INVENTORY OF ERRORS IN FEED COMPOSITION AND NUTRIENT INTAKE OF DAIRY COWS

INFLUENCE ON MILK YIELD AND HEALTH ON TWO DAIRIES IN CALIFORNIA

SEPTEMBER 2012

PREFACTORY NOTE

Part of Curriculum 2001 Veterinary Medicine at Utrecht University is a 12 week research traineeship. This paper is the final report of a study carried out at the Veterinary Medicine Teaching and Research Centre of UC Davis in Tulare, USA regarding loss of ingredients and nutrients between the truck which transports the feed ingredients to the farm and the feed bunk, and the influence of the resulting suboptimal feed and nutrient composition on milk yield and quality.

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ABSTRACT

Computer models used in ration formulation assume that nutrients supplied by a ration formulation are the same as the nutrients presented in front of the cow in the final ration. Deviations in nutrients due to feed management errors effects such as dry matter changes (i.e. rain), loading, mixing and delivery errors are assumed to not impact delivery of nutrients to the cow and her resulting milk production. To estimate how errors in feed management impact nutrients supplied to the cow, weekly total mixed ration (TMR) samples were collected and analyzed (Analab, Fulton, IL) for 4 and 5 pens (close up cows, fresh cows and 2 high milk producing cows pens) for 7 weeks on two California dairies. Differences among nutrient analyses from these samples and nutrients from the formulated rations were analyzed using Microsoft Excel. Differences among all formulated and supplied nutrients were significantly different among pens and P values were 0.5 for DM %, 0.2 for crude protein %, 0.3 for ADF %, 0.1 for NDF %, 0.04 for starch %, 0.4 for fat %, 0.08 for lignin % and 0.4 for ash %. Therefore feed management practices on all three dairies impacted nutrients supplied to the cow. However, differences among nutrients supplied due to diet changes for a pen were not significant. Therefore feed management impacts nutrient delivery to the cow but most diet adjustments are small relative to differences among pen rations. The largest source of errors in the loading, mixing and delivery process is the human work force due to its presence in every step of the feeding process and its vulnerability to errors.

THE RATIONALE FOR ADEQUATE NUTRITION

A lot of effort is put in the development of computer programs to optimize ration calculation for dairy cows in different stages of lactation. Nevertheless, this effort is wasted when errors are made in the TMR loading, mixing and delivery process. In practice, this process comprises many steps and any of these form a source of error to the desired Total Mixed Ration (TMR) composition.
This study was performed to trace sources of error in TMR composition and nutrient intake in dairy cows. On two dairies, during 7 weeks, we compared the calculated TMR-ingredient composition and nutrient composition with the delivered TMR-ingredient nutrient composition, composition of collected residuals and nutrient analysis of both. Also average nutrient intake was calculated using nutrient analyses of both delivered TMR as collected residuals. Using system analysis, we then tried to identify the main causes of error in TMR- and nutrient composition and feed intake on both dairies.

PATHWAY OF INGREDIENTS

FLOWCHART

A flow chart was used to show the path followed by the ingredients from storage up to uptake at the feed bunk. In the flow chart the factors are included that may influence feed composition and dry matter and nutrient intake. Critical control points in this process are the formulated diet, loading, mixing and delivery of TMR as well as residuals in order to monitor nutrient intake.

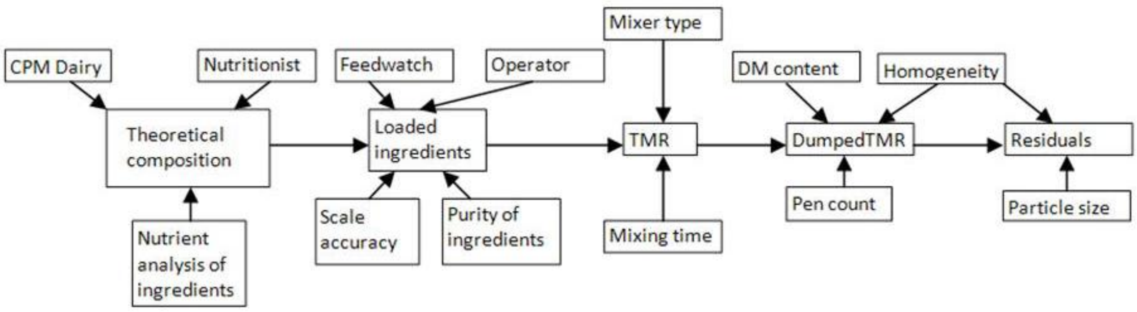


Figure 1: Flow chart showing possible sources of error effecting TMR composition and nutrient intake.

QUALITY OF FORAGE AND CROPS

To obtain a diet composition which approaches the formulated composition as much as possible, it is important place to trace and eliminate sources of quality loss of feed raw materials and nutrients, e.g. heating, mould growth, rodent damage etc.

Secondly, all crops should be stored at optimal dry matter content for that particular crop and, in case of silage, with an anaerobic atmosphere that encourages growth of lactic acid bacteria. Besides, secondary fermentation should be prevented by exposing only a small part of the silage to air after opening of the silage pile for usage. (1)

SOFTWARE

The Universities of Cornell and Pennsylvania, and the William H. Miner Agricultural Research Institute have developed a computer program for dairy cattle diet calculation, called the Cornell Pennsylvania Miner Dairy (**CPM Dairy**) Program. Using the entered nutrient composition of each ingredient and the nutrient requirements of the cows, related to age and stage of lactation and reproduction, the program calculates how much of each ingredient should be added to the TMR as well as the amount of TMR that should be fed per head per day. CPM Dairy. The program claims: 'to use mathematical techniques of linear and nonlinear programming to formulate least-cost diets and ensure that the nutrient requirements of the rumen microbes and cow are met.' (2)

On both dairies output from the CPM Dairy program was entered into the Feedwatch feed management program. This computer program calculates how much of each ingredient should be loaded into the mixer wagon for the number of cows in a certain pen. This information is uploaded to a computer in the mixer wagon where it shows the feeder on a screen how much he should load of each ingredient. Feedwatch also receives information about the actual amount of each ingredient loaded into the mixer wagon and the amount of TMR dropped at the feed bunk. (3)

Information about dry matter and nutrient intake can be used to predict milk production per head with the computer model Molly. Molly is a computer simulation model of a dairy cow described in the book 'Modeling Ruminant Digestion and Metabolism' by R.L. Baldwin, 1995. Molly is composed of differential Michaelis-Menten type equations that describe the metabolism of various nutrients. Molly predicts how energy metabolism, nitrogen flow, milk production (volume, fat and protein), amino acid metabolism and body composition changes per stage of lactation. In this study Molly was used to predict milk production per stage of lactation. (4)

FORMULATED DIET

With help of the CPM Dairy computer program, the nutritionist formulates an optimal diet for cows in different stages of lactation, using the available nutrient analysis of the forages, crops and feeds that were grown or bought by the dairy. (5) (2)

Before every feeding, residuals should be removed from the feed bunk and should be weighed in the mixer wagon again in order to calculate the average feed intake per head. Feedwatch also records this information. By combining the information about the total weight and percentage dry matter of the TMR and the total weight and percentage dry matter of residuals left at the feed bunk, Feedwatch calculates the actual dry matter intake per head. (3) (6)

Errors in diet formulation occur when feed ingredient samples are not representative for the total content of the storage bunker. Poor sampling technique, infrequent feed sampling and - testing and/or inaccurate laboratory analysis contribute to this source of error. In addition, the nutritionist can make calculation errors and there can be errors in the CPM Dairy computer model. Since CPM Dairy is a validated program and found to be an accurate software program (despite over prediction of microbial crude protein), the assumption is made that errors in nutrient composition, found in this study are not caused by errors in CPM Dairy (7). Even so, Rotz et al,1999 describe how software programs, based on different assumptions, can prescribe a different diet for the same group of cows. These diets mostly are in essence the same and are not necessarily wrong (8).

Using Feedwatch software, in the mixer wagon, the prescribed amount of each ingredient is shown on a display. For loading the prescribed amount, scales in mixer wagons should be calibrated regularly to reduce loading errors. (3)

Loading is carried out by employees and not by automatic mixer wagons. Human work force may result in larger errors than automatic equipment. Also employees may try to cover up an error, made earlier in the preparation of a batch, by adding more or less of another ingredient.

Apart from errors due to manual loading, contamination of the feed bunker with almond shells, stones, soil and dirt also leads to an erroneous feed composition without offering any nutrients. Rocks and soil can be scooped into the feed bunker together with spilled feed, but also while driving the mixer wagon along the drive way. Apart from leading to erroneous feed composition, rocks also will lead to lesions in the cow's mouth and to damage of the mixer wagon.

MIXING

Mixing blades are used as knives to reduce particle length to a size that makes it harder for cows to select and avoid certain particles. And mixing is also executed to uniformly blend the diet, in order to make sure every cow is offered the same diet and ideally, takes in the calculated amount of dry matter and nutrients. In case of poor mixing, lumps of an ingredient, for instance hay, will still be visible. In that case TMR cannot be distributed uniformly to the different head locks and the cows will be able to select the tastier particles out of the TMR.

Very long hay stems are more likely to be refused, whereas very short hay particles are more likely to be eaten. Very small hay particles however do not stimulate rumination and are so easily fermented that they may induce rumen acidosis. To provide sufficient structure for prevention of acidosis and laminitis, a minimum particle size of 3.5 mm is recommended, whereas not more than 8% - 10% of the particles should be longer than 2 cm (5) (9). In concordance with the conclusions of Dixon and Yang & Cardoza, Oshita et al. recently presented convincing evidence that the critical particle size for escape from the rumen is 3.3-3.4 mm (9) (10) (11).
Given the above considerations regarding the optimal particle size, maintaining a correct mixing time is very important.

Mixing too short results in an inhomogeneous TMR with long particles that can easily be sorted out and refused. And mixing too long results in very small particles, low in structural value, which in the end may contribute to the incidence of rumen acidosis and related diseases. (6) The optimal mixing time depends both on the amount and physical characteristics of the ingredients and should therefore be adjusted each time that the TMR recipe is changed (12).

AMOUNT DELIVERED

Nutrients supplied by the diet are calculated on a dry matter basis. By multiplying the required dry matter intake (DMI) for one cow in a particular pen by the number of cows per pen, divided by the dry matter content of included crops, the required amount of TMR to be delivered per pen is calculated. The TMR varies daily by 5 – 15%. (6)

When loading errors result in a lower amount of feed in the mixer, a smaller amount of TMR is delivered at the pen. Thus the DMI per head will be lower than prescribed.

In some instances a load of TMR is divided over more than one pen, for instance when two groups of cows receive a diet with the same feed composition. The amount dropped at each pen by the mixer wagon is calculated by multiplying the desired amount of dry matter per cow by the number of cows in that pen and is recorded in Feedwatch during feeding. If the amount dropped at the feed bunk and/or the dry matter content of the TMR and/or the number of cows in the pen differs from the calculated amount, dry matter intake of the cows will deviate from the prescribed intake.

When DMI drops for a prolonged period, milk yield will be affected. In addition, the reduced rumen fill results in lower rumen fermentative activity and gives the digestive system a chance to come to stasis. Prolonged stasis can lead to serious complications such as displaced abomasum.

OBJECTIVES

The primary objectives of this inventory study were to investigate to what extent:

1) The ingredient profile formulated by the nutritionist corresponds with the ingredient profile that is loaded into the mixer wagon.
2) The formulated nutrient composition corresponds with the actual nutrient intake.
3) There is a difference in accuracy of loading ingredients between the two cooperative herds.
4) There is a difference in particle size between TMR at delivery and residuals.

Secondary objectives were to investigate if:

5) The known influence of nutrient intake on milk production and composition can be observed during the study period.
6) Errors in feed intake are associated with the occurrence of nutrition related health events

HYPOTHESIS

The hypothesis of this inventory study was that TMR-ingredient composition and nutrient intake would be closer to the formulated composition and intake on a commercial dairy farm than on a non profit dairy farm. The secondary hypothesis was that more diet related health events would be observed when the delivered and consumed diet differ significantly from the formulated diet.

MATERIAL AND METHODS

HERDS

Two cooperative dairy herds around Tulare participated in this research project. Dairy 1 is a commercial dairy with 3500 dairy cows, focussed on high milk production. Dairy 2 is a non-commercial dairy with 1900 cows feeding a low cost diet. High milk production and profit is not a goal on dairy 2. The expectation was that ingredient composition and nutrient intake would be closer to the formulated amounts and less health events would occur on dairy 1 than on dairy 2.

On both dairies, per pen, a group of cows in the same stage of lactation was housed irrespective of parity except for first parity cows. On dairy 1, five groups of multiparous cows, in different stages of lactation, were observed. One group consisted of fresh and hospital cows. The cows remain in this pen for one or two days after parturition, except for hospital cows that remain until recovery. The second group of cows were early lactation cows. Cows remain in this pen from the second or third day in lactation up to 3 weeks in lactation. Both fresh and hospital cows as well as early lactation cows received the same diet, hereafter addressed to as **early lactation diet**. The third group consisted of high yielding cows, between 21 and 68 days in lactation. The fourth group contained mid lactation cows, between 68 and 165 days in lactation. Both high yield as well as mid lactation cows received the same **mid lactation diet**. The fifth group consisted of close up cows, in the last two weeks of dry period, which received **close up diet**.

On dairy 2, four groups of cows were included in the study. Early lactation cows, 1 to 40 days in lactation, high lactation cows, 41 to 80 days in lactation, mid lactation cows, 81 to 150 days in lactation and close up cows, in the last two weeks of dry period. On this dairy early lactation cows and high yield cows were fed the same **early lactation diet.**

Late lactation cows and far off dry cows were not included in the study.

FEED SAMPLING

Feed samples were taken for 7 weeks in a row. On both dairies, two samples were taken per feeding and per pen, once a week. The first sample was the TMR as delivered at the feed bunk and the second sample was the residual feed on the feed bunk 24 hours after feeding, just before the next feeding.

Half way the feed bunk a tub with a garbage bag was placed, that a-selectively received a TMR sample of about 4 kg, during the unloading process of the mixer wagon. Time of TMR delivery was noted as well as the number of cows in the pen.
Twenty-four hours later, residuals were collected a-selectively in a garbage bag halfway the feed bunk, by scooping up one square foot of residuals. The visual appearance of the residuals was noted.
From each garbage bag, a sandwich bag was filled with TMR or residuals, taking care that each sample was representative of the large TMR or residual sample. All sandwich bags were stored in the refrigerator up to 24 hours before they were all sent in for nutrient analysis by Analab, Illinois.

FEED INTAKE

FeedWatch was used to collect information on amount of ingredients loaded, amount of TMR dumped per pen, amount of residuals and number of cows per pen.

FEED ANALYSIS

Immediately after collection, extent of mixing, smell and visual moistness of the TMR sample were noted.

Particle size was determined using a particle separator similar to the Penn State Particle Separator was used, consisting of three sieves; a 19.0 mm plastic sieve on top, an 8.0 mm plastic sieve in the middle, a 1.18 mm metal sieve below and a plastic pan fitted to the bottom of the lower sieve. One kilogram of a well-mixed sample of TMR or residuals, was put in the top sieve and the sieve set was shaken horizontally four times. After each set of four shakes the particle separator was rotated one quarter turn, until a complete turn was made. In total the sieve was shaken 4 x 4 times.
The content of each sieve fraction was determined by weighing. The percentage of each sieve fraction was determined as the weight of the particles in the sieve divided by the weight of the sample.

The feed and residual samples were analysed at the commercial lab, Analab, Illinois for:

- moisture
- ash
- net energy lactation (NEL)
- crude protein (CP)
- soluble protein (SP)
- neutral detergent fibre (NDF)
- acid detergent fibre (ADF)
- lignin
- fat
- starch
- phosphorus
- sodium
- manganese
- potassium
- chloride
- magnesium
- sulphur
- zinc
- copper
- iron and
- calcium

HEALTH VARIABLES

Health variables were recorded by UC Davis students. The following health variables were recorded: body condition score, number of cows affected with retentio secundinarum, ketosis, milk fever and abomasum displacement either way.
Retentio secundinarum was noted when placenta had not come off within 24 hours after calving and abomasal displacement was noted when laparotomy was performed for the cause.
Important parameters to monitor the energy balance of fresh and early lactation cows were blood glucose and ketone bodies. Blood glucose levels below 3 mmol/L and levels of β-hydroxy-butyrate above 1.2mmol/L were used as signs of a negative energy balance (13) (14).

DATA ANALYSIS

NUTRIENT INTAKE

Nutrient intake per head was calculated using the following formula:

$$DMI = TMR\ (kg) * DM_t\ (\%)/n - Residuals\ (kg) * DM_r\ (\%)/n$$

in which:
DMI = Dry Matter Intake per head
TMR = Total Mixed Ration per pen

DM_t = % Dry Matter of TMR
DM_r = % Dry Matter of Residuals
n = number of cows in the pen

NUTRIENT ANALYSIS

Nutrient analysis of TMR and residuals was compared with the formulated nutrient composition which was imported from CPM. In Microsoft Excel, the unpaired two-sample unequal variance (heteroscedastic) T-test was used to compare formulated and actual nutrient composition and predicted and (estimated) actual milk quantity and composition.

PREDICTED MILK PRODUCTION

Predicted milk production was calculated using both CPM Dairy and Molly. CPM Dairy is based on formulas from Cornell University, the University of Pennsylvania and the William H. Miner Agricultural Research Institute and uses the expected milk production to formulate the nutrient composition of the diet. For predicting milk production, CPM Dairy was used backwards, by entering the actual nutrient intake. Molly is based on formulas from ‘Modeling Ruminant Digestion and Metabolism’ by R.L. Baldwin (1995). (2) (4)

Actual milk quantity and composition were compared with predicted milk production using NRC 2001 and/or the Molly model to estimate the impact of errors in feeding on milk production. (5)

Observational analysis was performed on the incidence of health events on dairy 1 in an attempt to determine the responsible nutritional factors.

STATISTICAL ANALYSIS

In Microsoft Excel, the unpaired two-sample unequal variance (heteroscedastic) T-test was used to compare calculated and actual ingredients loaded and calculated nutrient intake in comparison to actual nutrient intake.

RESULTS

DAIRY 1

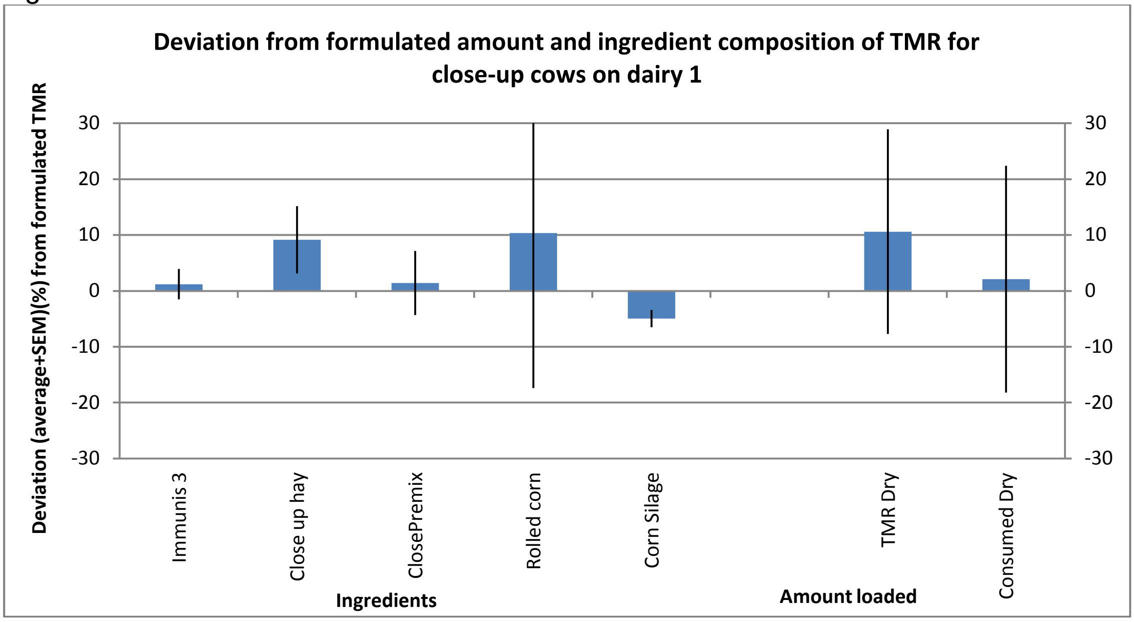
CLOSE UP COWS

TMR ingredient composition

Average percentage deviation (+SEM), from the formulated amount and ingredient composition of TMR for close up cows over 7 weeks, is shown in figure 2. The TMR contained 10% above the formulated amount of **Close-up hay** and **Rolled corn. Immunis 3, Close premix** and **Corn silage** were added close to the formulated amount (+1% and -5%). In addition to the formulated ingredients, 11% **Water** was added to the TMR. Excluding added water, 10% more TMR than formulated was delivered at this pen and the consumed amount was exactly the formulated amount. The formulated delivered amount, excluding the added water, is designated ‘TMR dry’, although this is not on a 100% dry matter basis. The consumed amount, excluding added water, as ‘Consumed dry’.

For two days no **Immunis 3** was added to the TMR. The data of these days were not included in the calculation of the average amount of **Immunis 3** added to the TMR.
The value of week 1 was not included in the calculation of the delivered and consumed dry TMR, because on that day 2.5 times the normal amount was fed and only 226 kg of residuals was reported, resulting in an unrealistically high consumed amount of dry TMR.

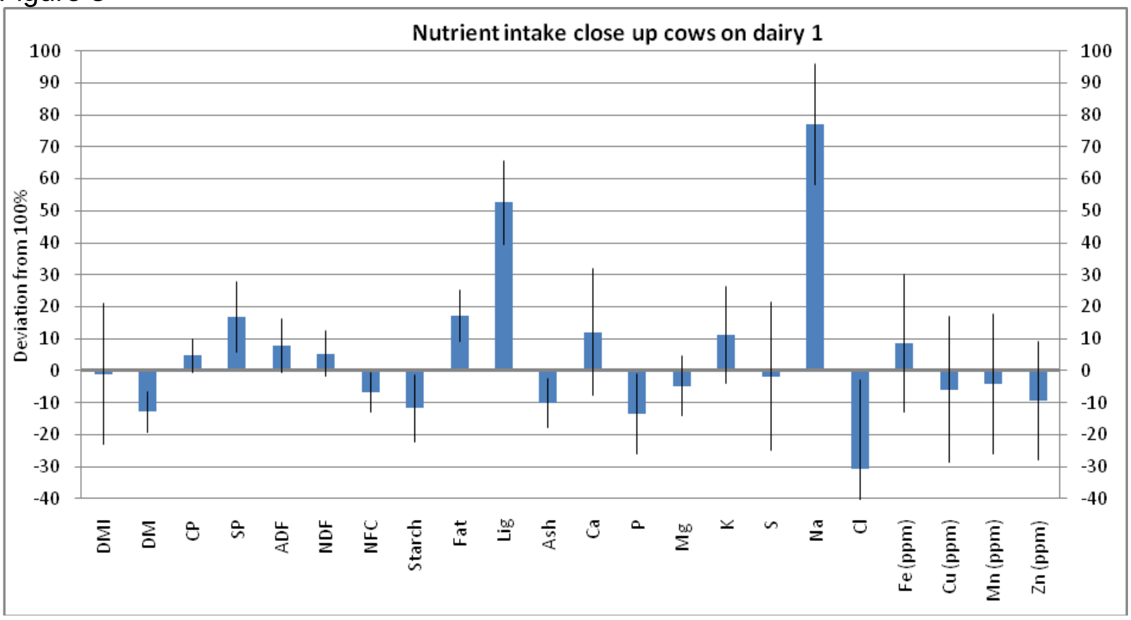
Figure 2



Nutrient intake

Average percentage deviation (+ SEM) of the actual nutrient intake from the formulated diet of close up cows on dairy 1 over 7 weeks is shown in Figure 3. Data of week 1 were excluded because dry matter intake was unrealistically high that date.
Due to the addition of 11% water, the dry matter content (P=0.003) of the TMR for the close up cows was significantly lower than formulated. Nevertheless, the dry matter intake in this pen was almost the formulated amount. The intake of soluble protein (+17%, P=0.03), fat (+17%, p=0.01) and lignin (+53%, p=0.0001) was significantly higher than calculated by CPM and sodium intake (P=0.002) was 77% higher than formulated. On the other hand NFC (-7%, p=0.04), starch (-12%, p=0.03), ash (-10%, p=0.02) and especially chloride (-31%, p=0.01) intake were significantly lower than formulated.

Figure 3



Incidence of nutrient related health events

In close up cows health events were not routinely monitored. Instead, the body condition was scored and urine pH was recorded to link diet composition during close-up time, to health events during parturition and at the start of lactation.
Over the following weeks, actual DMI, fat and mineral intake differed considerably, between –30% and +40% of the calculated intake.
Calcium intake was at the formulated level during the first 4 weeks, but increased during the last 3 weeks to 40% above the desired level.
Body condition score in close up cows varied between 3.5 and 4 in the first 4 weeks, but decreased to 3 in week 4, after which it increased again to 3.75. Average urine pH started at 5.2 for this pen, but increased to 6.5 at the end of this investigation.
Particle size of TMR varied between 65 and 80 mm, with an average length of 64 mm.

Figure 4

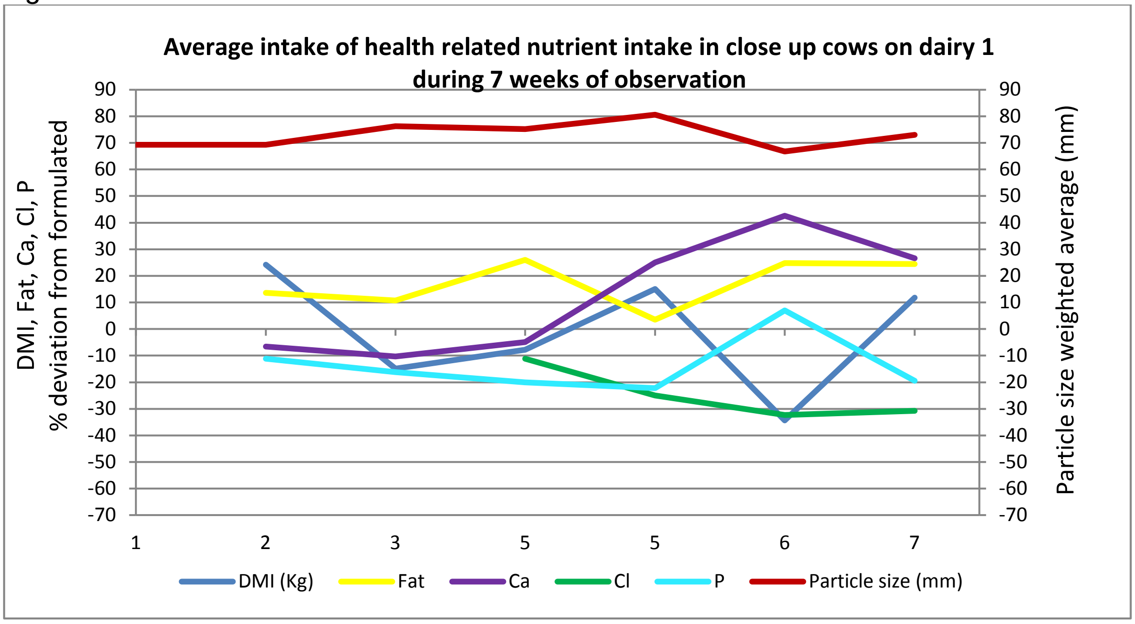
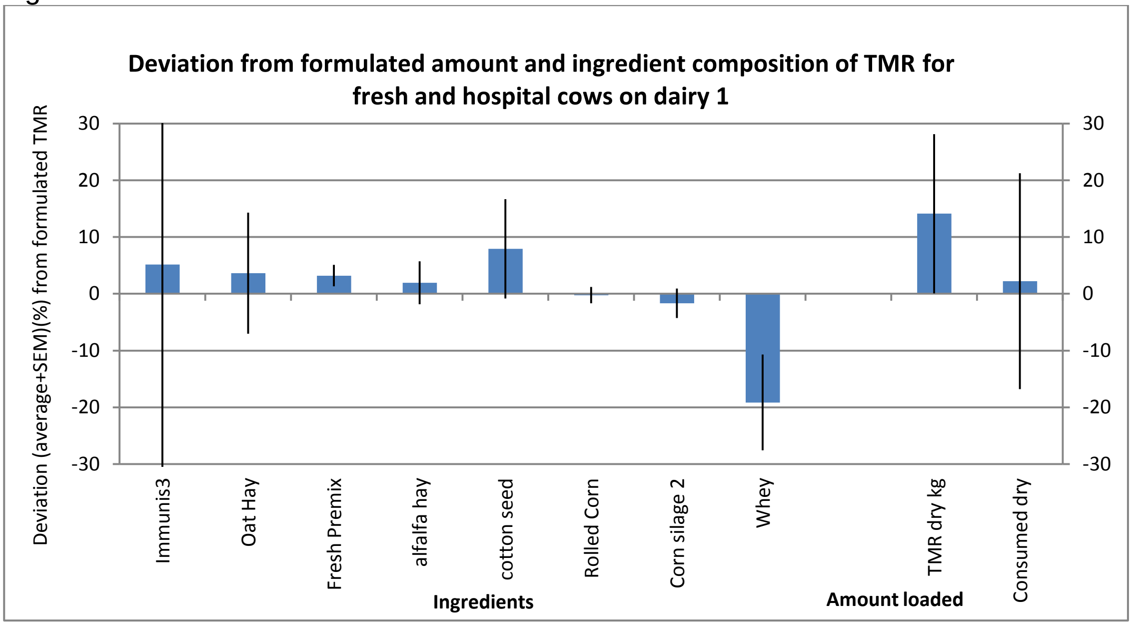


Table 1 Average body condition score and urine pH in close up cows on dairy 1

Week	1	2	3	4	5	6	7	Average	Normal
BCS	4	3,5	4	3	3	3,5	3,75	3.5	3.0
Urine pH	5.2		6.3				6.5	5.9	6 – 6.5

TMR ingredient composition

Figure 5

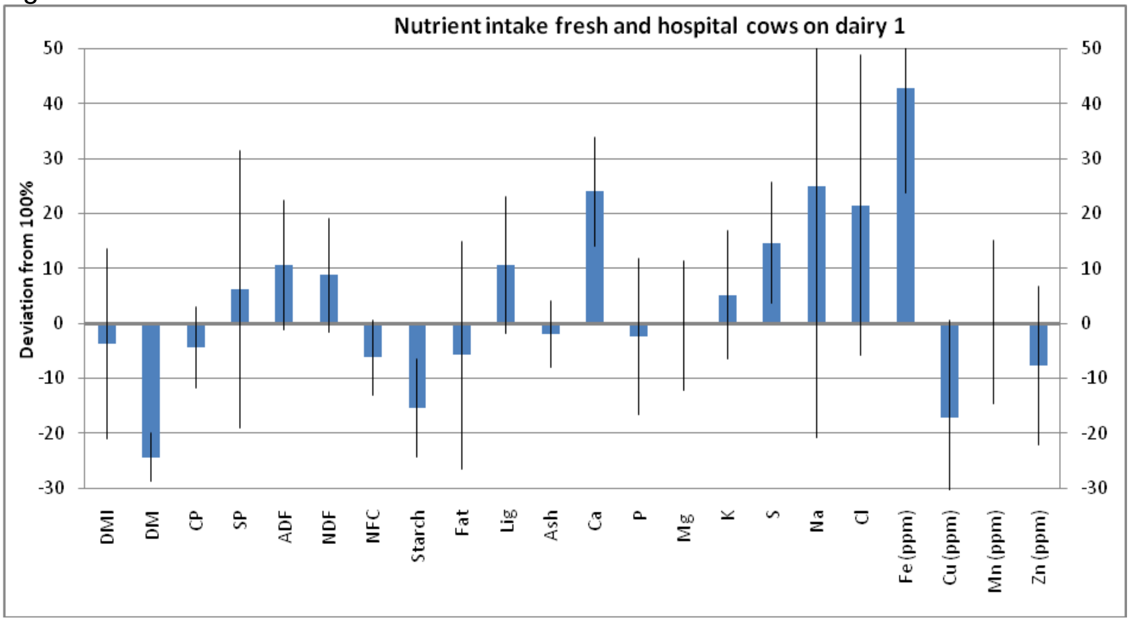


Average percentage deviation (+ SEM) of the amount and ingredient composition of the TMR for fresh and hospital cows over 7 weeks is shown in figure 5.
On average the ingredient composition of the TMR for fresh and hospital cows matched the formulated composition well, except for **whey**, of which on average 20% too little was added and **cotton seed** of which on average 8% too much was added.
Immunis 3 was added inconsistently; sometimes it was not added at all and sometimes added at twice the formulated amount. The TMR for fresh and hospital cows contained 20% added water, although it was not formulated. Water excluded, 14% more TMR than formulated was delivered to the fresh and hospital cows, but most of this was left as residuals, resulting in an actual consumption of dry TMR which was comparable to the calculated consumption.

Nutrient intake

Average percentage deviation (+ SEM) of the actual nutrient intake from the formulated diet of fresh and hospital cows over 7 weeks on Dairy 1 is shown in Figure 6. Due to the addition of water, which was not formulated, the dry matter content of the TMR was significantly lower (P=0.000001) than formulated. Dry matter intake was nevertheless close to the calculated amount. The intake of the minerals calcium (+24%, P=0.002), sulfur (+15%, P=0.02) and iron (+43%, P=0.01) was significantly higher than calculated. The main sources of iron are fresh premix, alfalfa hay and corn silage, each delivering about 30% of total iron intake. Although the intake of fiber components (+10%), sodium (+25%) and chloride (+21%) was higher than calculated, the difference was not significant, due to the large variation. The higher than calculated fiber intake is reflected in the elevated NDF, ADF and lignin intake. Intake of starch (P=0.002) and NFC (P=0.04) was significantly lower than formulated. Intake of zinc (-8%) and copper (-17%, P=0.02) was on average lower than calculated, but for zinc the difference was not significant due to the large variation.

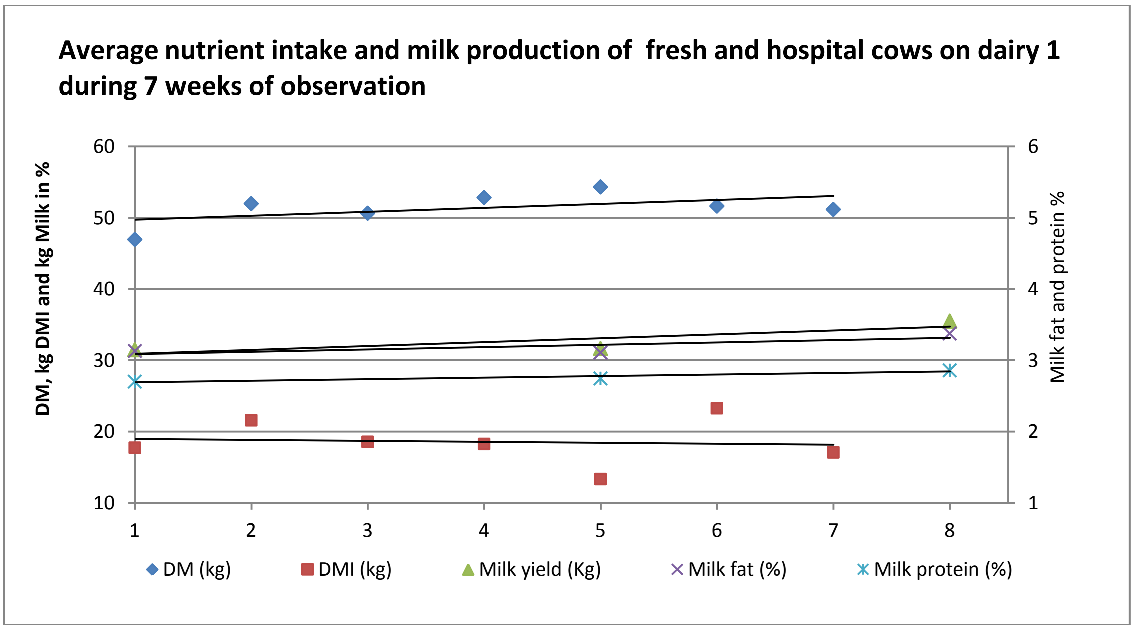
Figure 6



Relation between nutrient intake and milk production

Only once a month, milk yield per head was recorded and one single milk sample per head was tested for milk composition. Therefore only three data sets are available, of week 1, week 4 and week 8, just after the finish of the observation period.

Figure 7



The relation between nutrient intake and actual milk production and its course in time is shown in Figure 7. Over the weeks the dry matter content (% DM) of the TMR increased, although it was at all times lower than formulated due to the addition of non-formulated water. Over the weeks, dry matter intake (DMI) remained stable at 18 – 20 kg/head/day. Milk yield and milk fat content were about 10% higher in the sample from week 8 than in the sample from week 1.

Prediction of milk production

Figure 8

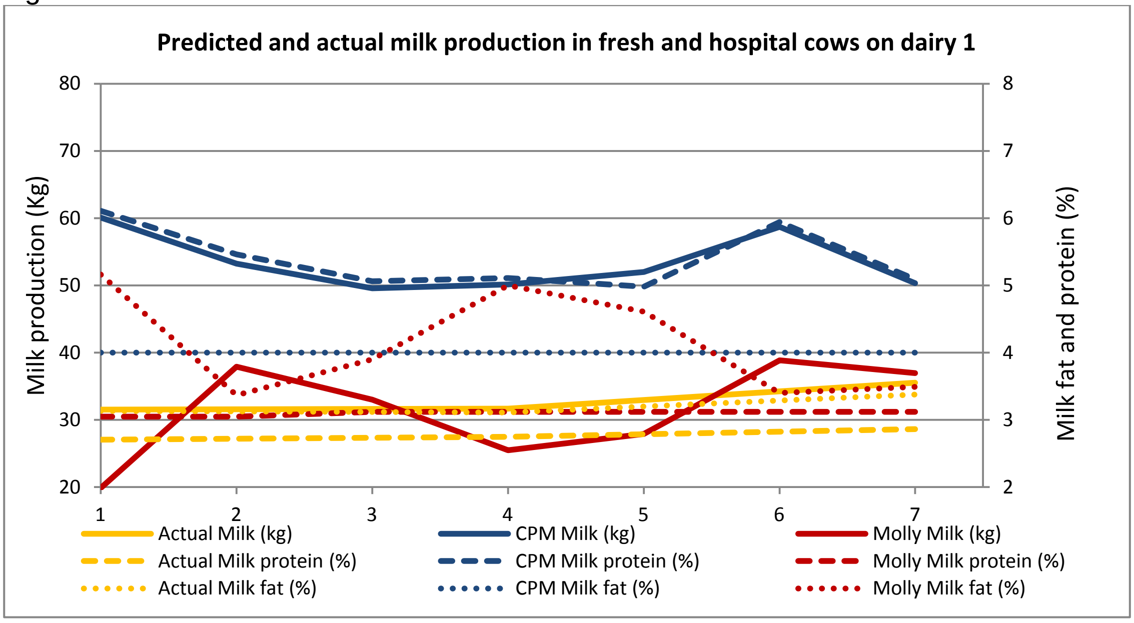


Figure 8 shows actual milk production and prediction of milk production by Molly and CPM.

Molly predicted a large increase in milk production from 19.9 kg to 37.9 kg in week 2, then a decrease to 33.0 kg and 25.5 kg in week 3 and 4 and over the last three weeks the predicted milk production increased again to 27.9 kg and 38.9kg. The predicted fat content showed an opposite trend, first a decrease from 5.2% to 3.4%, then an increase to 5% in week 4 and over the last three weeks a decrease again to 3.5 at the end of this investigation. The predicted protein content remained stable throughout the observation period at 3.1%.

CPM predicted a decrease in milk production 60 to 50 kg with a peak at 59 kg in week 6. The predicted protein content follows the trend of milk production, decreasing from 6.11% to 5.1% with a peak at 5.9% in week 6. These predicted levels of milk production and protein concentration are unphysiologically high. Predicted fat content remained stable at 4%.

Actual milk production increased slightly from week 1 to 7 with 4 kg from 31.5 to 35.5 kg. The fat and protein content of this milk follow the trend and increased from 3.1% to 3.4% and from 2.7% to 2.9% respectively.

Incidence of nutrient related health events

Figure 9

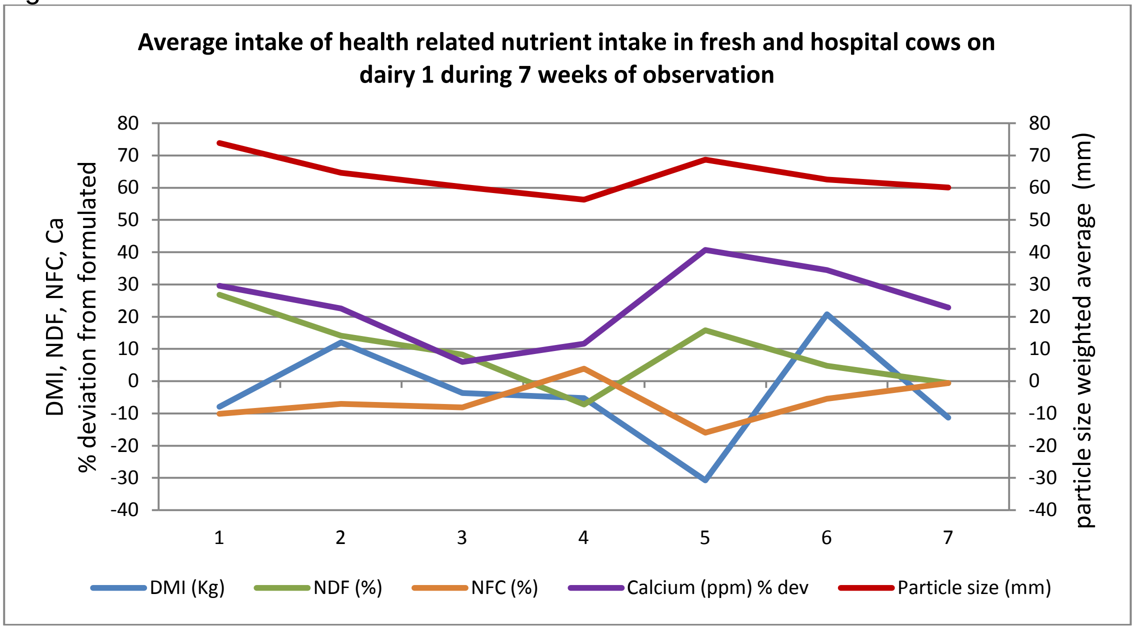


Table 2: Health events in fresh and hospital cows on dairy 1

Week	2	4	6	8	9
DA	1	2	2	1	5
Endometritis		2			
RP	1		1		

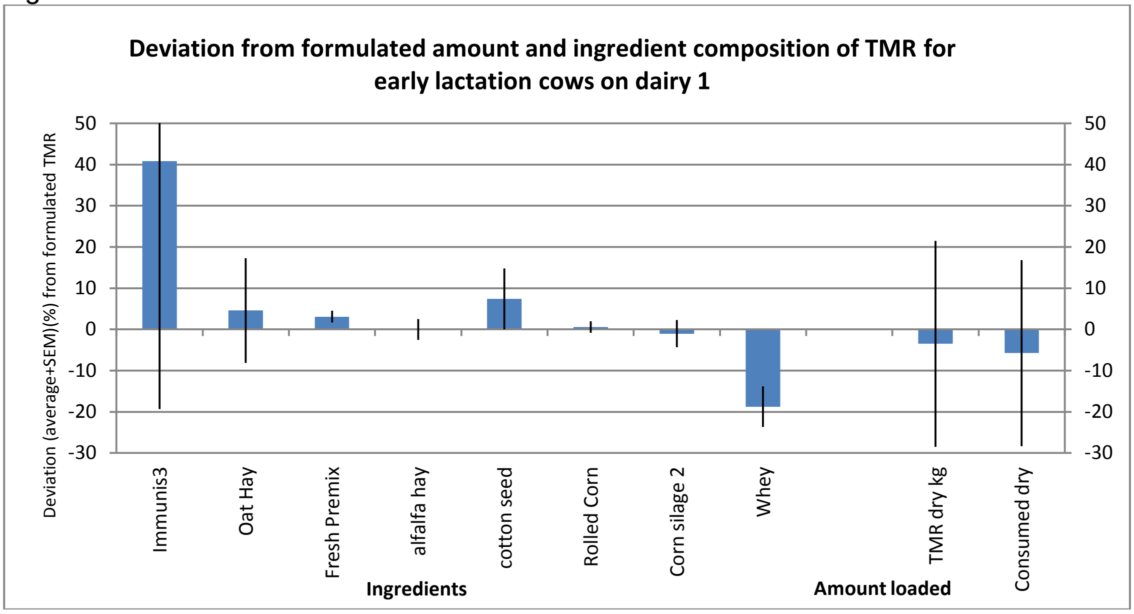
NDF and NFC intake were fairly constant and close to the formulated value, although at the start of the investigation, the intake of NDF was 25-30% above the formulated value. In week 4, NFC increased while at the same time NDF and DMI decreased. In this week, two Displaced Abomasums (DA) and two cases of Endometritis occurred.
Between week 4 and 6 dry matter intake was inconsistent; at first dry matter intake decreased to – 30% and in the next week DMI increased to + 20% of the formulated DMI. In week 5 calcium intake increased to + 40 % and NDF intake to +15% despite the reduced dry matter intake. At the same time intake NFC decreased in the opposite direction as NDF. During this period two Displaced Abomasums occurred and one Retained placenta.
During the observation period 5 DA's occurred (Table 2). After the finish of this investigation another 6 DA's occurred, one in week 8 and five in week 9. In addition, two infusions occurred in week 4, one retained placenta occurred in week 2 and one in week 6
Particle size (Figure 9) decreased from 74 mm at the start till 60 mm at the end of the investigation.

EARLY LACTATION COWS

TMR ingredient composition

This pen was only sampled 4 times because it was included in the trial only in week 4 of the study. **Immunis 3** was overdosed at 2 times the normal level. The other ingredients were in line with the calculated composition, except for **whey** which was 20% under-dosed. Also 19% **water** was added to the ration but not included in the formulation. Added water was not taken into account in the delivered amount of TMR. The amount of wet TMR delivered at the pen (water excluded) was 3% less than formulated. The consumed amount of the dry TMR (added water excluded) however, was 6% less than formulated.

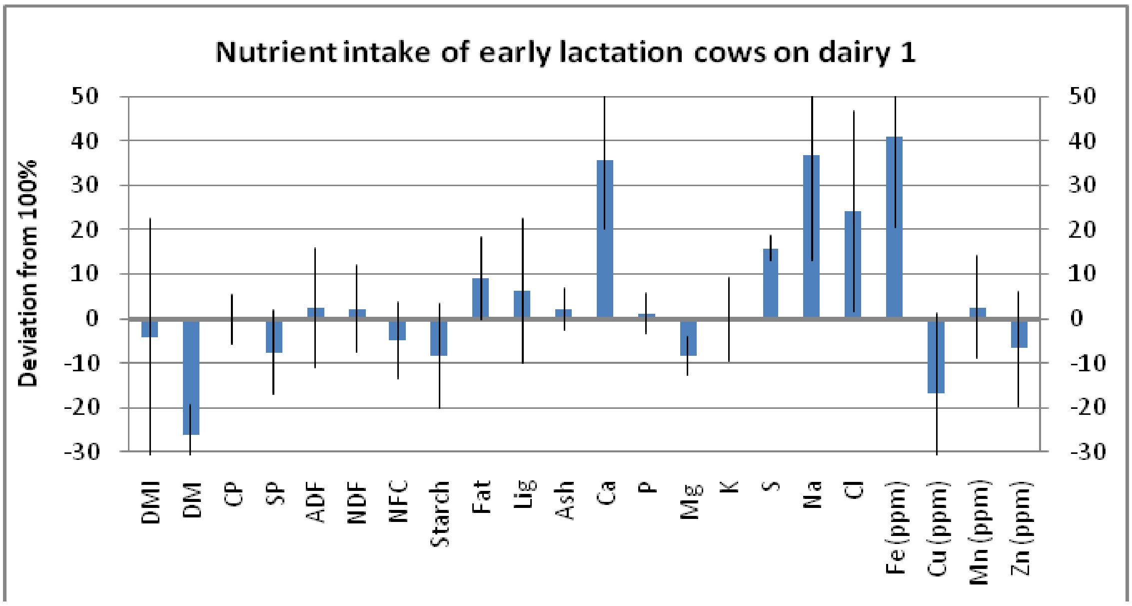
Figure 10



Nutrient intake

Although the dry matter content of the TMR for early lactation cows on dairy 1 was significantly lower (P=0.002) than formulated, dry matter intake was almost as high as the formulated amount.

Figure 11



Intake of the minerals calcium (P=0.04), sulfur (P=0.002) and magnesium (P=0.02) was significantly higher than calculated. Intake of NFC, starch, sodium, chloride, iron, copper and zinc were substantially lower than formulated, although the differences were not significant due to the large inter week variation. The fiber intake was higher than calculated, although not significantly due to the large variation. The high fiber intake is also reflected in the elevated ADF, NDF and lignin intake.

Relation between nutrient intake and milk production

Figure 12

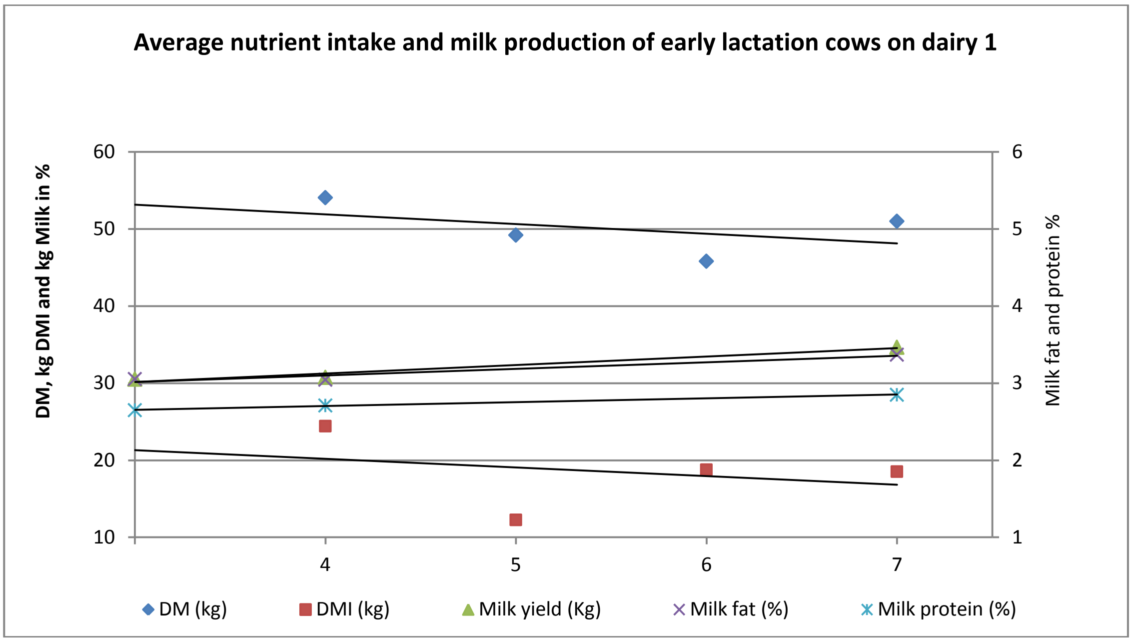
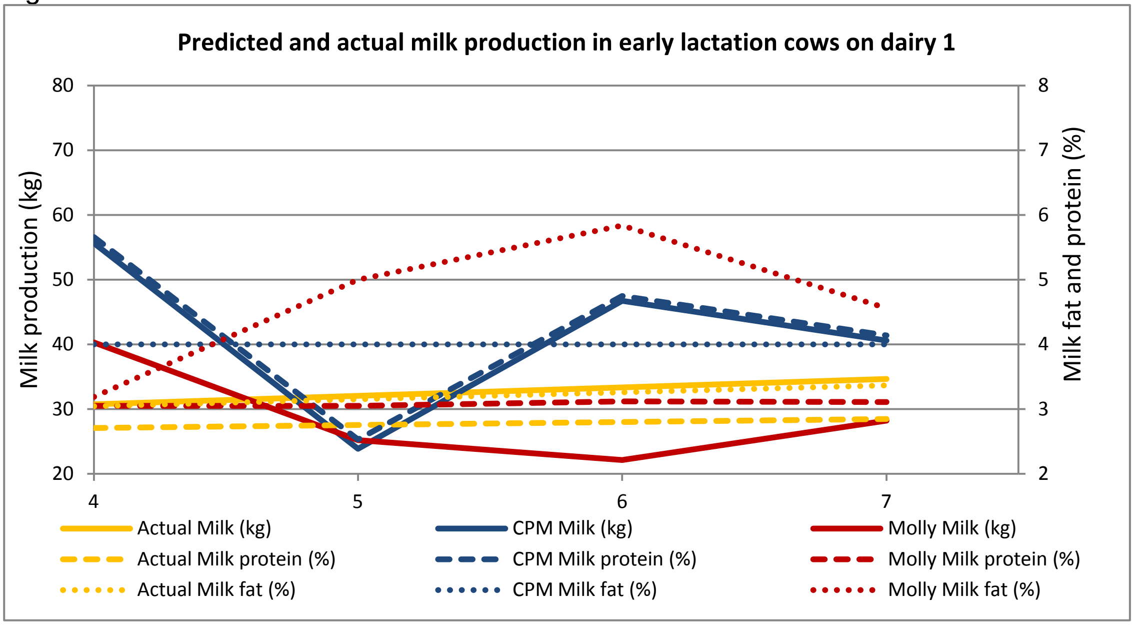


Figure 12 represents weekly nutrient intake and milk production and its course in time for early lactation cows on dairy 1. Dry matter intake decreased with almost 6 kilograms during the observation period and the dry matter content of the TMR decreased with 8% between week 4 and 6 and then increased again with 5%. This lower than formulated dry matter intake was not related to inaccurate pen counts, but most probably due to the added water. Despite the decrease in dry matter intake, milk yield (+4kg) and fat (+0.4%) and protein (+0.2%) content all increased about 10%.

Prediction of milk production

In early lactation cows, who received the same diet as fresh and hospital cows, **actual milk production** showed a 10% increase from 30.7 kg at the start of the observation period to 34.7 kg at the end of the observation period. The fat and protein content of the milk closely followed the trend of milk yield, each also increasing about 10%. Fat content increased from 3.1% to 3.4% and protein content from 2.7% to 2.8%.

Figure 13



Molly predicted a decrease in milk yield during the first two weeks from 40.3 kg to 22.2 kg and subsequently an increase to 28.2 kg during the last week. The predicted fat content followed the opposite direction, initially an increase from 3.2% to 5.8% and then a decrease to 4.6% on the last sample date. The predicted protein content was stable at 3.1% during the observation period.

CPM predicted a very sharp decrease in milk production between the first two test dates from 55 kg to 24 kg, then an increase again to 47 kg and finally another drop to 41kg. The predicted protein content exactly followed the line of milk production. The predicted fat content remained stable over the entire observation period at 4%.

Incidence of nutrient related health events

Figure 14

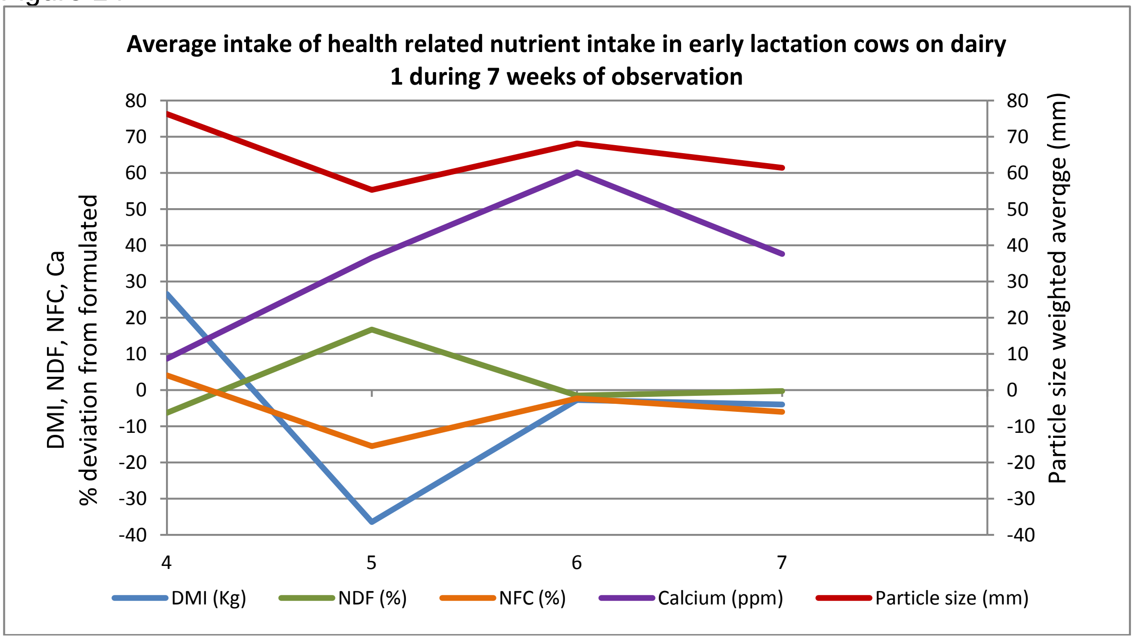


Table 3 Body condition score, blood parameters and occurrence of health events, in early lactation cows on dairy 1

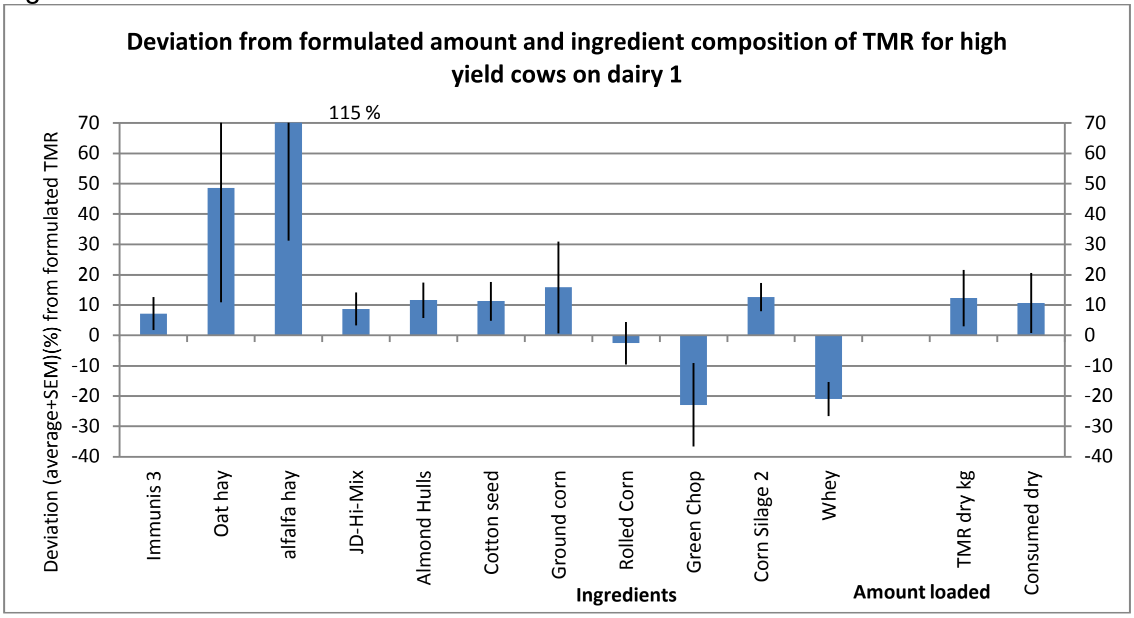
Week	4	5	6	7	8
BCS	3	3.5	3	2.8	
Glucose (mmol/L)		5.0		4.8	
BHB	1	1.6	1	1.3	
DA	1	1	2		6
OB			2		3

Health events were recorded in all, on average, 200 cows in this group. Measurements of β-hydroxy-butyrate and glucose levels and body condition score was performed weekly on 20, randomly chosen cows in this group.
At the start of the observation period, dry matter intake of early lactation cows was on average 5 kg per head more than formulated, but in the next week it dropped to 2/3 of the formulated amount. In this week NFC intake was also 20% lower, whereas NFC increased with 25%. In the following weeks DMI, NFC and NDF intake normalized to the calculated amount and remained stable during the last observation week. The NDF and NFC intakes move in opposite directions.
The graph of the **particle size** of the delivered diet is parallel to the graph of NFC and follows the trend of the dry matter content.
The calcium intake was higher than formulated throughout the entire observation period and even increased to + 60% between week 4 and 6, after which it decreased to + 38% in week 7.

In cows in transition phase, body condition score, blood parameters glucose and β-hydroxy-butyrate and health events such as displaced abomasums, and obstetric problems were measured. A level of 1 mmol/L β-hydroxy-butyrate is considered normal and during the observation period the average levels was not under 1 mmol/L. Also blood glucose levels were never lower than 3 mmol/L. During the observation period a total of 10 DA's occurred in this pen (ca 2% of calving during the observation period). One each in week 4 and 5, two in week 6, when also two cases of obstetric problems occurred, and 6 DA's in week 8, just after the finish of this investigation. In week 7 also 3 cases of obstetric problems were observed. The body condition in this pen was scored every week on 20, randomly selected, cows and was on average 3, although it differed considerably over weeks between 3.5 in week 5 and only 2.8 in week 7.

TMR ingredient composition

Figure 15



TMR for high yield cows on dairy 1 contained on average 10 to 15% more **Immunis 3**, **high yield premix**, **almond hulls, cotton seed, ground corn** and **corn silage** . On the other hand **green chop** (fresh chopped alfalfa), and **whey** were added 20% less than formulated to TMR. The lower amount of **green chop** was replaced by **oat hay** and **alfalfa hay. Oat hay** was added about 50% more than formulated and in addition the range was broad. **Alfalfa hay** was added over formulated + 115%. **Water** was added to balance the lower amount of whey which was added.

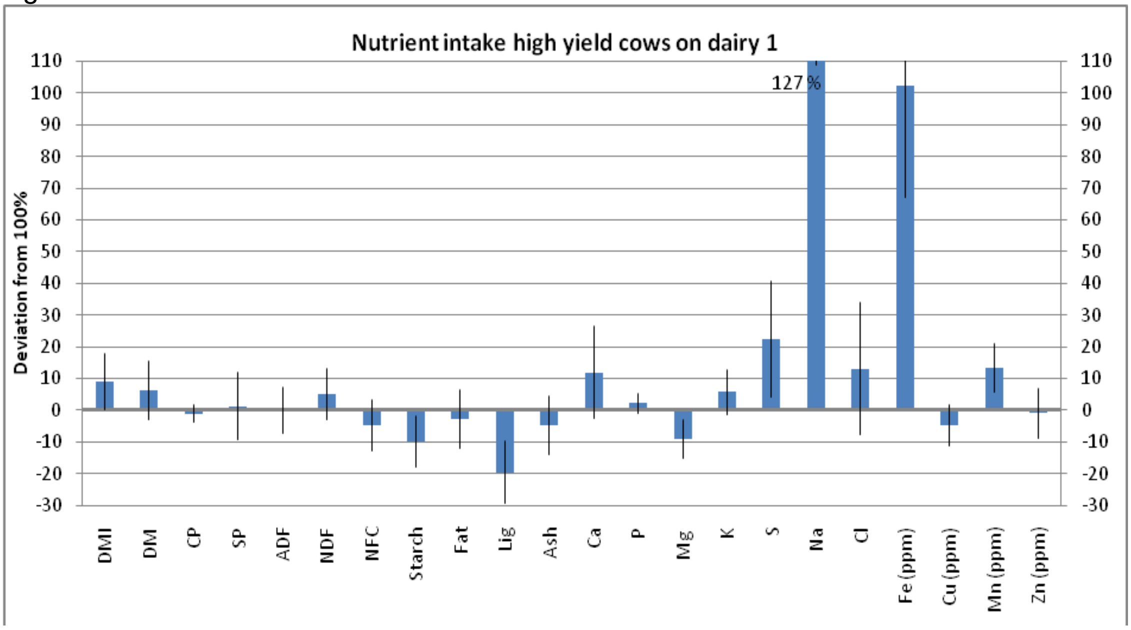
With the exclusion of the added water, 10% more TMR than formulated was delivered and consumed.

On one day, **Green chop** was not added at all. To adjust the dry matter content, about 9 times the normal amount of **alfalfa hay** was added to this TMR. Water was also added that day to balance the dry matter content. The data on this day were not included in the calculation of the average feed composition.

Nutrient intake

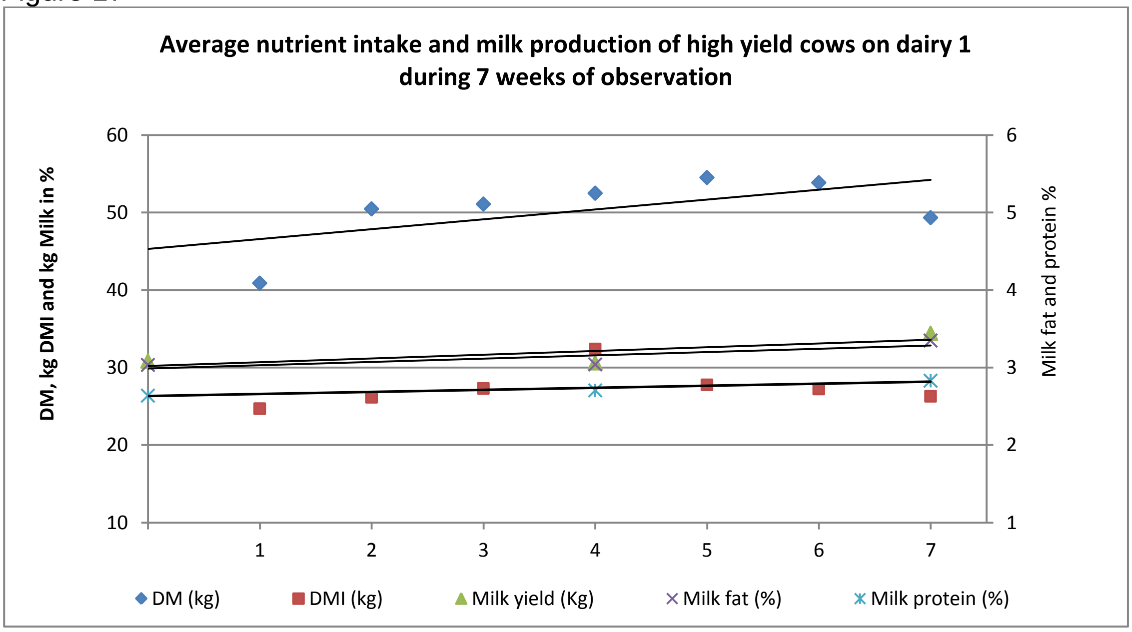
In figure 16 the average dry matter intake of high yield cows was significantly higher (P=0.05) than formulated. Of the macro components starch (-10%, P=0.01) and lignin (-20%, P=0.001) were consumed in significantly lower amount than formulated. Of the minerals, sulfur (P=0.04), sodium (twice the formulated amount, P=0.0002) iron (P=0.01) and manganese (P=0.01) were consumed in a significantly higher amount than formulated, but magnesium (P=0.005) intake was significantly lower than formulated. NDF was consumed in a higher amount than formulated, although the difference was not significant because the intake of NDF was lower from the second to the last week of observation (figure 19).

Figure 16



Relation between nutrient intake and milk production

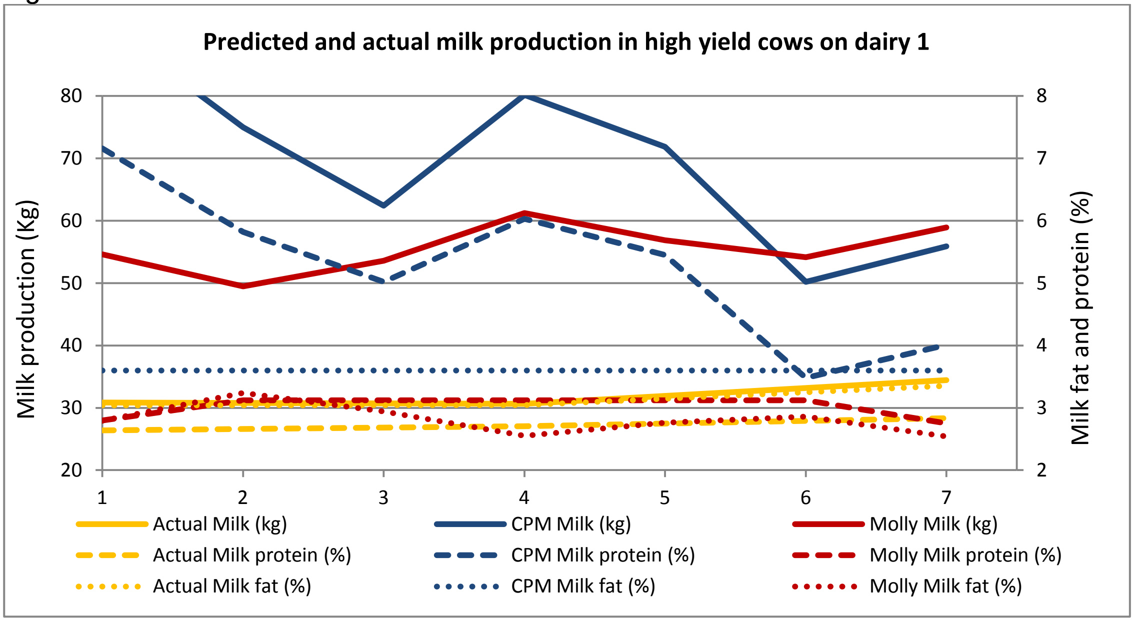
Figure 17



In the high pen the dry matter content of the feed increased with time. Dry matter intake was stable, except for a peak in the 4th week, when the pen count was 15% lower than normal. Milk yield and fat content remained stable at 30,0 kg and 3.0% respectively during the beginning of observation and then increased with 1.2% halfway the observation period to 34.5 kg and 3.4% respectively at the end of the observation period. Protein content increased steadily from 2.7% at the start to 2.8 % at the end of the observation period.

Prediction of milk production

Figure 18



The **actual milk production** of high yield cows remained stable during the first month of observation at 30.8 kg and increased with 12% to 34.5 kg over the second month of observation. The fat content closely followed the trend or milk production, remaining stable at 3% in the first four weeks of observation and increasing with 12% to 3.4% over the second month of observation. Protein content rose steadily from 2.6 to 2.8% during the observation period.

Molly predicted an increase in milk yield from 54.7 kg at the start to 59 kg at the end of the observation period, with varying milk yield over the weeks. The fat content was predicted to decrease from 2.8 to 2.5% during the observation period, with a variable fat content over the weeks. The protein content was predicted to remain stable at 3.0 ± 0.2 %.

CPM predicted a decreasing milk yield from 92 kg to 62 kg within the first three weeks of the observation period, than an increase back to 80 kg and yet another decline to 50 kg over the following three weeks. The predicted protein content closely follows the trend of milk production from 7% to 5%, back to 6% and then a decline to 3.5-4%The fat content was predicted to remain stable at 4%,

Incidence of nutrient related health events

Figure 19

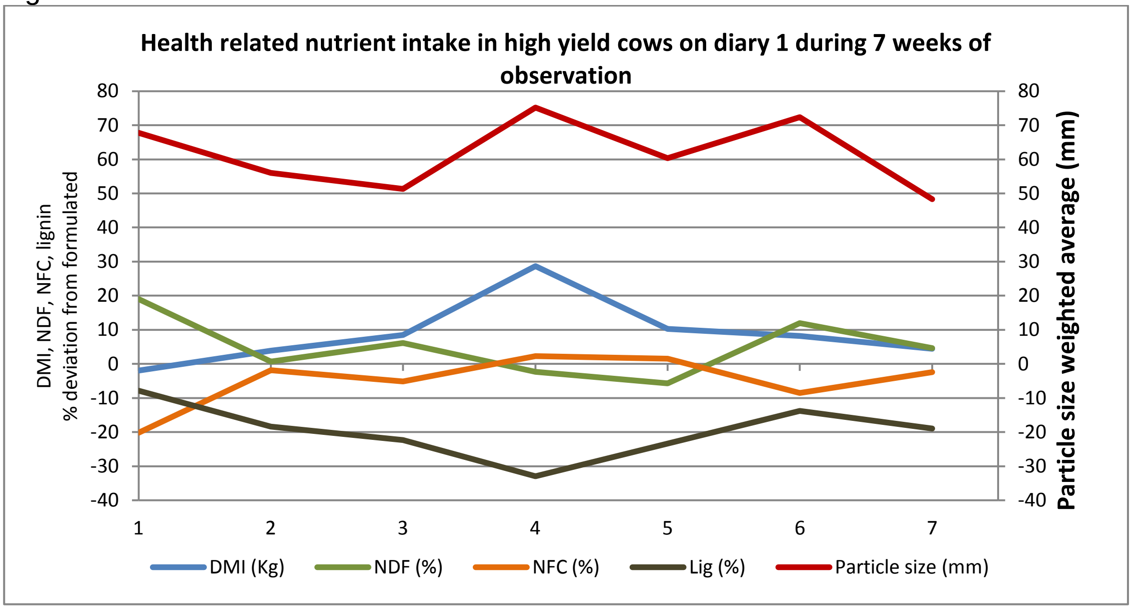


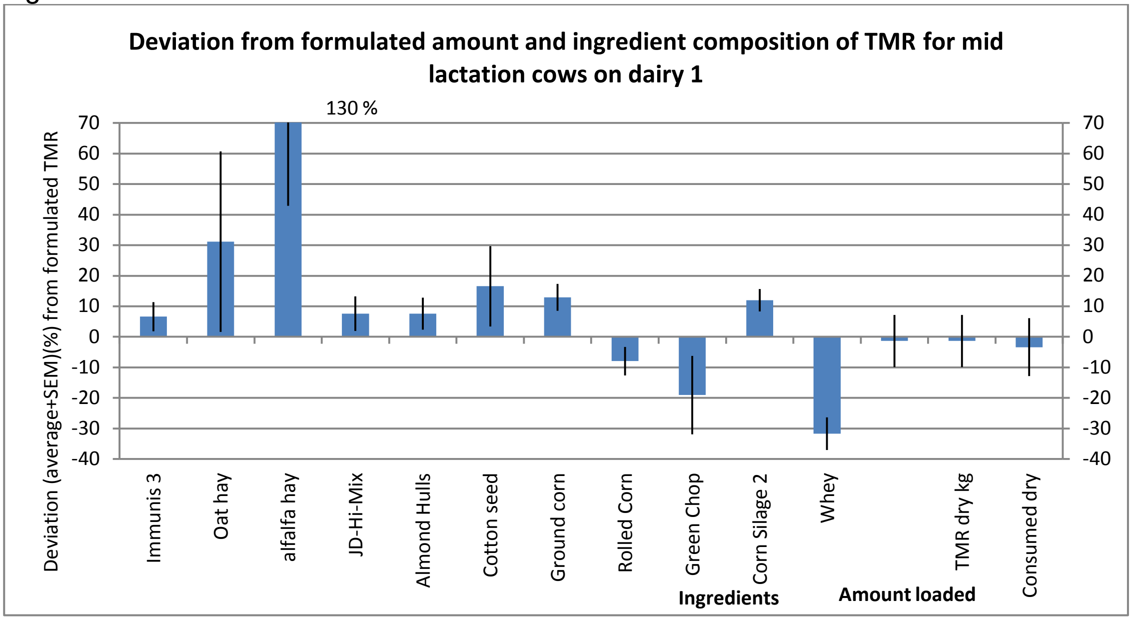
Table 4 Occurrence of health events in high yield cows on dairy 1

Date		26-10	31-10
DA		1	
Endometritis			
OB			
RP		1	1

Dry matter and NFC intake of high yield cows followed the same trend. DMI was 5 to 30% higher than formulated in 7 out of 8 observation weeks. NDF intake followed the exact opposite direction than the NFC intake, in amounts varying from -5% to +20% of the formulated intake. In comparison to the fresh and hospital cows, the intake of the nutrients varied much more over the weeks in the high yield cows. The lignin intake varied between -10 and -20% of the formulated amount, with a dip at -33% on the fourth observation day. The particle size of the feed was very variable, ranging from 50 to 75 mm with an average particle size of 62 mm. The particle size was at a very low level on third observation day, but increased to a level between 60 and 73 mm in the next three weeks, except for the last sample, in which the average particle size was again only 46 millimeters. The dry matter intake was fairly stable and only had a peak on the fourth observation day. Only one displaced abomasum occurred during this trial, on the during the third observation week. Two retained placentas were found during the fourth week of observation.

TMR ingredient composition

Figure 20

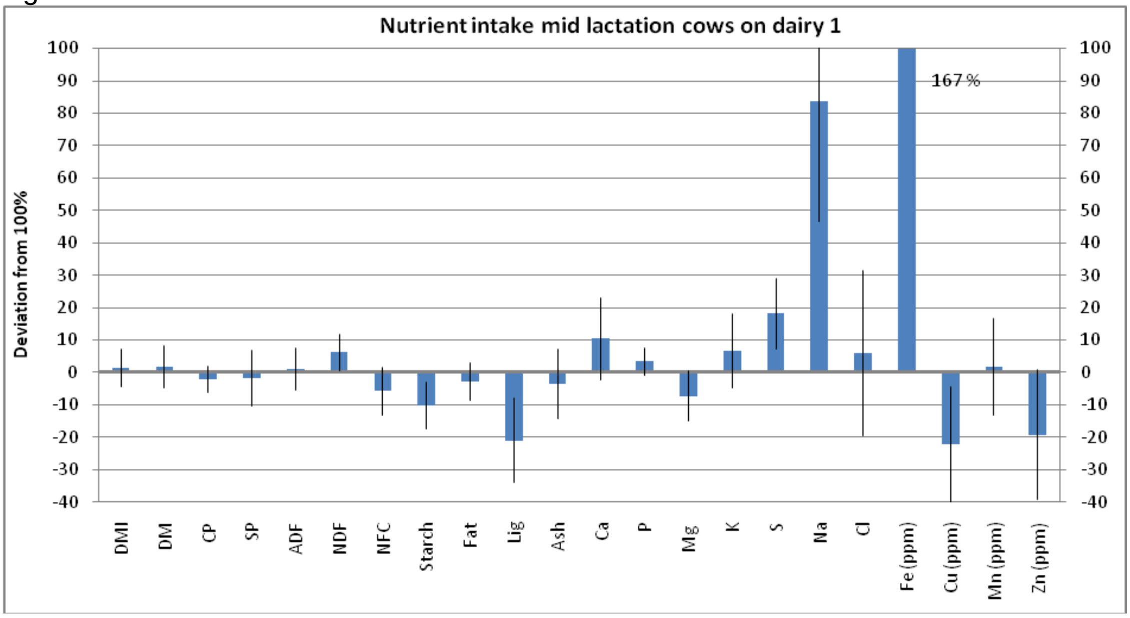


The diet for mid lactation cows on this dairy was the same as the diet for high yield cows, though from a different load. In the diet for mid lactation cows **Immunis 3** was on average added 6% above the formulated amount on average. **Oat hay** was added about 30% more than formulated and of alfalfa hay even more than twice as much as formulated (+130%) was added on average. Of **high premix, almond hulls, cotton seed, ground corn** and **corn silage,** 7 to 16% more was added than formulated. Of **green chop** 20% less than formulated was added and of **whey** 30% less than formulated. Excluding the added water, exactly the formulated amount of TMR was delivered and -3% was consumed.

One day, **Green chop** was not added at all. To adjust the dry matter content, about 9 times the normal amount of **alfalfa hay** was added to this TMR. Water was also added that day to balance the dry matter content. The data of this day were not included in the calculation of the average feed composition.

Nutrient intake

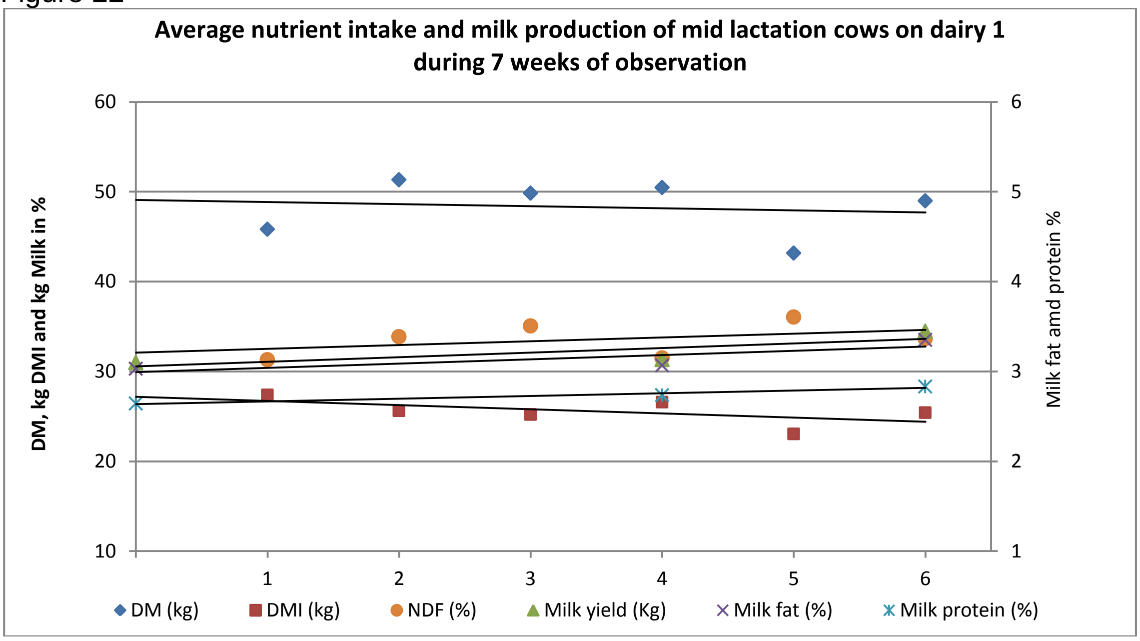
Figure 21



The average dry matter intake, dry matter content, protein, fat and ADF intake were very close to the formulated amount for mid lactation cows. The intake of lignin (P=0.004), starch (P=0.01), magnesium (P=0.05), copper (p=0.01) and zinc (P=0.03) was significantly (10 to 20%) lower than formulated. The intake of NDF (P=0.05), sulfur (P=0.02), sodium (twice the formulated amount (P=0.03)) and iron (P=0.03) was significantly higher than formulated for this stage of lactation. The average iron intake was even 3 times as high as formulated.

Relation between nutrient intake and milk production

Figure 22

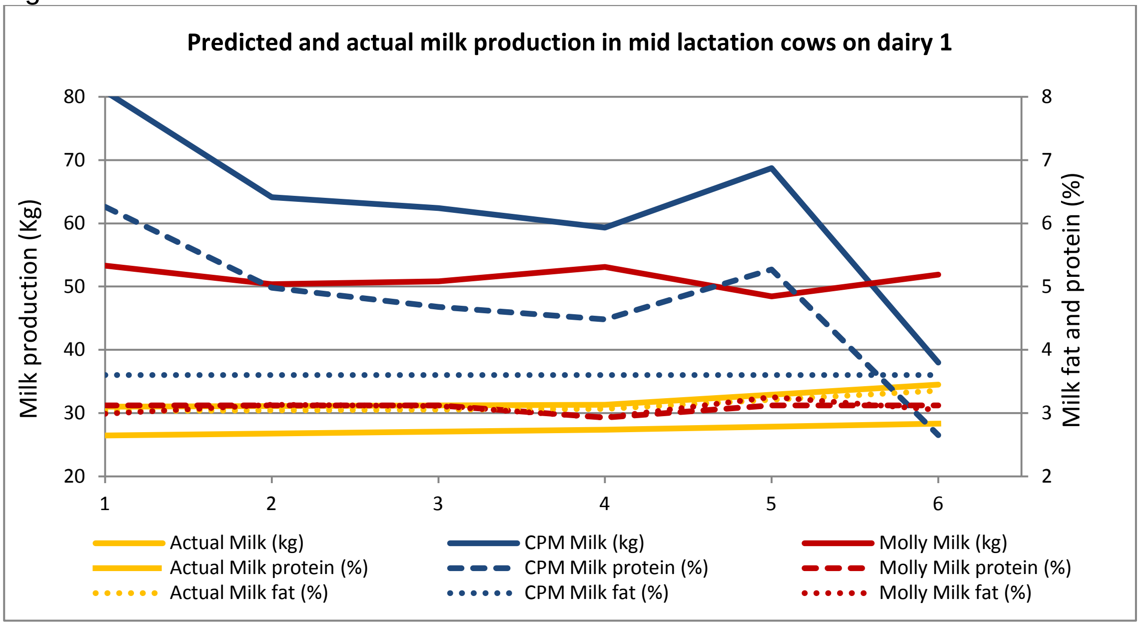


Dry matter intake of mid lactation cows declined steadily, with about two kilo’s during the observation period, from 27 to 25 kg/day. The average dry matter content of the diet remained stable at the formulated percentage although the inter-weekly variation was high.

The NDF intake increased slightly during the observation period. Milk yield and milk fat content remained stable during the first month of observation and both increased by about 10% during the second month of observation, whereas protein content increased steadily during the observation period from 2.6% at the start and 2.7% early in the second month of observation to 2.8% early in the following month.

Prediction of milk production

Figure 23



Actual milk production of mid lactation cows remained stable at 31 kg during the first month of observation and in the second month of observation increased 10% from 31 kg to 34.5 kg during the second month of observation. Fat content followed exactly the same trend starting at 3.0% and increasing to 3.4%. Protein content increased steadily throughout the observation period from 2.6% in the first month of observation to 2.7% in the second month of observation to 2.8% in the following month.

Molly predicted a very slight decrease in milk production from 53 kg to 52 kg with a stable fat content of 3.0% and a stable protein content of 3.1%.

CPM predicted a much larger decrease in milk yield from 80.89 kg to 59.3 kg during the first month of observation. In the first week of the second month of observation CPM predicted an increase in milk production to 69 kg and for the second week of the second month of observation a milk production of only 38 kg. The predicted fat content was stable but the predicted protein content followed the trend of milk production and decreased from 6.3% to 4.5% during the first month of observation, elevating to 5.3% in the first week of the second month of observation and then decreasing further to 2.7%.

MACRO DESCRIPTION OF TMR

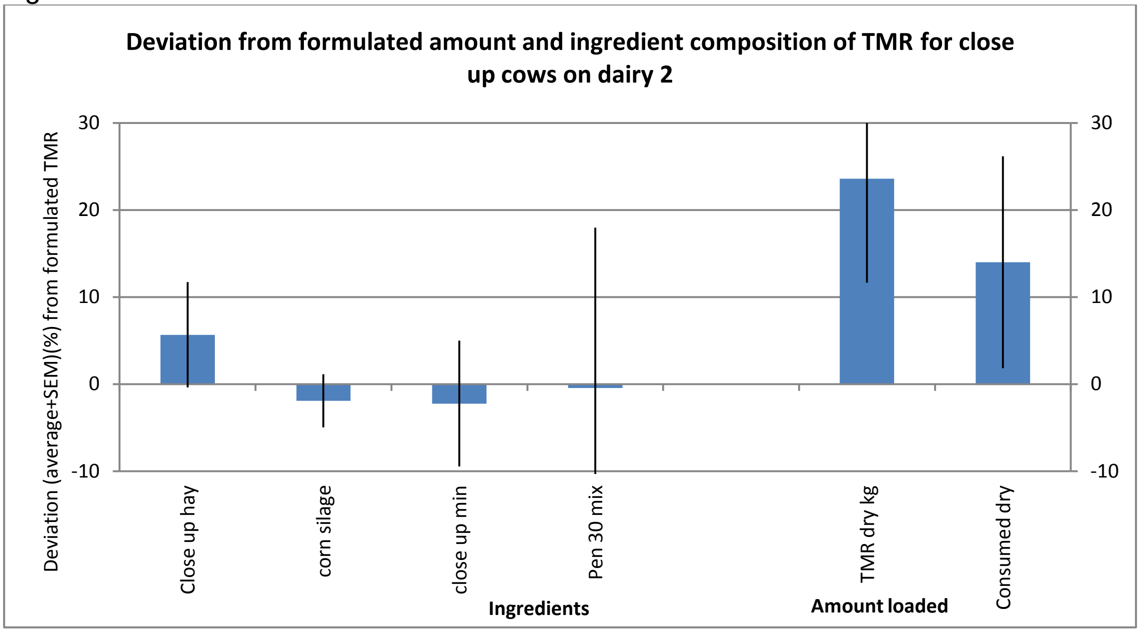
From a macroscopic view, TMR at dairy 2 was much dryer than TMR on dairy 1, because no water was added to the TMR. Regardless of the formulated dry matter content, the dry matter content of TMR on dairy 1 was always adjusted by addition of whey or water.

On dairy 2 TMR was usually very dry and polluted with stems, stones and lumps of hay, which led to sorting out more palatable ingredients and resulted in a longer particle length size in residuals as is shown in table 4. The TMR was also polluted with sticks, stones and leaves tended to fall from the stem. Residuals on Dairy 2, of course, still contained a lot of stones, and a lot of very long hay stems.

CLOSE UP COWS

TMR ingredient composition

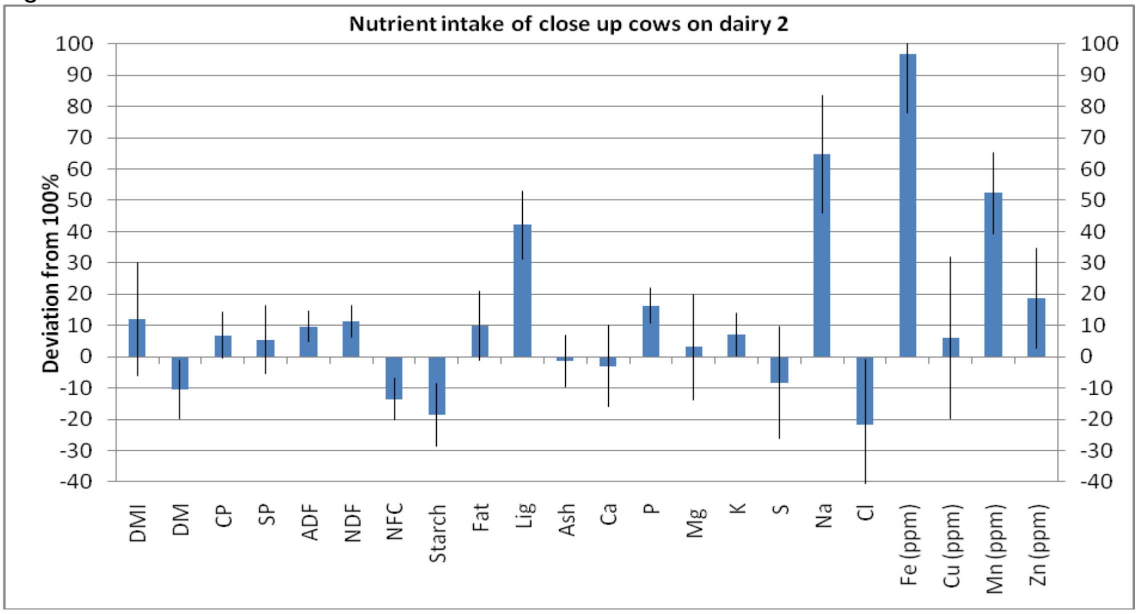
Figure 24



The average ingredient composition of TMR for the close up cows on this dairy was close to the formulated amount**. Dcad or close-up hay** was on average added 6% more than formulated; **Corn silage** and **minerals** were added 2% less than formulated and the ranges are not wide. Although **Pen 30 mix** on average was added exactly at the formulated amount, there is 18% variation. The actual amount delivered at this pen was 24% higher than formulated on average and one day even 73% more than formulated was delivered at the pen.

Nutrient intake

Figure 25



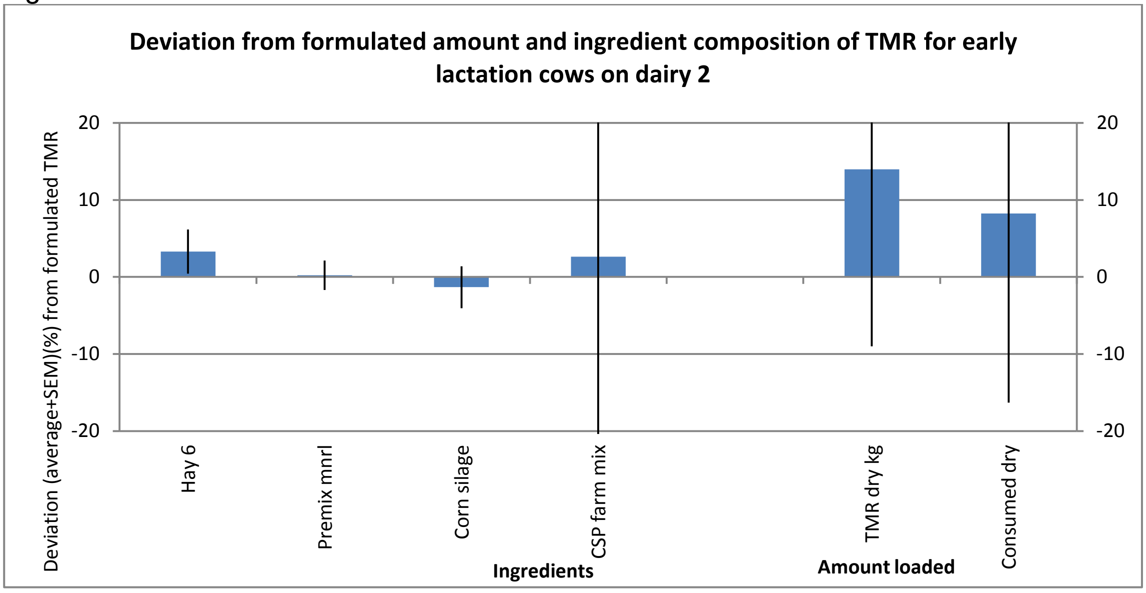
On average the dry matter content (P=0.02) of the TMR for the close up cows on dairy 2 was 20% lower than formulated. Dry matter intake was higher than formulated, as was the intake of fiber components ADF (P=0.003), NDF (P=0.002) and lignin (P=0.0003). Intake of NFC (P=0.02) and starch (P=0.01) was significantly lower than formulated. Of the minerals, intake of phosphorus (P=0.001), potassium (P=0.001), sodium (P=0.001), iron (P=0.0005), manganese (P=0.0004) and zinc (P=0.04) was significantly higher than formulated while intake of chloride (0.01) was on average less than the formulated amount.

Health events

Health events on dairy 2 were reported by veterinarians and farm managers. No health events were reported for close up cows.

TMR ingredient composition

Figure 26

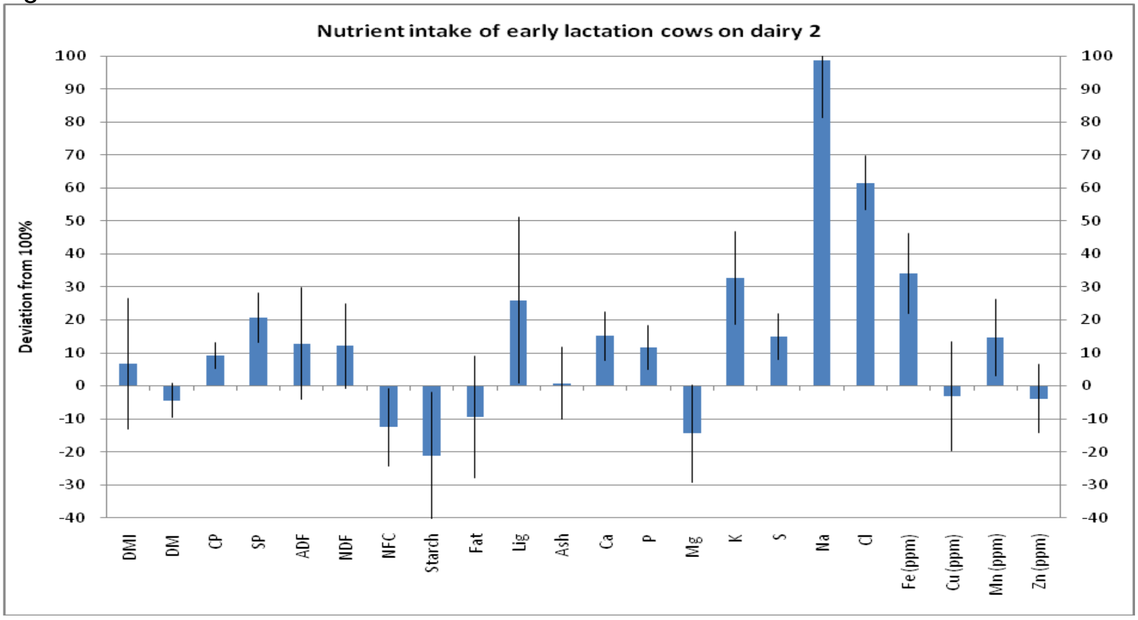


On dairy 2 both early lactation and high yield cows received the same diet. In addition to hay and corn silage this diet contained a **mineral mix** and a **farm mix** consisting of canola meal, dry distiller grains and wheat middlings.

The TMR for early lactation cows on average contained the formulated amount of almost all ingredients. Only in **hay** and **farm mix** was 3% more than formulated added. The range for the added amount of **mineral mix** was very broad however, between 37% less than formulated up to 42% more than formulated. The delivered amount of TMR at in this pen was on average 14% higher than formulated, but with a wide range between -9% and +37% of the formulated amount. The consumed amount of TMR was on average 8% higher than formulated, with a wide range between -17 and +33% of the formulated amount.

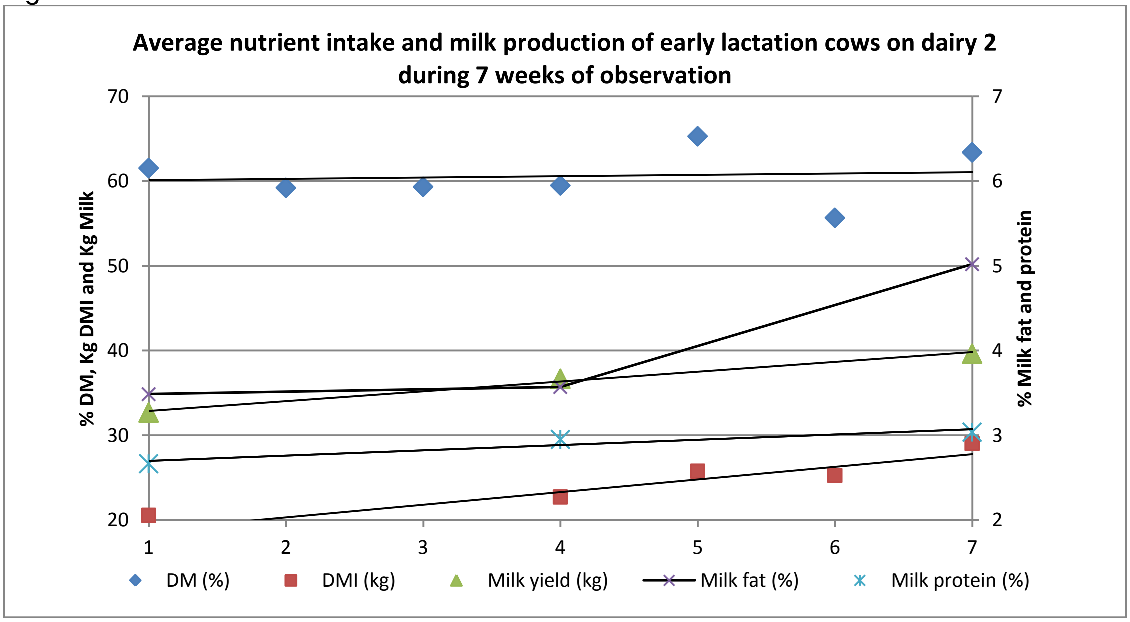
Nutrient intake

Figure 27



In the diet for early lactation cows, dry matter content was 5% lower than formulated, but due to the 14% overconsumption (see figure 27), dry matter intake was 4% higher than formulated, with a large variation within weeks. Crude protein intake (P=0.001) and intake of fiber components such as ADF and NDF were about 10% higher and lignin intake was 25% higher than formulated. NFC (P=0.02) and starch (P=0.01) intake was significantly lower than formulated. Fat intake on average was on average 5% lower than formulated, but the difference was not significant. The intake of ash was exactly at the formulated amount, although the intake of all minerals (calcium P=0.003, phosphorus P=0.001, potassium P=0.004, sulfur P=0.003, sodium P=0.0003, chloride P=0.00002, iron P=0.01, manganese P=0.03) that were fed in the mineral mix, were between 12% and 99% higher than formulated. Only the intake of magnesium (P=0.02), copper and zinc was lower than formulated, although not significantly, *Relation between nutrient intake and milk production*

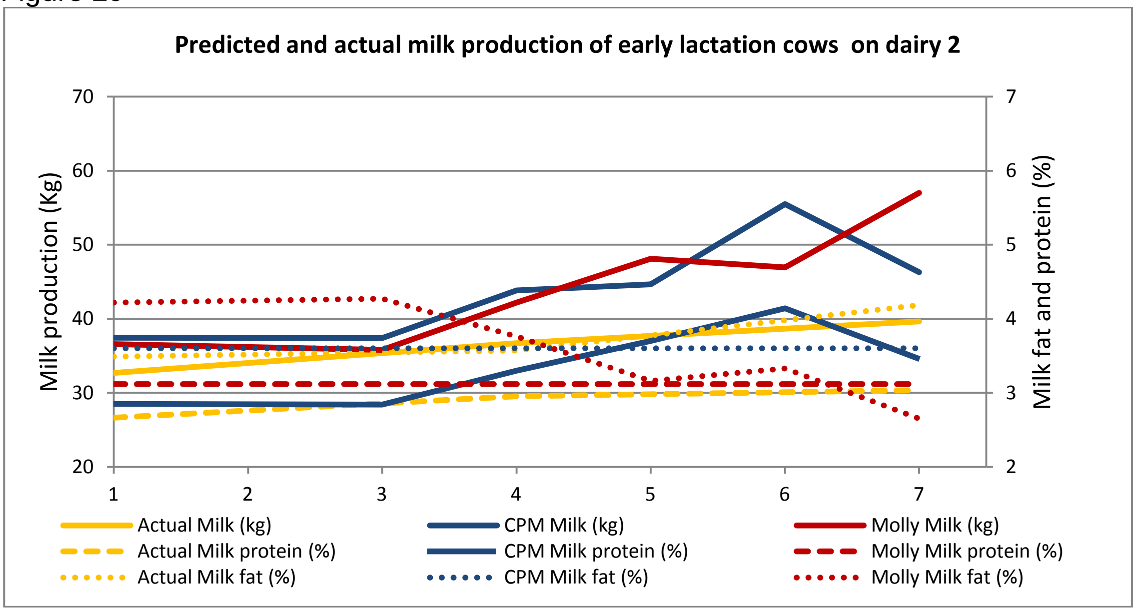
Figure 28



In figure 28, one outlying value of 33.8 kg/head dry matter intake on 3 the second month of observation was left out, because it changed the trend line greatly in the DMI graph for early lactation cows. Dry matter intake of early lactation cows increased continuously from 20 to 30 kg/day during the observation period, while the dry matter content of the TMR remained stable. During the observation period, milk yield and milk fat content increased 20%. Over the second month of observation, milk yield increased to 39.7 kg and milk fat increased from 3.5% up to 5.2% Protein content of the milk increased more slowly to 14% greater.

Prediction of milk production

Figure 29



The **actual milk production** of early lactation cows increased 20% from 32.7 kg milk at the beginning to 39.7 kg at the end of the observation period. Milk fat content also increased 20% from 3.5% to 4.2% and protein content increased 14% from 2.7% in the first month of observation to 3.0% in the following month.

Molly predicted a milk production of about 36kg at the end of the first month of observation and then a sharp increase in milk production to 57 kg at the end of the second month of observation. Molly predicted a stable milk protein content of about 3%, but the predicted fat content declines from over 4% during the first two weeks to 2.7% at the end of the observation period.

CPM predicted an elevation in milk yield from 37.5 kg to 46.3 kg with a peak production of 55.5 kg on the second month of observation 22nd. CPM predicted stable fat content of 3.6% and an increasing milk protein content with a peak concentration of 4.1 on the second month of observation 22nd and a final concentration of 3.5% at the end of the observation period. Data of the first month of observation 28th were left out because dry matter intake on that date was unrealistically high: 34 kg compared with an average intake of 24 kg during the observation period.

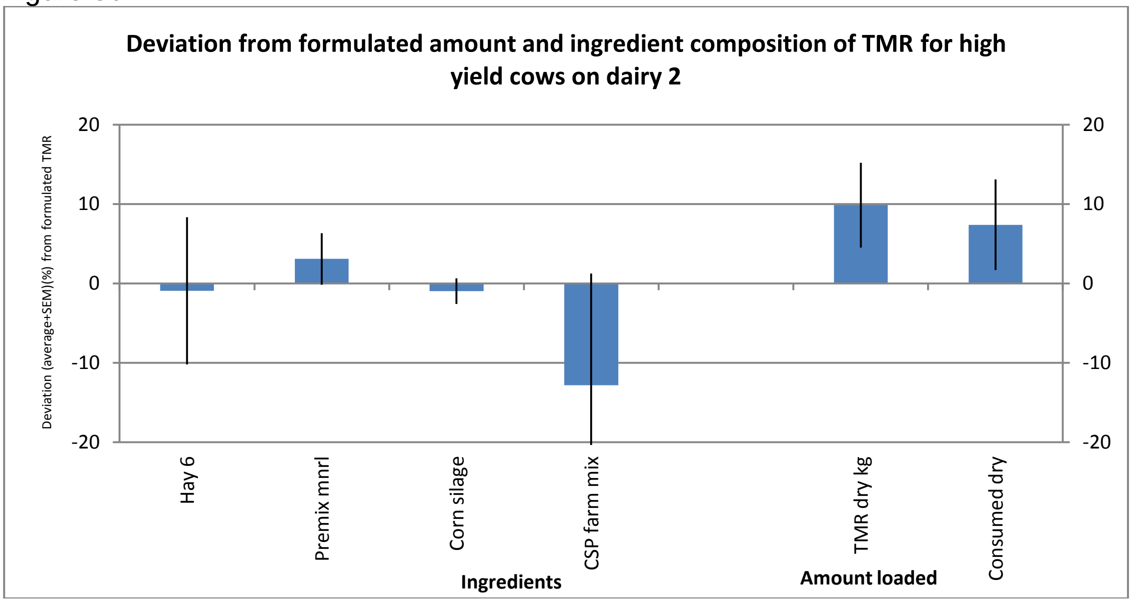
Health events

Health events on dairy 2 were reported by veterinarians and farm managers. In early lactation cows only a few cases of down cow syndrome were reported. Down cow syndrome may be caused by low plasma phosphate or calcium levels at the start of lactation, preventing the cow from rising, or by damage of the ischiadic nerve.

HIGH YIELD COWS

TMR ingredient composition

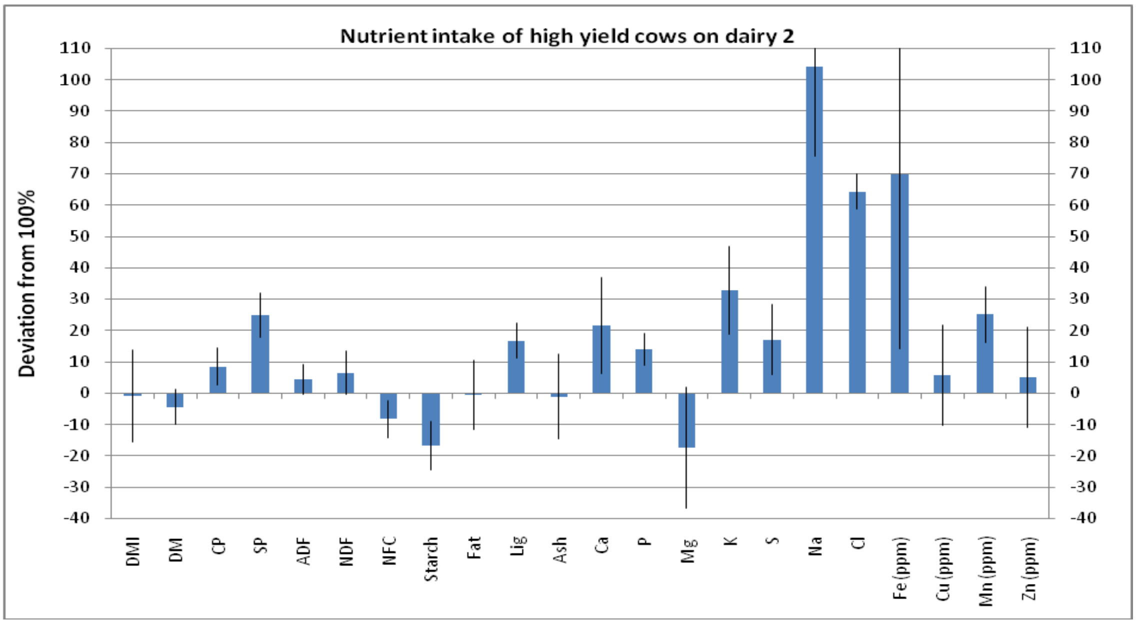
Figure 30



High yield cows were fed the same diet as early lactation cows, although from a different load. **Hay, mineral mix** and **corn silage** were on average added at the formulated amount within narrow ranges. Only in **CSP farm mix** was 13% less formulated added with a wide variation (-27 to +1%). The actual amount delivered at the pen was on average 10% higher than formulated and the consumed amount 7% higher than formulated.

Nutrient intake

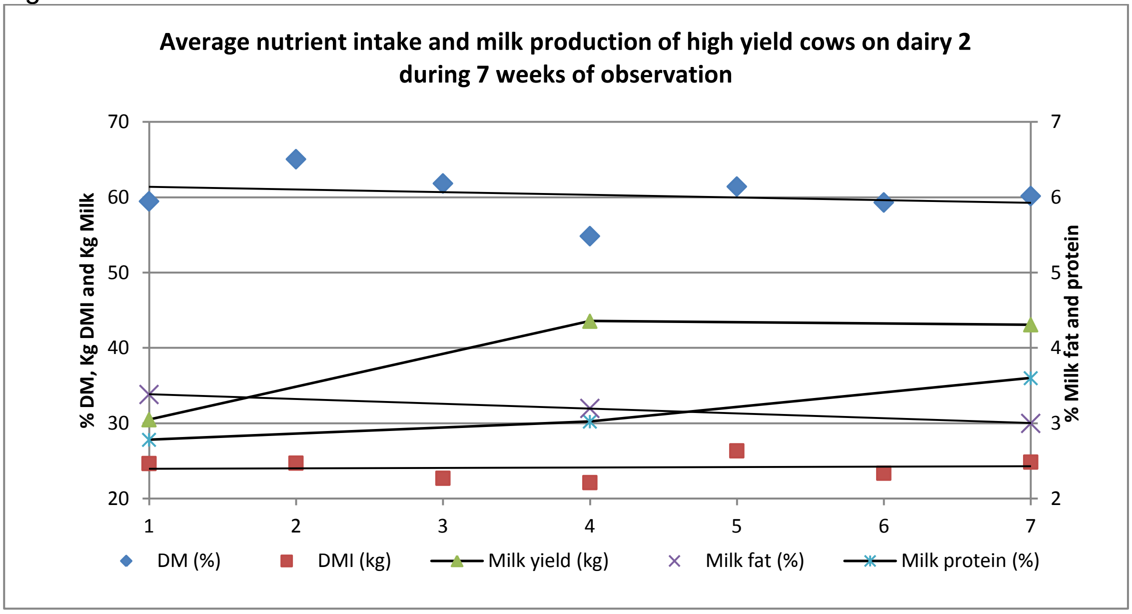
Figure 31



The dry matter content of the diet for high yield cows was 5% lower than formulated. Nevertheless, dry matter and fat intake were fed as formulated, although there was a large variation in dry matter intake between +17% and -17%. Crude protein (P=0.01) intake was significantly higher than formulated as were all minerals, which were fed in a mineral mix, except magnesium (P=0.03) which is consumed 18% less than formulated. Phosphate (P=0.001) and sulfur (P=0.01) were consumed about 8% more than formulated. NFC (P=0.01) and starch (P=0.00005) intake was significantly lower than formulated, but lignin (P=0.0005) and ADF (P=0.05) intake was significantly higher than formulated. Minerals calcium (P=0.02), sodium (P=0.003) and manganese (P=0.001) were also consumed in a significantly higher amount than formulated.

Relation between nutrient intake and milk production

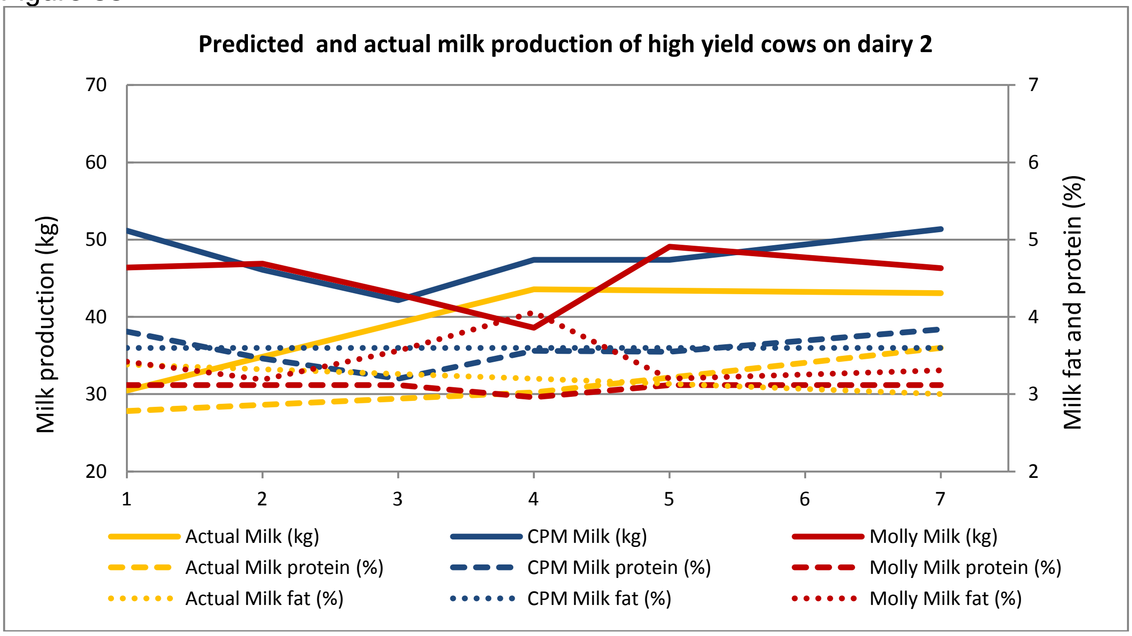
Figure 32



For high yield cows, dry matter intake and the dry matter content of the diet remained stable during the observation period. Milk production increased sharply in the first month of observation and then remained stable throughout the second month of observation. Milk protein content rose more steadily and continuously throughout the observation period, from 2.8% at the start to 3.6% at the end of the observation period. Milk fat content on the other hand decreased 10% during the observation period, from 3.3% at the start to 3% at the end of the observation period.

Prediction of milk production

Figure 33



The **actual milk production** of high yield cows on dairy 2 increased sharply from 30.5 kg at the start of the test to 43.6 kg in the second month of observation, and then remained stable at this level. Protein content increased steadily from 2.8% at the start to 3.6% at the end of the observation. On the other hand milk fat content decreased 10% from 3.4% at the start to3.0% at the end of the observation period.

Molly predicted a decrease in milk yield from 46.4 kg to 38.6 kg from the first month of observation through the second month of observation. In the third week of the second month of observation milk yield was predicted to peak at 49 kg and then to remain stable at 46 kg. Fat content was predicted to increase from 3.4% to 4.6%, and then to fluctuate between 3.2% and 3.9%. Protein content was predicted to remain stable at 3.1%.

CPM predicted first a decrease in milk production at the end of the first month of observation and then a slow increase in milk yield from 42.2 kg to 51.4 kg by the end of the second month of observation. Milk fat content was predicted to remain stable at 3.6% and milk protein content was predicted to follow the trend of milk production, first decreasing from 3.8% to 3.2% in the first week of the second month of observation and then increasing again steadily to 3.8% at the end of the second month of observation.

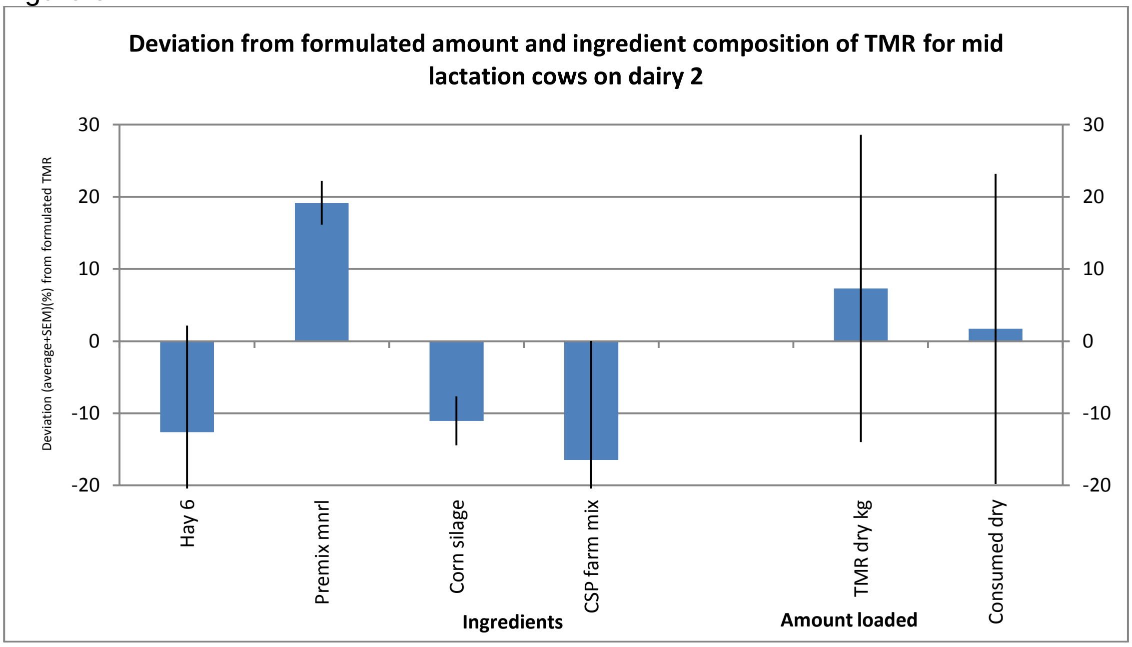
Health events

Health events on dairy 2 were reported by veterinarians and farm managers. No health events were reported for high yield cows.

MID LACTATION COWS

TMR ingredient composition

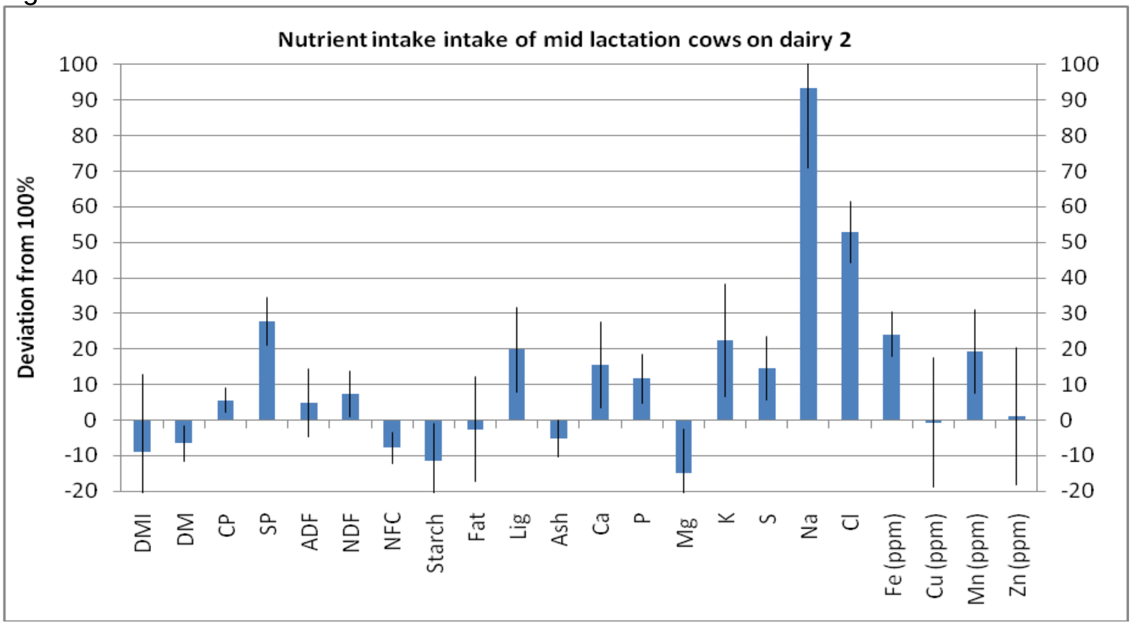
Figure 34



To the diet for mid lactation cows on dairy 2, of **hay, corn silage** and **CSP farm mix** between 11% and 16% less than formulated was added on average. On the other hand of **premix** on average 19% more than formulated was added. The actual amount delivered to mid-lactation cows was on average 7% more than formulated, while the consumed amount of TMR was 2% more than formulated.

Nutrient intake

Figure 35

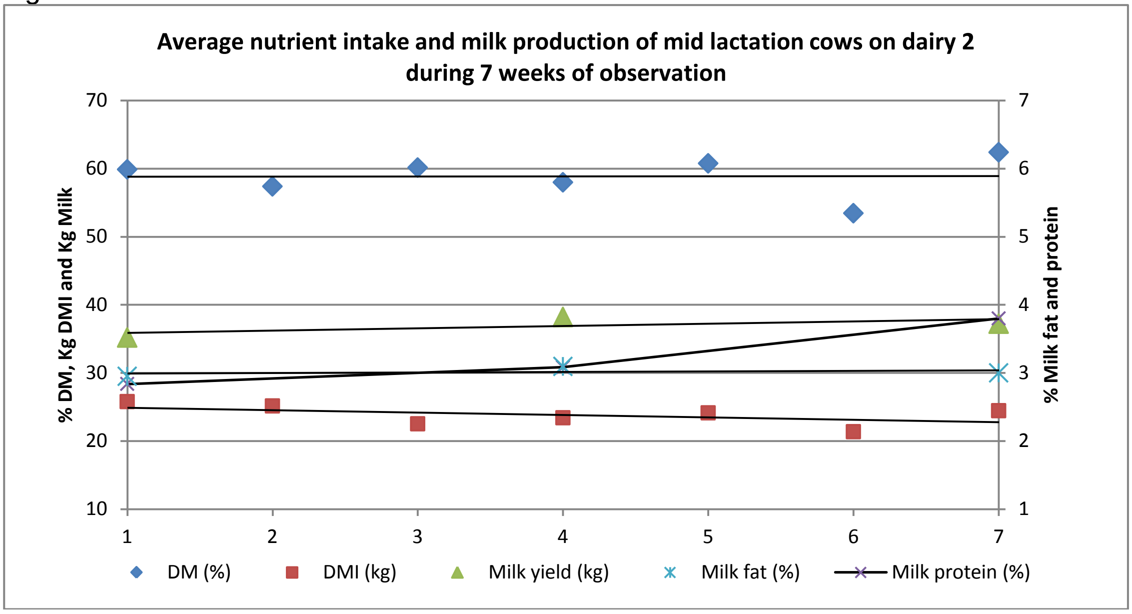


The dry matter content (P=0.01) of the diet fed to mid lactation cows on dairy 2 is significantly lower than was formulated. The dry matter intake was also lower than formulated, but the difference was not significant, due to the large variation. Intake of crude protein (P=0.01) and ADF was close to the formulated intake. Intake of NDF (P=0.03) and lignin (P=0.01) was 7% and 20% higher than formulated, Fat was consumed the amount formulated, although, the range it was consumed within is broad. NFC (P=0.002), starch (P=0.02), ash and magnesium (P=0.01) were taken in less than formulated. The intake of most minerals (-calcium P=0.03,(+16%), phosphorus P=0.01, (+12), sulfur P=0.01,(+14%), potassium P=0.01(+20%), sulfur P=0.01, (+15%), sodium P=0.001,(+93%), chloride P=0.00004,(+52%), iron P=0.0002,(+24%) and manganese P=0.01)(+19%) - was significantly higher than formulated. Only the intake of copper and zinc was as formulated and the intake of magnesium was 15% lower than formulated.

Relation between nutrient intake and milk production

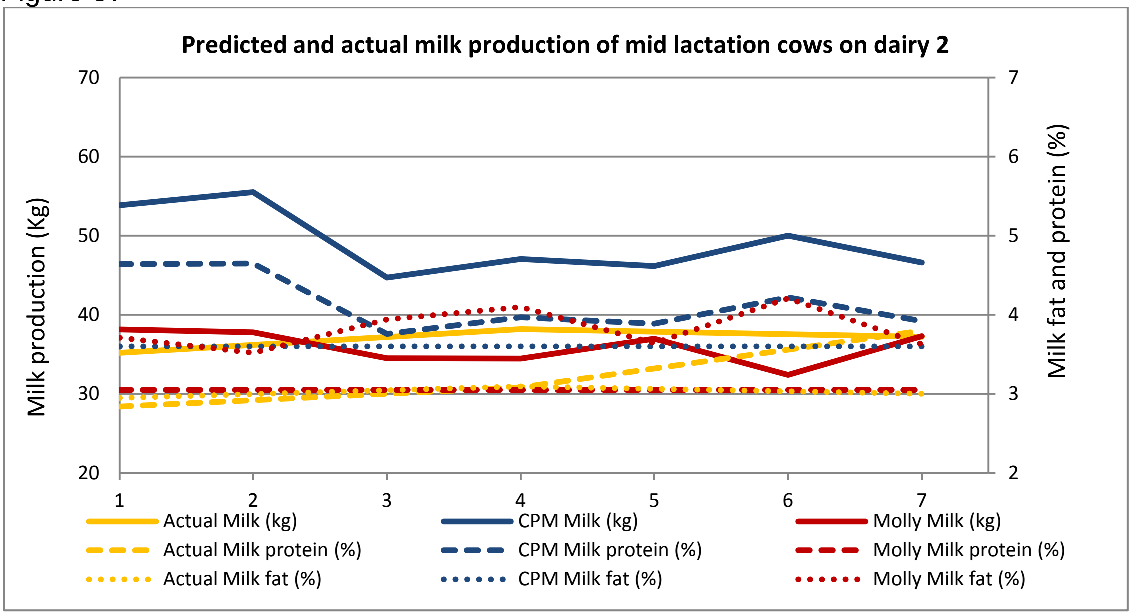
Figure 36 shows that in mid lactation cows on dairy 2, dry matter intake was slightly higher than formulated and declined slowly towards the formulated intake during the observation period. The dry matter content of the diet was lower than formulated but was stable throughout the observation period. Milk yield of mid-lactation cows on dairy 2 increased from 35,2 kg in the first month of observation to 38.2 kg in the second month of observation. In the second month of observation a slight decrease to 37.2 kg followed. Milk protein followed this trend with the same ratio; during the first month of observation milk protein increased from 2.8 to 3.1 and during the second month of observation it decreased to 3. Milk fat steadily increased from 3,0 and 3.1 to 3.8.

Figure 36



Prediction of milk production

Figure 37



The **actual milk production** of mid lactation cows on dairy 2 increased from 35.2 kg to 38 kg milk in the first month of observation and then declined slightly to 37 kg during the second month of observation. The fat content followed exactly the same trend, rising from 3.0% to 3.1% during the first month of observation and then declined back to 3.0% at the end of the second month of observation. The milk protein content rose continuously throughout the observation period, from 2.8% at the start of the observation period, to 3.80% at the end of the observation period.

Molly predicted a rather stable milk production fluctuating between a maximum of 38.2 kg and a minimum of 32.4 kg. The fat content was predicted to follow a trend exactly opposite to milk yield and fluctuating between 3.5% and 4.2%. Milk protein content was predicted to remain stable at 3.1%.

CPM predicted first a rather sharp decline in milk production from 55 to 46 kg and then a steady rise to a level between 48 and 50 kg of milk. Milk fat content was predicted to remain stable at 3.6%. Milk protein content was predicted to fall sharply during the first two observation weeks from 4.6% to 3.8% and then to remain stable at a level of 4 ± 0.2% during the second month of observation.

Health events

Health events on dairy 2 were reported orally by veterinarians and farm managers, but no health events were reported for mid lactation cows.

PARTICLE SIZE

The difference in particle size between TMR and residuals was used to monitor to what extent cows were able to sort out particles from the diet. If no selection would occur at all, the particle size of TMR and residuals would be identical.

Table 5: Average particle size (mm) of TMR and Residuals fed to cows on dairy 1 in different stages of lactation.

Dairy 1									
Fresh + hospital		Early lactation		High yield		Mid Lactation		Close up	
TMR	Residuals	TMR	Residuals	TMR	Residuals	TMR	Residuals	TMR	Residuals
61,02	59,18	64,24	71,37	60,17	44,01	61,50	57,15	71,53	67,80

Table 5 shows that on dairy 1 the average particle size in TMR for fresh and hospital, mid-lactation and close-up cows is 2 to 4 mm larger than the average particle size of residuals. The average particle size in TMR for high yielding cows was even 16 millimeter larger than the residuals. The TMR for early lactation cows is identical to that of fresh and hospital cows. Nevertheless the average particle size in TMR for early lactation cows was 7 mm smaller than the residuals.

Figure 38

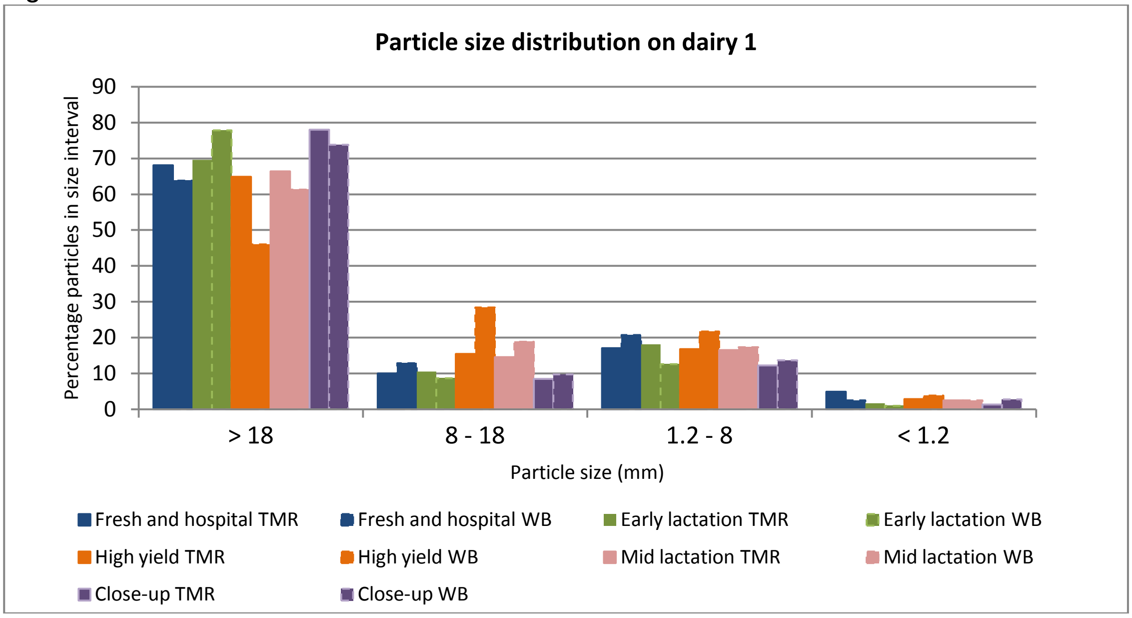


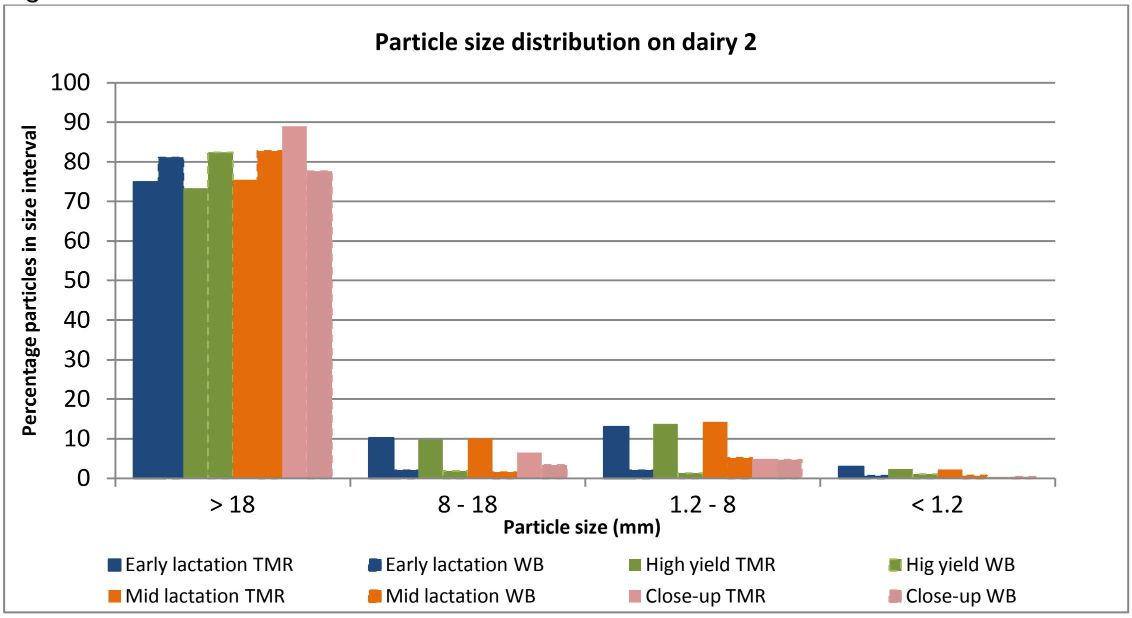
Figure 38 shows that, with the exception of early lactation cows, the cows ate more of the largest particles with an average size of 90 mm, and less of the particles between 8 and 18 mm. Early lactation cows appear to have eaten more of the intermediate particles and less large particles.

Table 6: Average particle size (mm) of TMR and Residuals fed to cows on dairy 2 in different stages of lactation.

Dairy 2							
Early lactation		High yield		Mid lactation		Close up cows	
TMR	Residual	TMR	Residual	TMR	Residual	TMR	Residuals
66,27	73,63	67,89	73,99	68,06	72,06	80,43	70,25

Table 6 shows that on dairy 2, the average particle size in TMR for early lactation, high yield and mid lactation cows was 4 – 7 mm **smaller** than the residuals. The average particle size in TMR for close-up cows on the other hand, was 10 mm larger than the residuals. These findings are confirmed by the size distribution (Figure 39), which shows that the early lactation, high yield and mid lactation cows ate more of the particles between 1.2 and 18 mm than of the large particles, whereas the close-up cows ate more of the large particles than of the intermediate particles.

Figure 39



DIFFERENCE BETWEEN DAIRIES

Table 7: Deviation from formulated amount of loaded ingredients

	Average	STD	Min	Max
Dairy 1	+9%	19%	68%	130%
Dairy 2	-2%	10%	84%	119%

Table 7 shows the average, standard deviation, minimum and maximum amount of all loaded ingredients on dairy 1 and 2. Records of Immunis 3 were not included because it is an additive that is fed in a very small amount and its wide range is already noted.

Ingredient composition on dairy 1 deviated grossly from the formulated composition. On dairy 2, TMR composition and amount fed approached the formulated amount more closely than on dairy 1, reflected by the smaller standard deviations on dairy 2.

DISCUSSION

ERRORS IN FORMULATION, PREPARATION, DELIVERY OF TMR AND IN NUTRIENT INTAKE ON DAIRY 1 AND 2

In all events shown in the *flowchart* errors occurred during the observation period on both dairies. The extent of some errors and their individual influences on both ingredient composition and nutrient are not quantified, but are nonetheless discussed in this discussion.

The influence of the **nutritionist** is shown in the fact that, although TMR on dairy 2 appeared much dryer than TMR on dairy 1, in comparison to the formulated amount, the dry matter content of TMR on dairy 2 was still lower. This is due to the high formulated dry matter content for TMR on dairy 2. Based on necessary dry matter limits to stored forages and silages and because of disadvantages of too low and too high dry matter content, the formulated dry matter content for TMR for dairy cows should not be lower than 60% to 65%. However, especially in high producing cows high dry matter content makes it easier to obtain a necessary dry matter intake. Too low dry matter content may lead to a too low dry matter intake and may lead to sorting behavior (15) (16). Although average dry matter contents of diets on both dairies are within these boundaries, formulated dry matter content on dairy 2 approaches the higher limit.

Deviation of actual dry matter content from the formulated amount shows that difference in formulation by the nutritionist contribute to calculated feeding errors even more than on-farm errors (loading, mixing, delivery, pen counts). Therefore, the formulated dry matter content of TMR should fit the used ingredients and their nutrient analyses on both farms. Nutrient analyses should thus often be repeated to formulate diets using the actual dry matter content of different forages. The extent to which the actual ration approaches the formulated ration depends on the accuracy of chemical and physical characteristic, such as dry matter content, of all forages used in formulation. In addition, if on dairy 1, addition of water is the standard procedure, the desired dry matter content, including added water, should be formulated and monitored.

Formulation of diets on dairy 2 should also be adjust as a result of the discrepancy between ash and individual mineral content and the imbalance of NFC, starch and fiber component in formulated diets on dairy 2.The addition of CSP farm mix and mineral mix to all groups of cows varied. On some sampling days they were fed more than the formulated amount and less on others observation dates. Nevertheless, the intake of all minerals, except magnesium, copper and zinc, was on average significantly higher than the formulated amount for all diets. This is possibly an indication that mineral content of CSP farm mix and mineral mix is not in balance with the nutrient composition of major mineral sources such as hay and corn silage and that the composition of both mixes should be adjusted to meet the formulated nutrient requirements for all groups of cows. More likely is, that the discrepancy between the low amount of ash and high amount of mineral intake is a result of the formulation by the nutritionist for a higher than actually fed ash content and a lower than actually fed amount of individual minerals. This also applies for the intake of NFC, starch, ADF, NDF and lignin, of which corn silage and CSP farm mix are main sources. These ingredients were added at almost the formulated amount and had small standard deviations. Nevertheless, nutrient intake derived from corn silage and mineral premix differed grossly from the formulated amounts. The most likely cause for this is inaccurate nutrient analysis of corn silage and CSP farm mix for which farm mix should be adjusted.

Loading is executed by farm hands on both dairies. Other than loading reports no other supervision is present on either dairy. Neither is there a reward for accuracy in loading, thus indifference in workers was observed on both dairies. On dairy 1, workers are not personally nor actively involved in the farm's achievements and receive no positive reinforcement for working accurately. On dairy 2 working at the dairy is used as positive reinforcement for good behavior in general although positive reinforcement is not continued after starting working on the dairy. If dairy work is not carried out properly workers are sent away (extinction), however feeding according to the formulated diet is not a criterion for extinction. The lack of attention to feeding according to the formulated diet and the lack of positive reinforcement for accuracy causes suboptimal performance in nutrition and thus in cow performance. (17)

The importance of accuracy in loading is illustrated by the influence of the deviation from the formulated amount of corn silage in different diets on dairy 1. Because corn silage

comprises such a large fraction of each diet, intake of NFC, starch and minerals is easily influenced by deviations in loading the main source of these nutrients.
Also, the addition of water to close up diet and early lactation diet on diary 1 is reflected in a 13% to 25% lower than formulated dry matter content of the diets with consequently a lower dry matter intake than formulated. If addition of water is desired, it should be formulated for to obtain a diet that meets dairy cow requirements. Nevertheless, as stated before addition of water leads to more instead of less sorting through the diet and to lower dry matter intake (18).
Mid lactation diet on dairy 1 always contained Immunis 3 in the formulated amount, no reason was given for the difference in accuracy of adding Immunis 3 to the different diets. Cotton seed is hard to load accurately because it is sticky and very light, this caused a higher addition and high standard deviation. The observed large deviation in loaded oat hay is also mentioned in Johnson, 2009, who stresses the bulky nature of oat hay. Johnson also describes a 4% average loading error within a range between 0% and 40% on a dairy in California, which is also shown in this study with an average loading error of 4,5 within a range of 0% up to 32%. Also a loading error of 3% is observed in alfalfa hay, corn silage and almond hulls. Loading errors in this study are only within this range for alfalfa hay and corn silage in early lactation cows on both dairy 1 and 2, but not for these ingredient, including almond hulls, in mid lactation cows on both dairies. One reason can be that alfalfa hay was used to compensate for not adding green chop on one occasion on dairy 1, however this does not explain the higher loading error of corn silage and almond hulls. Also no reason can be given for the higher loading errors on dairy 2.

Loading accuracy is not only influenced by operation accuracy of the farm hand, but also by the scales. Scales are the only tool to guide loading according to the formulated diet. Therefore, scales should be calibrated monthly and broken scales, such as on dairy 2, would be unacceptable in feeding dairy cows if high production was a main goal. On dairy 2 stones and stems are often found in the mixer wagon, being driven from the drive way onto the feed bunk and picked up with residuals. This not only pollutes the feed, but also wears out the blades of the mixer wagon.

The difference between **mixing** of TMR between dairies is caused by the difference in mixer wagons. The mixer wagon on Dairy 1 had much sharper blades, to cut long particles to the desirable length, resulting in a lower amount of very long particles and a TMR which was distinctly more uniform in particle length. On Dairy 2 the diet was dry and also tufts of hay were found on the feed bunk, not well mixed into the diet. This led to a larger variation in particle length than on dairy 1, enabling cows to sort out the tastier particles of intermediate length. Neither the type of mixer wagon nor mixing time were assessed as variables in this study.

The smaller particle size on dairy 1 led to the expectation that less sorting would occur. The contrary was observed however, the cows on dairy 1 sorted out the larger and intermediate particles from their diet. This is most probably caused by the addition of water. As Miller,states, addition of water leads only to a lower dry matter content and increase of sorting behavior, as is shown in all cows on dairy 1 except early lactation cows (18). This in contrast to dairy 2, where all cows preferred intermediate sized particles. On both dairies however, the particle size distribution was not in agreement with the requirements that a minimum particle size of 3.5 mm is recommended, whereas not more than 8% - 10% of the particles should be longer than 2 cm (5) (9). About 70% of all diets contained more than the required fraction of particles longer than 20 mm, because recommendations are based on studies using corn silage whereas diets in this inventory contained hay. According to Heinrichs it takes a maximum of 15 minutes of mixing to obtain TMR with a 6% to 8% fraction of particles longer than 18 mm when the fraction of particles >18mm at start is 12%. Both target diets in this study contained alfalfa hay (12). Also, with the addition of water care should be taken to avoid the amount of water to be so high that mould growth occurs, as happened on one occasion.

Accuracy of counting the number of cows present in different pens is also the most important influence on **dumping** errors. On many observation dates pen counts from Feedwatch did not meet the actual number of cows in the pens. This led to either delivering a larger than formulated amount at each pens, which leads to unnecessary residuals, or delivering a smaller than formulated amount which leads to underfeeding and may lead to lower milk production. A second cause of dumping errors is the change of forage dry matter content during storage that, in combination with loading errors leads to variations in diets dry matter content and influences the dumped amount dry matter per head. This theory is put in practice on dairy 1 where addition of water is not formulated, though it is added to TMR. However, the formulated amount of product is dumped despite its lower dry matter content resulting in a lower dry matter intake per head.

Calculation of **intake** was hindered by the collection of residuals. Unfortunately on Dairy 1 residuals were collected only every other day. The amount of residuals therefore had to be calculated by dividing the residuals of two days by two. Since the amount fed per day changed with the estimated pen count, the amount of residuals is not as accurately measured as when residuals would be collected on a daily basis.
On dairy 2, residuals were collected on a daily basis, however on many days no residuals were present. This may be a sign that the desired dry matter intake per head was not met. This hypothesis is supported by the observation that even on the one occasion that the actual dry matter intake per head was 10 kg more than formulated, still no residuals could be collected.

In close up diet on **dairy 1**, the lower than formulated intake of copper, NFC and magnesium is a result of a 3% lower than formulated addition of corn silage. Corn silage accounted for 27% of the diet, in which 3% difference leads to a large deviation from the formulated amount. In Early lactation diet on dairy 1, NFC, starch, ash and chloride intake were lower than formulated, because of a lower addition of corn silage, which accounted for even 47% of the load. The high uptake of minerals from **mid lactation diet** on dairy 1 mainly originated from fresh premix, corn silage and alfalfa hay. Although magnesium and copper are mainly derived from High Premix in mid lactation diet on dairy 1, the lower intake of both minerals is most probably caused by the lower addition of the second source of these minerals, green chop. The significantly higher intake of sulfur and sodium is caused by the high amount of added High premix, while the high iron intake was mainly derived from corn silage in this diet.

The lower intake of NFC from close up diet on **dairy 2** was mainly due to a loading error of corn silage, which accounted for 60% of the load and was added on average 2% less than formulated. The intake of fiber components ADF, NDF and lignin was mainly derived from corn silage, which was added less than formulated, but was secondly from hay, which accounted for 20% of the loads and was added 6% more than formulated and resulted in a higher intake of fiber components. Calcium was consumed less than the formulated amount in close up cows on dairy 2, which is favorable for the absorption of calcium post-partum as is explained in '*Health*'. Nevertheless, the high intake of potassium undermines the desired low cation, high anion balance. The higher than formulated intake of minerals was not derived from mineral mix, because it was added on average less than formulated, but more likely from hay, which is, with corn silage and mineral mix, an important source for minerals.

HEALTH

A secondary objective of this inventory study was to investigate to what extent errors in feed intake are associated with the occurrence of nutrition related health events.

On dairy 1, body condition score was recorded in close-up and early lactation cows, to monitor loss of body fat during transition. In week 5 a high average body condition score was recorded as well as an elevated concentration of β-Hydroxybutyrate (BHB) in the blood. At the same time a drop in TMR dry matter content and dry matter intake occurred, although enough feed was delivered. On the next day a high amount of residuals was collected, which in combination with the elevated BHB concentrations is a sure of a negative energy balance. Cows with a high body condition score in the transition period always have elevated BHB concentrations, but it is very likely that the low dry matter intake, caused by the low dry matter content, contributed extra to the induction of a negative energy balance.

Close up cows on dairy 1, had an average body condition score of 3.5, while a body condition of 3 is considered optimal. However, on observation dates cows are selected randomly for body condition scoring instead of following cows body condition score through lactation. Therefore, no conclusion can be drawn from trends appearing from data body condition scoring. The elevated body condition score also can't be related to the actual energy intake in the close up pen because cows stay in this pen for 2 weeks only. More likely is it due to overfeeding of energy in late lactation cows.

In TMR for close up cows calcium intake is kept as low as possible, in order to stimulate calcium absorption from the intestinal tract and calcium release from the bones. In observation week 5, 6 and 7 calcium intake was on average 40% higher than formulated, which has a negative influence on the desired low cation-anion balance. The very low pH of 5.2 on the first sampling day may be a reflection of a too high anion balance, although the average urine pH of selected close up cows was within the desired range during the next two sampling days. As milk fever was not recorded on dairy 1, any relation to milk fever could not be observed.

No health events were recorded on dairy 2, so no relation between nutrient intake and health events could be observed. However, close-up cows on dairy 2 received low-DCAD hay to prevent milk fever during the transition period. Calculation of nutrient intake shows that the close-up cows consumed less than the formulated amount of calcium, which stimulates the absorption of calcium from the intestine. Unfortunately intake of potassium was higher than formulated, while intake of chloride was lower than the formulated amount. The opposite is desired to reach a low cation-anion balance in close up cows.

MILK PRODUCTION

Another secondary objective of this study was to investigate if the known influence of nutrient intake on milk yield and composition could be observed. This objective was complicated by the fact that milk yield and composition were only analyzed and recorded once a month, during one single milking. A further complication was the large fluctuation in nutrient intake between different sampling days. Also the observed cows in every pen differed per sampling date for cows were moved to different pens from time to time. Therefore no conclusions could be drawn regarding the relation between nutrient intake and milk yield and composition.

Milk yield increased on both dairies during the observation period and was independent of dry matter or NDF intake. This implies that the increase in milk yield is most probably caused by the gradually colder weather, with less heat stress for the cows as a consequence.

On dairy 2 the variation in composition and consumed amount of TMR is smaller than on dairy 1. Rumen fermentation in the cows on dairy 2 will consequently be more stable. This may offer an explanation for the fact that milk yield on dairy 2 is consistently 10 to 27% higher than on dairy 1.

In early lactation cows on dairy 2, during the first four weeks of the observation period, milk yield increased , whereas milk fat content remained unchanged. This may be a reflection of the fact that during this period intake of dietary fat almost doubled. As shown by Coppock and Wilks, dietary fat stimulates milk yield, but not milk fat percentage (19). However, if the amount of fat present in the diet (e.g. corn oil), exceeds the emulsifying capacity of the cud, the cellulolytic activity of the rumen microbes is depressed, which leads to a lower digestibility of NDF, ash and fatty acids (20).

During the last three weeks of observation, milk yield continued to rise, however during this period milk fat content increased significantly as well. This rise in milk fat content probably reflects an episode of negative energy balance in this group of cows. If more milk is produced than the cows has energy for, this leads to a breakdown of body fat to generate the extra energy necessary for maintenance of body function and milk production and a higher milk fat content (14).

PREDICTED MILK YIELD AND COMPOSITION

When milk yield is calculated with CPM Dairy or Molly, the variation in milk yield and composition grossly exceeds the physiological boundaries of dairy cows. Especially CPM Dairy predicts milk productions above 50 kg. Level and weekly variation in milk yield, milk protein and milk fat content, predicted by CPM, also exceed the normal variation in cow's milk yield and composition. This implies that CPM is not a suitable model to predict milk production.

CPM dairy and Molly very well reflect the weekly differences in nutrient intake in their predictions of milk yield and composition but bear no relation to the actual milk yield and composition. This does not mean that these models can’t be used at all, but that they are only accurate when actual nutrient intake closely corresponds to the formulated diet composition and dry matter intake.

DIFFERENCE BETWEEN BOTH DAIRIES

Ingredient composition on dairy 1 deviated grossly from the formulated composition. On dairy 2, TMR composition and amount fed approached the formulated amount more closely than on dairy 1, reflected by the smaller standard deviations on dairy 2.

On dairy 2 milk yield was higher than in comparable groups of cows on dairy 1, which was probably a reflection of the more accurate nutrient intake on dairy 2.

On dairy 2 health events were not recorded on a daily basis, but were reported to us by the farm manager on our sampling days. On dairy 2 less major health events were reported than were observed on dairy 1. The better health condition on dairy 2 may be a result of the more accurate composition and loading of TMR. This was unexpected, because dairy 1 is a commercial farm, contrary to dairy 2 where high milk production is not a primary goal.

CONCLUSIONS

1. ***The largest source of error is human work force.***

The largest source of errors in the loading, mixing and delivery process is the human work force due to its presence in every step of the feeding process and its vulnerability to errors. The importance of accuracy is not shared with the workers nor is there any positive reinforcement for workers who work accurately. Workers need to be engaged to the dairy and its production results to become and stay motivated.

2. ***The ingredient profile formulated by the nutritionist did not correspond with the ingredient profile that was loaded into the mixer wagon.***

On dairy 1 the ingredient composition of TMR did not correspond to the formulated diet. Corn silage, which accounts for a large part of all diets was added in a smaller amount to close up and early lactation diet and in a larger amount to mid lactation diet.

Water was added to early lactation and close up diet on dairy 1 while it was not formulated. This reflected in a lower than formulated dry matter content of both diets. Water should either be left out of the diet or be formulated for.

Mid lactation diet on dairy 2 contained less of major forage ingredients, but did contain more premix mineral.

Some of these errors occur due to characteristics of the ingredient such as sticky cotton seed that fall in lumps or powdery premixes and mineral mixes that are easily blown away. Other loading errors occur due to inaccuracy of employees.

3. ***The formulated nutrient composition did not correspond with the actual nutrient intake.***

On dairy 1 the lower than formulated addition of corn silage resulted in a significantly lower intake of NFC, starch, ash, copper and magnesium in early lactation and close up cows. The higher than formulated addition of corn silage in mid lactation diet resulted in a much higher iron intake than formulated.

The non-formulated addition of water to early lactation diet on dairy 1 not only result in a lower than formulated dry matter content of the diet but also to lower than formulated dry matter intake.

Diets on dairy 2 contained more fibre components ADF, NDF and lignin and less NFC and starch than formulated although addition of major sources was close to the formulated amount. First of all, forage analysis must suit the actual forages used and diet formulation for dairy cows must fit using these analyses. Secondly, ash and individual mineral intake should correspond with each other within this formulated diet. And last, farm mix should be adjusted to supply the formulated nutrient composition based on forages.

4. ***No conclusions can be drawn regarding the influence of nutrient intake on milk production and composition.***

TMR was only collected 4 times a month and milk samples were only taken once a month. Nutrient intakes calculated from the 4 sampling days bare no relation to the monthly milk figures. Also data from both dairies show that in all groups milk yield and components increased from the beginning through the end of the observation period while dry matter intake, the dry matter content of the TMR and NDF intake were variable during this period.

5. ***Deviation of actual from formulated nutrient composition influenced the occurrence of health events like retained placenta, displaced abomasum and (endo)metritis.***

On dairy 1, displaced abomasums occurred in fresh and hospital and early lactation cows because of large fluctuations in particle size and intake of dry matter, and fiber components NDF, NFC and lignin.

It can't be concluded that on dairy 1 retained placenta occurred due to nutritional causes because too few events of retained placenta occurred and intake of calcium was significantly higher than formulated. Also too few events occurred to draw any conclusion about obstetric problems or (endo)metritis.

In close up cows on dairy 1 a high body condition score was seen. A high body condition score in close up cows should be avoided in these cows because a more extensive amount of fat will be set free at the start of lactation. This implies that TMR for far off and late lactation cows needs adjustment to a lower energy content.

The significantly lower than formulated intake of chloride and the higher than formulated intake of potassium, does not seem to influence urine pH, because the pH was found to be in the optimal range for close up cows during the entire study period.

6. ***Fluctuation in actual nutrient intake among weeks influences the occurrence of health events.***

On dairy 1 dry matter intake fluctuated in all pens during the study period, much more than on dairy 2, where dry matter intake was much more stable over all weeks. On dairy 1 among fresh and hospital, early lactation and high yield cows some DA's occurred during investigation, especially when fiber intake and/or particle length decreased and dry matter intake fluctuated strongly. On dairy 2 no health events were recorded, but veterinarians and farm managers reported no cases of DA.

7. ***There is a difference in accuracy of loading between the two cooperative herds.***

Contrary to the expectations, ingredients on dairy 1 were loaded with a larger standard deviation from the formulated amount than on dairy 2, which means that on dairy 2 less fluctuation occurs and feeding is more accurate and focused on formulated weight than on dairy 1. The minimum and maximum amount of individual ingredients loaded on dairy 1 was lower and higher than the minimum and maximum amounts on dairy 2. Accuracy of employees on dairy 2 was higher than on dairy 1.

8. ***There is a difference in particle size between TMR and residuals.***

On dairy 1 the average particle size in TMR for fresh and hospital, mid-lactation and close-up cows is 2 to 4 mm **larger** than the average particle size of residuals. The average particle size in TMR for early lactation cows was 7 mm **smaller** than residuals. With the exception of early lactation cows, the cows ate more of the largest particles with an average size of 90 mm, and less of the particles between 8 and 18 mm. Early lactation cows appear to have eaten more of the intermediate particles and less large particles. Particle size on this dairy did not meet the recommendation of 8%-10% particles >20 mm. This implies a too short mixing time.

On dairy 2, the average particle size in TMR for early lactation, high yield and mid lactation cows was 4 – 7 mm **smaller** than the residuals. The average particle size in TMR for close-up cows was 10 mm **larger** than the residuals. Early lactation, high yield and mid lactation cows ate more of the particles between 1.2 and 18 mm than of the large particles, whereas the close-up cows ate more of the large particles than of the intermediate particles.

RECOMMENDATIONS

- Ingredients must be loaded more accurately to the formulated amounts in order to maintain a balanced nutrient composition in TMR that better approaches the nutritional needs of cows.
- The dry matter content of forages needs to be analysed more frequently. The knowledge of the dry matter content of ingredients should be taken into account in the formulation of TMR.
- Water should not be added if not formulated.
- Pen counts need to be performed more often and more accurately. Inaccurate pen counts lead to under- and overfeeding with negative implications for milk yield and animal health.
- Mineral mixes need to be adjusted to the mineral content of the forage to meet the requirements for dairy cows in different stages of lactation, including close up cows when DCAD hay is fed.

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