Dry Matter Variability in Corn and Alfalfa Silages Fed to Dairy Cattle

by

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ABSTRACT

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Dry matter (DM) content of corn and alfalfa silages was measured by a handheld near infrared light (NIR) device and forced air-drying oven (FAO) on 13 d of a 17-d sample period on four farms. The effect of unaccounted DM content fluctuations on nutritional value of the mixed diet, its cost and associated nitrogen excretion were estimated using NRC (2001) calculations. Suitability of a handheld NIR device was assessed by comparison of DM measurements with FAO. The handheld NIR was found to have good accuracy (r = 0.848) and precision (Cb = 0.972) when measuring DM content of alfalfa silage, and had an even greater degree of accuracy (r = 0.917) and precision (Cb = 0.994) when measuring DM content of corn silage. Unaccounted DM content changes were identified in both feed ingredients but did not have a large impact on CP, NDF, ADF, N excretions or cost factors in any of the four cases.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
Cb	bias correction factor
CP	Crude protein
CPI	Crude protein intake
DM	Dry matter
FAO	Forced air oven
Int.	Intended
KMT	Koster moisture tester
N	Nitrogen
NDF	Neutral detergent fiber
MP	Metabolizable protein
NE	Net energy
NE_L	Net energy lactation
NIR	Near infrared reflectance
NRC	National Research Council
P	Phosphorus
r	Pearson's correlation coefficient
RSD	Relative standard deviation
SARA	Subacute ruminal acidosis
SD	Standard deviation
TMR	Total mixed ration

CHAPTER 1

LITERATURE REVIEW

General Introduction

Forages have an ability to rapidly lose and gain moisture, altering the dry matter (DM) content of corn and alfalfa silage ingredients. Previous literature has demonstrated the degree of DM variability in silages. Although DM content variability has been recognized and investigated in industry, a convenient, reliable, and rapid method of on-farm DM determination has not been well defined. Testing new technology like handheld near infrared (NIR) spectroscopy devices could offer a practical method of more frequent on-farm DM determination. Additionally, nutrient variation, such as crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF), could be minimized as forage ingredients could be fed more accurately and precisely on a daily basis. More precise feed management could result in better cow performance, reduced feed costs, and less environmental impact from nutrient excretions. The objective of this study was to investigate DM variability in silages and to estimate effects on nutrient concentrations in the diet, while implementing a new method of on-farm DM determination.

Dry Matter Variability in Silages

Deviation of nutrient values in delivered total mixed ration (TMR) from the formulated ration is inevitable. A recent study examining TMR precision and accuracy on commercial farms found that the TMR routinely differed from formulated ration targets, where underfeeding of CP, NDF and Na was common (Sova et al., 2014). Even a small deviation from formulated values could result in reduced productivity. Specifically, CP can have a direct effect on milk yield

(Colmenero and Broderick, 2006). Previous studies have investigated the various points in feed preparation and delivery for inconsistencies. Adjusting for DM changes in forage ingredients regularly has been identified as a key component of minimizing TMR variability (Buckmaster and Muller, 1994;Weiss & St. Pierre, 2009). Diets are routinely mixed on an as-fed basis, however the balanced TMR is formulated on a DM basis. If forage ingredients are not appropriately adjusted for the changing DM, the TMR can become nutritionally unbalanced (Rossow and Aly, 2013).

Factors that result in day-to-day variation in forage DM content have been identified in previously published literature. Growing conditions and maturity at harvest, storage method, management and climate changes over time can impact the DM and nutrient quality of stored silages (Holter, 1983; Rossow and Aly, 2013; St. Pierre and Weiss, 2015;). Weather conditions can be especially impactful when it comes to the portion of the bunk face mixed at feed out. The surface face of a horizontal bunker silo can be vulnerable to ambient weather conditions including various forms of precipitation that can contribute to fluctuations in forage DM (Holter, 1983). Feeding-out a minimum of 15 cm/d from the bunk face on horizontal bunkers is recommended to minimize aerobic deterioration resulting in nutrient losses (Pitt and Muck, 1993). In view of this, the fed-out component would represent the greatest exposed surface area and is subject to weather and climate factors, therefore potentially affecting ration mixing on a daily basis. Underestimating or ignoring these DM changes can affect the precision and accuracy of ration mixing.

Previous research has attempted to quantify the range in ingredient DM and nutrient variability over short time bouts. Researchers can take two approaches to DM variability; 1) the amount of day-to-day variation, and 2) deviation of values used in diet formulation. Holter

(1983) observed weekly changes of up to 7 percentage units over consecutive weeks of sampling corn silage. Similarly, Weiss et al. (2012) measured changes in ingredient DM concentration over a 14d period and found ranges in DM between farms to be 1.5-10.4 percentage units in corn silage and 3.4-19.1 percentage units in alfalfa silages. Weiss et al. (2012) have also speculated day-to-day variability can be as great as month-to-month variation. Silages and haylages typically comprise 60% or more of the diet of a lactating dairy cow, suggesting a large potential for impact on final nutrient delivery. Buckmaster and Muller (1994) determined by mathematical modeling that maintaining ingredient quantities within 1% accuracy could reduce overall uncertainty of the TMR to ≤5%. Determining what degree of ingredient DM deviation from the formulated ration could impact production as a result of nutritional deficiency needs further investigation. Additionally, ration formulation often considers the inconsistency of feed ingredients; therefore crucial nutrients such as CP are formulated to a greater concentration than required to avoid the risk of a deficiency (Weiss et al., 2012). Although over-formulation of nutrients is designed to safeguard against deficiencies, there are considerable economic, reproductive and environmental impacts that can result from over-feeding nutrients that need to be considered.

Outcomes of Unaccounted for DM Variability

Balancing management practices for production while minimizing environmental impacts has become a priority in the dairy industry. Nutrient management practices on livestock operations can be especially important in safeguarding water quality. A high level of accumulation of nutrients into the environment can cause eutrophication, resulting in damaging algal blooms in surface water (Tamminga, 1992; Andersen et al., 2002). Algal blooms can disrupt aquatic ecosystems through oxygen depletion from large algae biomasses and the production of toxins, resulting in mass mortalities of fish and potentially human illness from contaminated freshwater fish and seafood or unsafe drinking water (Andersen et al., 2002). Eutrophication and the development of algal blooms have been tied to build up of nitrogen (N) and phosphorus (P) (Tamminga, 1992; Andersen et al., 2002; Dou et al., 2003). Contributors of N and P to the environment, more specifically into surface waters, have been linked to several sources. Sewage and animal waste, aquaculture, and fertilizer run off are among the identified contributors. Manure containing N and P entering water bodies through run off and ground water is common, but there is the ability to minimize the amount of nutrients in the manure through more accurate diet formulation and precision feeding.

A leading feed management factor responsible for excessive nutrients in animal waste is the standard industry practice of formulating for greater than recommended nutrient values in the diet (Jonker et al., 2002; Dou et al., 2003; Swensson, 2003). Over-formulating nutrients is a strategy to safeguard against deficiencies in order to prevent production losses. Previous research has found P to be overfed 34% higher, than required (Dou et al., 2003) and N 11% higher than required on average (Jonker et al, 2002). Higher N in manure is associated with feeding excessive crude protein (CP), which is converted to other N containing compounds through protein digestion. Often ingredients within a TMR that are a valuable CP source can be highly variable, therefore the tendency is to formulate a diet above the recommended protein content to ensure requirements are always met (Weiss et al., 2012). Forages make up a large portion of the diet, therefore contributing significantly to the overall nutrient content. The need to over-formulate for specific nutrients could be reduced if the variability in the DM content of forages is better managed. Previous research agrees that diet formulation and feed management can prevent feeding above requirements for N and P, while reducing excess nutrient accumulation to the environment and leading to the potential for more efficient production (Tamminga, 1992; Kohn et al., 1997; Dou et al., 2003).

Improving production and farm profitability can be influenced by feed management factors. Managing feed ingredients by performing regular forage analysis can promote TMR consistency that could lead to better cow performance (Stone, 2008; Mikus, 2012). Milk yield aside, cow health may be influenced by variability in the diet. Frequency of displaced abomasum, ketosis, subacute ruminal acidosis (SARA), and poor fertility could be associated with dietary nutrient and energy fluctuations (Butler, 1998; Stone, 2004; Stone 2008). Animals receiving a highly variable diet are at higher risk of developing SARA (Stone, 2004). TMRs fed to dairy cattle typically contain a significant proportion of forages, which tend to have a large potential for variation (Stone, 2004; Stone, 2008; Mikus, 2012). Formulating diets with current forage analyses can account for changes in DM and carbohydrate composition that otherwise may lead to SARA (Stone, 2004). The tendency to over-formulate protein paired with DM fluctuations can lead to damaging levels of over-fed protein. High dietary protein may heighten reproductive health problems including reduced fertility and damaged embryo development (Butler, 1998). Inconsistency in forage components can also leave diets vulnerable to reduced NDF content. Insufficient NDF content in the diet can lead to reduced chewing activity and saliva production, causing lower ruminal pH, altering ruminal fermentation and increasing the risks of acidosis and milk fat depression (Mertens, 1997). Reducing variability is in the best interest of cow performance and profitability.

Feed costs are responsible for approximately 60% of the overall cost of a dairy operation. Maintaining consistency in the diet is not only beneficial to maximizing milk yields and maintaining health and reproductive success, but can reduce feed costs and improve feed efficiency (Stone, 2008; Mikus, 2012). Rising feed costs have heightened the importance of utilizing home grown forages and reducing the amount of purchased feed in the diet. However, forages inherently have more variability than concentrates and purchased feed mixes from a feed manufacturer are often more consistent than home grown feed ingredients (Stone, 2008). The monetary loss because of over-feeding nutrients is not yet well defined in the literature. Routine DM determination can allow for inclusion of less expensive home grown forages in the diet and decrease unnecessary over-feeding of forage ingredients.

Methods of On-Farm Dry Matter Determination

Laboratory forage testing can be time consuming and expensive. Producers who wish to test the DM of their forages between laboratory tests can perform their own on-site testing using various methods. Using a household microwave oven is a common practice among dairy producers. Farmer and Brusewitz (1980) investigated the limitations and accuracy of the household microwave as an alternative to laboratory testing for on-farm DM determination of forages. They concluded the microwave was a suitable alternative to laboratory testing. More recently, the microwave oven method of drying was found to have a strong linear relationship with the forced air oven (FAO) method, the recognized standard method, for corn silage and grass silage, indicating the microwave oven is a reasonably accurate method of DM determination (Pino and Heinrichs, 2014). However, there is a considerable potential for inaccuracy associated with the use of household microwave. Farmer and Brusewitz (1980) identified an average error of 4 percentage units when compared to laboratory oven drying. Similarly, Pino and Henrichs (2014) found variation of forced air ovens compared with microwave ovens to be 3.76%, while others have found microwave ovens to over-estimate DM content up to nearly 7 percentage units (Bouraoui et al. 1993).

The microwave oven can be a practical method of on-farm DM determination but must be operated diligently and cautiously to achieve accurate results (Farmer and Brusewitz, 1980). The microwave oven drying method, similar to FAO and Koster Moisture Tester (KMT, Koster Crop Tester Inc., Medina, OH), functions on the assumption that moisture alone is dissipated during the drying process, and therefore pre- and post-drying masses can be used to determine the moisture content. Laboratory FAO, KMT, and household microwave drying methods all run the risk of overestimating moisture content by the burning off of volatile compounds, such as alcohols and organic acids, if excessively dried (Bouraoui et al. 1993; Masoero et al., 2007; Pino and Heinrichs, 2014). However, household microwave oven energy is not uniformly absorbed throughout a sample and not all microwave ovens operate with the same amount of energy, increasing the risk of losing volatile compounds, causing chemical reactions, or burning of samples therefore yielding imprecise results (Bouraoui et al. 1993; Oetzel et al., 1993; Pino and Heinrichs, 2014). The literature agrees that achieving precision by using this method requires an experienced, skilled and patient operator to ensure samples are properly dried without burning (Oetzel et al., 1993; Pino and Heinrichs, 2014).

Another common method of on-farm DM determination is the KMT. The KMT includes a portable electric dryer with thermostatically controlled heat to dry the forage sample. The KMT method requires less operator skill and attention to achieve a DM reading (Oetzel et al., 1993; Pino and Heinrichs, 2014). Unlike the household microwave method, the operator does not need to tend to the sample during drying. However, the amount of time to obtain a DM reading is relatively long. Drying time for corn silage can reach more than 40 minutes and be longer than 60 minutes for grass silages for a 50 g sample (Pino and Heinrichs, 2014). The KMT has also been found to yield inaccurate results. The KMT frequently underestimates the DM of forage samples, which could be a result of not fully drying kernels in corn silages, and operator difficulties with attaining an accurate reading on the scale (Oetzel et al., 1993; Pino and Heinrichs, 2014), over drying and potentially burning off volatile compounds is also a risk due to the direct application of heat to the sample (Pitt et al., 1993). Total error of the KMT when compared to the standard method was 9.4% (Oetzel et al., 1993). Similarly, variation of KMT to the standard method was 6.8% on average (Pino and Heinrichs, 2014). High degrees of inaccuracy in forage DM measurements can translate into impactful changes to the quantity of forage ingredients in the diet. It is also important to consider researchers within a study may be more diligent when operating the KMT, potentially underestimating the degree of inaccuracy that may occur during commercial farm use.

A potential alternative to the household microwave oven and the KMT is Near Infrared Spectroscopy (NIR) in a portable format. Laboratory NIR technology was first used for forage analysis in 1976 by Karl Norris and colleagues (Berzaghi and Marchesini, 2014). The use of NIR is a rapid and relatively low cost laboratory technique that has been widely adopted (Berzaghi and Marchesini, 2014). NIR technology uses the near infrared region of the electromagnetic spectrum ranging from 780-2500 nm (Blanco and Villarroya, 2002; Berzaghi and Marchesini, 2014). By using reflectance and absorbance properties NIR devices can determine composition of samples, including DM, fibre, soluble carbohydrates, crude protein, crude fat and ash (Berzaghi and Marchesini, 2014). NIR technology eliminates the risk of burning off of volatile compounds as it has the ability to test undried samples, yielding a more reliable reading than alternative techniques (Masoero et al., 2007; Berzaghi and Marchesini, 2014). Although some research has challenged the accuracy of NIR spectroscopy, NIR has been tested and accepted as an approved laboratory technique (Berzaghi and Marchesini, 2014).

In recent years, portable versions of the technology have been developed to provide the opportunity for rapid on-farm DM determination and chemical analysis. Portable versions of NIR utilize a diode array with a smaller spectrum, limited by 1700 nm, limiting the information collected from a sample (Berzaghi & Marchesini, 2014). The portable NIR devices are relatively expensive and unfamiliar to producers (Berzaghi & Marchesini, 2014). Additionally, literature has validated NIR analysis in the laboratory setting but not thoroughly in the handheld format. Researchers utilizing a portable NIR device found overall error of measuring moisture to be lower than 2 percentage units (Mertens and Berzaghi, 2009), a relatively nominal degree of imprecision when considering the level of day-to-day variability that has been found in stored forages. Another study comparing a hand-held NIR device to FAO found no significant different (P>0.05) between the DM measurements of each method (Donnelly et al., 2016). The ability to test stored forages instantaneously on farm could allow producers to adjust rations more regularly and accurately according to their current DM, resulting in a more precise diet that could potentially improve production (Berzaghi & Marchesini, 2014).

Study Objectives

Limited research has tested handheld NIR spectroscopy devices as a practical on-farm DM determination method. Additionally, further understanding impacts of DM fluctuations in silages on the overall diet and farm profitability could encourage adoption of precision feeding technology. We hypothesize that a handheld NIR spectroscopy device will be accurate and precise for DM determination, and not adjusting for DM changes will result in the diet becoming nutritionally unbalanced, more expensive, and will impact the amount of N excretion in the manure. Therefore the purpose of this study was to investigate DM variability in silages and estimate effects on nutrient concentrations in the diet while implementing a new method of on-farm DM determination.

CHAPTER 2

OUTCOMES OF UNACCOUNTED DM VARIABILITY IN CORN AND ALFALFA SILAGES

INTRODUCTION

Feeding an accurate and precise ration is beneficial to the overall production and efficiency of a dairy operation. There is a considerable amount of variability in dry matter (DM) content of forage components in the diet of dairy cows, potentially altering the ingredient quantities in the total mixed ration (TMR). Inaccuracy in ingredient quantities can lead to deficiency or excess of nutrients delivered to the lactating herd, which could influence profitability and environmental impact (Andersen et al., 2002; Rossow and Aly, 2013). Increased nitrogen and phosphorus in animal waste can lead to eutrophication and damage to aquatic ecosystems (Tamminga, 1992: Andersen et al., 2002). Additionally, over- or under- feeding of nutrients, such as crude protein (CP) and neutral detergent fiber (NDF), can result in altered production, digestive function and reproductive success (Mertens, 1997; Colmenero and Broderick, 2006). Sizable amounts of feed can also be wasted leading to economic losses.

Variability in DM content of forage components in the diet is recognized and unavoidable. Sources influencing DM variability include climate and weather factors and bunk management, especially in horizontal cement bunkers with an exposed bunk face (Holter, 1983). A study measuring variability in DM of corn and alfalfa silages found ranges in dry matter to be 1.5 to 10.4 percentage units in corn silage and 3.4 to 19.1 in alfalfa silage percentage units over a 14-d sampling period (Weiss et at., 2012). The effect of DM variability on the diet can be minimized if ingredient quantities are adjusted according to changing DM content values. However, the options for on-farm DM determination have been time-consuming or inaccurate

(Pino and Heinrichs, 2014). Portable near infrared (NIR) spectroscopy devices are coming onto the market. Donnelly et al. (2016) compared a handheld NIR device with forced-air oven (FAO) drying and found no significant difference (P>0.05) between the DM content measurements, suggesting that handheld NIR devices may be a practical method of on-farm DM determination. More research on handheld NIR technology as an alternative to traditional on-farm DM determination tools is needed to determine reliability and practicality.

The objectives of this study were to (1) implement a handheld NIR spectroscopy device in on-farm DM measurements to determine suitability, (2) investigate day-to-day DM variability in silages to compare with previous literature, and (3) estimate the impacts of unaccounted for DM changes on nutrient balance of the diet, nutrient excretion, and economic losses.

MATERIALS AND METHODS

Feed Sampling

Four farms were selected for participation in the study. Farms were visited on 13 days during a 17-d period between June 7th and August 4th, 2017 for collection. The first 3 days of sampling were used for NIR device calibration, followed by 10 more days of sampling in 2 sets of 5 consecutive days for a total of 17 days. Silage samples were subjected to on-farm DM analysis by a handheld NIR device and FAO drying in a laboratory. All farms fed a TMR (Table 1) and stored corn and alfalfa silages in three-sided concrete horizontal bunkers. Mean lactating herd size was 164 ± 91 (mean ± SD) of primarily Holstein cattle.

Case 1 defaced feed bunkers using a bucket grapple. Samples were collected directly from the bucket before entering the mixer. Case 2 retrieved silages from feed bunkers with a rotating defacer that transfers feed directly from face to mixer. Samples were collected from debris at the base of the face at the time of mixing. Case 3 used a rotating silage defacer to create a pile that was sampled prior to loading into the mixer via a bucket loader. Case 4 used a bucket loader to transfer feed directly from the face into the mixer and samples were collected directly from the bucket before mixing. Unlike the other participating farms, Case 4 had roofed feed bunks.

Approximately one handful of feed was collected for every 3 m^2 of bunker face area, yielding 6 to 10 handfuls per batch. Sub samples were mixed in a plastic tote for immediate on-farm NIR analysis. Samples were sealed in plastic bags refrigerated at 4°C for ≤ 48 h until analyzed for DM in a FAO.

DM Content Analysis

On-site DM was measured with a handheld NIR device (Moisture Tracker™, Digi-Star LLC, Fort Atkinson, WI, USA). The NIR device was adjusted to oven DM contents of each ingredient from each farm using data from a minimum of 3 sample days prior to the sampling period as recommended by the supplying company. DM values recorded by the NIR device were an average of 30 readings taken on the sample. Prior to each measurement the device was internally calibrated using a calibration disk until a value of ≥ 99.80% calibration was achieved.

DM content of samples was determined by drying 100 g at 60 °C for 48 h in a FAO (AOAC International, 2000).

Comparison of Handheld NIR device and FAO drying method

On-farm handheld NIR device and laboratory FAO DM values were compared by regressing against one another and testing if the intercept was different from 0 and the slope was different from 1 (Figure 1 and 2). A Pearson's correlation coefficient (r) and bias correction factor (Cb) were calculated according to Lin (1989) to evaluate accuracy and precision, respectively.

Estimation of Nutrient Values Based on Unaccounted for DM Variability

Dietary concentrations of CP, NDF, and ADF calculated from feeding programs and ingredient DM contents supplied by the farm nutritionists were considered the formulated nutrient values. Day-to-day variability in calculated nutrient contents of mixed rations based on measured silage DM contents are presented as mean, SD, maximum and minimum in each of the four cases. Mean and SD of deviations in DM, CP, NDF and ADF contents of daily mixed rations from the formulated ration were also calculated. Maximum and minimum deviations from formulation targets were calculated as absolute values.

Nitrogen Excretion Estimation

Net energy- (NE) and metabolizable protein- (MP) allowable milk yields for each day's mixed ration, according to measured silage DM contents, were estimated using NRC (2001) equations. Manure CP loss was estimated as the difference between CP intake and CP output in milk (MP-allowable milk yield × 31 g CP/kg milk). Urinary CP loss was estimated as MP intake minus CP output in milk. Fecal CP was then estimated as the difference between manure and urinary CP. Day-to-day variation and deviation from the intended diet were calculated using the same process as for nutrient contents described above.

Economic Estimations

Milk value was calculated from NE- and MP-allowable milk yields using prices for fat, protein and lactose of $10.71, $7.45 and $1.52 per kg, respectively, according to the pricing available from Dairy Farmers of Ontario (DFO) at time of sampling. Feed cost per day per cow was calculated assuming values of $200 for excellent quality and $170 for good quality alfalfa silage, according to NDF and protein concentration, and a value of $95 for excellent quality corn silage, according to starch concentration. All cases had excellent quality corn silage and excellent or good quality alfalfa silage (Cecelia Curtis, Floradale Feed Mill Ltd., personal communication).

Table 2.1 Ingredient and nutrient composition of TMR (DM basis) of each case[1]

	Case 1	Case 2	Case 3	Case 4
	Component (% of DM)			
Ingredient				
Corn silage	45.69	26.02	37.23	43.37
Alfalfa Silage	23.85	33.57	16.71	28.85
Corn, distillers dry	-	-	-	7.97
Corn, ground	-	-	-	2.16
Straw, long chop	0.72	1.58	3.11	3.15
Brewers grain (wet)	-	6.42	7.03	-
Whole Cottonseed	5.49	-	-	-
Soybean meal	-	-	-	3.10
Tallow	0.85	-	-	-
Molasses	-	2.65	-	-
Vitamin/mineral mix	-	-	-	2.66
Protein supplement	23.39	29.75	35.92	-
Robotic milking system	-	-	-	8.75

pellet				
Nutrient				
CP	17.17	15.65	16.56	16.08
Soluble CP (% of CP)	35.90	33.01	51.33	35.93
NDF	29.27	31.13	34.92	35.93
ADF	18.88	19.18	21.24	22.54
Ether extract	6.28	3.91	4.00	3.94
NE_L[2] (Mcal/kg)	1.59	1.60	1.51	1.48

[1]Nutrient values were calculated using as-fed quantities of ingredients forage analysis and NRC (2001) calculations
[2]Estimated according to NRC (2001)

RESULTS

Precision and Accuracy of a handheld NIR device for DM determination

A regression comparing DM measurements of corn silage obtained with the handheld NIR device and FAO yielded a Pearson's correlation coefficient of $\mathrm{r} = 0.917$ and bias correction factor of Cb = 0.994, which corrects for "failure" of regression line to pass through zero. A regression comparing DM measurements of alfalfa silage from the handheld NIR device and FAO yielded a Pearson's correlation coefficient of $r = 0.848$ and bias correction factor of Cb = 0.972.

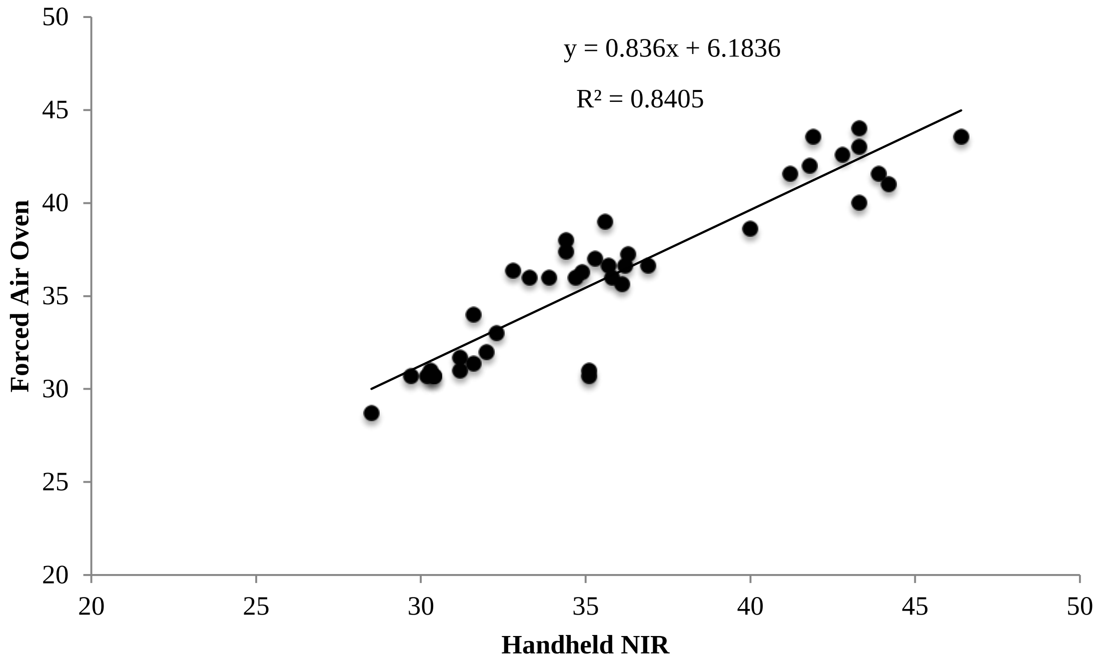

Figure 1. Linear regression of handheld NIR and FAO DM values of corn silage on 40 samples from 4 farms.

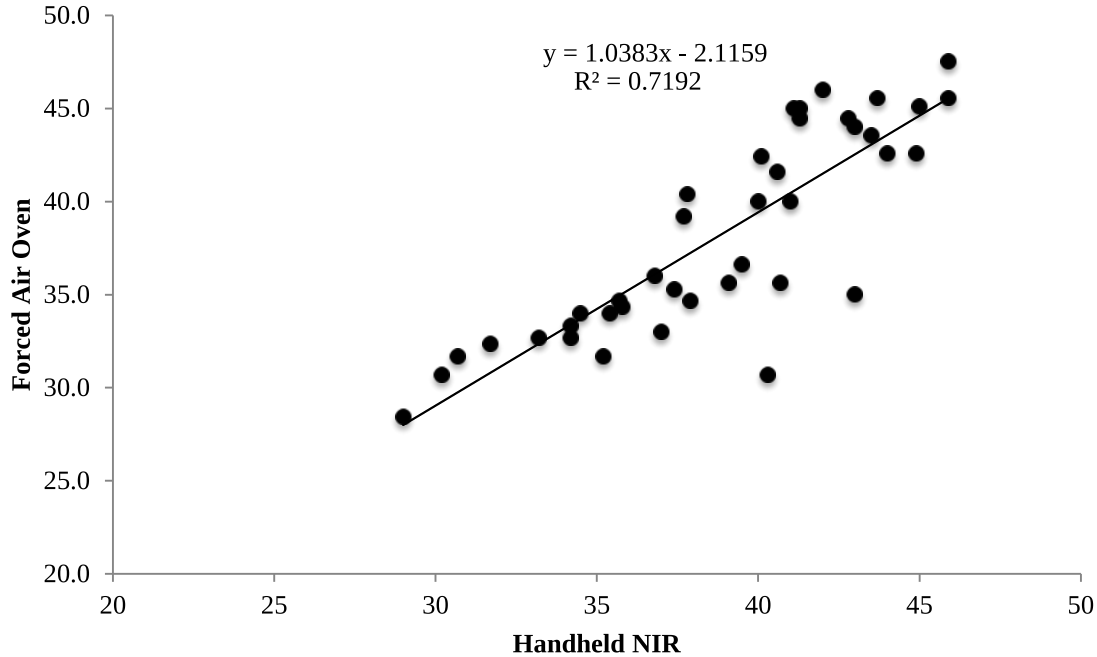

Figure 2. Linear regression of handheld NIR and FAO DM values of alfalfa silage on 40 samples from 4 sample farms

Day-to-day variability

Day-to-day variability in DM content is given in Table 2.2. Standard deviation of DM content in corn silage ranged from 2.95 to 6.37% of the mean across all four cases. The range in DM content exhibited a maximum of 7.61 percentage units, found in case 2, and a minimum of 4.00 units, found in case 4, during the sampling period. SD of DM content of alfalfa silage ranged from 4.76 to 9.64% of the mean across all four cases. Alfalfa haylage ranged in DM content a maximum of 15.84 percentage units, found in case 1, and a minimum of 4.95 units, found in case 2, during the sampling period.

Day-to-day variability in estimated CP supply from the diet is given in Table 2.3. SD of CP content ranged from 0.65% to 1.43% of the mean across all four cases. The largest range in percentage CP during the sample period was 1.01 percentage units and the smallest range was 0.35 units, in cases 1 and 4, respectively. The maximum range in daily CP intake during the sample period was 0.25 kg/(d·cow), found in case 1. The minimum range was 0.08 kg/(d·cow), found in case 4.

Day-to-day variability in estimated NDF contents of diets is given in Table 2.4. SD of NDF ranged from 0.26 to 1.66% of the mean across all four cases. The maximum range in percentage NDF during the sample period was 2.07 percentage units, found in case 2. The minimum range was 0.25 units, found in case 4. The largest range in NDF intake was 0.48 kg/(d·cow) in case 2 and the smallest range was 0.07 kg/(d·cow) in case 4.

Day-to-day variability in estimated ADF content of diets is given in Table 2.5. SD of ADF content ranged from 0.68 to 2.19% of the mean across all four cases. The largest range in ADF content during the sample period was 1.69 percentage units, found in case 2. The smallest range was 0.42 percentage units, found in case 4. During the sample period, the maximum range in estimated ADF intake per cow was 0.40 kg/(d·cow), found in case 2. The minimum range was 0.11 kg/(d·cow), found in case 4.

Table 2.2 Day-to-day variability in DM content of corn and alfalfa silages over a 17-day period[1]

	Corn Silage			Alfalfa Silage		
Farm #	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	36.67 ± 2.02	32.00	39.60	42.39 ± 4.09	31.68	47.52
Case 2	35.49 ± 2.26	31.00	38.61	33.97 ± 1.62	31.68	36.63
Case 3	30.46 ± 0.90	28.71	31.68	31.99 ± 2.55	27.72	35.64
Case 4	41.93 ± 1.31	40.00	44.00	42.63 ± 2.53	38.61	45.54

[1]13 of the 17 days samples were collected and dried by laboratory FAO (AOAC International, 2000) to determine DM values (sample days were days 1-3, 5-10, and 13-17).

Table 2.3 Day-to-day variability in estimated TMR CP content and supply over 17 days[1,2]

	% of DM			kg/(d·cow)		
Farm #	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	17.11 ± 0.25	16.70	17.71	4.15 ± 0.06	4.05	4.30
Case 2	15.81 ± 0.10	15.63	16.05	3.69 ± 0.02	3.65	3.75
Case 3	15.53 ± 0.11	15.39	15.77	4.18 ± 0.03	4.14	4.24
Case 4	15.88 ± 0.12	15.70	16.05	3.97 ± 0.03	3.93	4.01

[1]13 of the 17 days samples were collected and dried by laboratory FAO (AOAC International, 2000) to determine DM values (sample days were days 1-3, 5-10, and 13-17).
[2]CP values were estimated daily from formulated as-fed weights and measured DM contents obtained from FAO (AOAC International, 2000)

Table 2.4 Day-to-day variability in estimated TMR NDF content and supply over 17 days[1,2]

	% of DM			kg/(d·cow)		
Farm #	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	29.43 ± 0.27	28.68	29.74	7.14 ± 0.07	6.95	7.21
Case 2	31.75 ± 0.53	30.28	32.35	7.41 ± 0.12	7.07	7.55
Case 3	35.84 ± 0.20	35.52	36.09	9.64 ± 0.05	9.56	9.71
Case 4	35.72 ± 0.09	35.57	35.82	8.93 ± 0.02	8.89	8.96

[1]13 of the 17 days samples were collected and dried by laboratory FAO (AOAC International, 2000) to determine DM values (sample days were days 1-3, 5-10, and 13-17).
[2]NDF values were estimated daily from formulated as-fed weights and measured DM contents obtained from FAO (AOAC International, 2000)

Table 2.5. Day-to-day variability in estimated TMR ADF content and supply over 17 days[1,2]

	% of DM			kg/(d·cow)		
Farm #	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	19.01 ± 0.28	18.27	19.35	4.61 ± 0.07	4.43	4.69
Case 2	19.70 ± 0.43	18.51	20.20	4.60 ± 0.10	4.32	4.72
Case 3	21.65 ± 0.19	21.35	21.91	5.82 ± 0.05	5.74	5.89
Case 4	22.17 ± 0.15	21.94	22.36	5.54 ± 0.04	5.48	5.59

[1]13 of the 17 days samples were collected and dried by laboratory FAO (AOAC International, 2000) to determine DM values (sample days were days 1-3, 5-10, and 13-17).
[2]ADF values were estimated daily from formulated as-fed weights and measured DM contents obtained from FAO (AOAC International, 2000)

Agreement between Measured and Formulated values

Degree of agreement between measured DM values of corn and alfalfa silages and those used in diet formulation are given in Table 2.6 and 2.7, respectively. The SD of the deviation ranged from 3.11 to 5.94% of the formulated value across all four cases for corn silage and from 4.35 to 8.30% for alfalfa silage. The greatest deviation from the value used for diet formulation was 8.28 percentage units for corn silage and 12.12 units for alfalfa silage. The smallest deviations were 0% and 0.01% for corn and alfalfa silages, respectively.

Differences between estimated CP values and those in the formulated TMR are given in Table 2.8. The SD for deviation in CP content ranged from 0.66 to 1.43% of the formulated value across all four cases. The greatest deviation from the formulated value was 1.17% in case 3 and the smallest deviation was 0% in case 1. The greatest deviation from the formulated CP intake was 320 g/(d·cow) and the smallest deviation was 0 g/(d·cow).

Degree of agreement between estimated and formulated NDF values is given in Table 2.9. The SD for the deviation in NDF content ranged from 0.26 to 1.69% of the formulated value across all four cases. The greatest deviation from the formulated NDF content was 1.17 percentage units during the sample period, found in case 3. The smallest deviation was 0.02%, found in case 1. The greatest deviation from the formulated NDF intake per cow was 320 g/(d·cow), found in case 3, and the smallest deviation was 10 g/(d·cow), found in case 1.

Differences between estimated and formulated ADF values are given in Table 2.10. The SD for the deviation in ADF content of the TMR ranged from 0.67 to 2.25% of the formulated value across all four cases. The greatest deviation from the formulated ADF content was 1.02 percentage units while the smallest deviation was 0%. The greatest deviation from the formulated ADF intake was 240 g/(d·cow) and the smallest deviation was 0 g/(d·cow) during the sample period.

Table 2.6 Differences between daily corn silage DM contents and those assumed for TMR formulation over 17 days[1]

	Assumed DM%	Mean ± SD[2]	Deviation[3] Min	Max
Case 1	35.4	-1.27 ± 2.02	0.60	4.20
Case 2	37.5	2.51 ± 2.26	0.61	7.00
Case 3	23.4	-7.06 ± 0.90	5.31	8.28
Case 4	42.0	0.07 ± 1.31	0.00	2.00

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent maximum and minimum deviations from the values used in TMR formulation

Table 2.7.Differences between daily alfalfa silage DM contents and those assumed for TMR formulation over 17 days[1]

Case #	Assumed DM%	Mean ± SD	Deviation Min	Deviation Max
Case 1	42.3	-6.99 ± 4.09	3.72	12.12
Case 2	37.3	3.30 ± 1.62	0.64	5.59
Case 3	30.7	-1.29 ± 2.55	0.01	4.94
Case 4	49.0	6.27 ± 2.53	3.36	10.29

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent maximum and minimum deviations from the values used in TMR formulation

Table 2.8 Differences between estimated TMR CP contents/supplies over 17 days and those assumed in TMR formulation[1]

Case #	% of DM				g/(d·cow)			
	Int.		Deviation[3]		Int.		Deviation[3]	
	CP	Mean ± SD[2]	Min	Max	CP	Mean ± SD[2]	Min	Max
Case 1	17.17	-0.06 ± 0.25	0.01	0.54	4160	-11 ± 61	10	140
Case 2	15.65	0.16 ± 0.10	0.02	0.40	3650	42 ± 24	0	100
Case 3	16.56	-1.03 ± 0.11	0.79	1.17	4460	-282 ± 30	220	320
Case 4	16.08	-0.20 ± 0.12	0.03	0.38	4020	-50 ± 27	10	90

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent maximum and minimum deviations from the values used in TMR formulation

Table 2.9 Differences between estimated NDF contents/supplies over 17 days and those assumed in TMR formulation[1]

Case #	% of DM				g/(d·cow)			
	Int.		Deviation		Int.		Deviation	
	NDF	Mean ± SD	Min	Max	NDF	Mean ± SD	Min	Max
Case 1	29.41	0.02 ± 0.27	0.02	0.73	7130	6 ± 67	10	180
Case 2	31.13	0.62 ± 0.53	0.33	1.22	7270	143 ± 122	80	280
Case 3	34.92	0.92 ± 0.20	0.60	1.17	9390	252 ± 53	170	320
Case 4	35.93	-0.21 ± 0.09	0.11	0.36	8980	-49 ± 23	20	90

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent maximum and minimum deviations from the values used in TMR formulation

Table 2.10 Differences between estimated ADF contents/supplies over 17 days and those assumed in TMR formulation[1]

	% of DM				g/(d·cow)			
Case #	Int.		Deviation[3]		Int.		Deviation[3]	
	ADF	Mean ± SD[2]	Min	Max	ADF	Mean ± SD[2]	Min	Max
Case 1	19.03	-0.02 ± 0.28	0.00	0.76	4620	-8 ± 69	0	190
Case 2	19.18	0.52 ± 0.43	0.29	1.02	4480	119 ± 101	70	240
Case 3	21.24	0.41 ± 0.19	0.11	0.67	5710	113 ± 51	180	30
Case 4	22.54	-0.37 ± 0.15	0.18	0.60	5640	-98 ± 38	50	160

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)

[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation

[3] Values were calculated using absolute values to represent maximum and minimum deviations from the values used in TMR formulation

Nutrient losses

Day-to-day variability in estimated manure, urinary and fecal CP losses are given in Table 2.11. The SD of manure CP ranged from 0.50% to 3.08% of the mean across all four cases. The greatest range in manure CP during the sample period was 338 g/(d·cow), found in case 4. The smallest range in manure CP during the sample period was 44 g/(d·cow), found in case 3. The SD for urine CP ranged from 0.32% to 0.66% of the mean across all four cases. The maximum range in urine CP was 33 g/(d·cow), found in case 2. The minimum range in urine CP was 15 g/d per cow found in case 4. SD of fecal CP ranged from 0.77% to 6.19% of the mean across all four cases. The largest range in fecal CP during the sample period was 333 g/(d·cow), found in case 4. The smallest range in fecal CP during the sample period was 30 g/(d·cow), found in case 3.

Differences between estimated and formulated manure, urine and fecal CP losses are given in Tables 2.12a, b, and c. The SD of the deviation in manure CP loss ranged from 0.48 to 2.99% of the formulated value across all four cases. The greatest deviation in manure CP loss from that associated with the formulated ration was 357 g/(d·cow), found in case 4. The smallest deviation was 4.00 g/(d·cow), found in case 2. The SD for deviation in urine CP loss ranged from 0.33 to 0.65% across all four cases. The maximum deviation in urine CP loss from formulated was 71 g/(d·cow), found in case 3 while the minimum deviation was <1 g/(d·cow) found in case 2. SD of fecal CP ranged from 0.72% to 6.20% of the mean across all four cases. The largest deviation in fecal CP during the sample period was 358 g/(d·cow), found in case 4. The smallest deviation in fecal CP during the sample period was 2 g/(d·cow), found in case 1.

Table 2.11 Day-to-day variability in estimated CP losses over 17 days[1]

Case #	Manure CP			Urine CP			Fecal CP		
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	2943 ± 48.63	2881	3054	1450 ± 7.17	1442	1466	1493 ± 47.19	1420	1588
Case 2	2614 ± 74.60	2389	2681	1348 ± 8.83	1340	1373	1266 ± 75.63	1048	1332
Case 3	2826 ± 14.23	2810	2854	1647 ± 7.52	1637	1662	1179 ± 9.11	1165	1195
Case 4	2824 ± 86.92	2547	2885	1436 ± 4.65	1428	1443	1389 ± 85.91	1116	1449

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days include day 1-3, 5-10, and 13-17)

Table 2.12a Differences between estimated manure CP losses over 17 days and those assumed in TMR formulation[1]

		g/(d·cow)	Deviation[3]	
Case #	Int. Diet CP	Mean ± SD[2]	Min	Max
Case 1	2932	-10.73 ± 48.63	6.90	121.40
Case 2	2574	-39.76 ± 74.60	4.10	185.30
Case 3	2966	140.13 ± 14.23	111.50	155.70
Case 4	2904	79.89 ± 86.92	19.30	357.00

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

Table 2.12b Differences between estimated urine CP losses over 17 d and those assumed in TMR formulation[1]

		g/(d·cow)	Deviation[3]	
Case #	Int. Diet N	Mean ± SD[2]	Min	Max
Case 1	1455	5.12 ± 7.17	3.60	13.10
Case 2	1354	6.07 ± 8.83	0.50	18.90
Case 3	1709	62.21 ± 7.52	46.50	71.70
Case 4	1430	-5.57 ± 4.65	1.00	13.30

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

Table 2.12c Differences between estimated fecal CP losses over 17 d and those assumed in TMR formulation[1]

		g/(d·cow)	Deviation[3]	
Case #	Int. Diet N	Mean ± SD[2]	Min	Max
Case 1	1477	-15.85 ± 47.19	2.00	111.00
Case 2	1220	-45.83 ± 75.63	23.00	172.20
Case 3	1257	77.92 ± 9.11	62.00	92.00
Case 4	1474	85.46 ± 85.91	25.00	358.00

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

Economic Outcomes

Day-to-day variability in feed cost per cow is given in Table 15. The SD of feed cost ranged from 0.86 to 1.82% of the mean across all four cases. The greatest range in feed cost per cow was 0.35 \$/(d·cow), found in case 1. The smallest range was 0.15 \$/(d·cow), found in case 4.

Differences between estimated and formulated feed costs are given in Table 16. The SD of deviations in feed cost per cow ranged from 0.84 to 1.79% of the formulated value across all four cases. The greatest deviation in feed cost from that intended was 0.47 \$/(d·cow), found in case 3. The smallest deviation in feed cost per cow during the sample period was 0 \$/d/cow, found in case 4.

Day-to-day variability in milk value is given in Table 17. The SD of milk value ranged from 0.14% to 0.39% of the mean according to NE-allowable milk yield, and 0.79% to 1.74% of the mean for MP-allowable milk yield across all four cases. The greatest range in milk value per cow according to NE-allowable is 0.37 \$/cow and 1.66\$/cow for MP-allowable during the sample period, both found in case 2. The smallest range in milk value per cow according to NE-allowable is 0.07\$/cow and 0.65\$/cow for MP allowable during the sample period, both found in case 4.

Deviations in milk value from those associated with the formulated diet are given in Table 18. The SD of deviation of milk value ranged from 0.14 to 0.39% of the formulated value according to NE allowable milk and 0.80 to 1.71% of the formulated value for MP allowable milk across all four cases. The greatest deviation in milk value according to NE allowable was 0.31 \$/(d·cow) and 4.11 \$/(d·cow) for MP allowable during the sample period, both found in case 3. The smallest deviation in milk value per cow from the milk value associated with the intended ration according to NE allowable was 0 $/(d·cow) and 0 $/(d·cow) for MP allowable during the sample period.

Day-to-day variability in return over feed cost is given in Table 19. The SD of return over feed cost ranged from 0.12 to 1.82% of the mean across all four cases. The greatest range in return over feed cost was 1.47 $/(d·cow), found in case 2. The smallest range in return over feed cost was 0.10 $/(d·cow), found in case 3.

Differences between estimated and formulated returns over feed costs are given in Table 20. The SD of deviation in return over feed cost ranged from 0.12 to 1.82% of the formulated value, across all four cases. The greatest deviation was 0.81 $/(d·cow) and the smallest deviation was 0 $/(d·cow).

Table 2.13 Day-to-day variability in estimated feed costs over 17 d[1]

	$/(d·cow)		
Case #	Mean ± SD	Min	Max
Case 1	6.07 ± 0.11	5.94	6.29
Case 2	5.47 ± 0.08	5.39	5.69
Case 3	5.97 ± 0.05	5.89	6.07
Case 4	5.56 ± 0.05	5.48	5.63

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)

Table 2.14 Differences between estimated feed costs over 17 d and those assumed in TMR formulation[1]

Case #	$/(d·cow)		
		Deviation[3]	
	Mean ± SD[2]	Min	Max
Case 1	-0.08 ± 0.11	0.03	0.21
Case 2	-0.04 ± 0.08	0.01	0.18
Case 3	-0.39 ± 0.05	0.29	0.47
Case 4	0.02 ± 0.05	0	0.09

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

Table 2.15 Day-to-day variability in estimated NE milk value and MP milk value over 17 d[1]

	$/(d·cow)					
	Milk (NE)			Milk (MP)		
Case #	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Case 1	29.52 ± 0.08	29.41	29.72	30.46 ± 0.38	30.03	31.20
Case 2	27.26 ± 0.11	27.17	27.55	26.14 ± 0.45	25.64	27.40
Case 3	30.86 ± 0.06	30.81	30.96	33.86 ± 0.42	33.29	34.69
Case 4	26.12 ± 0.04	26.09	26.16	26.29 ± 0.21	25.95	26.60

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)

Table 2.16 Differences between estimated milk values and those associated with the formulated ration[1]

	$/(d·cow)							
	Milk (NE)				Milk (MP)			
Case #	Int. Milk value	Mean ± SD[2]	Deviation[3] Min	Deviation[3] Max	Int. Milk value	Mean ± SD[2]	Deviation[3] Min	Deviation[3] Max
Case 1	29.57	-0.04 ± 0.08	0	0.16	30.73	-0.27 ± 0.38	0.08	0.70
Case 2	27.32	-0.06 ± 0.11	0	0.23	26.56	-0.42 ± 0.45	0.15	0.92
Case 3	31.12	-0.26 ± 0.06	0.16	0.31	37.40	-3.54 ± 0.42	2.72	4.11
Case 4	26.09	0.03 ± 0.04	0	0.07	26.09	0.20 ± 0.21	0	0.51

[1] 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)
[2] Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation
[3] Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

Table 2.17 Day-to-day variability in estimated returns over feed costs over 17 d[1]

Case #	$/(d·cow)		
	Mean ± SD[2]	Min	Max
Case 1	23.45 ± 0.04	23.35	23.54
Case 2	20.66 ± 0.38	20.24	21.71
Case 3	24.89 ± 0.03	24.84	24.94
Case 4	20.55 ± 0.04	20.47	20.63

113 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)

Table 2.18 Differences between estimated returns over feed costs over 17 d and those associated with the formulated ration[1]

		$/(d·cow)	Deviation[3]	
Case #	Int. return	Mean ± SD[2]	Min	Max
Case 1	23.42	0.04 ± 0.04	0	0.12
Case 2	21.05	-0.38 ± 0.38	0.16	0.81
Case 3	24.76	0.13 ± 0.03	0.08	0.18
Case 4	20.55	-0.01 ± 0.04	0	0.08

1 13 of the 17 days samples were collected and dried by laboratory forced air oven to determine DM values (sample days were days 1-3, 5-10, and 13-17)

2 Values contain negative and positive numbers representing values over (+) and under (-) the value used in diet formulation

3 Values were calculated using absolute values to represent the maximum and minimum deviation from the values used in diet formulation

DISCUSSION

Linear regressions comparing FAO and handheld NIR device for DM of corn and alfalfa silage is found in Figures 1 and 2, respectively. In general, the NIR device has good precision and accuracy at measuring DM in silages when compared to FAO. Precision (*r*) refers to how close the handheld NIR measurements were to those of the FAO, and accuracy (Cb) refers to the variation in the difference between FAO and NIR measurements (Lin, 1989). The handheld NIR device was more precise and accurate in measuring corn silage (*r*=0.917, Cb=0.994) than alfalfa silage (*r*=0848, Cb=0.972), however both were suitable. These results agreed with findings from Donnelly et al. (2016), who found no significant difference between hand-held NIR device and FAO in corn and alfalfa silage DM measurements. Given the ability of the hand-held NIR device to measure wet samples quickly and accurately on-farm, incorporation into management practices could minimize impact of DM variability, especially due to the observed potential for DM change over a relatively short period of time.

Day-to-day DM variability in corn and alfalfa silage is represented in Table 2.2. During the 17-d sample period, the ranges in corn silage DM reach nearly 8% and over 15% in alfalfa silage. These results indicate that there are DM changes over a relatively short period of time that may be unaccounted for in day-to-day TMR mixing. Similarly, Holter (1983) observed changes in corn silage to change as much as 7% over consecutive weeks of sampling of DM content. Holter theorized that the week-to-week variability was likely due to the bunk face exposure to ambient weather conditions including rain, snow and ice. More recently, Weiss et al. (2012) recorded corn and alfalfa silage measurements of 10.4 and 19.1 percentage units, respectively. However, nutritionists of 50 dairy farms conducted the sampling for that study, and therefore there could be substantial sampling errors. Alfalfa silage tends to vary more than corn silage; this is likely due to crop growth patterns and overall larger characteristic variation of legume silages (Buckmaster & Muller, 1994; Stone, 2008; Mikus & Diamond, 2012).

Diets for dairy cows are formulated using current DM values and forage analyses to develop a balanced ration with target nutrient values and forage to concentrate ratios to optimize health and production. The current study found DM deviated from the values used in diet formulation up to 8.28 percentage units in corn silage and up to 12.12 percentage units in alfalfa silage (Table 8). Although variability in DM of forages has been well documented in the literature, measuring deviations from values used in diet formulations and the implications to overall nutrient content of the diet and the feed cost outcomes have not been thoroughly measured and discussed. Large deviations from the values used in diet formulation can result in production losses, negative health outcomes and feed cost implications due to incorrect ingredient quantities causing nutrient fluctuations (Rossow & Aly, 2013; Mikus & Diamond, 2012; Stone, 2008; Stone 2004).

In the present study, %CP differed from the formulated value a maximum of 1.17% as a result of unaccounted for DM changes, which translated into under-feeding of CP by 320 g/d per cow, found in Case 3 (Table 9). Although Case 3 had the largest change in CP, other cases experienced over- and under-feeding of protein during the sample period, however the tendency was to feed less than the formulated amount of CP as three of four cases have negative means. In all cases %CP remained relatively accurate with formulated values and reasonably precise, SD $\leq$ 0.25%. Deviations in %CP in the current study were not great enough to bring values below NRC requirements in any case, indicating a low risk of milk production losses due to dietary protein deficiency. However, the tendency to formulate for greater than required protein increases the risk of upward deviation from formulated values potentially causing poor reproductive outcomes and negative environmental implications due to excess nutrient excretions (Butler, 1998; Jonker et al., 2002; Dou et al., 2003; Swensson, 2003).

Specifically in Case 1, where the diet is formulated for 17.17% CP, any upward deviation from the target CP could decrease nutrient efficiency. A study by Broderick (2003) investigated dietary concentration of protein and energy that would minimize N excretions without depressing milk yield or altering milk components. Results indicated CP beyond 16.7% did not increase milk yield or improve components and N efficiency began to decrease. Previous work also suggests high dietary protein can also reduce progesterone concentrations during early breeding, potentially causing reduced fertility (Butler, 1998). The needless N excretions associated with feeding high dietary protein could be reduced if confidence in diet consistency improved, resulting in diets formulated closer to animals requirements.

NDF concentrations did not deviate more then 1.22% on any sample day in any case as a result of unaccounted for DM changes in in corn and alfalfa silages. Contrary to the findings of Sova et al. (2014) who found that when comparing delivered TMR to the formulated diet, half their sample farms routinely over- or under-fed NDF by more than 2%. The current study, however, only estimated changes in fibre components of the diet based on unaccounted for DM changes that alter ingredient quantities; it did not account for the potential nutrient losses within ingredients overtime or other sources of nutrient variability. Therefore, the deviation of NDF content from the value in the formulated diet may be underestimated. Underfeeding NDF can result in reduced chewing and saliva production, resulting in decreased ruminal pH altering fermentation in the rumen, therefore increasing the risk of acidosis and milk fat depression (Mertens, 1997).

A study by McBeth et al. (2013), also attempted to quantify the effect of unaccounted DM change on the diet over a 3 d period of applied 10% decrease in Forage DM and found cows consuming an unbalanced diet (not adjusted for changed DM) actually had improved milk yields and components. The authors theorized that could be a result of an increased concentrate to forage intake ratio, therefore increasing NE_L. This theory may also apply to the findings of the present study, as forages were more often wetter than assumed and often fed in a smaller proportion than intended.

Deviation in feed cost per cow associated with altered forage ingredient quantities can be found in Table 16. More often feed cost per cow was lower than the feed cost associated with the intended diet, represented by negative mean values. This is likely a result of corn and alfalfa silages more often having a lower DM content than the value used in diet formulation. It is important to recognize that reduced feed cost per cow is not necessarily beneficial because reduced feed cost per cow also translates into reduced milk value per cow (Table 18). These economic factors are compounded and represented as return over feed cost in Tables 19 and 20.

CONCLUSION

In the present study, a handheld NIR spectroscopy device was determined to be a suitable method of on-farm DM content determination. Sizable impacts on total diet nutrients, N excretion, or farm cost were not present as a result of unaccounted DM content changes in corn and alfalfa silages. We predict our findings may not be reflective of total changes in nutrient composition of the diet as not all sources of variability were accounted for. We propose incorporation of ingredient; total diet and milk analysis would demonstrate a larger degree of overall variation and deviation from the intended diet.

CHAPTER 3

GENERAL DISCUSSION

Feed costs continue to be the largest expense of a dairy enterprise. Monitoring DM variability of forage ingredients is an opportunity to minimize feed cost and maximize profitability. The tendency of over-feeding nutrients such as protein and energy is no longer a practice dairy producers can afford (James and Cox, 2008). Therefore, new feed management techniques and technologies that aid in precision feeding are becoming increasingly important. Additionally, formulating closer to dietary requirements of the animal will reduce nutrient excretions, which are increasingly under scrutiny in livestock farming operations (Stone, 2008).

New technologies, such as handheld NIR spectroscopy devices, are increasing the capacity of producers to more frequently, easily and accurately manage their forage DM and quality. Our findings support the use of handheld NIR spectroscopy devices for on-farm DM content determination. In addition the present study attempted to quantify the affect of altered ingredient quantities due to unaccounted DM changes on CP, NDF and ADF. Although these findings could be considered nominal, deviation from targeted values could be greater due to nutrient losses during storage, which were not accounted for. Ideally, silages are ensiled to create an anaerobic environment at a low pH to prevent aerobic microbial growth and facilitate the production of lactic acid to maintain a low pH. Despite producers' best efforts at packing and sealing ensiled forages, oxygen can still slowly diffuse through plastic, concrete and particularly exposed bunk faces allowing for growth of microorganisms that support the enzymatic and acid hydrolysis of structural carbohydrates, like hemicellulose, therefore reducing the NDF fraction in the forage (Rotz and Muck, 1994). Following recommendations such as feeding out a minimum of 15 cm/d from the bunk face can minimize these nutrient losses (Pitt and Muck, 1993), however further research into crucial nutrient losses like CP and NDF components could encourage more rigid monitoring of stored forages. Some handheld NIR spectroscopy devices have been developed to measure DM and chemical composition instantaneously on-farm. More research into the reliability and practicality of these more sophisticated devices could offer a suitable method of further precision feeding improvement.

Continuing research into DM changes and minimizing nutrient variability in the diet of dairy cows could reduce nutrient losses into the environment while maximizing production and profitability. New technologies, such as handheld NIR devices, should continue to be tested for suitability in commercial settings to support adoption from industry stakeholders. This research serves as a starting point to provide a foundation of information of the effects of DM variability on nutrients in the diet, farm costs, and environmental impact. Further understanding and investigation into the cow level impacts and production outcomes of DM and nutrient variability are needed to grow support and effectiveness of precision feeding practices and technology.

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