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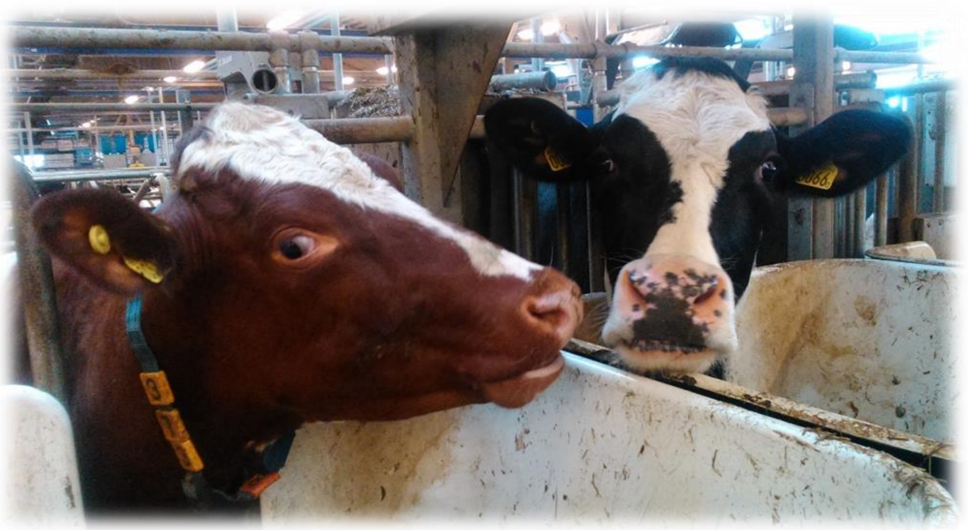
The effects of feeding low levels of concentrate to early lactating dairy cows

Adriana Llopis Palomares



Animal Nutrition and Management
Master´s thesis • 30 hec

Uppsala, Sweden 2016

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Credits: 30
Level: Second cycle, A2E
Course title: Degree Project in Animal Science
Course code: EX0551
Programme/education: Erasmus Mundus Masters Courses (Food of Life)

Place of publication: Uppsala, Sweden
Year of publication: 2016
Cover picture: Adriana Llopis Palomares
Title of series: Degree project / Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management
Number of part of series: 584
Online publication: http://stud.epsilon.slu.se

Keywords: early lactation, dairy cows, low concentrate, milk production, energy balance

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SUMMARY

Current concerns about sustainable agriculture and the needs to reduce the use of concentrates has led researchers to investigate new approaches in feeding systems for dairy cows. The beginning of lactation is a threatening episode in cow's life. The increasing nutrient demands for milk production often overcomes their capacity to ingest enough feed to supply their nutrient demands. In addition, exist other factors besides the physical constrains that may influence intake in cattle i.e. metabolic changes, diet composition or animal characteristics. The use of concentrates, which are rich in energy, seem to be crucial to compensate the energetic deficiencies in this lactation stage. Therefore, the hypothesis of this experiment was that cows fed with low concentrate levels during the first six weeks of lactation would have higher silage intake but lower milk yield and a more negative energy balance. Thirty-one cows were used in the experiment during their first six weeks of lactation. The herd comprised cows with different lactation number and two breeds, Swedish Holstein and Swedish Red. Two diets with different amounts of concentrate and *ad libitum* silage were offered. The low concentrate group (LC) received 4-5Kg of concentrate depending on lactation number and the High concentrate group (HC) received 14-15Kg. The concentrate was based on by-products with the peculiarity of being rich in neutral detergent fibre (NDF) (88% DM, 179g/Kg DM CP, 67.4 g/Kg DM Fat, 328 g/Kg DM NDF, 53.6 g/Kg DM Ash, 32.5 g/Kg DM Starch and 13.2 MJ/Kg DM ME). The silage used was clover-grass silage with low content in NDF and highly digestible (36.5% DM of fresh matter, 80% OMD, 138g/Kg DM CP, 391g/Kg DM NDF, 83g/Kg DM Ash, 11.7MJ/Kg DM ME and pH=4.3). All cow were milked twice daily in an Automatic Milking Rotary (AMR) system. Silage and concentrate intakes, milk yield, body weight (BW), and camera body condition score (BCS) were recorded on daily basis. Visual BCS and milk sampling for composition analysis were measured the second, fourth and sixth week of lactation for each cow. From the data collected, energy corrected milk (ECM) and energy balance (EB) were calculated. The effect of treatment was not significant for total dry matter intake (DMI), total metabolizable energy (ME) intake, energy corrected milk (ECM), energy balance (EB), and BCS. Silage intake was significantly higher within LC group. Effects of parity and breed were statistically significant for all the parameters measured except for the effect of breed and lactation number on energy balance. In conclusion, dairy cows fed with low concentrate diets during early lactation could compensate their energetic requirements for both body maintenance and milk production by eating more silage of high digestibility.

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1. BACKGROUND

1.1 Intake regulation in the Transition period

Parturition is an event of the animal life, which the organism has been preparing from the conception date. Mammals have evolved in favour of a successful rearing of their offspring. Hence, during late pregnancy and lactation, physiological mechanisms have been developed in order to lead nutrient partitioning towards milk synthesis. This generates an increase on energetic demands for the animals and in consequence inhibit their reproductive system until the recovery of the energetic deficiencies. In late gestation, mammals experience a decline in dry matter intake that reaches its lowest point at parturition day. The endocrine system, responsible of all the hormonal changes in the body, orchestrates the functioning of these mechanisms and accompanying to these changes, animals start to mobilise fat body reserves (Bauman & Currie, 1980). These events are especially particular in dairy cattle. After parturition, energetic demands towards milk synthesis increase drastically whereas the rise in intake is not proportional to the energetic demands. Hence, genetic selection has led to a prolongation of negative energy balance threatening the health status of the cow (Ingvartsen & Andersen, 2000).

1.1.1 Endocrine regulation

The ovaries and the placenta secrete progesterone during pregnancy. Progesterone is the responsible to maintain pregnancy but also is involved in growth and development of the mammary gland and inhibition of lactogenesis. It remains in high concentrations during the whole pregnancy upon time of parturition when it falls drastically (Sjaastad, et al., 2010). Drop in progesterone serves as a signal to increase the differentiation rate of mammary gland cells and consequently acquire the ability to synthetize milk components by the mammary gland (Sjaastad, et al., 2010).

A few days before parturition, other hormones start to appear on scene, there is an increase on plasma concentration of oestrogen and corticosteroids (Ingvartsen & Andersen, 2000). Their function is to induce lactation by stimulating the secretion of prolactin from the anterior pituitary. In addition, Green, et al.(1994) and Grummer, et al. (1990), proved the negative correlation between feed intake and β-17-estradiol in ewes and cows in late gestation, respectively. On the other hand, stress hormones are also associated with inhibition of feed intake (Ingvartsen & Andersen, 2000)

At parturition, there is a peak of prolactin and somatotropin (GH). Oestrogen and prolactin have a synergistic effect promoting cell differentiation of the mammary gland. Prolactin also influences the metabolism of the adipose tissue towards milk synthesis (Szczesnaa, et al., 2011), and stimulates the hypertrophy of the gastrointestinal tract in order to increase the absorptive capacity of nutrients (Bauman & Currie, 1980). GH is responsible to maintain lactation (galactopoesis). Somatotropin also influences the metabolism of both adipose tissue and liver. It stimulates lipolysis in the adipose tissue and gluconeogenesis in the liver, increasing plasma concentrations of non-esterified fatty acids (NEFA) and glycerol. At the same time, it inhibits lipogenesis in the adipocytes by making the tissue refractory to the effects of insulin in order to favour nutrient uptake by the mammary gland (Bell, 1995). GH also stimulates the secretion of insulin-like growth factor 1 (IGF-1) in the liver, which acts as mediator of the effects of GH in a wide variety of cell types. IGF-1 also acts a regulator of secretion of GH through a negative feedback loop. In late pregnancy the dip on DMI down-regulates the expression of GH receptor 1A (GHR 1A) in the liver. Therefore circulating GH cannot bind to the receptor and expression of IGF-1 decreases. The depletion of IGF-1 in blood enhances the secretion of somatotropin increasing nutrients partition towards milk production. The increase in intake in early lactation restores the expression of GHR 1A and nutrient portioning in the liver is rehabilitated. The level of uncoupling of this somatotropic axis in early lactation will influence the capacity of milk synthesis and increase the predisposition to suffer fatty liver or ketosis (Lucy, et al., 2001). As already mentioned, somatotropin and prolactin decrease the affinity of the receptors to insulin. Together with the decreased levels of circulating insulin in late pregnancy contributes to slow down the nutrients uptake and consequently stimulate fat mobilisation of body reserves (Bell, 1995). Another hormone involved is leptin, which is secreted by the adipose tissue. Leptin has satiating effects. In early lactation, negative energy balance reduces the synthesis of leptin. This fall in leptin is processed by the central nervous system and acts increasing appetite (Nowroozi-Asl, et al., 2016).

Intake regulation is integrated inside the limbic systems of the central nervous system. According to Miner, et al. (1990), neuropeptide Y (NPY) has an orexigenic effect in ruminants. Injections of NPY at the lateral ventricle of the brain resulted in greater intake for ewes. A proteomic study of the cerebrospinal fluid conducted in dairy cows showed that the concentration of pro-neuropeptide Y decreased after parturition possibly due to an increase cleavage of the pro-neuropeptide into its active form (NPY) and this could be linked with DMI regulation (Kuhla, et al., 2014).

1.1.2 Effects of nutrient metabolites on intake regulation

Intake decreases during late pregnancy generating a great mobilisation of body fat in order to meet the increasing energetic demands of the cow. Although it has not been fully demonstrated, is likely that non-esterified fatty acids (NEFA), and ketone bodies have an additional effect depressing DMI. If levels of NEFA continue to be high during early lactation, intake will not recover according to the increasing energetic demands. Thus, cows would prolong their negative energy balance and consequently be more prone to develop metabolic disorders.

Non-esterified fatty acids are the metabolites released to blood stream after lipolysis from the adipose tissue. There is a high correlation between fat mobilization and plasma concentrations of NEFA. Hence, they are good indicators of fat mobilisation. Once NEFA reach the blood stream either go to the mammary gland and in turn, incorporated in milk triglycerides, or are degraded in the liver via β-oxidation (Sjaastad, et al., 2010). There is an unproven hypothesis that fatty acid oxidation by the hepatocytes generate intake inhibitory signals mediated by vagal afferents to the central nervous system (Langhans, 1996). Hepatocytes have limited capacity to degrade NEFA via citric acid cycle. Instead, some acetyl-CoA is used to synthetize ketone bodies. These are released again into the blood stream and serve as an energy source by other tissues (Sjaastad, et al., 2010). In a study conducted in rats by Arase, et al.(1988), showed that chronic infusion of 3-hydroxybutyrate (3-OHB) in the brain decreased intake and body weight of the animals. Therefore, might be that ketone body β-hydroxybutyric acid (BHBA) has a central regulating effect in intake.

1.2 Role of diet composition on Intake and Milk production

Ruminants are forestomach fermenters. This means that nutrient breakdown is done by fermentation by the ruminal microflora. Carbohydrates, proteins and fat are the principal nutrients ingested in a ruminant diet. Dietary carbohydrates (cellulose, hemicellulose, pectin, soluble sugars and starch) are used as substrate of fermentation for ruminal microorganisms. The resulting compounds are volatile fatty acids (VFA) i.e. acetate, butyrate and propionate, which serve as an energy source for the body tissues including the mammary gland. Dietary fat only accounts for a small proportion of nutrient intake since the type of diet of ruminants usually is not rich in fat. Furthermore, they do small contribution in rumen fermentation since they are barely fermented (France & Dijkstra, 2005). Rumen hydrolases proteins to amino acids. The vast majority serves as substrate for microbial synthesis, which in turn is responsible to ferment carbohydrates into VFA. The portion of proteins that is not used by microorganisms passes directly to the abomasum and small intestine. Rumen Degraded Proteins (RDP) are the proteins fermented inside the rumen and non-degraded or bypass protein (UDP) is the portion that escapes fermentation. Microbial protein (MP) are the resulting proteins and other nitrogenous compounds from microbial fermentation. MP together with the bypass proteins are the major source of essential and non-essential amino acids for the host (Nolan & Dobos, 2005).

1.2.1 Neutral Detergent Fibre (NDF) and Non-fibrous Carbohydrates (NFC)

Neutral Detergent Fibre (NDF) constitutes fibrous compounds in plants i.e. cellulose, hemicellulose and lignin. On the other hand, Non-Fibrous Carbohydrates are simple sugars i.e. starch, glucose, sucrose and fructose.

There is a generalized assumption that diets containing higher amounts of NDF contribute to rumen fill and are poorer in metabolizable energy. From this reasoning emerges the idea that NDF has negative effects on DMI and consequently in milk production. Rabelo, et al. (2003), observed that high levels of NDF in the diet affected negatively DMI and lactation performance, especially in multiparous cows. During late pregnancy, cows had significantly lower DMI when fed a diet with high NDF content (40% NDF and 38%NFC in the low-density diet versus 32% NDF and 44% NFC of the high-density diet). However, these results did not carry over significantly in the subsequent lactation. Nonetheless, they claimed that an early lactation diet containing high amounts of NFC was beneficial for energy balance and lactation performance. The only significant effect observed post-partum was that multiparous cows had greater DMI and milk production irrespective of treatment. Notwithstanding, an earlier study conducted by Dhiman, et al.

(1995), concluded that the energy content in the diet may be even more important than the levels of NDF. In this study, different levels of alfalfa silage were offered to dairy cattle during a whole lactation period. Content of NDF increased linearly as more alfalfa silage was included in the diets. Moreover, the results showed that DMI and dry matter digestibility decreased significantly as the proportion of alfalfa silage increased, deriving to a greater rumen fill, which in turn, impaired DMI. However, the correlation between DMI and DM digestibility was not significant. Thereby, the significant effect of poor digestibility was dependent on the silage quality. Diets containing more alfalfa were poorer in energy than diets with more concentrate and thus, energy intake diminished. This fact was the causative of a prolonged negative energy balance during early lactation and consequently affected milk production.

Studies conducted in grazing systems have shown that not necessarily the amount of NDF can be detrimental for DMI and milk production. A retrospective study performed by Kolver & de Veth (2002), showed that fresh pasture grazing cows were able to maintain a low ruminal pH (pH= 5.8 – 6.2), despite the high levels of NDF (40%) contained in the diets. In addition, these levels of ruminal pH had a significant benefit for milk production parameters without compromising DMI. The authors claimed that NDF content was not determinant of bad ruminal fermentation; indeed fresh pasture contained high-fermentable NDF. In agreement with these arguments, Roche, et al. (2010) studied the effect on concentrate supplementation in grazing dairy cows receiving a diet with the same energy density. Results showed that when metabolizable energy was equal in both diets independently of the content in NFC, the effect in energy corrected milk, body condition score and body weight did not differed between treatments. Furthermore, the diet containing more NFC decreased significantly the content in milk fat. These results imply that if the energetic content of the diet is adequate in a given production stage, the nature of the carbohydrates and their implications in DMI will be relegated to a secondary plane.

1.2.2 Dietary Protein

As mentioned, ruminal bacteria degrade and transform most of the dietary protein ingested. Grummer, et al. (2004), reviewed the effect of UDP and RDP on intake. Most of the literature was consistent with the fact that these two nutrients do not affect DMI. Nitrogen sources of the diet do not have a direct effect in milk synthesis. A study about nitrogen utilization efficiency in dairy cows concluded that diets containing less protein did not had a detrimental effect in lactation and that it was the most efficient way to improve its utilization (Higgs, et al., 2013). In contrast, Whelan, et al. (2014), observed that milk yield and protein yield were significantly improved in diets rich in proteins and low in NFC. However, energy balance was better for cows consuming a diet poor in proteins and rich in NFC. Nonetheless, results from both studies could be conciliated since protein content of diets in Whelan, et al. (2014), experiment were half of the amount contained in Higgs, et al. (2013).

1.2.3 Dietary Fat

Even though dietary fat accounts for little proportion of energy uptake from a normal diet; dietary fat supplementation seems to have a marked inhibitory effect on DMI. Grummer, et al. (2004), affirmed that the effect could be seen with small changes in fat content in the diet (2% to 3.2% fat). Furthermore, they showed a strong relationship between fat inclusion and parity. Heifers seemed to be more sensitive to fat changes in the diet than multiparous cows. The fact that multiparous cows may have been exposed to supplemental dietary fat in previous events made them more tolerant.

Regarding milk production, dietary fat is the principal factor affecting milk fat synthesis in the mammary gland. Milk fat is formed by fatty acids of different length. Long-chain fatty acids come from preformed fatty acids in the body either from the rumen biohydrogenation of dietary fat or from mobilized fatty acids in the adipose tissue. Short-chain fatty acids are synthetized de novo inside the mammary gland. When fat is present in large amounts in the diet conjugation of linoleic acid (C18:2) is displaced towards its trans- isoform which has been described as having an inhibitory effect of the de novo synthesis of fatty acids in the mammary gland. In consequence, milk at yield is depressed. This disorder is known as milk fat depression (Bauman, et al., 2006).

1.3 Role of animal characteristics on intake and milk production

Individual characteristics of a cow also influence DMI during the transition period. Parity, body condition score (BCS) and breed have been described to play a role in intake and energy balance.

1.3.1 Effect of Parity

Effect of parity is usually present in research of dairy cows during their whole production cycle. In late pregnancy, lactation number seems to have a detrimental effect on intake. Marquardt, et al. (1977), showed a greater intake decline for older cows than heifers two weeks before parturition, 18 and 14% DMI, respectively. Furthermore, Hayirli, et al. (2002), also showed a similar trend. Multiparous cows decreased DMI relative to their body weight from 1.88% to 1.4% the last 21 days of pregnancy. While heifers decreased DMI from 1.7% to 1.3%. However, according to Grummer, et al. (2004), heifers can enter in negative energy balance (NEB) before calving since they have extra requirements for growth and their intake capacity is lower than multiparous cows. Feeding behaviour studies during lactation have also found differences between cows of different lactation number. Dado & Allen (1994), observed that during early lactation multiparous cows had higher DMI than primiparous cows. Moreover, DMI was positively correlated to body weight and milk production. In support to these findings Beauchemin, et al. (2002) observed that multiparous cows ate 9% more and produced 4 Kg of milk/day more than primiparous cows. Intake capacity of multiparous cows was greater due to their bigger rumen sizes.

Multiparous cows produce more milk than primiparous cows. This difference may partially be explained by differences in hormone concentrations from the beginning of lactation. In primiparous cows, their lower intake capacity is accompanied with significant higher levels of leptin and IGF-1 before calving. The increased levels of these hormones contribute to reach a satiety state. However, the innate requirements for energy, demand greater mobilization of body reserves and in turn, plasma concentrations of NEFA and BHBA increase. The rise of plasma NEFA and BHBA before calving indicates that primiparous cows can enter in negative energy balance before calving (Wathes, et al., 2007). After parturition levels of leptin drop significantly and there is a surge in somatotropin while IGF-1 continues to be high. This has direct consequences on the recovery of intake and affects milk production. The higher concentrations of IGF-1 will affect the recoupling of the somatotropic axis necessary for milk production since it has inhibitory effects on the secretion of GH. Therefore, less milk will be produced. Even so, an important characteristic of primiparous cows is that exists a positive relationship between milk yield and plasma BHBA. This means, that their livers have better capability to degrade fatty acids towards milk production and thus, indirectly, to suffer less metabolic disorders. In addition, primiparous cows can maintain BCS postpartum better than multiparous cows. The high concentrations of IGF-1 post-calving has positive effects against body condition loss. Furthermore, the steepest fall of leptin concentration also will contribute to the maintenance of BCS since intake will be stimulated (Wathes, et al., 2007).

In comparison, multiparous cows have greater intake before parturition but they also experience a deepest intake depression. Therefore, levels of NEFA and BHBA can be significantly higher if the level of intake suppression is high. In consequence, their risk to enter in negative energy balance, suffer post-partum metabolic disorders and affect milk yield increases because their oxidative ability of fatty acids in the liver is not as efficient as in primiparous cows. There is a strong negative relationship between milk yield and plasmatic levels of BHBA. On the other hand, if multiparous cows are in an acceptable NEB during the first weeks of lactation they will be able to recouple their somatotropic axis faster than primiparous cows because of their greater intake capacity (Wathes, et al., 2007).

1.3.2 Effect of BCS

Body Condition Score (BCS) is a qualitative measuring tool used to evaluate the proportion of body fat in dairy cows. In dairy cattle management, BCS is an important parameter of consideration in order to monitor different aspects of cattle productivity. The studies discussed below have shown that BCS at calving has an effect on lactation DMI, BCS loss post-calving, milk yield, immunity and reproduction performance. BCS is a dynamic parameter that its optimal point is dependent on the management system, breed or lactation stage. Therefore, an optimal BCS would be the one that expresses the maximum potential of milk production and genetic merit in a cow. Nonetheless, even the optimum recommendations can vary from farm to farm, there is a general agreement that dairy cattle should calve with a BCS between 3 and 3.5 (Roche, et al., 2009).

Level of fatness of an individual will influence DMI before and after calving. Hayirli, et al. (2002), demonstrated that animals that were scored as obese had greater declines of intake before parturition than cows that were classified as thin or medium. Total DMI depression of the studied groups were 28%, 29% and 40% for thin, medium and obese cows, respectively. This severe drop in intake of obese cows could lead to a higher predisposition to suffer metabolic disorders after calving due to extended NEB in early lactation. Stockdale (2007), studied the incidence of post-calving disorders related to BCS. The results showed that only cows with high BCS suffered clinical hypocalcaemia and a greater incidence of subclinical ketosis. The author argued that cows high BCS had greater lipid mobilization due to a deeper decrease in DMI before calving. Thus, triggering a status of oxidative stress, which in turn, would favour the development of the above-mentioned diseases. Bernabucci, et al. (2005), observed that cows with high BCS had significantly higher plasma concentrations of NEFA and BHBA due to a greater BCS loss after calving. Furthermore, their results of TBARS (thiobarbituric acid-reactive substances) and ROM (reactive oxygen metabolites) analysis revealed that fat cows were undergoing with stress oxidative conditions before and after parturition.

This strong relationship between BCS pre-calving and body reserves mobilization after parturition has an indirect consequence in DMI because nutrient blood metabolites (i.e. NEFA and BHBA) have inhibitory effects in DMI (Ingvartsen & Andersen, 2000). Furthermore, attempts to increase DMI and avoid higher fat mobilization during early lactation have had little effect (McCarthy, et al., 2007). Notwithstanding, cows can mobilize body reserves using different strategies according to their actual level of fatness in order to face the requirement overload in early lactation. Weber, et al. (2013), observed three different levels of fat mobilization in early lactating cows. Cows that had greater fat mobilization had higher BCS before parturition. These cows after calving had lower DMI, entered in a severe NEB and blood metabolites like NEFA and intake regulatory hormones increased. On the contrary, cows that mobilized less body reserves had lower BCS prior calving but DMI in early lactation was significantly higher than the other groups. Furthermore, these cows faced a small NEB and moderate changes in blood metabolites and hormones mainly due to their high DMI. Cows that mobilized fat in an intermediate level had similar patterns in DMI and blood metabolites as cows with high mobilization, principally because they had higher plasmatic concentration of leptin. Despite the differences, energy corrected milk (ECM) was not statistically different among groups.

In general prolonged negative energy balance in early lactation provoked by a low intake has detrimental effects in milk yield. Cows that are above the optimal recommendations (BCS $<$ 3.5) have decreased milk production due to a greater depression in DMI during early lactation. The deeper NEB of these cows impede to meet the energetic demands for milk production and thus, affecting milk yield. Inversely, cows that are below or in optimal BCS (BCS$\leq$3.5) have greater milk yield. Cows that have low BCS eat more and therefore there is a greater availability of energy that can be used for milk synthesis increasing lactation efficiency (Garnsworthy & Topps, 1982).

1.3.3 Effect of Genetics

Genetic selection has played an important role improving milk production but in consequence, has affected indirectly other physiological mechanisms. Differences between and within breeds not only exists for milk production, but also in the rate of mobilizing fat reserves, intake, BCS or body weight. These differences arise when observing different breeds in the same management system. Cows genetically selected for specific environmental conditions will perform differently and be less efficient when placed in different managements systems, which they have not been selected for. For instance, cows selected for intensive farm systems and high milk yields are not able to express fully their genetic potential when farmed in low-input management systems (grazing systems). Thus, threatening their metabolic status and milk production. McCarthy, et al. (2007) and Horan, et al. (2005), compared three strains of Holstein-Friesian breed under grass-based management systems. The results showed that the strain selected for high milk production had lower BCS and grater condition loss during lactation while strains selected for lower milk yield were able to maintain a stable BCS. Furthermore, BCS profiles of the three strains observed had an inverse relationship with the lactation curve shape. High producing cows still produced more milk but they mobilized more body reserves. Therefore, under grazing-management systems these cows had to mobilize much more body reserves towards milk synthesis than less productive cows. In addition, milk persistency after peak of lactation was lower in high producing cows. On the contrary, when these cows were supplemented high levels of concentrate, high producing cows performed much better. Differences between strains could be influenced by a different degree of decoupling of the somatotropic axis as demonstrated Lucy, et al. (2009).

French (2006) studied the relationship between breed and DMI depression during late pregnancy. The results showed that Holstein cows had significantly higher body weight and DMI than Jersey cows. However the magnitude of DMI depression was higher for Holstein cows ($p<0.01$). Furthermore, Jersey cows were able to maintain energy balance more constant than Holsteins. Hence, breed was an influential factor affecting DMI and EB pre-partum. Another study Friggens, et al. (2007), hypothesized that breed caused differences in energy balance during lactation. Results for body reserves mobilization were significant in early lactation, being Danish Holsteins who had greater mobilization. However, these breed differences disappeared as lactation progressed. Although breed differences were present for mobilization of body reserves, the low correlations observed between phenotype and genotype for energy balance during early lactation indicated that during this period EB was poorly mediated by genetics. Nonetheless, for the whole lactation the authors concluded that genetics influenced the different patterns of energy balance observed.

1.4 Effects of feeding strategies on intake, energy balance and milk production

Research about feeding strategies in dairy cows dates back in the early 80's (Gordon, 1982). The main purpose has always been to increase production while minimizing feed inputs, in other words, increase milk production efficiency. During early lactation, milk production has an increasing trend until it peaks after approximately 60 days in lactation. However, during this period, increased requirements for milk production trigger to a negative energy balance, which has direct consequences in health and reproduction (Ingvartsen, et al., 2001). Through the years, different feed strategies have aroused in order to maximize peak yield because it is considered the major determinant of total lactation performance. Traditionally, the common recommendation was to feed high amounts of concentrates in early lactation in order to increase peak yield and decrease the amount of concentrates after the lactation peak in order to compensate feeding costs (Olsson, et al., 1997). Concentrates are energetic rich sources that contribute to minimize the negative energy balance in early lactation. However, not only the amount of concentrate is important to achieve a high peak yield, the rate of inclusion from the beginning of the lactation or the availability of roughages are also important factors that may influence milk production (Ingvartsen, et al., 2001). In addition, as discussed in previous sections, exist other factors playing an important role too.

Gordon (1982) studied the benefits of providing flat rates of concentrate from the beginning of lactation in milk production in first lactation cows. The experimental design consisted in two different concentrate pattern allocations. One group of cows received a flat rate of concentrate of 6.8Kg/day until 182 days in milk (DIM) and the other group received 8Kg/day until 90 DIM and afterwards decreased concentrate amount to 5.4Kg/day, imitating the traditional step-feeding system. The results showed that cows from the first group had significant greater silage intakes (>60Kg) and milk yields were not affected by treatment at any stage of lactation. These events opposed to the current literature at the time since it was considered that the level of feeding in early lactation had a major effect on the subsequent lactation performance. However, the author argued that differences in the results could be explained by the restricted availability of forages in the previous studies and because the second part of the lactation in the experiment was at pasture. Then the conclusion was that given ad libitum forage, constant allocation of concentrate could produce as high yields as the strategies designed to maximize peak yield. Posterior research supported the idea that allocation pattern of concentrate in early lactation had no significant effects on milk production and body condition loss and thus, using flat rates of concentrate with ad libitum access to forage was profitable. Nonetheless, the quality of the forage had to be taken into consideration because poor quality forages resulted in decreased intakes, milk yields and health. Furthermore, it was argued that high-yielding cows could benefited if fed according to their yield potential since they could be offered as much concentrate as their energetic requirements (Taylor & Leaver (1984) and Poole (1987)). Contrary to these results, in similar experimental conditions Aston, et al. (1995), reported that milk yield increased linearly on flat rate diets containing higher amounts of concentrate. The experimental design included diets containing 3, 6, 9 or 12 Kg of concentrate in early lactation. Although results for milk yield increased by concentrate level in the diet, milk fat content decreased with diets containing three or twelve kilograms of concentrate. It was argued that cows receiving low amounts of concentrate (3Kg) were in a compromised energetic status and thus, milk fat synthesis was affected. Conversely, cows receiving the highest amounts of concentrate (12Kg) depressed milk fat synthesis due to changes in ruminal fermentation. In addition, high levels of concentrate contributed to minimize weight loss. The authors also agreed that step-feeding system did not have any significant benefit in milk production when compared to a flat rate system.

Few years later, Olsson, et al. (1997), studied the effects of different levels of concentrate in rations fed individually to Swedish dairy breeds. All diets contained the same amount of energy and protein but differed on the ratio concentrate: forage, from 1Kg to 9Kg of concentrate per day. The results showed that the concentrate: forage ratio did not have an effect on intake neither for milk yield. The authors argued that due to the high quality of the forage, cows receiving a diet high in forage could obtain sufficient energy to meet their requirements. Moreover, low amounts of concentrate could be actually more convenient since was observed that cows eating higher amounts of concentrate had gastrointestinal problems (i.e. diarrhea). Nonetheless, results for health issues among treatments were not significant. In continuity with previous studies, Ingvartsen, et al. (2001), compared the effects on intake and lactation performance in dairy cows fed with two different increasing rates of concentrates (+0.5Kg/day and +0.3Kg/day) and a complete diet containing mixed forage and concentrate. Regarding the comparison of the two rates of inclusion, the authors reasoned that faster increase of concentrates (0.5Kg/day) resulted in a marked silage intake depression with high intake substitution of forage by concentrate. Furthermore, these cows experienced a greater weight loss during the first three weeks of lactation without any significant increase in milk production compared to the other group. On the other hand, the authors evoked that feeding a complete diet had significant benefits. Intake was improved up to 24% the first three weeks of lactation and energy corrected milk was significantly higher.

Total mixed rations (TMR) gave new research insights about feeding systems in dairy cattle. This feeding strategy granted potential benefits in terms of intake and milk production. Andersen, et al. (2003), studied the effects of high concentrate proportion in TMR diets on milk production and DMI during the first 16 weeks of lactation. Results showed that DMI was not affected between treatments having 25% or 75% of concentrate, although there was a strong tendency favouring the high concentrate group. Furthermore, in terms of energy intake the differences were strongly significant due to differences in diet composition of NDF and starch. This favoured the cows receiving 75% of concentrate to produce up to 15% more milk yield, which in terms of standardized milk was translated to 11% ECM more. In addition, cows receiving less concentrate had greater losses in body weight and body condition the first eight weeks of lactation. Similar results were observed in a least extreme study including two breeds of cows (Holstein and Normand). Cows receiving a higher portion of concentrates (30%) produced more milk, in terms of yield and fat content, and mobilized slightly less body reserved than the group receiving 15% concentrate. However, the incidence of digestive disorders tended to be greater in the high concentrate group, particularly in the Holstein breed. Regarding the energy balance between the treatment groups revealed that although milk production increased with more concentrate allowance, energy balance was slightly improved. Most of the additional energy within the high concentrate treatment group went to produce more milk at expenses of other body requirements. The following stages of lactation culminated with a lower lactation persistency for those cows receiving more concentrates (Delaby, et al., 2009).

In the recent times, interest about feeding concentrates to cows has decreased. The volatility of market prices for this kind of feedstuffs has increased the susceptibility to meet the requirements in high-input farm systems. Furthermore, the massive use of concentrates for livestock has destined large areas of arable land, which could be used to feed the population, to crop animal feedstuffs. Ruminants are less competitive for food with humans as could be monogastric animals. Due to the anatomy and physiology of their gastrointestinal system, they can degrade feed sources that are not edible for human consumption. On that sense, feeding large amounts of concentrates restrict them to express their innate ability to convert fibre-rich resources into edible energy for human consumption via milk or meat (Eisler, et al., 2014). Therefore, new perspectives in dairy farming have emerged in order to decrease the use of concentrates towards more sustainable systems.

Observational studies have compared cow performance and health between organic and conventional farms. The principal difference between these two management systems is diet composition, where organic farms include higher proportions of roughages in the diets. The most common traits measured in these studies are milk yield and composition, energy balance, body weight, body condition and health status. Results have shown that milk yield is lower in organic farms but metabolic status is not compromised when receiving diets that are less energetic. This suggests that cows in organic conditions can adapt their production according to their feed intake (Roesch, et al. 2005 and Fall, et al., 2008). Interestingly, a similar study evaluated cost and income revenues in farms that did not use concentrates as part of the diet. It was concluded that although milk production was lower, the marginal income per cow was not different from conventional systems. (Ertl, et al., 2014).

Under experimental conditions, effects of concentrate levels in the diet seem to be controversial depending on the length of the observational period. In a study conducted during the whole lactation period, low levels of concentrates (6Kg) in diet had significant lower results in milk and fat plus protein yields compared to high levels of concentrate (10Kg). Nonetheless, the response to concentrate for milk production was greater with low levels concentrate, 1.38 Kg milk/Kg concentrate and 0.5Kg milk/Kg concentrate in low concentrate and high concentrate levels, respectively. Treatment group did not affect body condition and body weight. In addition, the effect of genotype was present. Purebred Holstein were more productive with higher levels of concentrate inclusion in the diet than crossbred Holstein x Jersey (Vance, et al., 2013). Horn, et al. (2014), observed similar results when compared diets containing 3.7Kg and 7.5Kg of concentrate in dry matter basis. For the whole lactation period, cows within the high concentrate group had significantly greater ECM yields than cows receiving less concentrate. However, BCS, BW and reproductive performance were not affected by treatment. Within the same experiment, results for the early lactation period were not the same as those observed for the whole lactation. ECM and BCS were not significantly affected by treatment. Furthermore, the analysis of blood metabolites in early lactation revealed that cows with a low concentrate diet were not in a worse metabolic status than cows eating more concentrate since blood metabolites (i.e. glucose, NEFA and BHBA) were similar. Focusing on the metabolic profiles in early lactation in cows receiving different amounts of concentrate, Reist, et al. (2003), observed that cows eating low concentrate diets had more negative energy balance but it did not affect milk production. The metabolic profiles of cows receiving less concentrates showed low plasma concentrations of glucose insulin and IGF-1 whereas concentrations of NEFA, BHBA and GH were high. These showed that although low concentrate diets contributed to a more stressful metabolic status cows could adapt successfully to their energetic demands. Therefore, it is likely that although low concentrate diets given during the whole lactation may affect milk production, there is little effect when fed in early lactation.

2. HYPOTHESIS

The hypothesis of this experiment was that cows fed low concentrate levels during the first six weeks of lactation would have higher silage intake but lower milk yields and a severe negative energy balance.

3. MATERIALS AND METHODS

This experiment was carried out at the Swedish Livestock Research Centre (Lövsta forskningscentrum) from the 1st of February of 2016 to 18th April of 2016.

3.1 Experimental design

In this study, dairy cows received two levels of concentrate and forage *ad libitum* during their first six weeks of lactation. The first group received a low concentrate ration with 4-5 kg/day of concentrate depending whether the cows were in the first lactation or more. The second group received an increasing rate of concentrate from the beginning of the lactation up to reaching a maximum of 14-15 Kg/day by the 24th day of lactation. Afterwards the amount of concentrate was maintained stable until the cows left the experiment. The day when cows entered into experiment (2 days post-calving) 2-3Kg of concentrate were offered as a base and the allocation pattern consisted in 0.5Kg/day until they reached the stipulated maximum. The cows included in this study calved between the 1st of February and 12th of March of 2016 and where then followed until their sixth lactation week.

3.2 Herd and Management

Thirty-one cows were included in the experiment. The animals entered in the trial randomly, according to their calving date. Two different dairy breeds formed the herd, Swedish Holstein (SH) and Swedish Red (SH). In addition, the experiment included both, primiparous cows (heifers) and multiparous cows (2 or more lactations). The distribution between both treatment groups was done according to parity and breed. In total 18 cows joined the low-concentrate groups and the remaining (n=13) joined the high-concentrate group. The inequality between groups occurred in order to maintain the equilibria on the distribution criteria since cows were included into the experiment by calving date. Cows entered to the experiment 2-3 days post-calving.

The cows were kept in a free-stall barn with an individualized automatic feeding system. All cows had access *ad libitum* to forage and water at any time of the day. Concentrate was automatically dispensed according to their stipulated concentrate ration using individual feed stations. The cows were fitted with transponders that communicated to a central management software. This allowed automatizing individual feed dispensation and to record both intake levels of forage and concentrate into the central computer. All cows were milked twice daily (a.m. and p.m.) in an Automatic Milking Rotary (AMR) system.

The researchers conducted a general monitoring checklist twice a week in order to avoid possible incidences with the feed rations, milking or health issues that could not have been noticed by the farm staff.

3.3 Data Collection

Forage intake was recorded from each cow and feeding bunk on daily basis. Individual concentrate intake was also recorded daily at the feed stations. Body weight and body condition score were recorded on daily basis at the entrance of the milking parlour using a scale and a BCS camera (DeLaval body condition scoring BCS, DeLaval International AB, Tumba, Sweden), respectively. Milk yields were recorded automatically at each milking time.

Milk samples to analyse milk composition were taken on the second, fourth and sixth week of lactation for each cow in the experiment. The samples of each week were collected at evening milking and the consecutive morning milking. Milk sampling containers were used to collect the milk and were kept under refrigeration temperatures until time of analysis. Milk analysis was performed the day after the sampling.

Additionally to the BCS camera records, the researchers used a visual method to score body condition in a 5-point scale. Visual body condition evaluation was performed the second, fourth and sixth week of lactation of each cow. The scoring results were given by the consensus of two operators.

3.4 Feed composition and analysis

Before parturition, cows and heifers received an *ad libitum* diet containing 80% first cut grass-clover silage and 20% straw. The silage used in this experiment was first cut grass-clover silage. The silage ratio of grass:clover used in both diets was unknown since they contained silage from leys lying between 1 and 4 years of antiquity. All silages were treated with the additive Promyr and stored in concrete bunker silos. Silage used during the experimental period was evaluated for nutrient composition in periods of two weeks. Silage samples were analysed as described by Åkerlind, et al. (2011) for DM at 60ºC (with correction of losses of volatiles), ash, CP, NDF and in vitro organic matter digestibility by the method of Lindgren (1979) for calculation of metabolizable energy. Table 1 shows the chemical composition of silage used in the pre-partum diet and the experimental diet.

Table 1 Chemical composition of pre-partum and experimental silage.

	Pre-partum	Experimental
DM g/Kg fresh matter	316	365
OMD (%)	80	80
CP g/Kg DM	127.6	138
NDF g/Kg DM	n.a*	391[1]
ME MJ/Kg DM	11.5	11.7
Ash g/Kg DM	88.4	83
pH	4	4.3

*Not analysed

[1]Value obtained before ensiling

The concentrate used in this trial was a pelleted mix of by-products containing principally sugar beet pulp (SBP), rapeseed meal (RS) and distiller's grains (DG). Minerals were also provided within the concentrate using a Premix (AAK Sweden AB, Karlshamn, Sweden). Table 2 and 3 show the ingredient and chemical composition of the concentrate, respectively.

Table 2 Ingredient composition of the concentrate

Ingredient	% DM
Sugar beet pulp	50.1
Rapeseed meal[1]	16.8
Distiller's grain	15
Wheat bran	8
Fatty acids[2]	3.9
Molasses	2
Palm kern expeller	4
Premix[3]	0.2

[1]ExPro® (AAK Sweden AB, Karlshamn, Sweden)
[2]AkoFeed Cattle (99% Fat; 45% C16:0; 37 C18:1)
[3]Containing minerals, vitamins and trace elements

Table 3 Chemical composition of the concentrate

Nutrient	
DM, % fresh matter	87.7
CP, g/Kg DM	179
Crude fat, g/Kg DM	67.4
NDF, g/Kg DM	328
Ash, g/Kg DM	53.6
Starch, g/Kg DM	32.5
ME, MJ/Kg of DM[1]	13.2

[1]Predicted, not analysed value

3.5 Energy Balance and Energy Corrected Milk Calculations

Energy balance was calculated as the difference between total energy intake and energy requirements. Energy requirements were calculated as regression line points where the x-value represented the sum of maintenance and milk production requirements. In first lactation cows and additional 8MJ/day were added in concept of growth requirements. Both energy requirements and energy corrected milk (ECM) were calculated according to Spörndly (2003) using the following formulas:

$$Energy\ Balance\ (EB) = Energy\ intake - Energy\ requirements$$

Energy requirements:

$$Maintenance\ (MJ/day) = 0.57 * (Kg\ of\ BW^{0.75})$$

$$Milk\ production\ (MJ/day) = 5 * (Kg\ ECM/day)$$

$$Growth = 8MJ/day$$

Regression line:

$$Y = 1.11x - 13.6$$

Energy Corrected Milk:

$$Kg\ ECM = (Kg\ milk * 0.01) + (12.2 * Kg\ fat) + (7.7 * Kg\ protein) + (5.3 * Kg\ lactose)$$

3.6 Milk Analysis

Milk samples were analysed for fat, protein and lactose content by Fourier Transform Infrared (FTIR) analysis using CombiFoss 6000 equipment from Foss.

3.7 Statistical Analysis

All data were analysed with SAS (version 9.4, SAS Institute Inc. Cary, NC, USA). Silage intake, DMI, NDF intake, ME intake, energy balance, Kg of milk per day and energy corrected milk were analysed using a mixed model (PROC MIXED). The random variable was considered as cow and repeated measure was lactation week. Lactation number, treatment, breed, lactation week and lact.week x treatment were established as fixed factors. BW change and BCS change, camera and visual, were analysed using a General Lineal Model which included treatment as the only fixed factor. Least square mean values and statistical significance of the parameters measured are shown in the following section. All results were considered significant when *p-value* was <0.05.

Figures were created with Microsoft Office Excel 2013 using the least square means of the parameters analysed statistically, except for Figure 5 and 6 that were created using the BW and BCS averages from the database.

4. RESULTS

Table 4. Treatment effects on Silage intake, Dry Matter Intake (DMI), Metabolizable energy (ME), Energy Corrected Milk (ECM) and Energy Balance (EB), Total Neutral Detergent Fibre (NDF) including the level of significance for breed, lactation number, lactation week and lactation week*treatment of each of the measured parameters from week 1 to 6 of lactation.

	***Treatment*[2]**		***P-values***				
	LC	**HC**	**Treatment**	**Breed**	**Lactation No.**	**Lact. week**	**Treat. x Lact. week**
Silage Intake[1]	16.3	12.2	<0.001	0.03	<0.001	<0.001	<0.001
DMI[1]	20.1	20.8	0.39 (n.s.)	0.03	<0.001	<0.001	0.02
ME Intake	240.5	256.1	0.12(n.s.)	0.03	<0.001	<0.001	<0.001
NDF Intake[1]	7.6	7.6	0.95 (n.s)	0.03	<0.001	<0.001	0.39 (n.s.)
Kg Milk/ day	31.5	32.1	0.66 (n.s)	0.003	<0.001	<0.001	0.06 (n.s)
ECM	33.7	35.6	0.29 (n.s.)	0.01	<0.001	<0.001	0.21 (n.s.)
EB	-10.3	-4.4	0.63 (n.s)	0.42 (n.s)	0.91 (n.s.)	<0.001	0.65 (n.s.)

Silage Intake = Kg of silage consumed in DM basis
Total DMI = Total Kg of silage and concentrate intake in DM basis
ME = Total metabolizable energy consumed including silage and concentrate (expressed in MJ/day)
Total NDF intake = Total kg of neutral detergent fibre consumed from both silage and concentrate in DM basis
ECM = Energy corrected milk (expressed in Kg of milk/ day)
EB = Energy balance (expressed in MJ/day
Treat x Lact. week = Interaction between treatment and lactation week
LC= Low concentrate treatment
HC = High concentrate treatment

[1]The results are expressed in Kg/day

[2] Least Square Means of the experimental period

Silage Intake was significantly higher ($p<0.001$) for cows receiving the Low concentrate diet (LC), indeed cows in the LC group ate on average four kilograms more than the HC group (Table 4). Breed and lactation number had a significant effect over silage intake. Swedish Holstein (SH) had greater intake (15.2 Kg) than Swedish Red (SR) cows (13.3 Kg) and multiparous cows ingested more silage than primiparous cows, 16.1Kg and 12.4Kg, respectively. In terms of total DMI and Metabolizable Energy (ME), which included the sum of concentrate and silage, the effect of treatment was not significant (Table 4) meaning that cows were consuming similar amounts of dry matter and energy. There was a significant interaction between treatment and lactation week for both parameters, $p=0.02$ and $p<0.001$, respectively. However, Figure 1 shows that the significant differences observed belong to intake differences at beginning and end of the experiment. The effect of breed and lactation number over DMI and ME intake continued to be significant ($p<0.001$) for these measurements. Regarding total NDF intake, the effect of treatment was not significant for both diet types (Table 4). Nonetheless, significant results were observed for the effects of lactation number where multiparous cows in accordance with DMI results had greater intake of NDF. The effect of lactation week was significant for NDF intake but the interaction between treatment and lactation week was not ($p=0.39$). Figure 2 shows the evolution of NDF intake between treatment groups during the experimental period.

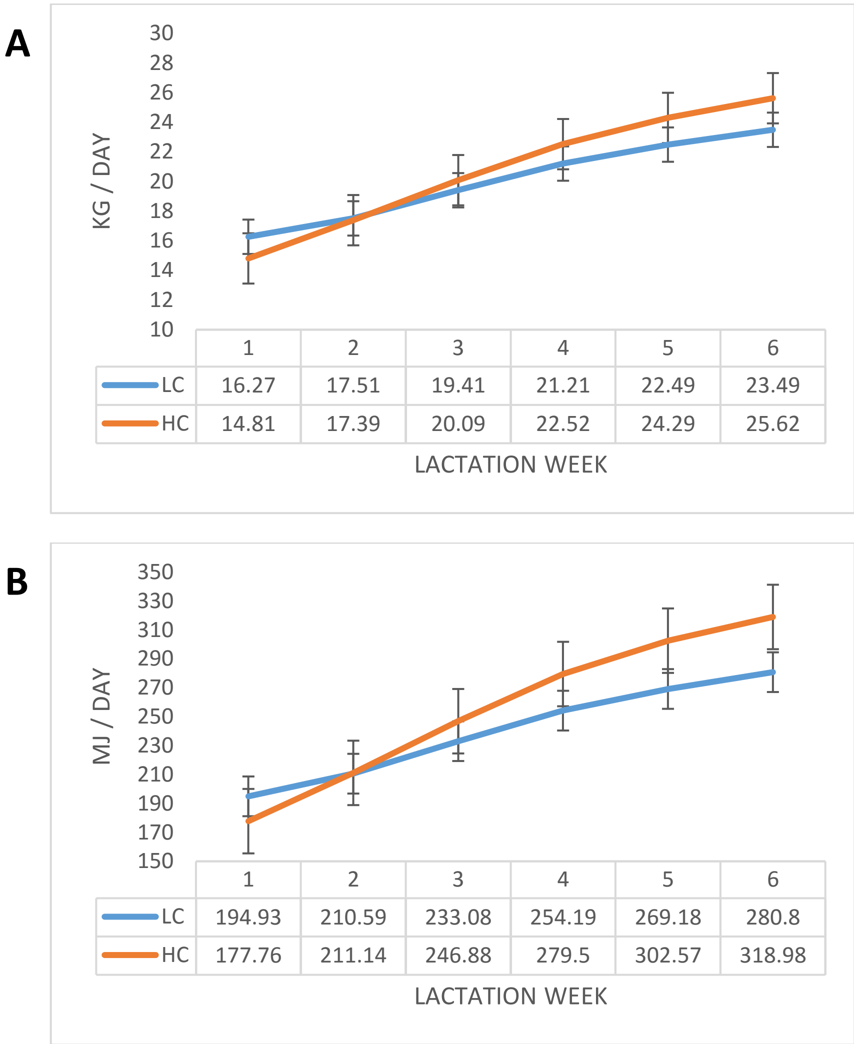


Figure 1 A: Least Square Means with error bars of Dry Matter Intake (DMI) for cows offered Low concentrate (LC) and High concentrate (HC) diets. **B:** Least Square Means with error bars of Metabolizable Energy (ME) intake of cows offered Low concentrate (LC) and High concentrate (HC) diets.

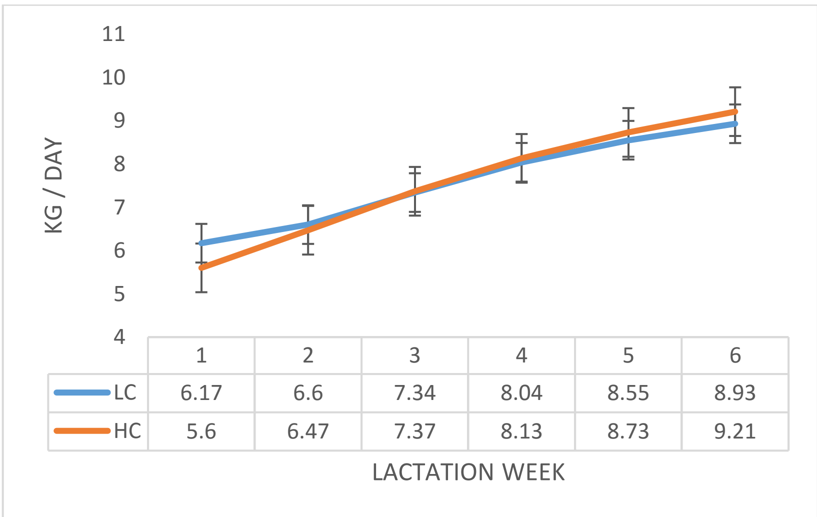
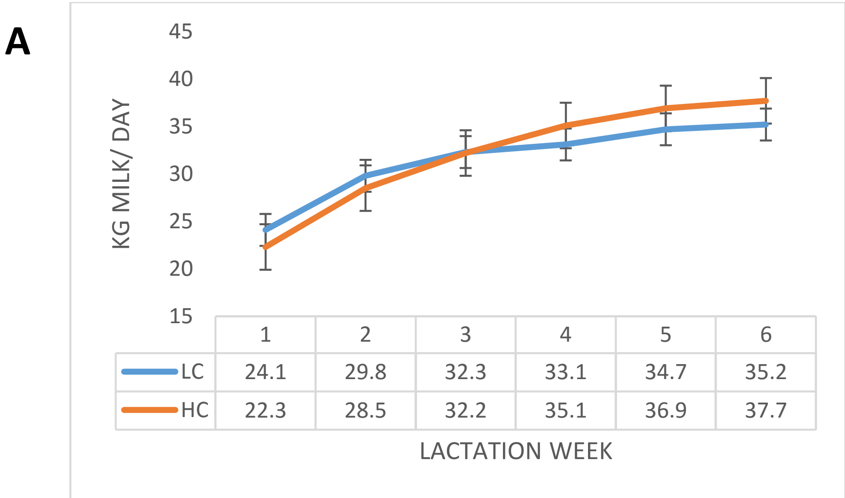


Figure 2 Least Square Means with error bars of Total Neutral Detergent Fibre (NDF) intake of cows offered Low concentrate (LC) and High concentrate (HC) diets.

Results in milk production (Kg of milk and ECM) were not significantly affected by treatment. However, the interaction of treatment and lactation week tended to be significant for milk yield (Table 4). Milk composition was similar in both treatments with no significant effects. Nonetheless there was a tendency of increasing milk fat throughout the experimental weeks in the HC group (Table 5). This may explain the divergence on ECM the latter lactation weeks (Figure 3B), although the statistical results were not significant. Effects of breed, lactation number and lactation week were consistent with previous results ($p < 0.05$) (Table 4). Swedish Holstein and multiparous cows produced more milk, in terms of Kg and ECM, than Swedish Red and primiparous cows.



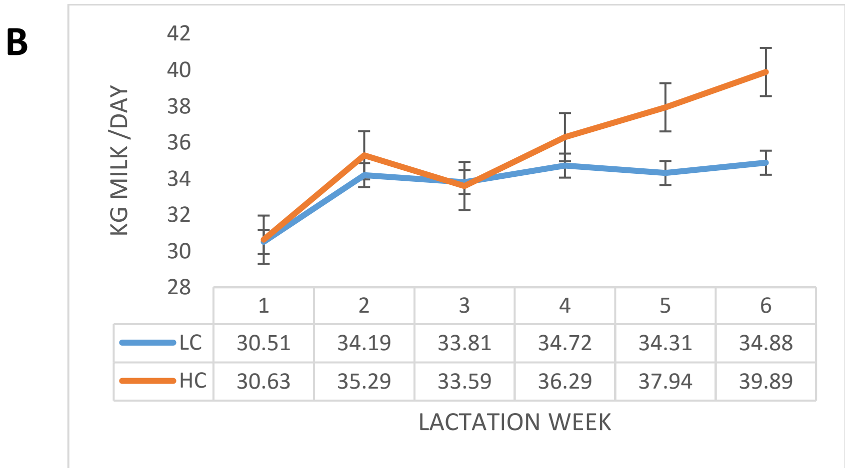


Figure 3. Least Square Means with error bars of **A**: Kg of Milk/day and **B**: Energy Corrected Milk (ECM) of cows offered Low concentrate (LC) and High concentrate (HC) diets

Table 5. Least square means of milk composition for cows offered Low concentrate (LC) and High concentrate (HC) diets.

	Treatment		***P-values***		
	LC	**HC**	**Treatment**	**Lact. week**	**Treat. x Lact. week**
% Fat	4.4	4.8	0.28 (n.s)	<0.0001	0.07 (n.s)
% Protein	3.4	3.4	0.75 (n.s)	<0.0001	0.36 (n.s)
% Lactose	4.8	4.7	0.15 (n.s)	0.001	0.98 (n.s)

LC cows tended to have lower energy balance (EB). However the effect was not significant among groups (p=0.63). Figure 4 shows the evolution of EB for both treatment groups along the experimental period. The effect of lactation week was significant but no interaction was found between treatment and lactation week (p=0.65). Effects of breed and lactation number were not significant.

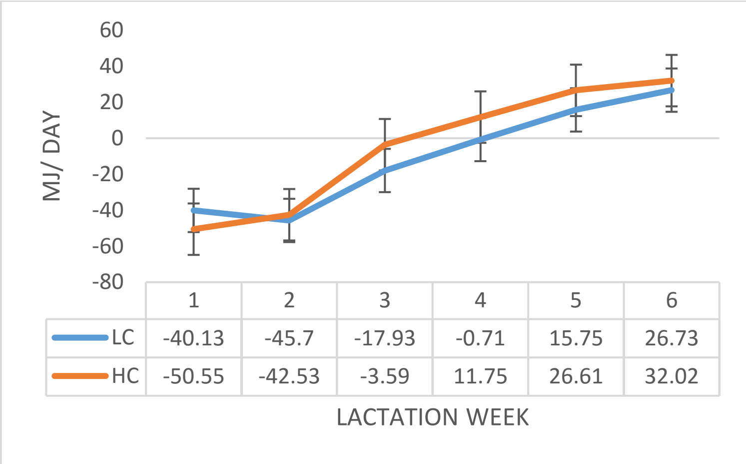


Figure 4 Least Square Means with error bars of Energy Balance (EB) of cows offered Low concentrate (LC) and High concentrate (HC) diets.

Table 6. Treatment effects on Body Weight Change (BWC), Visual BCS Change and Camera BCS Change observed during the experimental period.

	Treatment[1]		***P-values***
	LC	**HC**	**Treatment**
BWC[2]	-16.1	-1.9	0.16
Visual BCS[3]	-0.4	-0.04	0.04
Camera BCS[3]	-0.3	-0.2	0.05

LC= Low concentrate treatment; HC= High concentrate treatment

[1]Least Square Means

[2]Expressed in Kg. Data collected weekly

[3]Data collected the 2nd, 4th and 6th week of lactation

Cows from the LC group entered to experiment with a greater body weight (BW) than cows belonging to the HC (Figure 5). However, although treatment effect was not significant, LC group had a more pronounced BW loss (Table 6). Nonetheless, in terms of BCS change for both observational methods (visual and camera) the effect of treatment resulted to be significant. Cows from the LC group lost almost half body condition scoring point during the experiment. Even though the differences between groups were not dramatic, BCS change rate could be appreciated in Figure 6.

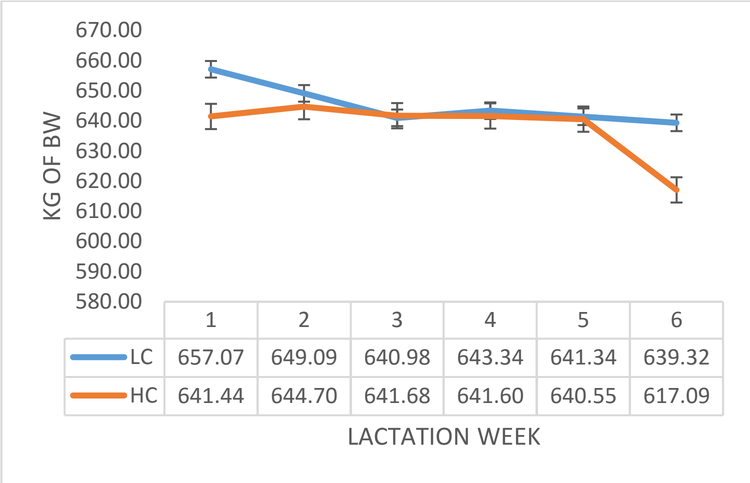


Figure 5. Evolution of the weekly average BW during the first six weeks of lactation for Low concentrate (LC) and High concentrate (HC) treatment groups.

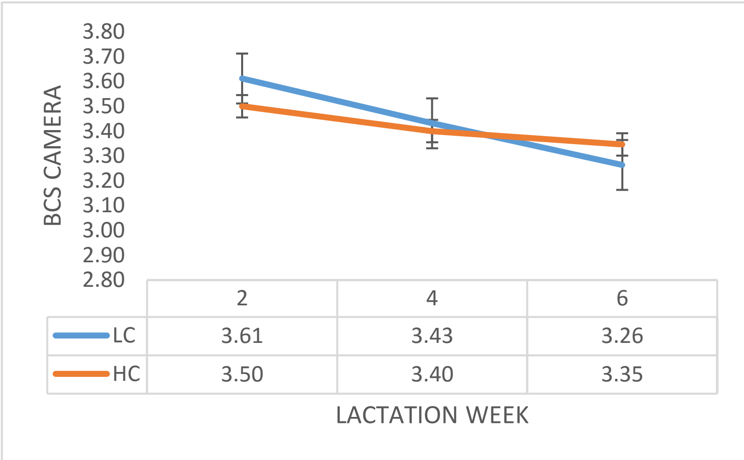


Figure 6. Evolution of the average BCS recorded with the camera for Low concentrate (LC) and High concentrate (HC) treatment groups during observational days.

5. DISCUSSION

5.1 Effect of Breed

The significant effects of breed on intake and milk production parameters, were consistent with the literature reviewed in the background (Friggens, et al., 2007; Horan, et al., 2005; McCarthy, et al., 2007). Although the reviewed research was done in different breeds than those used in this experiment, the results agree in the sense that the existing differences are what permits them to be named as two different breeds.

Swedish Holsteins (SH) were heavier than Swedish Red (SR) cows, 645 Kg and 603 Kg, respectively. Average camera BCS records of SH was 3.2, indicating that cows were not over conditioned. Therefore, these results point that SH were larger animals and thus, had greater intake capacity. Results for silage intake, total DMI and ME intake were then in consonance with their expected intake capacity, being SH who had the greatest intakes in dry matter and energy basis.

Regarding milk production SH produced significantly more milk (34.1Kg of milk /day) than SR cows (29.6 Kg of milk /day). Both breeds were distributed equally between the two treatment groups. However, effect of treatment was not significant for ECM. This reveals that Swedish Holstein cows can produce more milk irrespective of feeding level. Furthermore, their greater intake may have potentiated milk production since DMI has positive effects on the recoupling of the somatotropic axis (Lucy, et al., 2009). Sources consulted about the specific breeds used in this study specify that in general Swedish Holstein cows produce about 1000 Kg of milk more than Swedish Red cows per lactation (Lindhé, B, 2004).

5.2 Effect of Parity

Effect of parity was statistically significant for all the parameters measured except for energy balance. In the current study, multiparous cows had the greatest intakes. This reflected the positive relationship between lactation number and intake capacity. Multiparous cows also produced more milk than primiparous cows. These results are consistent with Beauchemin, et al. (2002) who observed greater intake and milk yield in multiparous cows. Results for energy balance were similar for both parity groups. Grummer, et al. (2004) and Wathes, et al. (2007) stated that primiparous cows could enter in a negative energy balance even before calving due to their lower intake capacity and hormonal status. Least squares means from the present study showed that primiparous did not entered in an early negative energy balance when compared with multiparous cows. Therefore, indicates that primiparous cows had the ability to compensate the differences in DM and ME intake via other pathways that were not explored in this experiment. A metabolic profile analysis would be convenient in order to know whether similar metabolic changes occurred as Wathes, et al. (2007) observed.

5.3 Effect of Concentrate Level

The chemical composition of the feedstuffs used are of special interest for the results observed in this experiment. The silage was poor in NDF (391g/Kg DM) and highly digestible (80% OMD), which gave a direct benefit to cows of the LC group in order to cover their energetic demands. In contrast, the concentrate, which was made of by-products, contained high levels of NDF (328 g/Kg DM) and relatively low proportions of starch (32.5 g/Kg DM). This is reflected on the results of total NDF intake where both treatment groups had similar NDF intakes. Silage intake was significantly higher in the Low concentrate group. However, the differences in total dry matter intake and metabolizable energy were not significant. Cows from the low concentrate group were able to compensate the energetic deficiencies due to the lack of concentrate by eating more silage. The results for silage intake are consistent with Ingvartsen, et al. (2001), who observed a high substitution rate of forage by concentrate in rations where the inclusion of concentrate was faster (+0.5Kg/day), the same used in this experiment.

The present study had no significant differences in NDF intake nor for DM intake nor ME intake between treatment groups. Dhiman, et al (1995), observed that diets containing high levels of NDF did not impair intake if the silage used was of good quality. Similar appreciations have been reported in studies performed in grazing systems where levels of NDF in the diet are usually high. Kolver & de Veth (2002) observed that using pastures with high content in high-fermentable NDF did not compromise DMI. In addition, Roche, et al (2010), stated that the energetic density of the diet was actually more important for a proper lactation performance than the nutrients per se that feed contains. The fact that silage was rich in ME (11.7 MJ/Kg DM) and offered *ad libitum* may have contributed to equate the total energy intake. Olsson, et al. (1997), feeding silage with similar energy content as in this experiment did not find significant differences on intake when high ratios of silage: concentrate were used. In addition to these findings, the authors did not observe any differences in milk yield during the experimental period when feeding low concentrates, and concluded that with good quality forages cows could obtain enough energy to cover their energetic requirements. This affirmation was in agreement with the current findings for energy balance and milk production. Treatment effect on EB and milk production was not statistically significant, meaning that all cows could adapt successfully to their energetic demands. From this study, it cannot be concluded which cows were in a worse metabolic status. Further analysis of blood metabolites is needed.

Body Weight Change during the experimental period was not significant between both treatment groups. However, the effect of treatment on BCS change in both of the methodologies used were statically significant. Cows from the LC group lost between -0.3 to -0.4 BCS points during the experiment while cows that belonged to the HC group only lost -0.04 to -0.2 BCS points. On the other hand, it is important to consider that cows from the LC group had on average higher BW and BCS than HC cows. These results are consistent with the study of Weber, et al (2013) where BCS before parturition had significant effects on BCS and BW change, and metabolic status during early lactation. Cows that had a BCS over the optimal point at calving presented greater mobilization of fat body reserves and lower DMI that, in turn, made them to develop a severe negative EB and an increase of blood metabolites. On the contrary, cows that calved below or with the optimal BCS had less fat mobilization, greater DMI and a less severe negative energy balance. The fact that in the present study cows from the LC group calved with a BCS above the optimal point may have contributed to the significant results between treatments. In addition, the effect of treatment on BCS change could not be understood other way. Even though the ratio concentrate:forage was different between treatment groups, all cows consumed similar amounts of DM, NDF and energy and thus, the effect on each treatment group should have been comparable. In support to this idea, Horn et al (2014) did not observe significant differences between cows that were offered different amounts of concentrates on BCS, EB or ECM during early lactation.

6. CONCLUSIONS

Cows fed with low concentrate levels during their first six weeks of lactation ingested higher quantities of silage. However milk yield and energy balance were not affected by eating less concentrate when compared with a group eating higher amounts of concentrate. Therefore, dairy cows fed with low concentrate diets were able to compensate their energetic requirements for both maintenance and milk production by eating more silage, which was highly digestible, and with low NDF content.

7. ACKNOWLEDGMENTS

I would like to give a special thank you to PhD student Johanna Karlsson for your time and help during the experiment. I would be lost without your advices and settings at the farm. I will never forget the time we spent collecting different kinds of samples. We made a great team. Acknowledgments also go to Post-Doc. Mikaela Patel who also helped at any time during the sampling days and for many car rides to the farm. To my supervisor Prof. Kjell Holtenius, thank you for all your support despite the limiting factor, time. Lastly, I would like to thank my family for all the support and means to reach my goals.

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