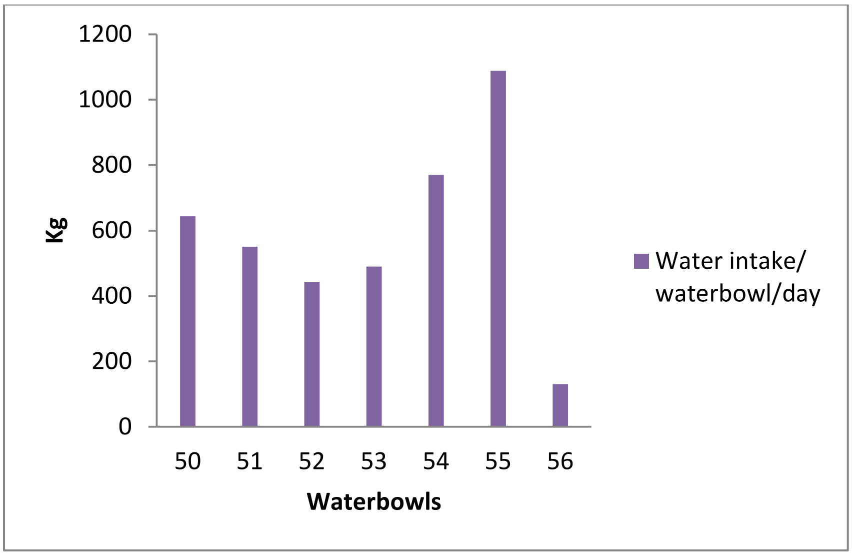

Figure 9. Daily water intake from the different water bowls by 92 dairy cows during the entire observation period (56 days).

The 37 cows in this study drank 56.0 % of their total daily intake between 8:00 to 20:00 (Figure 10), while the cows in the study of Castle & Thomas, (1975) drank 74% of their total daily intake from 09:00 to 21:00 hours (free stall barn). Other studies in free stall barn and tie-up stall found that most of the water intake was during daytime (Cardot et al., 2008; Nocek & Braund, 1985; Osborne et al., 2002). The difference between a loose house system and a tie-stall is that the cows in the loose house system need to walk to the water bowl and feed table, however, in a tie-stall the feed and water is right next to the cows. The rank order in a loose house system and tie-up system may affect the drinking behaviour.

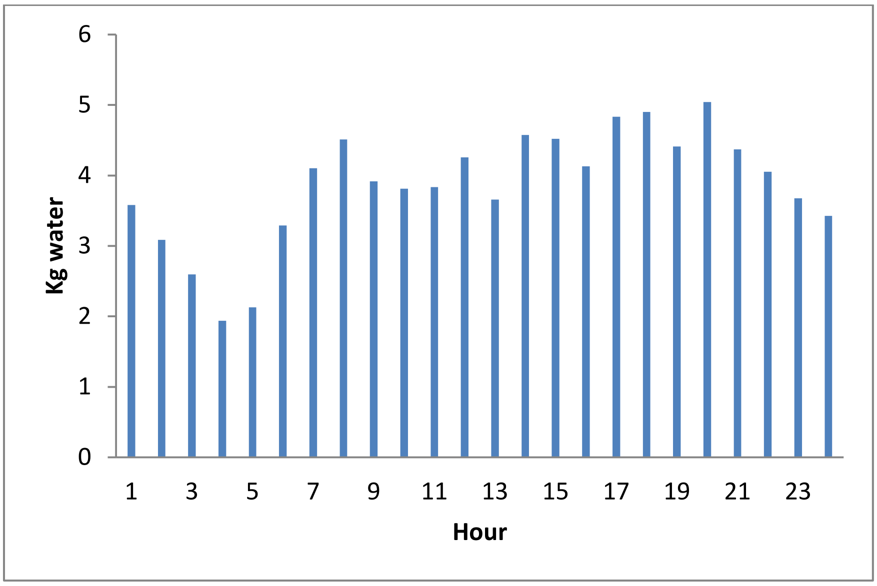

Figure 10. Hourly intake of drinking water for the 37 cows used in the final evaluation.

There was a numerical difference between SH and SRB cows in that the SH cows drank more water/hour during the day (10-24 hours) while the SRB cows drank more during the night (1-3 hours) (Figure 11). One explanation could be that the SH cows was higher ranked than SRB cows. SH cows have usually higher milk production and therefore consume more water. SRB cows drank when it was less crowded around the water bowls during the nights. The average weight for SH cows was 665 kg and for SRB cows was 636 kg. In a study, they could see that heavier cows have a high water intake (Meyer et al., 2004).

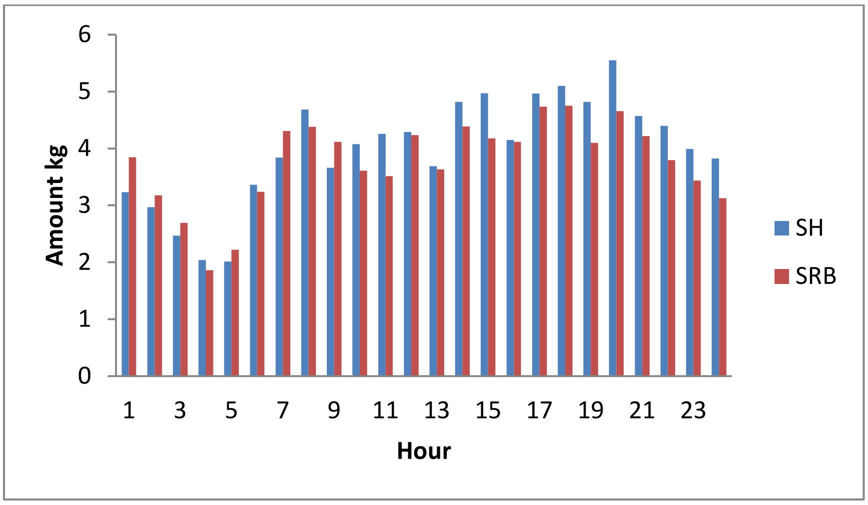

Figure 11. The daily water intake for cows (n= 37) of the different breeds Swedish Holstein (SH) (n= 16) and Swedish Red (SRB) (n=21).

Heavy cows drank more/hour during both day and night (Figure 12). This was the combined effect of more registrations/day, longer duration/registration and higher water intake/registration (Figure 13). According to Meyer et al., (2004) heavier cows have a high water intake. Another explanation could be the milk production for the cows. Heavier cows can produce higher milk yield due to they eat and drink more. Moreover, restricted water intake has resulted in body weight loss (Little et al., 1980; Steiger Burgos et al., 2001). On the other hand, Andersson (1987) and Andersson and Lindgren (1987) could not see any relation between body weight and water consumption.

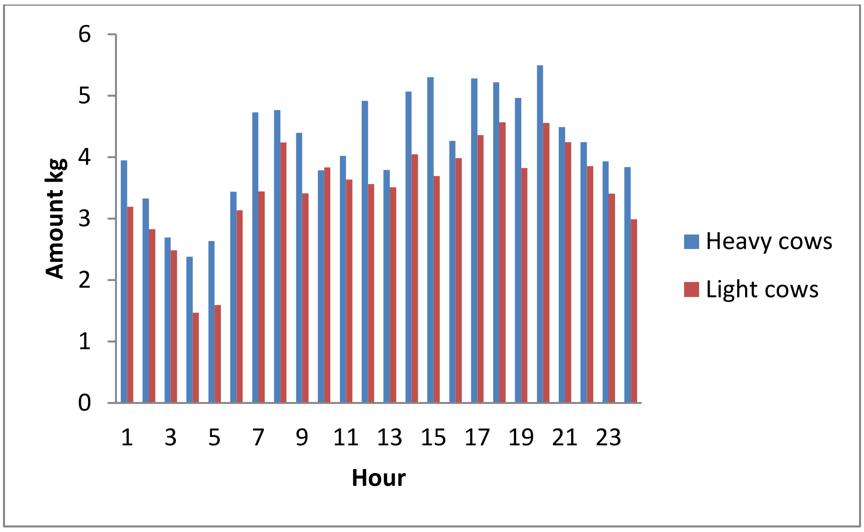

Figure 12. Daily water intake for cows of different live weight (n= 37). Heavy cows weighed 657-806 kg and light cows weighed 534-652 kg

The difference in water intake between the ranking groups during a day is presented in Figure 13. Low ranked cows drank numerically more half of the day and especially around 8, 12, 14 and 17 (Figure 13). However, the lower ranked cows had fewer registrations and shorter duration/registration compared to high ranked and sub-dominant cows. Lower ranked cows had also highest water intake/registration. An explanation that low ranked cows had few registrations and shorter duration compared to the other ranks could be that the higher ranked cows chased the lower ranked away from the water bowl. Another study showed, when the herdsman took in the cows to the barn and gave them roughage. The cows lined up at the manger, but the higher ranked cows usually chased the lower ranked cows away from what looked like a load of roughage, and during the same time the lowest ranked cows searched for an opening whereby they could get to the feed (Schein & Fohrman, 1955). The hours when the low ranked cows drank were usually when the feed wagon was in operation.

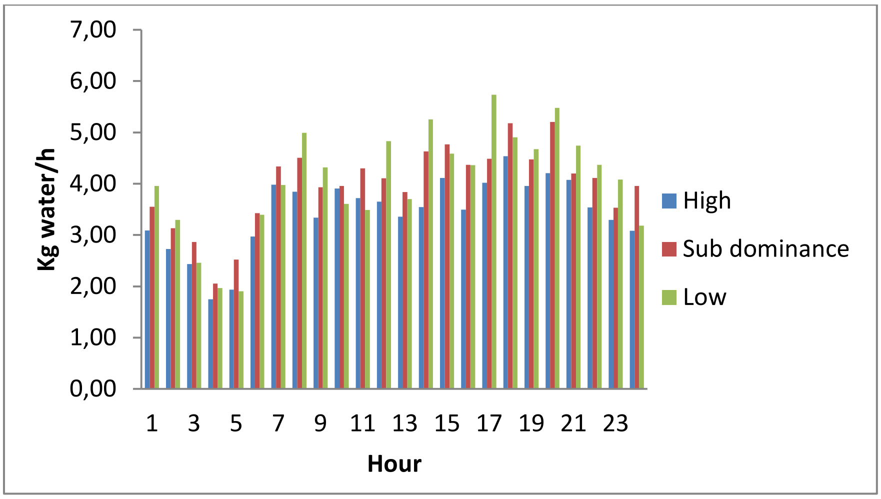

Figure 13. Daily water intake (kg/hour) for cows of different rank, n= 37.

There was a numerical difference between cows of different parity regarding the number of registration/day, duration of each registration and daily drinking water intake. Parity 3 cows drank more around hour 4, 7-10, 14, 16-20 and 22-23 of the day (Figure 14). In a study, they could see that older cows are often higher ranked than younger cows (Lindberg, 2001). A significant correlation between high rank and weight in cows was found by Andersson (1987) and one explanation was that the cows with higher rank could consume more of the feed than the low ranked cows. Additionally, from the observation period, the newly calved heifers that were taken in the group had it hard in the beginning because they were chased away from the water bowl and the feed stations before they knew how to act in the group. This is a normal thing that happens in the commercial farms when the newly calved cows enter the group.

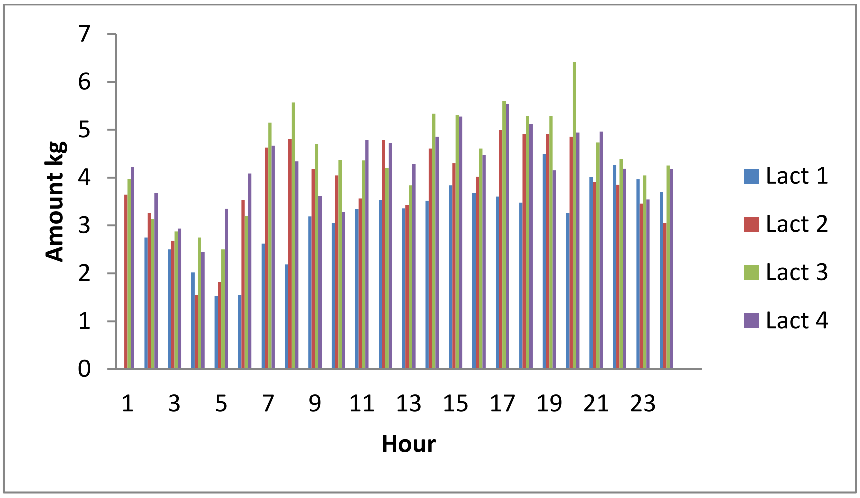

Figure 14. Daily water intake (kg/hour) day for cows of different lactation number, n=37.

8.4 Drinking behaviour and whether water accessibility was limiting water intake

The 37 cows in the study had 10 to 60 registrations during a day and that could be explained by that they were not concentrated when they were drinking (Figure15). The total drinking duration/day was between 7.4-69.0 min (Figure 16) and a maximum duration of 2.2-17.5 min/registration (Figure 17). Long drinking duration occurred among both high and low ranked cows, while a high ranked cow had the shortest drinking duration (Figure 17). The drinking rate was 1.2 – 12.5 kg/min (Figure 18). The cow that drank 12.5 kg/min was a sub-dominant cow and in parity 3. The cow's total drinking duration was only 7.4 min/day. In the tie-stall study of Dado & Allen (1994), the cows had 14 drinking bouts/day with 6.4 kg each and the duration was 18.5 min/day drinking. However, a bout is several registrations and that can explain why our study had more registrations than Dado & Allen's study. Cows in a free stall visited the water station 7.6 ± 3.4 times/day (Cardot et al., 2008).

The average duration/registration was 6.5 min for low ranked cows and 7.5 min for the sub-dominant cows. The lowest ranked cows had 24.8 registered visits/day and the sub-dominance cows had 28.3 registered visits/day. The maximum water intake/registration was largest for low ranked cows and smallest for high ranked cows.

It was noticed that many of the cows coughed after they had drunk or between the registrations during the observation. An explanation could be that they drank too fast due to stress or due to too fast water flow.

There were many cows in the feed area when the feed wagon came with feed, especially during the morning when sometimes there was no feed in the boxes. After the cows had eaten they drank water and when there were many cows at the same time in the area, some of the cows needed to wait to drink and some drank and walked to next water bowl, drank and continued to a third water bowl. Some of the cows could do this for approximately 30 min before they went to the resting area or milking robot. Due to that many cows wanted to drink at the same time, those that drank first were those with higher rank and first and second parity cows who wanted to be higher in rank and therefore tried to drink but were chased away from higher ranked cows. Other studies could also see that the drinking occurred around milking and feeding, probably because the cows was dehydrated after milking, and drinking and feeding are generally synchronized behaviors (Nocek and Braun, Cardot et al., 2008 & Osborne et al., 2002).

There was no significant difference between the breeds ($p > 0.10$) regarding number of registration per day. Number of registration/day for SRB was 26 and for SH 27.6. For the maximum duration/registration SRB had 7.5 min/registration and SH 6.8 registration/min. The average water intake/registration was 3.6 kg for SRB and 3.9 kg for SH. In this study there was not a wide difference between the breed.

There was a main difference among cows regarding both the number of registrations/day and the duration/registration. This can indicate stress for some of the cows and may be caused by the crowding of many cows in the feeding area, where most water bowls were located, during the hours when new silage was distributed to the silage feeding stations.

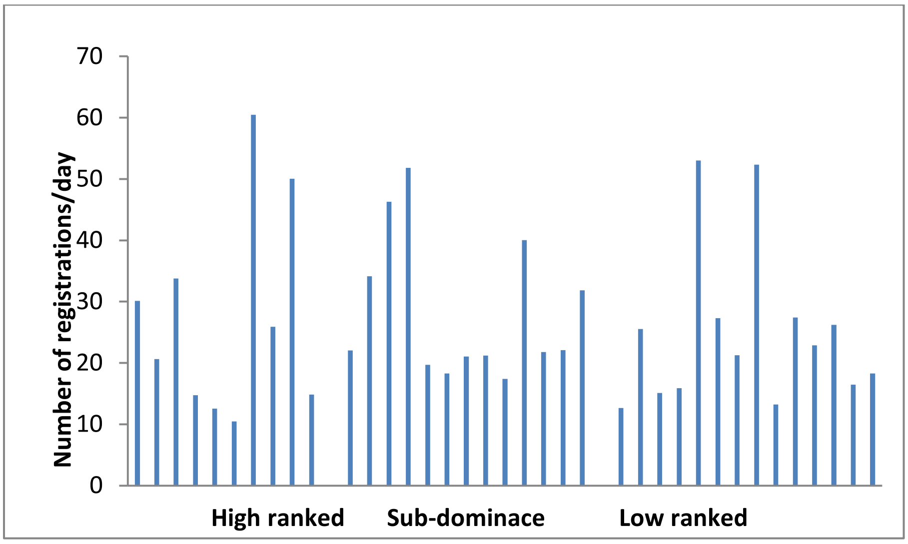

Figure 15. Number of water bowl registrations/day for the 37 cows in rank groups used in the final evaluation.

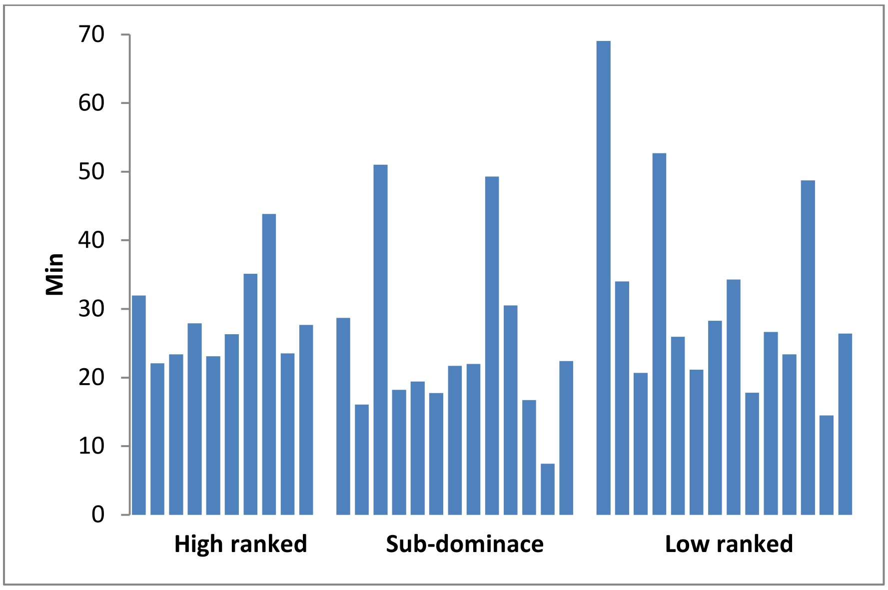

Figure 16. Total drinking duration per cow and day for the 37 cows and rank groups used in the final evaluation.

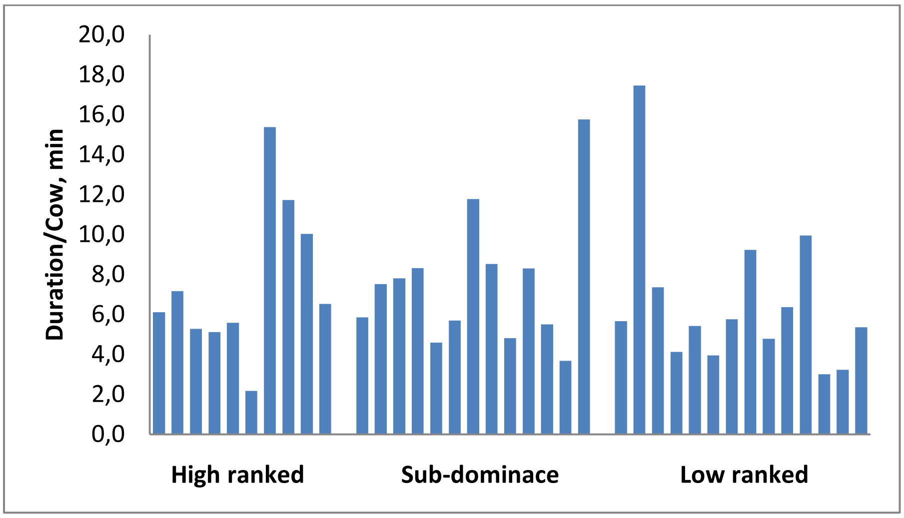

Figure 17. Maximum duration of a drinking water registration for the 37 cows and rank groups used in the final evaluation.

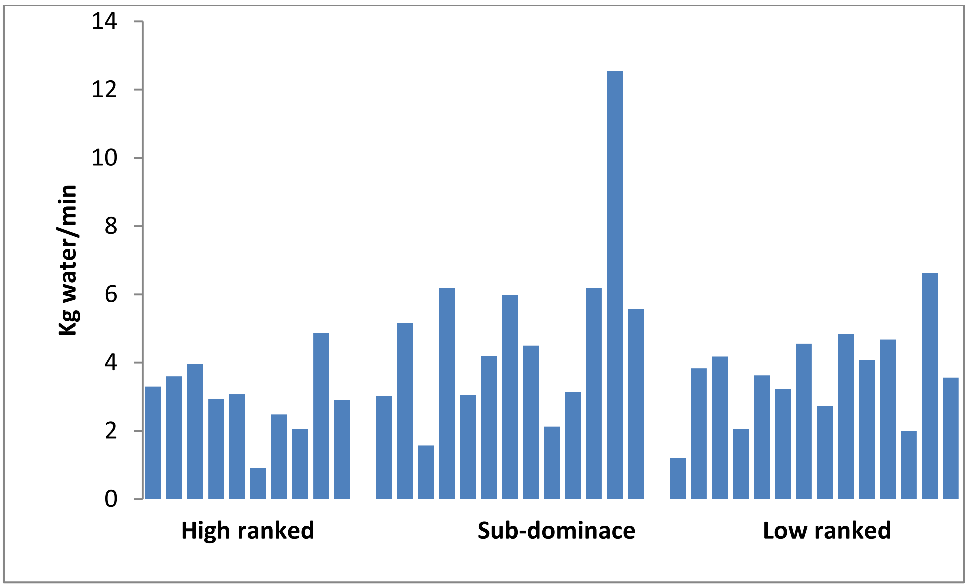

Figure 18. Drinking rate (kg water/ min) for the 37 cows and rank groups used in the final evaluation.

The cow in lactation number 6 was taken out because she was only one. The cows in lactation number 4 had least drinking registration/day and also, the maximum duration was lowest for lactation 4 (Figure 20). The number of registrations increased with the first three lactations, but cows with lactation number 4 had the lowest number of registrations/day. Usually, the milk yield increase during the first three lactations and this could explain the higher water intake and also higher feed consumption. Moreover, figure 19 shows the average weight from the different party compared to figure 20 that shows the number of registration/day, an increase in weight and lactations number can be compared with higher lactation number gives higher registrations/day for the cows.

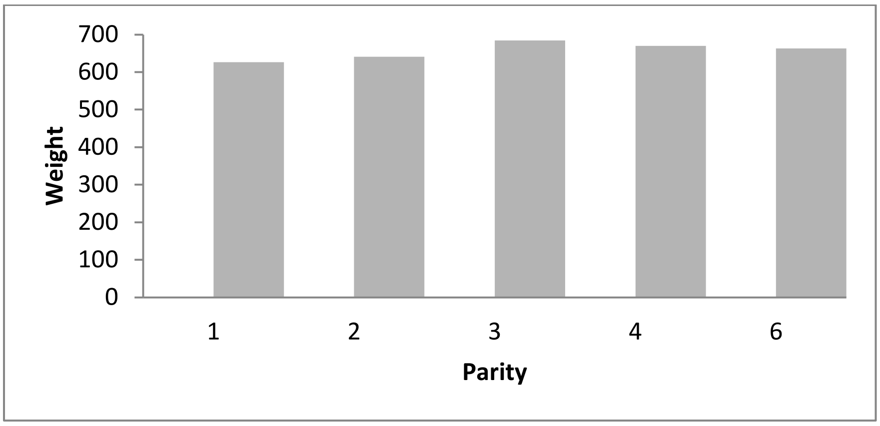

Figure 19. The average weight for cows of different parity

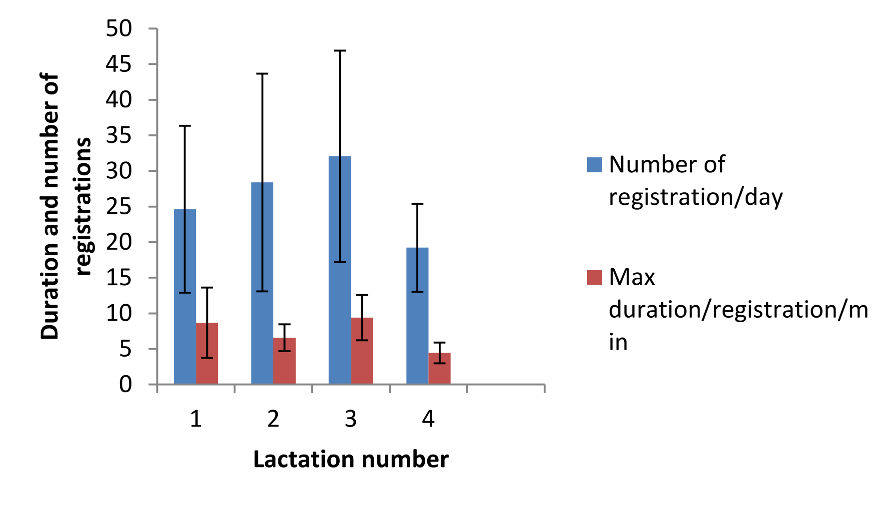

Figure 20. Average duration and average number of registration for cows of different lactation number (n= 36). Bars indicate standard deviation. Effect of lactation number was significant for max duration ($p < 0.02$) but not for number of registrations ($p > 0.10$)

Table 6. The difference rank order for the parity.

Rank	Parity 1	Parity 2	Parity 3	Parity 4
1	2	4	2	2
2	3	5	3	2
3	4	5	3	1

Cows with lactation number 4 had shortest drinking duration and smallest number of registrations/day and the only cow with lactation number 6 had the (numerically) longest duration. The cow with lactation number 6 also had the numerically highest water intake/registration while cows with lactation number 2 had the numerically smallest water intake/registration (Figure 21). In a study, they could see that the water intake for a lately calved cow improved with 67% from the week before calving to the week after calving with a further enlarge of 27% from the week after calving to the third week of lactation (Osborne et al., 2002).

Heavy cows had numerically more registrations/day and longer duration/registration and significantly higher maximum water intake/registration than light cows (Figure 22). Meyer et al. (2004) also observed that water intake increased with increased body weight. This could be explained by that heavier cows need to eat more and because of that drink and have more drinking bouts/day to drink enough water to their requirement.

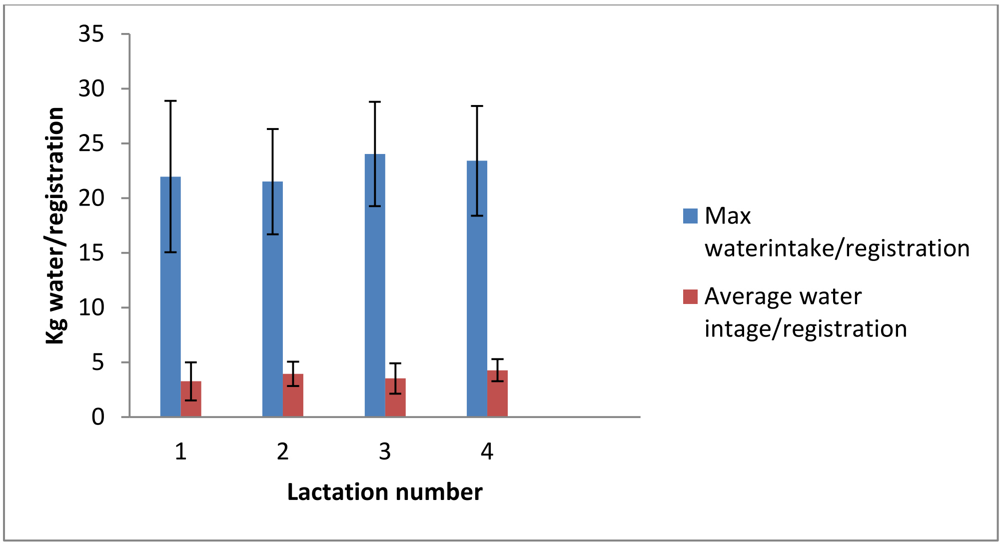

Figure 21. Max water intake and average water intake of each drinking registration for cows of different lactation number (n=36). Bars indicate standard deviation. Effect of lactation number was not significant (p > 0.10)

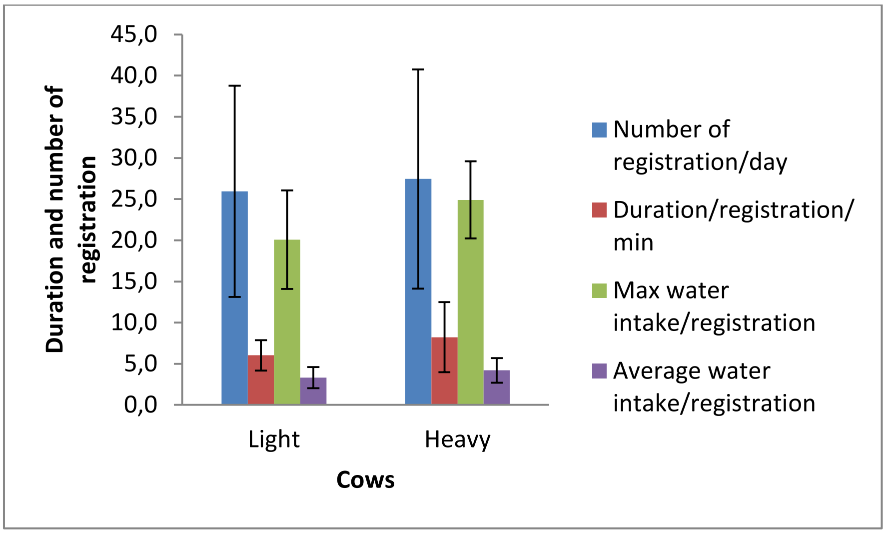

Figure 22. Average duration and average number of registration and also, average max water intake and average water intake of each registration for cows of different body weight. Light cows weighed 534-652 and heavy cows weighed 657-806 kg. Bars indicate standard deviation. Effect of body weight was significant for max water intake/registration (p = 0.02) but not for other variables in the graph.

9 Conclusion

The observational study of the prototype system for automated recording of drinking water intake in the VMS barn at Funbo-Lövsta research Centre showed that many cows were not correctly identified when drinking. Of all the 88 cows only 42% cows were correctly identified during the period. After rebuilding the system with a new antenna placement, registered water intake increased for 21 of the 37 cows, indicating a more reliable identification of the cows. Because of poor transponder identification during the main study, only 37 cows could be used for addressing the other aims of the study.

The water intake was positive correlated to milk yield, DMI, total water intake, potassium intake, sodium intake, Na intake and nitrogen intake in the feed. The ration of DM concentration was not correlated to the drinking water intake. The individual drinking water intake was 23.9-130.4 kg/day and the total water intake was 55.9-203.5 kg/day. When several factors were entered into the stepwise regression, only milk yield and K intake became significant.

From the observations, the 37 cows drank 56 % of their total daily water intake between 8:00-20:00. The rank orders in a loose house system affect the drinking behaviour. The cows in the observation almost always drank water after they had been milked. Heavy cows, SH cows, lower ranked cows and parity 3 cows were cow categories that drank numerically most water/hour during a day. Older cows had often higher rank than younger cows.

The cows had 10-60 registration during a day and 7.4-69.0 min total drinking duration. High ranked cows had the shortest drinking duration. There was a main difference among cows regarding both the number of registrations/day and the duration/registration. This can indicate stress for some of the cows and may be caused by the crowding of many cows in the feeding area, where most water bowls were located, during the hours when new silage was distributed to the silage feeding stations. There were 7 water bowls and some of the cows had favourite water bowls which they only drank from. It could not be seen that the water bowl accessibility was limiting the water intake.

10 References

Andersson, M.,(1985). Effects of drinking water temperatures on water intake and milk yield of tied-up dairy cows. *Livestock prodction science,* 12, 329-338.

Andersson, M., (1987). Effects of number and location of water bowls and social rank on drinking behaviour and performance of loose-housed dairy cows. *Applied animal behaviour science,* 17, 19-31.

Andersson, M. & Lindgren, K., (1984). *Effects of access to drinking water at feeding and social rank on performance and behaviour of tied-up dairy cows,* Uppsala : Swedish university of agricultural sciences.

Andrew, S., Erdman, R. & Waldo, D., (1995). Prediction of body composition of dairy cows at three physiological stages from deuterium oxide and urea dilution. *Journal of dairy science* , 78, 1083-1095.

Araujo Dias Coimbra, P., Pinheiro Machado Filho, L. C. & Hötzel, M. J., (2012). Effects of social dominance, water trough location and shade availability on drinking beahiour of cows on pasture. *Applied animal behaviour science,* 139, 175-182.

Arias, R. & Mader, T., (2011). Environmental factors affecting daily water intake on cattle finished in feedlots. *Journal of animal science*, 89, 245-251.

Appleby, M.C. & Manson, F.J., (1990). Spacing of dairy cows at a food trough. *Applied animal behaviour science*, 26, 69-81.

Barr, G., Dickson, D., Johnson, L. & Wieckert, D., (1970). Social dominance and temperament of holstein cows. *Journal of dairy science,* 53(7), 904-907.

Beede, D. K. (2006). Evaluation of water quality and nutrition for dairy cattle. (red.), *High plains dairy conf*. (ss. 129–154) Albuquerque, NM.

Broom, D. M. & Ferguson Fraser, A., (1997). *Farm animal behaviour and welfare.* 3 red. Wallingford: CAB International.

Burgos, M., Senn, M., Sutter, F., Kreuzer, M. & Langhans, W., (2001). Effect of water restriction on feeding and metabolism in dairy cows. *Am journal physiol regulatory integrative comp Physiol,* 280, 418-427.

Cardot, V., Le Roux, Y. & Jurjanz, S., (2008). Drinking behavior of lactating dairy cows and prediction of their water intake. *Journal of dairy science,* 91, 2257-2264.

Castle, M. E. & Thomas, T. P., (1975). The water intake of British Friesian cows on rations containing various forages. *Animal production,* 20, 181-189.

Collis, K., (1976). An investigation of factors related to the dominance order of a herd of dairy cows of similar age and breed. *Applied animal ethology,* 2, 167-173.

Dado, G. & Allen, M., (1994). Variation in a relationships among feeding, chewing and drinking variables for lactating dairy cows. *Journal of dairy science,* 77, 132-144.

Dahlborn, K., Akerlind, M. & Gustafsson, G., (1998). Water intake by dairy cows selected for high or low milk-fat percentage when fed two forage to concentrate ratios with hay or silage. *Swedish Journal of Agricultural Research* 28: 167-176.

Davis, C.L., Murphy, M.R. & Woodford, S.T., (1984). Water dynamics of dairy cattle as affected by initiation of lactation and feed intake. *Journal of dairy science*, 67, 2336-2343.

Fisher, L., Dinn, N. & Tait, R. &. S., (1994). Effect of level of dietary potassium on the absorption and excretion of calsium and magnesium by lactating dairy cows. *Canada journal of animal science,* 74, 503-509.

Friend, T. & Polan, C., (1974). Social rank, feeding beavio, and free stall utilization by dairy cattle. *Journal of dairy science,* 57(10), 1214-1220.

Hafez, E. S. E., (1969). *The behaviour of domestic animal.* 2 red. Bailliere, Tindall & Casse,l London.

Holter, J. & Urban, W., (1992). Water partitioning and intake prediction in dry and lactating holstein cows. *Journal of dairy science,* 75, 1472-1479.

Kramer, E., Stamer, E., Spilke, J., Thaller, G. & Krieter, J., (2009). Analysis of water intake and dry matter intake using different lactation curve models. *Journal of dairy science*, 92, 4072-4081.

Khelil-Arfa, H., Boudon, A., Maxin, G. & Faverdin, P., (2012). Prediction of water intake and excretion flows in Holstein dairy cows under thermoneutral conditions. *The animal consortium,* 10, 1662-1676.

Koichi, H., Sato, S. & Tarumizu, K., (1993). The influence of social factors on allogromming in cows. *Applied animal behaviour science*, 38, 235-244.

Kume, S., Nonaka, K., Oshita, T. & Kozakai, T., (2010). Evaluation of drinking water intake, feed water intaek and total water intake in dry and lactating cows fed silage. *Livestock science* , 128, 46-51.

Lanham, J. K., Coppock, C. E., Milam, K. Z., Labore, J. M., Nave, D. H., Stermer, R. A. & Brasington, C., (1986). Effects of drinking water temperature on physiological responses of lactating holstein cows in Summer. *Journal of dairy science,* 69(4), 1004-1012.

Lindberg, C. (2001). Social behaviour in farm animals. I: L. H. Keeling . (red), Oxon, UK: CABI Publishing Oxon, UK, 37-58.

Linn, J., Lukas, J. & Reneau, J., (2008). Water intake and dry matter intake changes as a fedding management tool and indicator of health and estrus status in dairy cows. *Journal of dairy science,* 91, 3385-3394.

Little, W., Sansom, B., Manston, M. & Allen, W., (1976). Effects of restricting the water intake of dairy cows upon their milk yiled, body weight and blood composition. *Animal production*, 22(03), 329-339.

Little, W. & Shaw, S.R., (1978). A note on the individuality of the intake of drinking water by dairy cows. *Animal Production,* 26, 225-227.

Martin, D., (1985). Water and minerlas. I: D.W. Martin Jr., P.A. Mayes, V.W. Rodwell, D.K. Granner Martin., red. *Harper's review of biochemistry.* Los Altos, CA: Lange med, p. 650.

Metz, J.H.M. (1983). Food competition in cattle. I: S.H. Baxter, M.R. Baxter, and J.A.D. MacCormack (editors). (red), *Farm animal housing and welfare.* Boston : Martinus Nijhoff, 164-170.

Meyer, U., Everinghoff, M., Gädeken, D. & Flachowsky, G., (2004). Investigations on the water intake of lactating dairy cows. *Livestock production science,* 90, 117-121.

Miller, K. & Wood-Gush, D. G., (2010). Some effects of housing on the social behaviour of dairy cows. *Animal production,* 53(03), 271-278.

Morris, M. J. & Winchester, C., (1956). Water intake rates of cattle. *Journal of animal science,* 15, 722-740.

Muller, C. & Botha, J., (1994). Effect of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 1. Feed and water intake, milk production and milk composition. *South Africa journal animal science,* 24(2), 49-55.

Murphy, M., Davis, C. & McCoy, G., (1983). Factors affecting water comsumption by holstein cows in early lactation. *Journal of dairy science,* 66, 35-38.

Murphy, M. R., (1992). Water metabolism of dairy cattle. *Journal of dairy science,* 75, 326-333.

Nocek, J. & Braund, D., (1985). Effect of feeding frequency on diurnal dry matter and water consumption, liquid dilution rate, and milk yiled in first laktation. *Journal of dairy Science,* 68, 2238-2247.

National research council, (1996). I: *Nutrient requirements of beef cattle.* Washington D.C: National academy press, 80-82.

National research council, 2000. I: *Nutrient requirements of beef cattle.* Washington, D.C.: National academy press, 153.

National research counsil, (2001). I: *Nutrient requirement of dairy cattle.* Washington D.C: National academy press, 178-183.

Osborne, V., Leslie, K. & McBride, B., (2002). Effect of supplementing glucose in drinking water on the energy and nitrogen status of the transition dairy cow. *Canadian journal of animal science,* 82, 427-433.

Pinheiro Machado Filho, L. C., (2004). Designing better water troughs: dairy cows prefer and drink more from larger troughs. *Applied animal behaviour science,* 89, 185-193.

Reinhardt, V. & Reinhardt, A., (1981). Cohesive relationship in a cattle herd (Bos indicus). *Brill,* 77(3), 121-151.

Schein, M. W. & Fohrman, M. F., (1955). Social dominance relationships in a herd of dairy cattle. *The british journal of animal behaviour,* 3(2), 45-55.

Sjaastad, Ö., Sand, O. & Hove, K., (2010). *Physiology of Domestic Animals.* 2 nd edition red. Oslo: Scandinavian Veterinary Press.

Smith Thomas, H., (2009). *The cattle health handbook preventive care, diseases tretments & emergency procedures for promoting the well-being of your beef or dairy herd.* United states: Versa press.

Statens jordbruksverks föreskrifter och allmänna råd om djurhållning inom lantbruket. (2010). Jönköping. (SJVFS 2010:15).

Strand, T., (1997). *Faktorer som påverkar vattenintaget hos mjölkkor och hästar,* Uppsala: Institutionen för djurfysologi.

Spek, J. W., Bannink, A., Gort, G., Hendriks, W. H. & Dijkstra, J., (2012). Effect of sodium chloride intake on urine volume, urinary urea excretion, and milk urea concentration in lactating dairy cattle. *Journal of dairy science* 95, 7288-7298.

Stricklin, W., (1976). Spatial and temporal dimensions of bovine behaviour and social organisation. *Dissertation abstract international,* 7, 31-39.

Sykes, J., 1995. *Animals and fowl and water.* Yearbook of agriculture.

11 Appendix

Table 7. Calculated mineral content in the silage for all days in the study.

		Total content of minerals and N in the fed silage, g/kg DM. Calculated from mixer and feed conveyor loggers					
DM	Day	Ca	P	Na	Mg	S	K
30,4	2014-09-22	7.6	3.8	6.2	3.2	2.6	34.2
30,4	2014-09-23	8.7	3.8	9.2	4.0	2.7	34.2
30,4	2014-09-24	9.3	3.9	10.9	4.4	2.7	34.2
30,4	2014-09-25	6.8	3.7	4.0	2.6	2.5	34.2
30,4	2014-09-26	6.6	3.7	3.4	2.5	2.5	34.2
30,4	2014-09-27	5.7	3.7	0.7	1.8	2.4	34.2
30,4	2014-09-28	10.8	4.0	15.4	5.5	2.9	34.2
30,4	2014-09-29	9.2	3.9	10.7	4.3	2.7	34.2
30,4	2014-09-30	6.6	3.7	3.2	2.4	2.5	34.2
30,4	2014-10-01	5.7	3.7	0.7	1.8	2.4	34.2
		5.7	3.7	0.7	1.8	2.4	34.2
30,4	2014-10-03	8.1	3.8	7.5	3.5	2.6	34.2
30,4	2014-10-04	11.3	4.0	16.6	5.8	2.9	34.2
30,4	2014-10-05	5.7	3.7	0.7	1.8	2.4	34.2
30,1	2014-10-06	7.7	3.4	4.4	2.9	2.5	32.8
30,1	2014-10-07	10.0	3.5	10.9	4.5	2.7	32.8
30,1	2014-10-08	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-09	11.4	3.6	14.8	5.5	2.9	32.8
30,1	2014-10-10	11.3	3.6	14.4	5.4	2.8	32.8
30,1	2014-10-11	11.4	3.6	14.8	5.5	2.9	32.8
30,1	2014-10-12	14.4	3.8	23.2	7.7	3.1	32.8
30,1	2014-10-13	9.3	3.5	8.9	4.0	2.7	32.8
30,1	2014-10-14	9.4	3.5	9.1	4.1	2.7	32.8
30,1	2014-10-15	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-16	9.9	3.5	10.7	4.5	2.7	32.8
30,1	2014-10-17	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-18	11.4	3.6	14.8	5.5	2.9	32.8
30,1	2014-10-19	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-20	7.8	3.4	4.6	2.9	2.5	3.8
30,1	2014-10-21	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-22	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-23	12.4	3.6	17.8	6.3	3.0	32.8
30,1	2014-10-24	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-25	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-26	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-27	8.0	3.4	5.2	3.1	2.5	32.8

30,1	2014-10-28	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-29	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-30	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-10-31	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-11-01	6.4	3.3	0.6	1.9	2.4	32.8
30,1	2014-11-02	8.5	3.4	6.7	3.5	2.6	32.8
30,1	2014-11-03	9.9	3.5	10.5	4.4	2.7	32.8
30,4	2014-11-04	14.0	3.7	22.8	7.5	3.1	32.6
30,4	2014-11-05	6.2	3.2	0.6	1.8	2.4	32.6
30,4	2014-11-06	17.5	3.9	32.7	10.1	3.4	32.6
30,4	2014-11-07	9.7	3.4	11.0	4.4	2.7	32.3
30,4	2014-11-08	11.3	3.5	15.6	5.6	2.8	32.3
30,4	2014-11-09	11.1	3.5	14.9	5.4	2.8	32.3
29,1	2014-11-10	12.0	3.6	17.4	6.1	2.9	32.3
29,1	2014-11-11	9.0	3.4	9.0	3.9	2.6	32.3
29,1	2014-11-12	8.0	3.3	6.1	3.2	2.5	32.3
29,1	2014-11-13	7.1	3.3	3.7	2.6	2.4	32.3
29,1	2014-11-14	6.1	3.2	0.7	1.8	2.3	32.3
29,1	2014-11-15	6.1	3.2	0.7	1.8	2.3	32.3
29,1	2014-11-16	6.1	3.2	0.7	1.8	2.3	32.3

Table 8. The minerals content from the concentrate from the average content during the days under the period.

	DM	Ca g/kg ts	K g/kg ts	P g/kg ts	Mg g/kg ts	Na g/kg ts	S g/kg ts	Aska	Rp g/kg ts
5575	89.1	9.3	10.0	6.7	4.6	3.7	3.9	68.4	186.1
5576	88.6	11.9	13.6	7.9	5.2	4.0	5.0	88.7	284.4

Table 9. The water intake/registration for all the 37 cows.

Cows	Max. Kg	Averg. Kg	Min. Kg	Cows	Max. Kg	Averg. Kg	Min. Kg
5	21.2	4.3	0.12	**990**	29.1	8.6	0.08
10	31.8	6.5	0.08	**1389**	27.8	10.3	0.08
17	20.7	4	012	**1427**	1.1	2.3	0.12
24	31.7	5.4	0.08	**1505**	27.1	6.1	0.12
26	24.6	4.8	0.08	**1560**	15.9	1.8	0.08
32	21.1	4.4	012	**1563**	27.6	1.8	0.12
33	27.4	4.6	0.12	**1565**	24.5	4.1	0.08
37	20	2.9	0.08	**1617**	27.2	3.2	0.08
40	20.6	6.9	0.12	**1619**	27.5	3.2	0.08
94	29.3	6	0.08	**1621**	29.9	7.5	0.08
139	20	3.2	0.08	**1624**	26.6	6.7	0.12

140	28.1	9.3	0.08	**1661**	20.3	4	0.08
142	14.4	2.5	0.08	**1672**	28.2	5.3	0.12
143	18.6	4	0.08	**1694**	22.3	7.5	0.08
154	14.1	3.4	0.08	**5393**	22.2	7.3	0.12
156	22.8	5.9	0.08	**6475**	32.5	5.1	0.08
163	21.5	6	0.02	**6535**	26.8	9	0.08
973	32.1	9.1	0.08	**6546**	26.9	9	0.12
979	18.5	2.8	0.08				

Table 10. The win and losses for the cows around the water bowls.

Cows	Win	Lose	Equale	Cows	Win	Lose	Equale
3	1	2	0	**1389**	0	1	0
4	7	7	0	**1427**	3	0	0
5	1	2	0	**1505**	1	6	0
9	0	0	0	**1513**	0	1	0
10	4	4	0	**1527**	3	0	0
14	4	3	0	**1530**	1	0	0
17	4	8	0	**1538**	2	2	0
24	9	3	2	**1545**	8	2	0
26	4	2	0	**1552**	0	0	0
32	6	3	0	**1558**	0	2	0
33	0	5	1	**1560**	11	1	0
35	0	0	0	**1563**	1	2	0
36	0	0	0	**1565**	2	1	0
37	3	4	1	**1591**	2	0	0
40	10	2	0	**1604**	1	0	3
50	5	0	0	**1612**	0	0	0
52	2	3	0	**1617**	3	0	0
55	4	2	1	**1619**	2	0	0
61	0	2	0	**1621**	6	2	0
94	1	0	0	**1624**	2	2	0
124	3	1	0	**1629**	4	1	0
133	2	0	0	**1635**	4	2	0
137	3	2	0	**1661**	3	1	0
139	1	0	1	**1666**	1	0	0
140	0	0	0	**1672**	1	0	1
142	1	12	0	**1675**	4	5	0
143	1	1	0	**1677**	0	0	0
147	1	2	0	**1694**	6	7	0
154	10	3	0	**1695**	9	8	0
155	2	2	0	**1697**	1	0	0
156	4	1	0	**5393**	1	4	1
160	8	3	0	**5404**	0	2	0

163	6	1	0	**5406**	3	2	0
168	0	3	0	**6475**	2	3	0
183	2	5	0	**6506**	1	9	0
207	0	0	0	**6510**	0	0	0
964	1	3	0	**6534**	0	4	1
973	2	2	0	**6535**	1	3	0
979	1	3	0	**6536**	1	5	0
982	2	0	0	**6539**	1	6	0
990	2	4	0	**6541**	3	0	0
991	2	2	1	**6542**	2	5	0
992	3	4	1	**6543**	1	2	1
1007	1	1	0	**6546**	2	2	0
1382	3	0	0				

Table 11. The observation journal used to see if the right cow registered at the same time.

Observation day: Time change for the water bowls:
Temperature:

Time	Cow	Water bowl	Behaviour