Field study of the drought's impact on feeding strategy and biological parameters in early lactation dairy cattle

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Abstract

The summer of 2018 was unusually warm and dry. For animal production, this resulted in poor pastures, reduced harvests of crops, such as roughage and grains, and increased risk for heat stress in the animals. The drought led to problems as in shortage of animal feed, which made the feeding of dairy cattle difficult. This field study was performed to research how Swedish dairy farmers handled the drought and feed situation. Eleven farms were visited, and the farmers were asked questions from a questionnaire, regarding whether they experienced that they were affected by the drought and feed situation or not, questions about the feeding strategy on the farm, if alternative feedstuffs were used and if the farmers had been required to sell or slaughter animals because of the feed situation. The farmers had different experiences of the drought where some of them tried feeding alternative feedstuffs as bean straw, peas, whole crop silage, silage from fallow land or a complementing compound feed. Some farmers needed to slaughter or sell animals due to the lack of feed. In total, 59 primiparous cows in their early lactation were included. The examined cows were of the breeds Swedish Holstein (SH), Swedish Red (SRB) and Jersey cattle. In addition to the questionnaire, feed samples were collected from the roughage used, to see if relations could be found between the result of feed samples and other studied parameters. Milk- and blood samples were collected from 3-10 cows from each farm. These cows were also body condition scored. It was studied if a relation could be found between any experienced problems caused by the feed situation, and the studied biological parameters. These parameters were levels of myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0) and oleic acid (C18:1 cis-9) in milk, and levels of β-hydroxybutyrate (BHB), non-esterified fatty acids (NEFA), glucose, insulin and insulin-like growth factor 1 (IGF-1) in blood plasma, body conditions and feed samples. The feed samples were analysed for contents of dry matter (DM), metabolizable energy (ME), ash, crude protein (CP) and neutral detergent fibre (NDF). The majority of the examined cows (93%) had body conditions between 3.0 and 4.0 of a scale of 1-5, where 1 is emaciated and 5 is obese. Approximate energy balances on herd level were estimated via the software IndividRAM which showed that the herds were between 92 and 109%. Relations were found between some of the studied parameters, with different parameters identified on the different farms. Statistical analyses showed significant correlations between C14:0 and C18:1 cis-9; NEFA and C18:1 cis-9; BHB and C18:1 cis-9; BHB and C14:0; BHB and glucose; BHB and NEFA. An analysis of variance (ANOVA) showed significant differences between the farms regarding the levels of the milk fatty acids C14:0, C16:0, C18:0, plasma components BHB, NEFA, glucose, IGF-1 and body conditions.

Keywords: dairy cattle, drought, energy balance, feeding, metabolism

Sammanfattning

Sommaren 2018 var ovanligt varm och torr. Detta resulterade bl.a. i försämrade beten, minskade skördar av grödor, såsom grovfoder och spannmål. Torkan orsakade problem som exempelvis djurfoderbrist, vilket försvårade utfodringen av mjölkkor. Denna fältstudie gick ut på att undersöka hur svenska mjölkbönder hanterat torkan och fodersituationen. Elva gårdar besöktes och lantbrukarna fick frågor från en frågeenkät som handlade om huruvida de påverkades av torkan och fodersituationen eller inte, frågor om utfodringsstrategin på gården, om alternativa fodermedel använts och om lantbrukarna behövt sälja eller slakta djur till följd av fodersituationen. Lantbrukarna hade olika upplevelser av torkan, där en del testade att utfodra alternativa fodermedel som bönhalm, ärter, helsädesensilage, ensilage från trädad mark eller ett kompletterande pelleterat foder. En del av lantbrukarna behövde slakta eller sälja djur till följd av fodersituationen. Totalt ingick 59 kor som var i tidig laktation och nyligen fått sin första kalv. De kor som undersöktes var av raserna Svensk Holstein (SH), Svensk rödbrokig boskap (SRB) och Jersey-boskap. Utöver frågeenkäten togs foderprov från det grovfoder som användes för att se om samband fanns mellan foderprovsanalysen och andra studerade parametrar. Mjölk- och blodprover togs från 3-10 kor från varje gård. Dessa kor hullbedömdes även. Det undersöktes om samband kunde finnas mellan eventuella upplevda problem på grund av fodersituationen, och de studerade biologiska parametrarna. Dessa parametrar var koncentrationer av myristinsyra (C14:0), palmitinsyra (C16:0), stearinsyra (C18:0) och oljesyra (C18:1 cis-9) i mjölk, och koncentrationer av blodplasmakomponenterna β-hydroxybutyrat (BHB), icke-esterifierade fettsyror (NEFA), glukos, insulin och insulinliknande tillväxtfaktor (IGF-1), hull och foderprover. De grovfoderprover som togs analyserades för torrsubstans, innehåll av smältbar energi (ME), aska, råprotein (CP) och fiber (NDF). Majoriteten av de undersökta korna (93%) hade hull mellan 3,0 och 4,0 på en skala från 1-5, där 1 är undernärd och 5 är överviktig. Ungefärliga energibalanser på besättningsnivå uppskattades med datorprogrammet IndividRAM som visade att besättningarna var mellan 92 och 109%. Samband fanns mellan en del parametrar. Vilka parametrar som hade ett samband varierade mellan gårdarna. Statistiska analyser visade signifikanta korrelationer mellan C14:0 och C18:1 cis-9; NEFA och C18:1 cis-9; BHB och C18:1 cis-9; BHB och C14:0; BHB och glukos; BHB och NEFA. En variansanalys (ANOVA) visade signifikanta skillnader mellan gårdarna gällande koncentrationer av mjölkfettsyrorna C14:0, C16:0, C18:0, plasmakomponenterna BHB, NEFA, glukos, IGF-1 och hull.

Nyckelord: energibalans, metabolism, mjölkkor, torka, utfodring

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Abbreviations

AMS	Automatic milking system
BCS	Body condition score
BHB	β-hydroxybutyrate
CP	Crude protein
DIM	Days in milk
DM	Dry matter
DMI	Dry matter intake
EB	Energy balance
FA	Fatty acid
IGF-1	Insulin-like growth factor 1
IVOMD	In vitro organic matter digestibility
LCFA	Long-chain fatty acids
ME	Metabolizable energy
NDF	Neutral detergent fibre
NEB	Negative energy balance
NEFA	Non-esterified fatty acids
OMD	Organic matter digestibility
PMR	Partly mixed ration
SH	Swedish Holstein
SRB	Swedish Red
TMR	Total mixed ration

1   Introduction

1.1   The drought and its consequences

The summer of 2018 was one of the warmest and driest summers in Sweden in a long time. In 2017 the summer was cold and rainy (SMHI, 2018) with low roughage crops, which caused problems when the summer 2018 did not enable farms to compensate for the low crop yields the previous year. The last time there was such a cold and rainy year with a following warm and dry summer in Sweden, was in year 1867 and 1868 respectively (SMHI, 2017). In 2018, there was only 50-75% of the usual rainfall in the middle and south areas of Sweden (SMHI, 2018). Production of cereals and roughage was markedly hampered in the driest areas where the groundwater degree was low. A warm and dry weather condition can also cause slow regrowth of pasture. An estimation made in September 2018 showed that many farmers only had been able to harvest 50% of the production compared to earlier harvests. This consequently led to a shortage of feed e.g., which resulted in difficulties in feeding of dairy cattle for some farmers around the country (LRF, 2018). In August and September, the precipitation finally increased in many parts of Sweden (SMHI, 2019), which contributed to regrowth of the pastures (LRF, 2018). The drought and its consequences are important to investigate since it is a current topic and the feeding is very crucial on dairy farms.

2 Literature study

2.1 Alternative feedstuffs and possible solutions

When the pasture is dry and there is a poor growth, an alternative is to move the animals to forests, where they can eat brushwood, fern and leaves (Dahlström *et al.,* 2018). Fallow land, which is arable land that is resting from production of crops, can be harvested, ensilaged and fed to the cows as well (Jordbruksverket 2018). However, this is not a suitable feeding strategy for high-producing cows and therefore, farmers may need to buy alternative feedstuffs, either as a complementing feed or as a replacement. As Växa Sverige, farmers' cooperative advisory service and cow database, states on their website, cereals and legumes can be harvested as whole crops. Växa Sverige also underline the importance of accuracy in the ensiling process, especially when ensiling smaller amounts of roughage. Grass from fallows may be more suitable for older animals, dry cows and suckler cows. A long pasture period is advantageous to save feed, which can be possible when the pastures are good.

To be prepared for further dry summers where the result can be a lack of feed, it can be positive to arrange a storage of larger quantities of roughage. The animal owners may need more forward planning for slaughter of animals to avoid queues (Växa Sverige, 2018). Otherwise farmers may need to cull animals due to lack of feed which can result in lowered prices on the market for slaughter animals (Shrum *et al.,* 2018).

2.2 Milk fatty acids

Approximately 50% of the milk fatty acids (FA) are produced in the mammary gland. The remaining FA are preformed and comes from triglycerides in circulating chylomicrons or very low density lipoproteins (Sjaastad *et al.,* 2010). The milk

fat in ruminants mostly consists of triglycerides. An approximately distribution of them is that 70% are saturated, 25% monounsaturated, 2.3% polyunsaturated and 2.7% trans FA (Månsson, 2008). The saturated and long-chained FA are mostly myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0) (Mansbridge & Blake, 1997), where C16:0 stand for around one third of the FA taken up from the blood. Most of the remaining preformed FA are carbon chain length of 18 such as C18:0, oleic (C18:1 cis-9) and linoleic acid (Sjaastad *et al.*, 2010).

2.2.1 Milk fatty acids as markers of metabolic status

In a study by Jorjong *et al.* (2014) it was investigated if milk FA could be used as indicators to discover detrimental levels of non-esterified fatty acids (NEFA) in blood plasma, where ≥0.6 mmol/L was defined as threshold. A conclusion was that milk fat C18:1 cis-9 could be useful to early discover detrimental blood plasma levels of NEFA in dairy cattle in the second week of lactation, since increased level of C18:1 cis-9 in milk was positively correlated with an increase in NEFA in blood plasma. However, it was also concluded that the positive correlation between NEFA and milk fat C18:1 cis-9 concentrations was moderate and that more research is needed (Jorjong *et al.*, 2014).

Martin *et al.* (2015) performed a study where a part of it was to investigate if milk FA could be possible as predictors of onset of luteal activity (OLA). It was found that cows with late OLA were in deeper negative energy balance (NEB). These animals also had a lower proportion of the milk FA C14:0 and C16:0, compared to the early OLA group. The concentrations of C18:0 and C18:1 cis-9 were lower in the early OLA group compared to the late (Martin *et al.,* 2015).

2.3 Blood plasma components

The metabolism is reflected by metabolites and hormones in blood plasma. The monosaccharide glucose is a major nutrient for the cells in the body. Glucose is utilized for energy or stored as glycogen in liver and skeletal muscle cells and can also be converted to triglycerides in the liver. Insulin is the most important hormone in the regulation of the metabolism of glucose, amino acids and lipids. β-hydroxybutyrate (BHB) is produced in the liver as a result of partial oxidation of FA in virtually all mammals but in ruminants BHB can also be produced in the rumen epithelium by oxidation of butyrate produced by fermentation of dietary carbohydrates in the rumen. Insulin-like growth factor 1 (IGF-1) is a peptide that

mediates the growth-stimulating effect of growth hormone, a hormone which has a direct effect on the metabolism of tissues in the body (Sjaastad *et al.,* 2010).

2.3.1 Energy balance

The concentration of NEFA partly reflects the metabolic state and degree of mobilization of adipose tissue in dairy cattle. High levels of NEFA is related to a NEB (Pullen *et al.,* 1989). It is well known that deep NEB the period after calving can increase the risk for postpartum diseases (Suthar *et al.*, 2013). The degree of NEB is characterized by the increase of NEFA and BHB and decrease of glucose and IGF-1 level in blood plasma (Esposito *et al.,* 2014). At the onset of lactation, glucose synthesis by the liver increases and glucose oxidation by peripheral tissues decreases. These are important metabolic adaptions in this phase. After the parturition the cow is usually in a NEB as a result of the transition from pregnancy to lactation. The energy demands that are needed for milk production normally outpaces the energy intake (Overton, 2003). The lipolysis occurs to compensate the energy requirements, which results in a release of NEFA into the bloodstream (Herdt, 1997). The mobilization of NEFA from adipose tissue increases after parturition (Bauman & Currie, 1980). When the cow is in NEB the liver becomes refractory to growth hormone (GH) and a decrease of the level of IGF-1 occur, which is further related to a decrease of insulin (Bell *et al.,* 2000).

2.4 Body condition

Body condition scoring (BCS) of cattle is an important management tool since it may reflect the welfare of the animal. An optimum calving body condition is thought to be 3.0 to 3.25 of a 5-point scale which is usually applied in BCS of cattle. According to Roche *et al.* (2009), a low BCS is in relation to a reduced production and reproduction, while a BCS of ≥3.5 can be associated with a reduction of dry matter intake (DMI) and milk production and increased risk of metabolic disorders. As mentioned in the study by Roche *et al.* (2009), cows that are in 50 to 100 days after calving usually have a lower body condition than the optimal. It is also stated that the impact of management and feeding on early post-calving (1-4 weeks post-calving) BCS loss is small until after the natural period of insulin resistance and when the somatotropic axis is activated (Roche *et al.,* 2009).

2.5 Impact of feeding on blood plasma components and milk fatty acids

In a study by Obese *et al*. (2018), the diet's impact on some blood plasma metabolites in early lactation cows was investigated. It was shown that the intake of dry matter (DMI) and metabolizable energy (ME) density had an impact. Four different diets, differing in DMI and ME content, were fed to the cows. One with low DMI and ME (called LL), one with low DMI and high ME (called LH), one with high DMI and low ME (called HL) and one with high DMI and high ME (HH). A conclusion was that the levels of BHB, glucose, IGF-1 and urea in blood plasma were affected by the different diets. The BHB concentration was higher in the cows consuming the HL and LL diets, compared to the other diets. With the HH and LH diets, the concentration of glucose was higher. The level of IGF-1 was higher with the HH diet. The cows that were eating the LL diet had higher urea concentrations in the blood plasma. However, the concentrations of NEFA were similar in the four diets (Obese *et al.,* 2018).

In a study by Douglas *et al*. (2007) periparturient cows were fed different diets; two control diets, one fed to meet 120% of the energy requirements (called CA) and one fed to meet 80% of them (called CR). The third diet was supplemented (called S) with mostly saturated free FA. The diet contained 47% of C16:0, 36% of C18:0 and 14% of C18:1 cis-9 and were fed to meet 120% of the requirements. The last diet (called U) was similar to the diet with saturated free FA (called S) but where the cows additionally were abomasally infused with soybean oil (which would make the diet plus infused fat meet 120% of requirements). It was concluded that the groups fed S, U or CR had higher concentrations of NEFA in blood plasma before calving. The cows fed U had decreased concentrations of BHB after calving. Moreover, the cows consuming diet U had lower levels of 16:0 and 18:0, compared to the cows fed diet S. Prepartal feed restriction had an impact on long-chain fatty acids (LCFA) profiles (Douglas *et al.,* 2007).

2.6   Aims of the study and questions

This study aimed to investigate how Swedish dairy farmers managed the drought and lack of feed during and after the summer of 2018 and give examples of alternative feedstuffs that were used. Furthermore, the study aimed to analyse if relationships could be found between the farmers' experiences of the drought and feed situation, based on the answers of a questionnaire, and the estimated energy balances (EB) on herd level, the nutrient composition of used feeds, levels of some blood plasma components and milk FA, and body conditions of early lactating primiparous cows. In addition, it was investigated if certain milk FA reflected the metabolism of primiparous cows in early lactation.

Questions to be answered are following:
- How was the drought and feed situation handled on the eleven included dairy farms? Which alternative feedstuffs were used?
- Where there any relationships between the farmers' experiences of the drought and feed situation and the actual EB on herd level, nutrient composition of used feeds, levels of blood plasma components and milk FA, and body conditions of the examined primiparous cows?

3 Materials and methods

3.1 Experimental design

Eleven farm visits were performed during September and October 2018, where information regarding the feeding strategies were obtained, and feed-, blood- and milk samples were collected. The farms that were available for the present study were linked to a research project focusing on tools to identify optimal calving interval in individual primiparous cows. Thus, only primiparous cows in their 3rd to 28th day in milk were included in the blood- and milk sampling and BCS.

In total, 59 primiparous cows were included. The participating farms had dairy cattle of the breeds Swedish Red (SRB), Swedish Holstein (SH), and a few cross-breds, Jersey cattle and Swedish mountain cattle (SMC). The examined cows were of the breeds SRB, SH and Jersey cattle. Eligible farms were those that fulfilled the criteria stated in Table 1. The farms had 100 or more dairy cows and the herds were included in Swedish milk recording system. On the farms the milk yields of the cows were measured daily to keep records of the production. All of the farms had a milk production of 9000 kg ECM or more. The farms had loose-housing systems. Lastly, the mean value of calving interval was 14 months or less, the reproduction index was >22 (2017) and gestation percentage on the farms was 31-90% (2017). Milk- and blood samples were collected, and body condition was scored from between three to ten animals from each farm. The number of examined cows from each farm differed because of the variation of number of primiparous cows in early lactation on the farms at that time. In addition to this a feed sample was taken from the roughage that was used on each farm.

Information about the farms in the present study, regarding milking- and feeding systems are presented in Table 2. The number of lactating cows on the farms in September 2018, number of examined cows and proportion of breeds of all the cows on the farms are shown in Table 3.

Table 1. *Criteria for the farms to participate in the study*

Criteria
At least 100 dairy cows
The herd is included in Swedish milk recording system
Continuous measuring of milk yield
A milk production not less than 9000 kg ECM
Loose-housing
Mean value of calving interval <14 months
Reproduction index >22 (2017), gestation percentage 1st calf 31-90% (2017)

Table 2. *Information about the farms regarding if they had an automatic milking system (AMS) or milking parlour as milking system, and whether the feed was a total mixed ration (TMR) or partly mixed ration (PMR)*

Farm	Milking system	TMR/PMR
A	AMS	PMR
B	Milking parlour	PMR
C	AMS	PMR
D	AMS	PMR
E	AMS	PMR
F	AMS	PMR
G	AMS	PMR
H	AMS	PMR
I	Milking parlour	TMR
J	AMS	PMR
K	AMS	PMR

Table 3. *Information about the farms regarding number of lactating cows at that time (both primiparous and multiparous cows), number of cows examined in the present study and proportion of breeds (SH, SRB, crossbreed, Jersey cattle or SMC)*

Farm	Lactating cows	Examined cows	SH	SRB	Crossbr.	Jersey cattle	SMC
A	124	4	52%	27%	21%		
B	103	4	16%	81%	3%		
C	120	3	76%	29%	5%		
D	228	10	77%	19%	4%		
E	139	8	46%	3%	51%		
F	210	4	54%	32%	14%		
G	149	8	31%	23%	26%	19%	1%
H	121	6	98%		2%		
I	116	4	68%	6%	26%		
J	134	3	5%	55%	40%		
K	203	5	92%	3%	5%		

3.2 Questionnaire

On the visits the farmers were asked questions concerning the feeding strategy on the farms and if this summer's drought had an impact on the feeding and choice of feedstuffs. The farmers were asked questions from a questionnaire, as a semi-structured interview. The questions are presented in Table 4. Regarding the feeding strategy, the farmers were asked if they experienced if they were affected by the drought and feed situation. They were also asked if changes in choices of feedstuffs had been carried out. The questions 4, 5, 6 and 8 were included to collect information for the software IndividRAM, that was used to estimate energy balances on herd level.

Table 4. *Questions asked on the farm visits, regarding the feeding strategy applied on the farms*

1. Were you required to make changes in the feeding strategy because of the drought and feed situation?
2. If yes; What alternative feedstuffs do you feed the cows?
3. Have you sold or slaughtered animals as a consequence of the drought?
4. How much and what kind of roughage is fed to the herd per day (kg or kg DM)?
5. How much and what kind of concentrate is fed to the herd per day (kg)?
6. How much and what kind of minerals is fed to the herd per day (g)?
7. Are animals fed a TMR or PMR?
8. Amount of residues on the feed table?

3.2.1 Estimation of energy balances

Information regarding the milk production (milk delivery amount and contents of fat, protein and urea) on the farms was collected from the receipt from the latest milk delivery. The concentrates, cereals, roughages and minerals used on the farms and the amount of each of them fed to the herd per day were noted. Moreover, information regarding residues on the feed tables and the amount of milk consumed on farm were collected. This information was then applied in the software IndividRAM, a Nordic feed evaluation system. With this information IndividRAM estimates approximate EB for the herds (IndividRAM, 2018).

3.3 Feed analysis

From each farm, a feed sample of approximately one kilogram was taken from the roughage or feed used. These samples were desirably collected from the feed mixer or close to the feed table, but not directly from the feed table to avoid that the feed components were separated by the cows which would generate unrepresentative samples. The samples were collected by hand (with protecting plastic gloves on) and put in plastic bags that were carefully sealed. During the transport from the farm to the lab the samples were chilled in a portable cooler (+1 to +8°C) and thereafter stored in a freezer (-22°C) at the department for approximately 6 weeks. The roughage was analysed on the department's laboratory, for DM density, content of ME, neutral detergent fibre (NDF), crude protein (CP) and ash. To calculate the moisture and DM content, an in-house method was used. For the NDF analysis, a standard operation procedure, amylase neutral detergent fibre method (aNDFom) was applied (Chai & Udén, 1998). For the determination of total nitrogen per CP, the Kjeldahl method was used. The rumen In Vitro Organic Matter Digestibility (IVOMD) was determined with a standard operation procedure where the sample is incubated with rumen fluid-buffer mixture. With this method the IVOMD can be calculated and the ME content and organic matter digestibility (OMD) can be estimated (Lindgren, 1979). Ash percentage were determined via the AOAC official method 942.05 (Jennische & Larsson, 1990).

3.4   Milk samples

The milk samples were collected at different times of the day regardless the time of milking (in the AMS or milking parlour) and feeding. From each examined individual a milk sample was collected from one quarter of the mammary gland. First the teat was disinfected, and 3-4 squirts of milk were discarded before milk was collected, by hand-milking, into test tubes with bronopol (2-bromo-2-nitropropane-1,3-diol). Samples were directly cooled in a portable cooler (+1 to +8°C) during transport and later stored in a refrigerator (+4°C) at the laboratory at the Department of Animal Nutrition and Management until the analysis was performed. The analysis was completed within seven days from sampling. The milk samples were carefully warmed-up to 38°C before analysis and then analysed for fat content and FA composition, which was performed with the FTIR-spectroscopy (Fourier Transform Infrared Spectroscopy) analysis with a Combi-Scope FTIR 300. The fat content was used to calculate gram FA (C14:0, C16:0, C18:0 and C18:1 cis-9) per gram total fat.

3.5   Blood samples

After disinfection, blood samples were collected from the coccygeal artery or vein into 10 mL vacuum tubes containing lithium heparin as anticoagulant. The blood samples were centrifuged within one hour after the sampling and plasma harvested were stored in a refrigerator at -20°C. The thawed plasma samples were analysed for BHB, NEFA, glucose, insulin and IGF-1 at the laboratory at the Department of Animal Nutrition and Management. The concentrations of BHB were analysed using a kinetic enzymatic method (BHB Assay kit, MAK041; Sigma-Aldrich, St. Louis, MO). When analysing the NEFA concentrations, an enzymatic colorimetric test (NEFA C, Wako Chemicals GmbH, Neuss, Germany) was used. The glucose levels were analysed with an enzymatic method (Boeringer Mannheim D-Glucose, UV-method, Kit no: 10716 251 035 (r-biopharm, Roche), Food diagnostics). For the insulin concentrations, a commercial enzyme immunoassay method adapted for bovines was applied (Mercodia Bovine Insulin ELISA, Mercodia AB, Uppsala, Sweden). The concentrations of IGF-1 were analysed with a commercial immuno-assay (Human IGF-1 ELISA, Mediagnost).

3.6   Body condition score

Before the BCS on the eleven farms, the method used in the present study was practiced on Swedish Livestock Research Centre at SLU, Lövsta. On the farm

visits, the selected primiparous cows were scored for body condition with a scale of 1 to 5 with 0.25 points increments according to Edmonson *et al.* (1989). The lowest score (1) indicates an emaciated condition while the highest score (5) indicates obese condition. The shape of the spine, the area between the hooks, between pins and hooks and between tail head to pins were observed (Figure 1). Photos were also taken of each examined cow.

Figure 1. The sheet which was used for BCS (Edmonson *et al.*, 1989).

3.7 Statistical analyses

The statistical analyses were carried out using the software Minitab 17. It was studied if correlations between the milk FA C14:0 and C18:1 cis-9 and the blood plasma components BHB, NEFA, glucose, insulin and IGF-1, could be found in the examined individuals. Mean values were calculated and correlation coefficients between the milk FA and blood plasma components were obtained. The results of the statistical analyses that were shown to have a correlation coefficient of $>\pm0.50$ were discussed. A statistical analysis of variance (ANOVA) was performed to study if significant differences could be found between the farms regarding levels of C14:0, C16:0, C18:0, C18:1 cis-9, BHB, NEFA, glucose, insulin and IGF-1.

4 Results

4.1 Questionnaire's result

In Figure 2, Yes/No-answers from the questions are presented. Seven of eleven farmers experienced that they were affected by the drought. Eight farmers tried feeding alternative feedstuffs, regardless if they experienced that they were affected by the drought and feed situation or not. Four of the farmers that tried alternative feedstuffs bought in a supplementary compound feed to either complement the roughage because of its poor nutrition value or to partly replace it because of the lack of roughage. Three farmers were required to sell or slaughter animals.
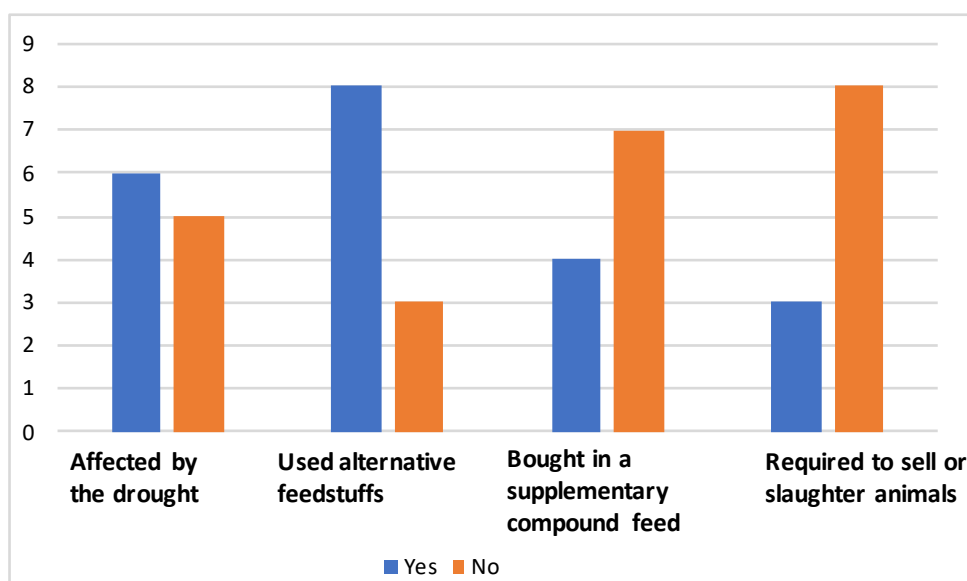

Figure 2. Number of farmers that answered 'Yes' or 'No' regarding if they experienced that they were affected by the drought and its consequences, if they tried feeding alternative feedstuffs and how many of these that bought in a supplementary compound feed, and if they were required to sell or slaughter animals as a consequence of the drought and feed situation.

On most of the farms, the ordinary feed ration consisted of a concentrate, minerals, roughage, and wheat, barley and/or oats, normally mixed and smashed. Of the farmers that experienced that they were affected by the drought, there was farm C that tried feeding bean straw which they mixed with the silage. Farm E, F, G and J were farms where they also expressed that they were affected. On these four farms they bought in a complementing compound feed. Feeds that were used on these farms was for example "Rosa Grönmix" from Svenska foder, that can replace parts of the ration of roughage. A complementing feed as "Komplett Grov" from Lantmännen, was fed to the cows on three of these farms. On farm E they added silage from fallows and on farm I and J they added whole crop silage to the ration. Farm H was a farm where they were only able to harvest 70% of the usual roughage production and the farmer experienced that they were affected by the drought. On this farm they had a large storage of roughage and they did not need to buy feed despite the poor harvest caused by the drought.

Four farmers experienced that they were not affected by the drought and feed situation. However, two of them tried with feeding alternative feedstuffs this year. Farm B added peas to the feed ration this year. On farm A they added whole crop silage. Taking advantage of all of the harvest, like whole crops, is one way to save up roughage. Farm D and K were not affected by the drought and feed situation and made no changes in the feeding strategy.

Most of the farmers expressed that they were especially careful with not discarding any feed because of the feed situation and made sure the feed table was empty before they added new feed. A common concern among the farmers was the queues for slaughtering animals, as a consequence of the drought. When they needed to slaughter animals due to the lack of feed this summer, the queues were longer than usual, which made it difficult to send animals to slaughter. In some cases, farmers kept animals with poor milk production instead of slaughter them because they knew about the slaughter queues. It was shown that three of the eleven farmers had been required to sell or slaughter animals because of the feed situation. Some of the farmers expressed that a concern is if the next summer would be as dry as the summer 2018.

When the farm visits took part, in September and October, the areas of the farms had finally received rain. This resulted in regrowth of grass on the pastures which also contributed to a longer pasture period. In Table 4, data of precipitation and mean temperature from SMHI are presented to get an overview of the weather of the summer year 2018 and earlier years. It can be seen that there was a decrease in

precipitation and increase in temperature on most of the farms in May to September year 2018, compared to the five years before.

Table 4. *The mean precipitation (in millimetre) in May to September year 2013 to 2017, and in the same period year 2018, and mean temperature (in °C) in May to September year 2013 to 2017 and in the same period year 2018, in the areas of the farms (SMHI, 2019)*

Farm	Experience of drought	Prec. 2013-2017	Prec. 2018	Temp. 2013-2017	Temp. 2018
A	Not affected	59.7	55.1	14.2	13.9
B	Not affected	59.6	51.3	14.1	16.5
C	Affected	67.9	53.6	15.2	17.5
D	Not affected	73.8	60.0	13.6	15.9
E	Affected	77.1	32.8	14.4	16.6
F and G	Affected	45.0	32.7	14.5	16.7
H	Affected	36.9	32.8	14.4	16.8
I	Affected	54.4	54.6	13.7	15.9
J	Affected	73.9	43.1	13.6	16.2
K	Not affected	70.9	48.8	15.1	17.4

4.2 Feed analyses

From each farm a sample was taken from the roughage fed to the cows at that time. The roughages varied in DM contents. It can be observed that the feed sample from farm C had a low content of ME. The feed samples that contained grass silage only are presented in Table 5. The feed samples that contained grass silage mixed with bean straw, whole crop silage and/or a supplementary compound feed can be seen in Table 6.

Table 5. *Result of DM content, ME (MJ/kg DM), ash, CP and NDF (% of DM) in the feed samples consisting of grass silage only.*

Farm	Sample content	DM	ME	Ash	CP	NDF
A	Grass silage	27.0	10.6	11.4	18.9	47.2
B	Grass silage	50.2	10.9	8.3	17.2	49.5
D	Grass silage	60.2	10.8	8.7	14.2	49.7
E	Grass silage	46.9	11.8	9.0	16.4	47.1
H	Grass silage	57.5	11.5	9.4	15.4	48.2
K	Grass silage	23.8	11.4	9.7	20.8	55.2

Table 6. *Result of DM content, ME (MJ/kg DM), ash, CP and NDF (% of DM) in the feed samples consisting of roughage mixed with bean straw, whole crop silage or a complementing compound feed (complement).*

Farm	Sample content	DM	ME	Ash	CP	NDF
C	Grass silage, bean straw	57.0	5.3	7.6	13.6	43.9
G	Grass silage, complement	85.4	12.1	7.9	18.9	44.0
F	Grass silage, complement	47.5	12.0	6.7	16.9	44.7
I	Grass silage, whole crop silage	47.3	11.2	9.1	13.3	47.4
J	Grass silage, complement, whole crop silage	60.2	11.6	7.2	17.0	47.1

4.3 Milk analyses

In Figure 3 the levels of the milk FA C16:0, C18:0, C18:1 cis-9 and C14:0 are presented. The level of C18:0 on farm F was low (6.89 g FA per 100 g total fat). The level of C18:1 cis-9 was low on farm A and F (16.5 and 16.17 g FA per 100 g total fat). Further, the level of C14:0 on farm H and K (9.93 and 9.49 g FA per 100 g total fat) were low compared to the other farms. In Figure 4 the average milk yields on the farms the years 2016, 2017 and 2018 in the period May to September are presented. It can be seen that there are no extensive decreases in milk yield on the farms as an possible consequence of the feed situation.
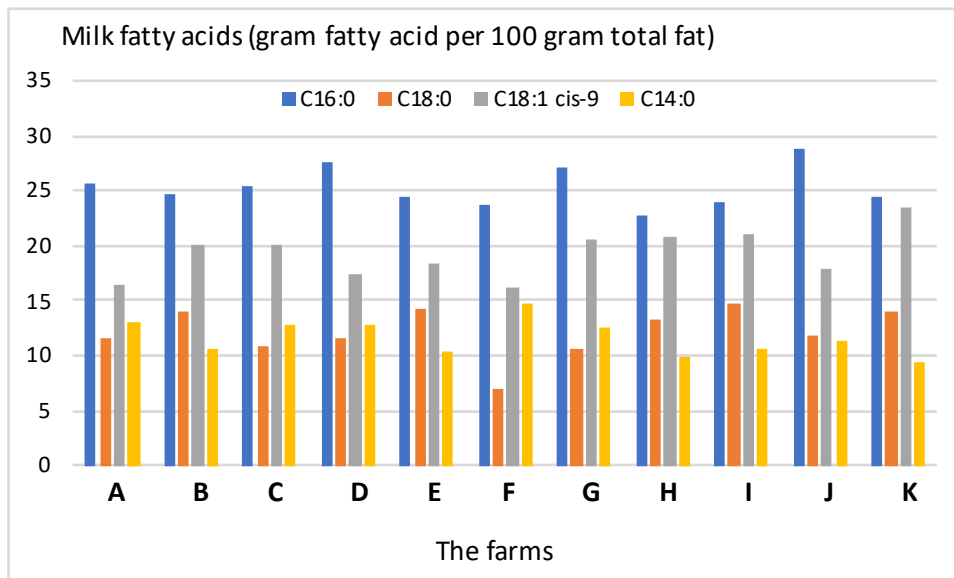

Figure 3. The levels of C16:0, C18:0, C18:1 cis-9 and C14:0 in g FA per 100 g total fat. They are presented as mean values for each farm.
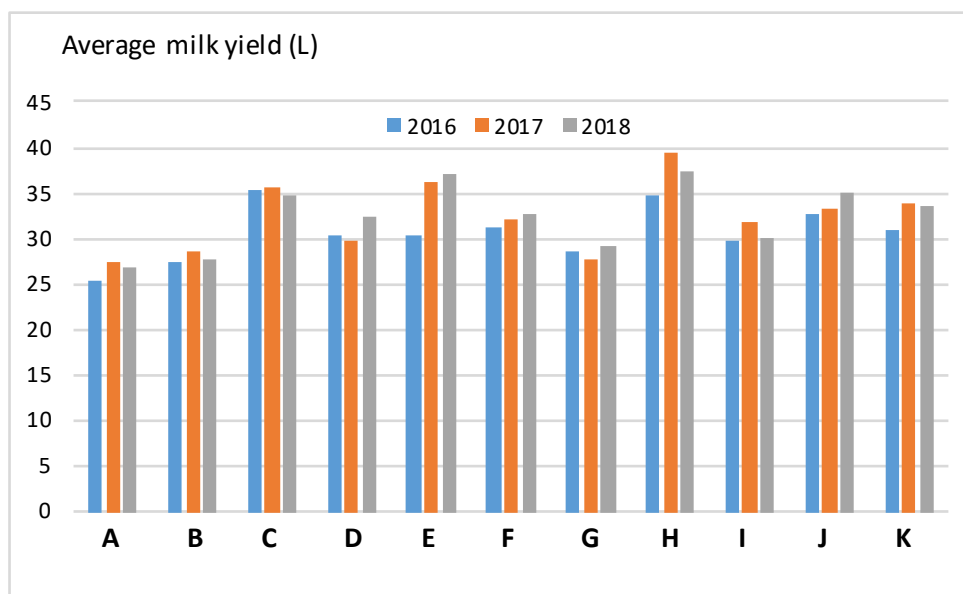
Figure 4. The average milk yield (L) on the farms in the period May to September the years 2016, 2017 and 2018 (data from Swedish milk recording system).

4.4 Blood plasma metabolites and hormones

The statistical analysis of variance (ANOVA) showed that there were significant differences between the farms regarding the BHB levels in plasma. In Figure 5 it can be seen that farm K had the highest concentration of BHB (1.55 mM). Farm K also had the highest level of NEFA (0.63 mmol/L), seen in Figure 6. It can be observed that farm D, E and J had low levels of NEFA (0.14, 0.16 and 0.14 mmol/L) compared to the other farms. Regarding the NEFA levels in plasma, there were significant differences between the farms. Concerning the glucose levels, presented in Figure 7, farm H and K had the lowest levels (2.84 and 2.79 mmol/L) and farm A and I the highest (3.97 and 3.85 mmol/L). Further, there were significant differences between the farms considering the glucose levels. Regarding the insulin levels, presented in Figure 8, farm K had the lowest (0.08 µg/L). There were no significant differences between the farms concerning the insulin level in plasma. The levels of IGF-1 are showed in Figure 9. Concerning the concentrations of IGF-1 there were significant differences between the farms. Farm J had the highest level (173.5 ng/mL) and farm K the lowest (57.21 ng/mL).
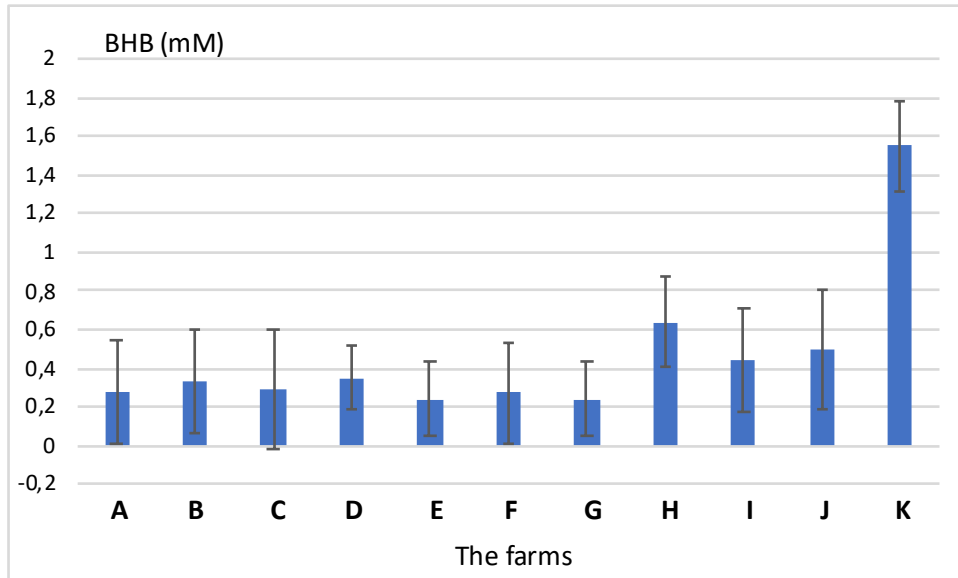
Figure 5. The levels of BHB in blood plasma (mM) presented as mean values for each farm, and standard error (SE) of the means.
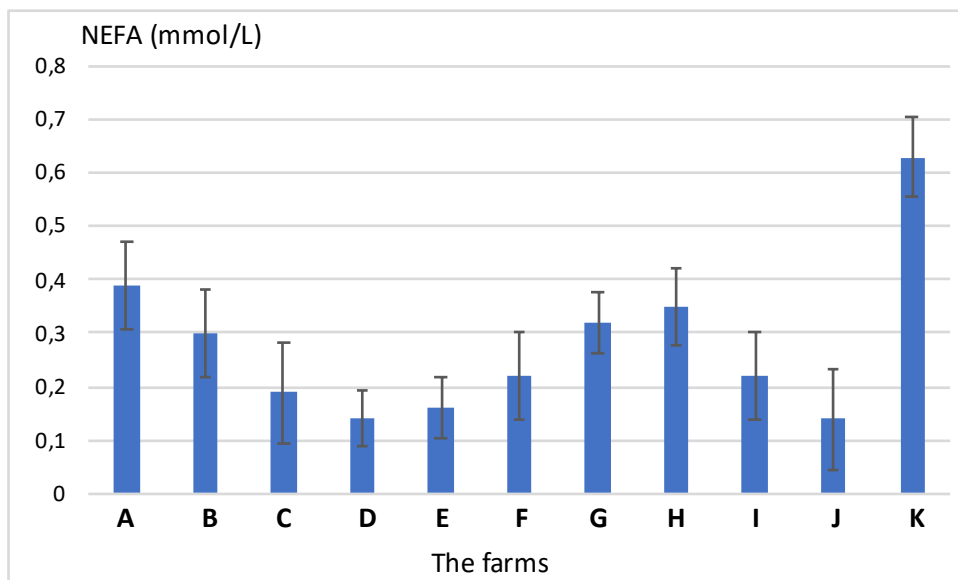

Figure 6. The levels of NEFA in blood plasma (mmol/L), presented as mean values for each farm, and SE of the means.
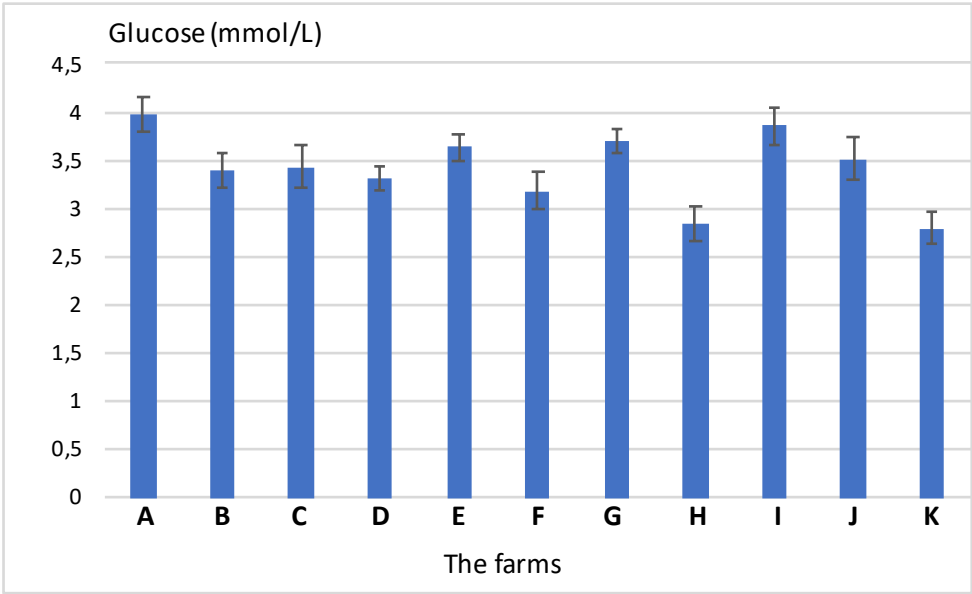
Figure 7. The levels of glucose (mmol/L), presented as mean values for each farm, and SE of the means.
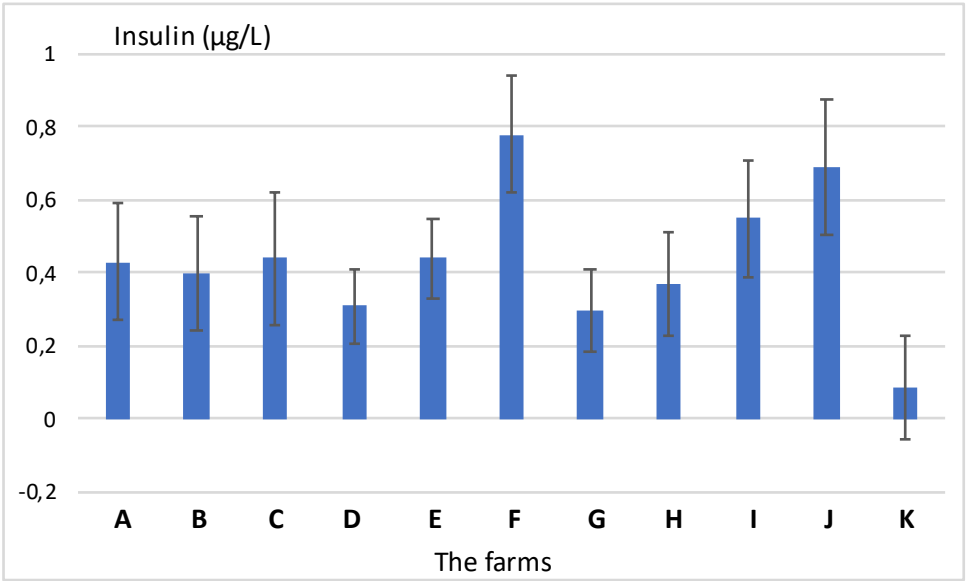

Figure 8. The levels of insulin in blood plasma (µg/L), presented as mean values for each farm, and SE of the means.
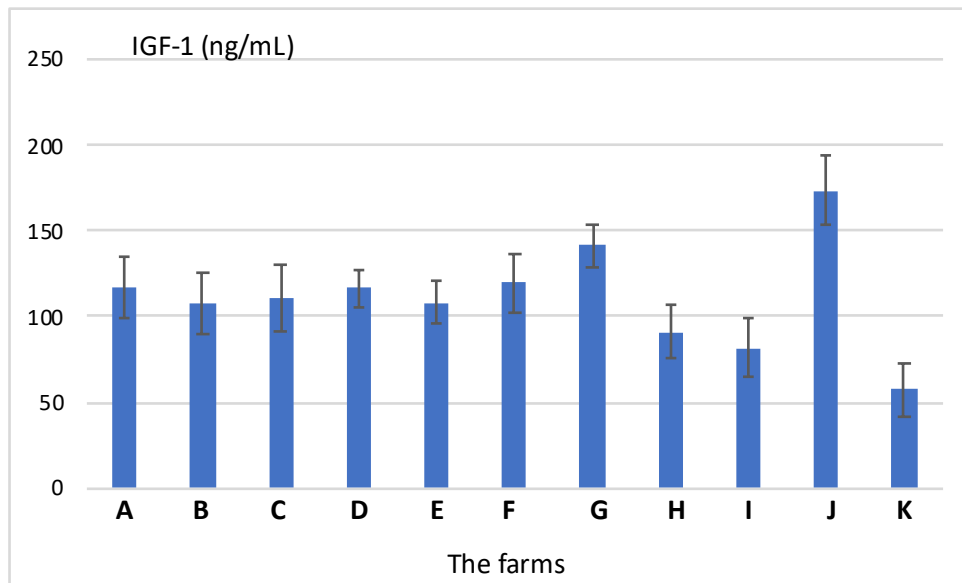
Figure 9. The levels of IGF-1 in blood plasma (ng/mL), presented as mean values for each farm, and SE of the means.

4.5   Body condition

Figure 10 shows the means of BCS on each farm, and standard errors (SE) where it can be observed that the means of body conditions ranged from 3.0 to 3.75 of the scale of 1-5. The body conditions of all the examined cows ranged from 2.5 to 4.25. Most of the individuals (93%) were between 3.0 and 4.0. The statistical analysis showed significant differences between the farms regarding the means of body conditions.
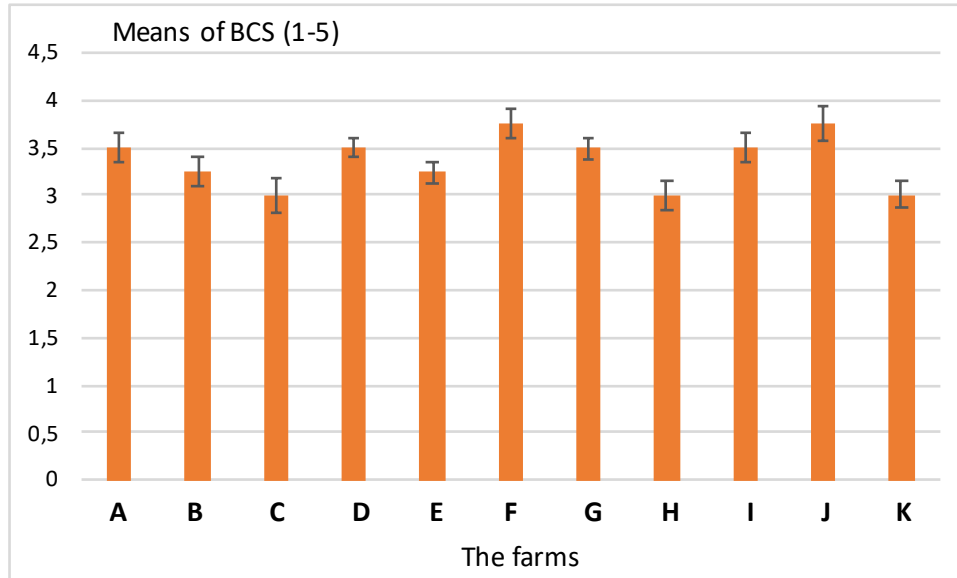
Figure 10. The means of BCS on the farms on the scale of 1-5, and SE of the means.

4.6 Energy balance on herd level

The calculated EB on herd level, that are presented in Figure 12, were estimated using the software IndividRAM. The EB were ranging from 91.6 to 109.2%.
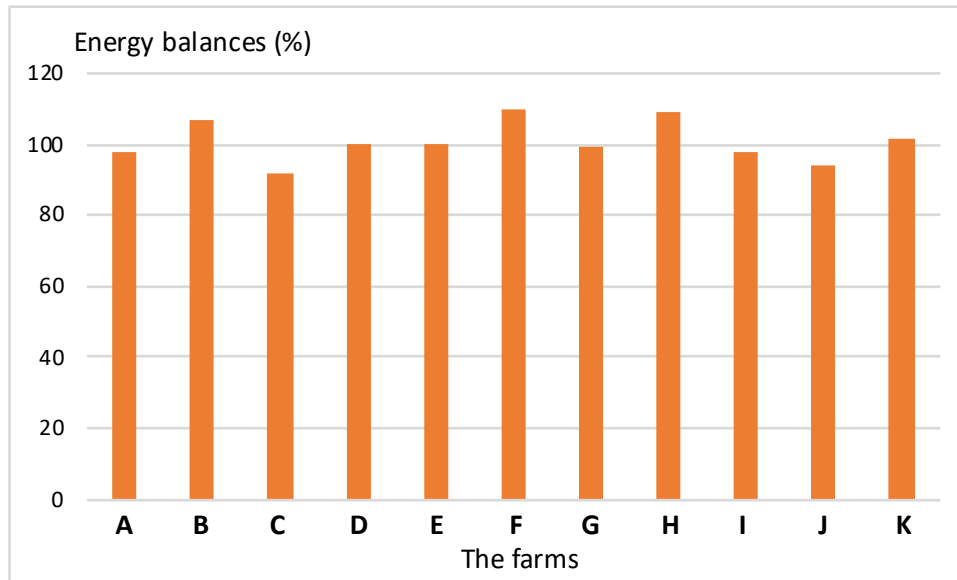
Figure 12. The EB (%) on herd level calculated via IndividRAM.

4.7 Correlations between milk fatty acids and blood plasma components

In Table 7 the correlation coefficients between the milk FA C14:0 and C18:1 cis-9 and all the blood plasma components are presented. The correlation coefficients that were $>\pm0.50$ were between C14:0 and C18:1 cis-9; NEFA and C18:1 cis-9; BHB and C18:1 cis-9; C14:0 and BHB; glucose and BHB, and NEFA and BHB.

Table 7. *Correlation coefficients between the levels of C14:0, C18:1 cis-9, insulin, glucose, NEFA, IGF-1 and BHB on the farms, where the correlation coefficients >±0.50 are bold*

	C18:1 cis-9	C14:0	Insulin	Glucose	NEFA	IGF-1
C14:0	**-0.650**					
	<0.001					
Insulin	-0.314	0.263				
	0.017	0.046				
Glucose	-0.390	0.402	0.239			
	0.003	0.002	0.071			
NEFA	**0.539**	-0.408	-0.439	-0.351		
	<0.001	0.001	0.001	0.007		
IGF-1	-0.413	0.495	0.400	0.496	-0.498	
	0.001	<0.001	0.002	<0.001	<0.001	
BHB	**0.665**	**-0.549**	-0.259	**-0.673**	**0.518**	-0.368
	<0.001	<0.001	0.050	<0.001	<0.001	0.005

4.8   Differences between the farms

In the statistical analysis of variance (ANOVA), that was performed with the general linear model and adjusted sums of square, it was found that there were significant differences between the farms regarding the concentrations of C14:0, C16:0 and C18:0 in milk, BHB, NEFA, glucose and IGF-1 in blood plasma and the body conditions.

5 Discussion

5.1 The eleven farms

There are relations between some of the studied parameters. The reason to the different relations on the farms is difficult to know and therefore this needs to be further researched. On farm E, it was expressed that they struggled with the feed situation and bought supplementary compound feed to compensate for the low roughage crop. They also added grass from fallow land to the ration, fallows might have a lower nutrition value compared to silage, since it is arable land resting from crop production. This indicates that this herd managed the drought despite the farmer's experience.

An interesting farm to discuss is farm K, where the farmer expressed that they were not required to make changes concerning the feeding strategy. The levels of NEFA and BHB in blood plasma were high in the examined individuals, which were in early lactation. According to Esposito (2014) it was stated that an increase in NEFA and BHB and decrease of glucose and IGF-1 in blood plasma are related to NEB, which corresponds to the present study. However, the EB estimated with IndividRAM was good on farm K. In this farm the levels of insulin, IGF-1 and glucose were lower than in the other farms. The level of C18:1 cis-9 was high and the level of C14:0 was low. Taken together these results indicate that the metabolism was compromised at least among the sampled sub-population of the early lactating primiparous cows on this farm.

Farm J was one of the farms that was required to change the feeding strategy as a result of the feed situation. The levels of C18:0 and C18:1 cis-9 were low and C14:0 high. The FA profile indicates a low lipolytic activity of the adipose and

while the mammary *de novo* synthesis was relatively high. The levels of glucose and IGF-1 were high. Regarding the high glucose and IGF-1 in blood, this corresponds to the results of the study performed by Obese *et al.* (2018) where it was stated that the levels of IGF-1 and glucose were higher in the cows consuming the diets with high ME content. It may be assumed that this herd accurately handled the shortfall of feed.

The NEB on farm C may be in relation to the questionnaire, where the animal owner expressed that they were affected by the feed situation. However, since all the examined cows on the eleven farms were in early lactation (3rd to 28th DIM), they are at higher risk to be in NEB. Thus, the NEB may not be caused by the drought and changed feed strategy.

On farm I they had problems with small harvests this summer and therefore harvested whole crops and planned to harvest grass from fallow land. The level of NEFA was low and the estimated EB on farm I was close to 100%, which is good. However, the level of C14:0 was low and C18:1 cis-9 was high compared to the other farms, which can be related to the questionnaire where they expressed that they were affected by the drought. Farm F was also one of the farms which changed feeding strategy. The EB on herd level was high. On farm F the level of C18:0 was low. Douglas *et al.* (2007) concluded that prepartal feed restriction has an impact on LCFA profiles. The cows that were fed a diet with supplementation of mostly saturated free FA to meet 120% of the requirements and where the cows were abomasally infused with soybean oil, had lower level of 18:0 and 16:0. However, in the present study, whole crop silage was added to the ration, and not restrictions in the diet as in the study by Douglas *et al.* (2007). Though, in both studies the feeding strategy might have had an impact on the level of the milk FA C18:0.

On farm A the farmers did not experience problems because of the drought. The level of C18:0 and insulin were low compared to the other farms. On farm H the farmer expressed that they were affected by the drought. The large storage of roughage may have contributed to that they did not need to buy feed despite the poor harvests on this farm. In the examined cows from farm H the level of C14:0 was low. On farm G, changes in feeding strategy were performed because of the drought and feed situation. Farm A was a farm where they expressed that they were not affected by the drought and feed situation. However, when comparing the results of A and G, it can be observed that the results on these farms were quite similar except for a lower level of insulin on farm G. Thus, the responses to the

questionnaire and changes in feeding strategy may not always relate to the parameters included in this study.

Jorjong *et al.* (2014) stated that the milk FA C18:1 cis-9 can be useful to discover detrimental levels of NEFA in blood plasma (≥0.6 mmol/L). This can be related to the present study, where the correlation coefficient between NEFA and C18:1 cis-9 was 0.54. Other correlation coefficients that were >±0.50 were between the levels of C14:0 and C18:1 cis-9; BHB and C18:1 cis-9; C14:0 and BHB; glucose and BHB, and NEFA and BHB, on the farms. The statistical analysis of variance, performed with the general linear model and adjusted sums of square, showed significant differences between the farms regarding the levels of C14:0, C16:0 and C18:0 in milk, and glucose, BHB, NEFA and IGF-1 in blood plasma and the results of BCS. There were differences between the farms regarding energy metabolism and EB. However, it may be difficult to know what these differences depend on. Since there are significant differences between the herds, it would have been interesting if a clear relation was found between these parameters and the feeding strategy and response of the questionnaire on the different farms. Since farm K was the farm that diverged the most regarding the results of the milk FA and blood plasma components, it was of interest to see if the result of the statistical analysis of variance would be different when this farm was not included. When this statistical analysis was performed without farm K, the result was similar. Significant differences were found between the farms regarding BCS, all of the milk FA and blood plasma components, except for insulin (data not presented).

On some of the farms the animal owner had to slaughter animals because of the feed situation, which is consistent with the study by Shrum *et al*. (2018) where they stated that culling of animals on the farm can be a consequence of the drought. The body conditions of all the examined cows were between 2.5 and 4.25. The means of the body conditions on the farms were ranging between 3.0 to 3.75 which indicated that the average body condition on the farms were good. A reason to the result may be that all cows were primiparous. The variance of body conditions may be wider in cows differing in ages. Since the examined cows on the farms were in early lactation (3rd to 28th DIM), they might have been prioritized regarding the feeding. There may have been cows in the herds that were more affected by the drought and changed feeding strategy than the examined individuals. The proportion of breeds varied between the farms. However, the examined cows in the present study were of the breeds SH and SRB.

According to SMHI (2019), there was a decrease in precipitation and increase in temperature in most of the areas of the participating farms in the summer year

2018 (SMHI, 2019). Regarding the data of the precipitation and temperature from SMHI, there are no clear relations between the weather data, and the result of the questionnaire and studied parameters. When the farm visits took part in September and October, the precipitation had increased, and the temperature began to decrease. Hence, the milk- and blood samples were not collected at the warmest and driest period, which is important to have in mind when analysing the results. They might have been different if they were collected during the warmest and most problematic period of the summer since this increases the risk for e.g. heat stress in the animals.

5.2 Limitations and potential errors in the study

The EB on herd level were estimated by the software IndividRAM. It has to be emphasised that this estimation is based on a number of assumptions about energy intake and energy requirements. The data thus must be interpreted with caution. Nevertheless, the primiparous cows sampled in the herd with lowest estimated EB clearly showed a metabolic pattern indicating deep NEB. Furthermore, the answer given by farmers in response of the questionnaire must be evaluated with great caution since it was a semi-interview and not a recorded interview. It was performed by a person who interviewed for the first time, which may have an impact on the result.

Regarding the BCS, it was performed by people who did not have prior experience of this, which may have affected the result. Another factor that also need to be considered is that there was a variation in number of animals that were included at each farm. On some farms blood- and milk samples were collected from only three or four cows, while on another farm ten cows were examined. The cows examined were primiparous and in early lactation. Since the farms had varying numbers of lactating cows, with a range of 103-228 cows, it may have an impact on the number of cows that were included in the study. In addition, it is of importance to have in mind that the examined individuals may not be the ones that were affected by the drought. As mentioned, it is possible that there are cows in the rest of the herds were affected. To achieve more representative results, a larger number of animals examined per farm than three to ten cows would be desirable. Moreover, eleven farms are not a large number of farms, which is important to have in mind when analysing the data.

The feed sample from farm C had a markedly low ME. Reasons can be errors in the sampling or errors in the analysis. A reason may be that the feed sample col-

lected on this farm was taken from a part in the batch that was not closely mixed. It is difficult to know if the batch is thoroughly mixed.

Concerning the milk- and blood samples from the examined cows, it would have been interesting to compare the levels in the present study with levels of the different parameters during a normal year. Although the determined milk FA were related to the EB of the cows it must be underlined that the FA content of the consumed feed might affect the milk FA profile. Furthermore, the time of the day the milk- and blood samples were collected varied between the farms. The time of collection of the samples in relation to feeding and milking may have an impact on the results. It would have been desirable if the milk- and blood sample were collected the same time of the day on all of the farms and if the time of feeding and milking were taken into consideration.

6   Conclusions

In the present study, it was found that alternative feedstuffs such as bean straw, whole crop silage, grass silage from fallow land, peas and complementing compound feeds have been fed to dairy cows due to the feed situation. Despite the experienced problems on the included dairy farms, it seems like the farmers managed the feed situation. Relationships were found between the farmer's experience of the drought and feed situation, and the studied biological parameters, on some of the farms. There were significant differences between a number of blood parameters and also on some measured milk FA reflecting the metabolism. It may thus be concluded that energy metabolism and EB varied between herds. However, the relationship between the summer's drought and following feed scarcity and the metabolism of early lactating primiparous cows was not evident. This study confirmed other studies showing significant correlations between plasma NEFA and C14:0 and C18:1 cis-9. Also, other metabolites were significantly correlated to the milk FA although the relationships were weaker.

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