Utilizing near-infrared technology to assess changes in corn silage dry matter and the effects of feeding a starling resistant supplement to dairy cattle

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Abstract

Two studies were conducted that focused on either the accuracy of hand-held near infrared spectrophotometer (NIR) units and two on-farm testing methods compared to conventional 105°C oven drying of corn silage or the use of a starling resistant supplement in total mixed rations (TMR) for lactating dairy cattle. Study 1 evaluated the accuracy of three NIR units (Digi-Star Moisture Tracker, Topcon Agriculture, Fort Atkinson, WI), food dehydrator (FD) (Nesco®, Two Rivers, WI), and a Koster Tester (KT) (Koster Moisture Tester, Inc., Brunswick, OH) to conventional 105°C forced air oven drying. Samples were taken at four Kansas dairy farms and analyzed for DM daily for 20 d. Two calibrations were tested within each NIR unit: NIRu was the DM predicted from the factory-preset calibration, and NIRc was a bias-adjusted DM prediction based on the average difference of oven-dried corn silage and NIRu over the 20-d study. Average oven DM of corn silage was 38.38% ± 0.59 for the 20-d experiment. All three NIRu measurements were lower ($P<0.05$) than the oven value. While all 3 NIRc predictions were similar ($P>0.05$) to oven value. KT value was similar ($P>0.05$) to the oven, while FD value was over estimated DM. ($P<0.05$). The hand-held NIRS units accurately predicted DM content of the corn silages when the factory preset calibrations were corrected for bias. While the food dehydrator over-estimated the DM of the corn silage and the Koster Tester accurately predicted DM. Study 2 was designed to evaluate the lactation performance of post-peak dairy cattle when using a starling resistant grain supplement. Sixteen prim- and multiparous Holstein cows were housed individually in a tie-stall barn, milked 3x daily, and fed 2x daily. Cows were fed two nutritionally similar diets: 1. TMR with grain in mash form and 2. TMR with grain supplement in a pellet with a 0.953-cm diameter. This study was designed as a single reversal experiment with two 14 d periods with the first 7 d used for an adaptation period and the last 7 d used for data collection in each period. Dry matter intake (DMI), water intake, and milk production was recorded daily. Feed ingredients, TMRS, refusals, and milk samples were collected the last 3 d of each period for analysis. TMRs and refusals were analyzed for particle size distribution with a Penn State Particle Separator. The pelleted supplement had a higher ($P<0.05$) percentage of DM retained on the 8.0-19.0mm sieve than the mash supplement as the pellet diameter was >8.0mm and could not pass through that sieve. There was no effect of diet ($P>0.05$) for DMI, feed efficiency, milk component percentage, and protein yield. There was a diet effect ($P<0.05$) for milk production, fat-corrected milk, energy-corrected milk, solid-corrected milk, and fat yield with lower observed values when cows were fed the pelleted supplement. This leads to the conclusion while a 0.953-cm diameter pellet will reduce starling consumption, it may result in lower milk production of post-peak Holstein cows.

Keywords: forage; feed moisture; 105°C oven; grain; pellet; bird

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Dedication

I dedicate this to my grandparents who have joined their Lord in heaven, Derald Thomas and Helen Thiessen. Without their love and support, I have no question that I would not be here today. I am truly and eternally grateful for the things they did for me and I will always strive to live my life to the values they instilled in my life.

Chapter 1 - Literature Review: Application of a Hand-held Infrared Meter for Determining Corn Silage Moisture

Introduction

With today's high feed costs and low milk prices, dairy producers are looking for additional ways to increase economic efficiency and maximize milk production. These goals have been a common theme throughout history, but have become increasingly important in today's volatile market. Utilizing scientific research, we continue to develop new methods, techniques, and technology to allow producers to maximize time and economic efficiency.

Due to the high cost of feed and need for ever improving animal health, research for detecting dry matter (DM) variation with on-farm testing has increased in recent years. This review of literature will primarily focus on monitoring DM variation and the use of handheld near-infrared spectrophotometers (NIRS) to determine forage moisture content.

Forages account for 45-60% of the DM found in dairy rations and can vary in immensely in DM content, making it the largest formulation obstacle for dairy producers and nutritionists to overcome. Dairy rations are formulated on a DM basis and estimate the dry matter intake (DMI) of cattle to maximize health and production. When changes in cow production and/or health are observed, a simple change of DM content of the feeds could possibly be the reason (Mertens et al., 2004). With the increased use of total mixed ration (TMR) feeding systems, monitoring of the DM content of forages has become vitally important. Many different TMR's are thought to be fed to a group of cows each day: the one formulated by the producer or nutritionist, the one given to the feeder to mix, and the one the feeder actually fed. However, these may not all be the same as the one consumed by the cows due to DM variation of individual feeds. By reducing DM variation of forages, producers can lower feed costs, improve animal health, and/or increase milk production (Weiss et al., 2009).

Time and efficiency of testing is always a struggle with dairy producers. Producers have many aspects of the operation to focus on and sometimes monitoring DM of forages is deemed as a lower priority. Silva Del-Rio (2010) found in a study of large California dairy farms using corn silage that 52.3% of dairies evaluated DM at least once a month, and only 8.3% determined DM weekly or more often. While most people realize this is not sufficient, it is often not done due to time constraints (Weiss and St. Pierre, 2009). Routine on-farm measurement and correction of ingredient DM presents an opportunity to improve the consistency of TMRs. This can be achieved by using reliable on-farm methods to detect changes in DM, which will allow for a more accurate mixing of diets on dairy operations.

The use of technology throughout the dairy industry has increased immensely over time. While the number of dairy farms in the United States has decreased, herd size and productivity has risen. In the past, dairy operations have been heavily dependent upon labor, but advances in technology have allowed the industry to move towards reliance on technological and managerial innovations (Khanal et al., 2010). The use of NIRS technology provides producers with rapid, low cost, and accurate determinations of feed composition to allow for greater efficiency of time (Corson et al., 1999). Furthermore, the use of ration balancing software to match the nutrient composition with nutrient requirements allows producers to maximize profitability.

Causes and Effects of DM Variation

Much research reviewing the causes and effects of DM variation has been described over the years. With many causes and effects being identified, researchers and producers have realized the importance of good forage management skills. While the goal of harvesting and storing forages is to minimize the DM variation, managerial and environmental changes can have a direct impact on forage DM variation that will effect performance and/or health of the cattle.

Farms use many different types of forage storage structures, while the most common are tower silos and horizontal or bunker silos with advantages and disadvantages. Changes in hybrid, field, or other factors can impact the true composition of the silage as the silos are filled and unloaded in a continuous fashion (Weiss and St. Pierre, 2009). Regardless of the type of storage structure, DM content has been shown to vary 5 to 10 units on a weekly basis (Pino and Henrichs, 2014). Research conducted at the U.S. Dairy Forage Research Center showed that weekly composite samples of silages had a DM variation of 3 to 8 units for corn and alfalfa silages sampled (Mertens et al., 2004).

Weather has a large role in DM variation of feeds, especially forages. While DM content can change gradually over time in perfect conditions, abrupt changes could be caused by rain, snow, or extreme temperature changes (Holter, 1983; Mertens et al., 2004). A 5 to 15 unit change in DM content is possible in exposed bunker silos after a heavy rain or snow event (Mertens et al., 2004). Extreme heat may also influence DM content of the feeds, by drying out any exposed face of the bunker or loose forages that are not covered. An abrupt change in DM content may cause the ratio of concentrate to forage to change if no adjustment in DM occurs (Holter, 1983). These abrupt changes may cause a decrease in DMI, thus altering the nutrient balance and ratio of feedstuffs in the TMR that is consumed by the cattle. For example, if a ration is formulated to include 40% corn silage on a DM basis that is at 40% DM, a decrease of DM to 30% would make the total amount of corn silage 33% of the ration on a DM basis. McBeth et al. (2013) studied the effects of wetting corn silage to decrease DM content of corn silage by 10 units and found that when diets were left unbalanced after a transient change in DM it decreased NDF and forage NDF concentrations by 1.6 and 2.6 units as well as increased starch content by 2 units.

Feed management can play a part in ensuring an adequate DM content of the TMR. TMR feeding systems may cause a dietary imbalance by combining different ingredients with inaccurate DM content estimations (Oetzel et al., 1993). Producers and nutritionists formulate rations on a DM basis to ensure that cattle are receiving nutrients in specific amounts to, at the very least, meet the requirements for production, health, and growth (Mertens et al., 2004; McBeth et al., 2013). For operations using home-grown forages, the variation within-farm should be used to evaluate the associated nutritional risk (St. Pierre and Weiss, 2015). Workers mixing the rations for the cattle are doing so on an as-is basis, or what the feed weighs with moisture included. The study conducted at the U.S. Dairy Forage Research Center sampled TMRs from multiple herds and when compared to the DM content formulated in the ration and found that 25% of the samples were significantly different (Mertens et al., 2004). Therefore, assessing the DM content of the feeds and tracking them on an ongoing basis is important to ensure the worker can do his job correctly (Pino and Heinrichs, 2014).

The act and method of sampling can be another source of DM variation. Forages are heterogeneous, highly variable, and may account for over 50% of the DM consumed by lactating cows (Mertens et al., 2004; Mertens, 2006; St-Pierre and Cobanov, 2007). While sampling is an unresolved issue in animal production, its potential impact on performance and profitability has been gaining more attention in recent years (St-Pierre and Cobanov, 2007). Using a larger sample size helps to reduce error when determining DM of a particular feedstuff whereas small samples may have large variations between them (Mertens et al., 2004). Additionally, determining an optimal and reasonable sampling schedule may help reduce performance and economic loss. St-Pierre and Cobanov (2007) found that by using a model to optimize a forage sampling schedule will save producers $80 to $100/cow per year.

The effects of DM variation can be devastating to a producer's economic efficiency. Kellems et al. (1990) found that DM consumption by cattle can directly impact milk production. Research showing the addition of water to silage decreasing silage DM content by 8 units reported a 0.9 to 2.6 kg decrease in milk yield the following day (Mertens and Berzaghi, 2009; Boyd and Mertens, 2010). When less forage DM content is being delivered to the animal, fiber levels can drop below accepted standards causing the rations to become high in energy; high-energy rations can cause cows to develop acidosis symptoms and decrease production and health of the animal (Mertens et al., 2004). A study by McBeth et al. (2013) showed when cows were fed wetted corn silage for a short period of time, NDF and forage NDF decreased and starch increased when diets were not balanced for correct DM content. Additionally, McBeth (2013) showed that even an abrupt addition of water to silage in a nutrient balanced diet, tended to decrease ($P < 0.10$) DMI when compared to control diets.

Particle size can also be affected by loss of DM. Kononoff et al. (2003) reported that the particle mass <1.18mm was significantly different ($P < 0.05$) for corn silage differing in moistures of 58.0 and 34.4% suggesting even though small, moisture loss in corn silage may affect particle size. Moisture content and/or different particle size alters the degradation variables, ruminal degradability, and rate of degradation of corn silage (Zou et al., 2016). Close monitoring of DM content may help to avoid any nutritional disaster that may cause adverse effects to production and health of the animals (Mertens et al., 2004).

On-farm Testing Equipment

Having a quick and reliable method to accurately estimate DM content of feeds can save producers and nutritionists a lot of nutritional disasters (Mertens et al., 2004). Forages are the most variable feeds and must be tested regularly. The Karl Fischer method is the gold standard to measure DM content of fermented forages, but takes specialized training, equipment, technical skill, and intense labor (Mertens et al., 2004). The most cost effective way to achieve DM content is by doing it on-farm and in a time efficient manner (Oetzel et al., 1993). Many different types of testing methods are available, but the most popular on farms are: forced air oven drying (FAO), Koster Moisture Tester (Koster Crop Tester, Inc., Strongsville, OH), food dehydrator, and microwave oven (Oetzel et al., 1993; Mertens et al., 2004; Pino and Heinrichs, 2014).

Forced air oven drying is one of the most accurate and common method to determine DM in the laboratory (Pino and Heinrichs, 2014). But, because of the high cost for equipment and time required, it is not used regularly in the field. FAO uses hot air flowing within a chamber and extracting it with fans outside the chamber. When comparing DM determination for true water loss, drying a sample at 55°C for 24 hours in a FAO provides a reliable reference method to other methods of DM determination (Mertens et al., 2004). The results of FAO could be biased based on the loss of volatile fatty acids, residual alcohols, and protein degradation could factor into an inaccurate determination of DM in forages (Minson and Lancaster, 1963; Oetzel et al., 1993; Mertens et al., 2004). Additionally, charring and/or burning of a sample could cause you to inaccurately determine DM because more than just water was lost (Minson and Lancaster, 1963; Mertens et al., 2004). Petit et al. (1996) found that FAO could be an acceptable drying method when analyzing for DM in a large number of samples.

The Koster Moisture Tester (KMT) is a fairly inexpensive and quick way to determine forage moisture. KMT uses flowing hot air through a sample in an open container. Advantages of the KMT are that it does not require constant operator attention, can be done quicker than FAO, and is cheaper and safer than some laboratory methods. It was designed as a simple, rugged, and portable device that could be operated by anyone with minimal training. However, it has been found to under estimate the DM significantly (Oetzel et al., 1993; Pino and Heinrichs, 2014). Pino and Heinrichs (2014) hypothesized that this could be caused by the loss of small particles escaping during processing or corn kernels being left undried.

As most dairies feed more than one wet feed, a method that allows for multiple samples to be dried at one time would be ideal. Food dehydrators are a common household item that can be found at most stores that sell household appliances. They are designed to use dry moist foods at a relatively low temperature and have the capacity to dry multiple samples. Mertens et al. (2004) found that samples dried in a food dehydrator for 24 h at 71°C had slightly lower DM content than reference values. But, one disadvantage is that samples on the middle and bottom shelves do not dry as quickly as the top, causing an incorrect determination of DM (Mertens et al., 2004).

The use of a microwave oven has been widely used to determine forage moisture in the dairy industry. Microwave ovens are another common household item and use electromagnetic radiation to polarize the water molecules to produce thermal energy in a process called dielectric heating. The microwave can quickly determine DM similar to the FAO with small error (Pino and Heinrichs, 2014). However, it requires trained personnel that are completely dedicated to determining DM for the duration of the method (Oetzel, 1993; Mertens et al., 2004; Pino and Heinrichs, 2014). Like the FAO, charring and/or burning of the sample is common and may cause an incorrect DM estimation.

There are advantages and disadvantages to each regularly used on-farm testing method. They can either required a trained and dedicated worker, extensive amount of time, or costly equipment. The choice of method to determine DM on-farm depends on the feedstuff being tested, time required, repeatability, and accuracy of which it can determine correct DM content of a feed (Oetzel et al., 1993; Petit et al., 1997; Pino and Heinrichs, 2014).

Near-Infrared Spectrophotometer Technology

During recent decades, the use of near-infrared spectroscopy (NIRS) has become a commonly used and increasingly analytical method due to its characteristics of being fast, cost efficient, non-destructive to samples, and not involving the use of hazardous chemicals (Liu et al., 2011). The future of the dairy industry can be shaped by the ever growing advancement of this technology. NIRS has many agriculture and food industry applications such as: fatty acid composition of sunflower oil, analysis of curds during cheese making, estimating lignin content of forest products, mastitis diagnosis in cow milk, and analysis of feces to estimate dietary composition (Corson et al., 1999). Furthermore, the application of NIRS technology to estimate the nutrient composition of feedstuffs has been widely and successfully used (Norris et al., 1976; Abrams et al., 1987; Givens et al., 1997; Corson et al., 1999).

The definition of near infrared light is the wavelength of 800 to 2500 nm (Givens et al., 1997). Spectroscopy is defined as looking at light based on the interaction of electromagnetic radiation in the matter that is being analyzed. When a sample is irradiated, light is absorbed selectively according to specific vibration frequencies of the present molecules and then gives rise to a specific spectrum (Givens et al., 1997). The C-H, O-H, and N-H vibrations correspond to the NIRS bands, which originate from the mid-infrared region fundamental bands (Wu et al., 2008). Typically, a NIRS analyzer consists of a light source, monochomator, sample holder or sample presentation interface, and a detector, allowing for transmittance or reflectance measurements (Reich, 2005).

The greatest advantage to NIRS analysis is the lack of reagents and wastes produced by traditional chemical analyses; additionally as it is a multi-analytical technique, many determinations can be made simultaneously (Givens et al., 1997). Nevertheless, the need for high precision and time consuming calibration procedures are among the greatest disadvantages. To improve linearity and optimize precision of calibrations, NIRS requires many advanced multivariate calculation techniques (Tran et al., 2010). However once calibrated, NIRS analysis can be simple to use and operate (Givens et al., 1997; Corson et al., 1999). NIRS can be a valuable tool to quickly analyze a sample to properly adjust TMR to provide adequate nutrients to dairy cattle.

The use of NIRS analysis has been used successfully for many years in the determination of major chemical constituents and estimate the digestibility of forages (Sørenson, 2004). Popularity and acceptance of NIRS analysis in the dairy industry has been helped by being a rapid and accurate method of identifying composition of feedstuffs without any chemical pretreatment that may damage the sample. It is a tool that is successfully and widely used to evaluate forage and feedstuff nutrition (Norris et al., 1976; Abrams et al., 1987; Givens et al., 1997; Corson et al., 1999). However, constant calibration is needed to adapt devices to new measurement and sample conditions, such as chemical composition, temperature, sample presentation, and the like (Workman, 2017). Additionally, the use of daily diagnostics of the device is needed to ensure consistent and accurate results (Stuth et al., 2003).

Conclusions

After evaluating published research, the monitoring and evaluation of DM on-farm may help increase profitability and efficiency of dairy farms. This is dependent on rapid and accurate on-farm testing methods and properly adjusting rations based on this determination. If DM is accurately determined by any method, there will typically be an increase in animal performance and/or total farm profitability. The impact of DM variation helps researchers understand the importance of efficient and accurate on-farm DM determining methods.

Estimation of DM content for accurately delivering the correct nutrient balance to dairy cattle calls for regular testing and proper testing methods. Some farms do test for DM on a regular basis, there are still farms that could minimize DM variation of TMR by testing feedstuffs regularly and efficiently to minimize nutritional disasters. While DM variation can be minimal at times, these acute variations can impact cow health, performance, and overall profit for the farm.

The use of NIRS has the ability to allow producers to have access to a fast and reliable method of determining DM content. NIRS increases speed of DM determination while not damaging the samples (Liu et al., 2011). While variation in nutrient analysis is real and controllable, more progress in methodology and repeatability needs to be further explored by researchers (Mertens, 2006; Weiss and St-Pierre, 2009).

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Chapter 2 - Literature review: Development of an integrated pest management tool for commercial dairies: feeding a pelleted supplement that is resistant to bird depredation

Introduction

European Starlings (*Sturnus vulgaris*) have been nominated to the "100 Worlds Worst" invaders by the Invasive Species Specialist Group (Lowe et al. 2004). Starlings that are found outside of their native range of Europe and North Africa are considered one of the most destructive bird species in the world (Lowe et al., 2004). Since the late 1800s, when European Starlings were introduced to the United States, their population has grown exponentially (Cabe, 1993; Linz et al., 2007). Feare in 1984 estimated that North America was home to over one-third of the world starling population. Starlings are found on all continents except Antarctica while only being native to Europe and North Africa (Rollins et al., 2009).

Most of the time starlings feed mainly on seeds, fruits, and insects very inconspicuously (Tinbergen, 1981), however in the winter months starlings tend to congregate in large numbers around concentrated animal feeding operations (CAFOs, i.e. dairies and feedlots) (Lee, 1987). Birds can cause many issues to nutrient delivery, animal health, and economic success to livestock producers. The main reason starlings are drawn to CAFOs is the continuous supply of fresh feed that is delivered daily. This fresh feed allows for a consistent food supply with a high concentration of nutrients that are vital to the survival of the species. Pimental et al. (2005) found that the damage caused by starlings alone can cause losses in excess of US$800 million annually to the agriculture industry. Starlings specifically prefer energy dense components of the ration (i.e. starch) (Depenbusch et al. 2011). While nutritionists and producers strive to provide a homogenous and nutritionally balanced ration to cattle, this loss of nutrients by starling consumption can have major health and economic consequences.

Both cattle and wild birds harbor the microorganism responsible for six of the nine human diseases tracked by the Centers for Disease Control and Prevention (CDC) including

Campylobacter, *Listeria, Salmonella*, *E. coli* O157:H7, *Yersinia*, and *Cryptosporidium* (LeJeune et al., 2008). Birds in close proximity to humans and livestock tend to have a higher prevalence of antimicrobial resistant organisms when compared to birds farther away from human and livestock environments (Allen et al., 2010). These diseases can cause not only economic losses, but have health implications to both humans and livestock.

Finding a solution is key to containing the problems associated with the large starling population. Many attempts have been made, however the most effective tool is DRC-1339 (3-chloro-4-methylaniline hydrochloride) which is the only toxicant approved for lethal bird control by the U.S. Environmental Protection Agency (USEPA) (Eisemann et al., 2003). Public opposition is the main deterrent for the use of this tool due to the potential for environmental risk (Linz et al., 2015). Attempts to find more humane integrated pest management strategies are needed due to the public opposition to DRC-1339.

Problems Associated with Starlings

Dairies and feedlots are prime feeding grounds for invasive starling populations (LeJeune et al., 2008; Depenbusch et al., 2011). Significant economic damage to dairies and feedlots by invasive starlings has been well documented over the years. Depenbusch et al. (2011) estimated that starlings cost feedlots around $0.92/head/day by consumption of finishing rations. In 1999, there was an estimated $600,000 loss in three feedlots located in Kansas combined (US Department of Agriculture, 2000). Researchers surveyed producers in Wisconsin, New York, and Pennsylvania and estimated losses of $9,339.14 on farms experiencing 1 to 1,000 birds, while dairies experiencing greater than 10,000 birds lost $64,401.51 annually due to feed loss due to birds (Figure 2.1; Shwiff et al., 2012). This economic loss due to feed loss along with the low price of milk that producers have been receiving in recent years, has put a significant strain on producers economic success.

Animal performance is also negatively impacted by depredating birds in feedlots and dairies as starlings frequent them during the winter months when the ground is snow-covered and/or frozen. The biggest draw to feedlots and dairies for starlings are the overall abundance of high-energy feeds available (Linz et al., 2007; Depenbusch et al., 2011). Nutritionists formulate rations for cattle to meet nutritional requirements for cattle and any variation can have a large impact on animal production, efficiency, animal health, and a producer's economic success. Past research has shown that in a feedlot setting, where cattle were fed in bird-excluded areas, cattle showed an increase in weight gain (Wright, 1973; Feare and Swannack, 1978). Based on overall consumption of feed, it has been found that starlings can consume up to 50% of their body weight in feed each day (Forbes, 1995). For example, a mature starling weighs approximately 85 g and could consume about 42.5 g of feed daily. So, a flock of 10,000 starlings could possibly consume up to 425 kg of feed daily on livestock operations. Starlings are able to consume feed very quickly at about 28.6 g per hour and prefer to feed during the morning hours (Glahn and Otis, 1981). It has been suggested that consumption of high-energy feed ingredients at the bunk by birds reduce animal performance (Feare, 1984). Recently, conclusions have been drawn by looking at nutritional data for finishing rations that were exposed to starlings could possibly decrease feed efficiency and growth rates in feedlot cattle (Depenbusch et al., 2011). Carlson et al. (2018) looked at the ingredients starlings prefer and found that out of what a starling consumes, 44.5% is from the concentrate or energy dense portion of the TMR.

While consumption of feed by birds is a large economic loss in the livestock industry, it is also associated with the spread and amplification of microbiological hazards. These hazards include *Escherichia coli* 0157:H7, antimicrobial resistant (AMR) strains of *E. coli* and *Salmonella enterica*, *Mycobacterium avium paratuberculosis*, and many others (Corn et al., 2005; Linz et al., 2007; LeJeune et al., 2008; Gaukler et al., 2009; Carlson et al., 2011a; Kauffman and LeJeune, 2011; Carlson et al., 2015; Medhanie et al., 2016). Wild birds are known vectors of many infectious and harmful microbiological hazards. The spread of diseases is the result of excretion of feces into feed and water sources. Carlson et al. (2011b) found that *S. enterica* contamination was reduced when the number of starlings on feedlots was also reduced. Additionally, disease transmission has been found between cattle and birds that share the same feed and water sources (Carlson et al., 2015). Not only does transmission to cattle pose a threat to the livestock industry, but has the potential to be harmful to humans as well. Even by small amounts, reducing the carriage of foodborne pathogens in birds may have an impact on both public health and the economy. It has been suggested that in the United States alone, bird-borne diseases could exceed $1 billion annually in herd health costs (Pimental et al., 2005), while human medical costs from *E. coli* and *Salmonella* spp. are estimated at over $400 million annually (Linz et al., 2018).

Possible Solutions

Possible solutions to control bird populations are very limited in today's world due to strong public opposition in the use of lethal control methods and the lack of other effective tools (Shwiff et al., 2012). Lethal control of starlings through the use of DRC-1339 (3-chloro-4-methylanilne hydrochloride) is the most effective way of controlling bird populations and is the only current toxin for lethal bird control registered by the U.S. Environmental Protection Agency (USEPA) (Eisemann et al., 2003). While DRC-1339 is lethal to birds, there is no threat to predators or scavengers who may eat the already deceased bird as it is metabolized and excreted quickly after consumption by birds (Eisemann et al., 2003). Conservation and animal rights organizations show a strong opposition to the use of toxic or lethal compounds due to the slow death of the affected bird (Linz et al., 2015). Another large obstacle to overcome in the use of DRC-1339 is that non-target species, such as song birds or desirable birds, are also susceptible to consumption and death. So, targeting starlings or invasive species is hard to achieve. There are also other pesticides that are available to help control populations. Chemical frightening agents such as 4-aminopyridine is a restricted use pesticide that causes birds that have consumed treated grain or pellets to act erratically and give warning cries to scare away other birds (Linz et al., 2007). Unfortunately, this still can be a lethal product as any bird that consumes may die. Similar to DRC-1339, this can be a hard product to use because in theory any bird, target or non-target, could consume it and die (Linz et al., 2007).

However, there are more humane ways of managing starling populations. These tools include propane exploders, pyrotechnics, hawk kites, ultrasonic sounds, and others, but these tools are still highly ineffective (Linz et al., 2007). More recently, there has been a push to find better tools to control the bird population. Carlson et al. (2018) suggested that using particle sizes less desirable or less attainable by starlings could help prevent nutritive losses in TMR’s. The use of a pellet of high-energy components with a diameter of 0.953-cm was found to reduce consumption of feed by starlings by ≥79% as outlined in table 2.1 (Carlson et al., 2018).

Conclusion

After evaluation of published research, starlings have been found to cause large economic, health, and public opinion implications. Starlings can cause large economic losses for animal feeding operations by consumption of high-energy feedstuffs (Linz et al., 2007; Depenbusch et al., 2011). This consumption has the potential to reduce animal performance such as reduced milk production or weight gain (Feare, 1984). Another possible way that starlings may cause economic loss is by the spread of diseases that are not only lethal to livestock, but humans as well. Controlling the population of invasive starlings near livestock operations has been shown to reduce the prevalence of harmful microbiological hazards (Carlson et al., 2015). While the prevalence of these diseases has been documented, the economic damage caused is hard to quantify.

The use of lethal and non-lethal prevention tools has been well documented over the years. However, the use of these tools has disadvantages. Lethal prevention tools are met by public opposition and are hard to control, while non-lethal tools are highly ineffective (Linz et al., 2007). In conclusion, finding cost-effective and nonlethal ways to control bird consumption of livestock feeds may be the way to overcome economic losses without public opposition and damage to non-invasive wildlife populations.

Figures and tables

Table 2.1 Assessment of pelleted feed as a deterrent to starling consumption of livestock feed supplies. From Carlson et al., 2018.

Pellet diameter (cm)	Sample size (n)[1]	Feed offered (g)	Feed consumed (g)[2]	95% CI[3]	Bonferroni mean difference[4]
2.22	11	150	6.25	2.22-10.29	A
1.91	11	150	6.08	2.05-10.12	A
1.27	11	150	5.62	1.58-9.65	A
0.95	11	150	16.82	12.78-20.85	B
0.55	11	150	75.14	71.10-79.17	C
0.39	11	150	80.45	16.42-84.49	C

[1] 11 cages per treatment. Each cage had 2 starlings.
[2] Mean consumption/cage per treatment group over 24-h period.
[3] 95% confidence intervals for the mean consumption/cage.
[4] Different letters identify non-overlapping confidence intervals based upon Bonferroni-adjusted LSM estimate

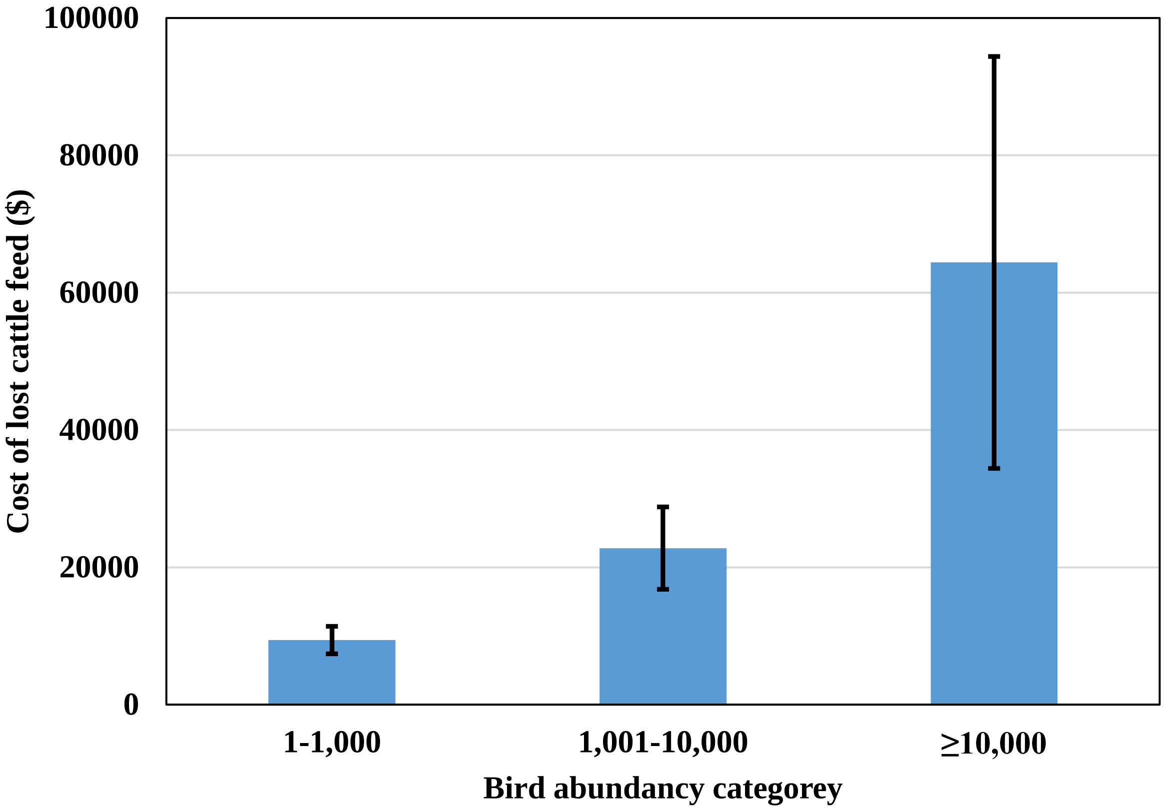

Figure 2.1 Weighted means and standard error estimates of production costs from cattle feed lost to birds by bird abundance category. Cost estimates reflect annual cost to producers in 2009. Adapted from Shwiff et al., 2012.

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Chapter 3 - Application of a hand-held infrared meter for determining corn silage moisture

Abstract

This study compared the accuracy of three hand-held near infrared spectrophotometer (NIRS) units (Digi-Star Moisture Tracker, Fort Atkinson, WI) and two other testing methods for predicting DM compared to conventional oven drying at 105°C of corn silage. Corn silage samples (1,500 g) were obtained from four commercial farms in Kansas and analyzed for DM daily for 20 d. Two calibrations were also tested within each unit: NIRu was the DM predicted from the factory-preset calibration, and NIRc was a bias-adjusted DM prediction based on the average difference between 105°C oven-dried corn silage and NIRu over the 20-d experiment. The NIRc was determined after the experiment was completed. Each sample was scanned 20 times by each NIRS unit and the average predicted DM was recorded as the DM. This process was replicated three times with each NIRS unit. Two duplicate 100 g subsamples were dried by three different methods: food dehydrator at 71°C (Nesco®, Two Rivers, WI), Koster Tester (Koster Moisture Tester, Inc., Brunswick, OH), and 105°C oven. Oven-dried samples were placed into a 55°C oven and dried for 48 h and then dried in a 105°C oven for 24 h to obtain the final DM daily. Data were analyzed using PROC MIXED (SAS, version 9.4), with method, method*farm and method*day as fixed effects and equipment as a random effect. Average oven-dried DM of corn silage was 38.38% ± 0.59 for the 20-d experiment. The three NIRu predictions of 35.87 ± 0.59, 32.43 ± 0.59, and 32.97% ± 0.59 were significantly different from the oven-dried DM value ($P < 0.05$), while all three NIRc predictions of 38.40 ± 0.74, 38.41 ± 0.74, and 38.38% ± 0.74 were similar to oven-dried DM value ($P > 0.05$). The DM predictions for the food dehydrator and Koster Tester of 38.73 ± 0.59 and 38.22% ± 0.59 respectively. The food dehydrator value was different from oven-dried samples ($P < 0.05$), while the Koster Tester value was similar to oven-dried samples ($P > 0.05$). The hand-held NIRS units accurately predicted DM content of the corn silages when the factory preset calibrations were corrected for bias, while the food dehydrator over-estimated the DM of the corn silage and the Koster Tester accurately predicted DM as compared to oven-dried values.

Key Words: corn silage, dry matter, on-farm

Introduction

Low milk prices and high costs of production has increased the need for ways to improve economic efficiency. One area of research that has been shown to impact both production and economic efficiency is DM variation in forages. Due to the ease of preservation and increased quality, silages and/or high moisture feeds have been favored over the years (Lahr et al., 1983). Finding methods to determine DM in high moisture feeds on-farm without the use of expensive lab equipment would help producer's be more efficient and economically successful. Improved animal health, increased milk production, and lower feed costs can be achieved by monitoring DM variation effectively (Weiss et al., 2009).

Many factors can cause variation in DM of forages. Examples of factors that may cause variation in DM are harvest maturity, storage structure, packing density, feeding management, and weather (Borreani et al., 2017). While any combination of these can cause varying DM, each presents their own set of challenges to manage at the farm level. Regardless of storage structures, 3 to 10 unit variations in DM weekly have been observed (Mertens et al., 2004; Pino and Heinrichs, 2014). Total mixed ration (TMR) systems are widely used in the dairy industry as a way to present a ration to cattle and is formulated on a DM basis by the producer and/or nutritionist. Any variation in ingredient DM has the potential to cause an imbalance of dietary nutrients if the ingredients have inaccurate DM estimates (Oetzel et al., 1993). When sampling TMR, Mertens et al. (2004) found that 25% of the samples differed in DM content vs. the formulation.

These factors causing DM variability may cause many different reactions in cattle, but will almost always directly impact milk production (Kellems et al., 1990). When DM variability occurs, it may lead to insufficient NDF content in the diet that may lead to reduced chewing activity and saliva production, lower ruminal pH, and altered ruminal fermentation which may cause an increased risk of acidosis and milk fat depression (Mertens, 1997). Monitoring DM variability in feedstuffs is in the best interest of cow health and performance and the producer's economic success.

Sampling forages and testing on-farm can be a cost and time efficient way to help minimize variability in ration DM compared to laboratory methods that can be time consuming and expensive. Laboratory methods such as the Karl-Fischer titration method and forced-air ovens have been shown to provide accurate DM determinations, but also require specialized equipment and/or chemicals and can become quite expensive (Mertens et al., 2004; Pino and Heinrichs, 2014). Many different options are available to producers who wish to test forages on-farm including food dehydrators and Koster Moisture Testers (KMT) (Koster Moisture Tester, Inc., Brunswick, OH). While each method is relatively cost efficient, each has different disadvantages.

A possible alternative to a food dehydrator and KMT is Near Infrared Spectroscopy (NIR) in a portable device. NIR technology was first used in a laboratory setting in 1976 by Karl Norris and colleagues for forage analysis. The use of NIR technology as a laboratory technique has been widely adapted over the past few decades as it is quick, relatively low cost, and eliminates the use of chemicals all while not damaging the sample (Liu et al., 2011). The application of NIR technology has been proven successful in determining the nutrient composition of a wide range of feedstuffs (Norris et al., 1976; Abrams et al., 1987; Givens et al., 1997; Corson et al., 1999; Sørenson, 2004).

Recently, portable versions of NIR technology has been developed and have allowed producers a rapid on-farm method for determining DM and nutrient composition of different feedstuffs. Mertens and Berzaghi (2009) utilized a portable NIR device and found the overall error of measuring moisture to be less that two percentage units; which is a relatively small degree of error when considering the day-to-day variation found in stored forages. Additionally, other researchers have found that when comparing a handheld NIR device to a forced air oven there was no difference in DM determination once the device was calibrated (Donnelly et al., 2018). NIR technology has the ability to allow producers the opportunity to balance rations based on DM of different feedstuffs that vary greatly from day-to-day quickly and efficiently.

Limited research has been conducted on the use of handheld NIR devices for practical on-farm DM determination. The objective of this study was to determine if handheld NIR devices, when compared to a lab method, are accurate in determining DM in corn silage on-farm. Additionally, other common methods of on-farm DM determination were explored to determine their accuracy.

Materials and Methods

Corn silage samples (1,500 g) were taken daily at three commercial dairy farms in Kansas and the Kansas State University Research and Teaching Dairy Unit over a 20-d period (Figure 3.1). Three hand-held near infrared spectrophotometer (NIR) units (Digi-Star Moisture Tracker, Topcon Agriculture Americas, Fort Atkinson, WI) were utilized. Two calibrations were tested within each unit: NIRu was the factory set calibration, and NIRc was bias-adjusted based on the average difference of the 105°C oven-dried samples and NIRu estimations over the 20-d experiment. Each sample was scanned 20 times by each NIR unit to predict DM and replicated three times with each unit (Figure 3.2). Two duplicate 100 g subsamples were taken and dried in three different methods. The methods were a food dehydrator (Nesco®, Two Rivers, WI), Koster Moisture Tester (Koster Moisture Tester, Inc., Brunswick, OH), and 105°C oven. Samples were weighed prior to being placed into their respective methods and immediately after for DM determination. The food dehydrator was set to 71°C and ran for 24 hours. The Koster Moisture Tester was run for 50 min and then for 5 min thereafter until weight did not change by more than 0.1 g between subsequent measurements. Oven-dried samples were placed into a 55°C oven and dried for 48 h and then weighed and placed into a 105°C oven for 24 h to obtain a true DM. The oven dried samples were used as the reference method in this study. Statistical analysis was done by using PROC MIXED procedure of SAS (Version 9.4, SAS Institute, Inc., Cary, NC) with method, method*farm, and method*day as fixed effects and equipment as a random effect.

Results

Average DM of all four farms combined for each method are in Table 3.1. The average DM of all four farms in the 105°C oven-dried samples was 38.38% for the 20-d trial. The DM determination for each unit using the NIRu calibration was 35.87 ± 0.59, 32.43 ± 0.59 and 32.97% ± 0.59, respectively, and were different ($P < 0.05$) than the oven-dried determination. The NIRu calibrations underestimated the DM of each sample when compared to the reference. Similarly, the food dehydrator was also different ($P < 0.001$) than the oven-dried samples with a DM value of 38.73 ± 0.59 and the Koster Moisture tester was similar ($P > 0.05$) to oven-dried samples with a DM value of 38.22% ± 0.59. The food dehydrator overestimated the DM of each sample, while the Koster Moisture Tester accurately determined DM. When using the NIRc calibration, the DM values of all three units were 38.40 ± 0.74, 38.41 ± 0.74, and 38.38% ± 0.74, similar ($P > 0.05$) to the oven-dried values. There was also a farm by day interaction ($P < 0.001$), showing that the DM of silage varied from day to day on each farm. Figures 3.3, 3.4, 3.5, and 3.6 show the average DM values of the 105°C oven, NIRc, Koster Moisture Tester, and food dehydrator for each farm over the 20-d experiment, while figure 3.7 shows the average of all farms over the 20-d experiment.

Discussion

Forages are among the most variable feedstuffs used in the dairy industry. A farm by day interaction was found in this trial showing that the average DM values on each farm differed from day-to-day over the 20-d sample period. Previous research has shown similar results. Holter (1983) found that after sampling over consecutive weeks there was as much as a 7 unit week-to-week change in corn silage DM. Holter suspected that this variability was likely due to corn silage exposed to ambient weather condition such as heat, rain, snow, and ice and found that a decrease in DM by 6 units following a heavy rain event changed the concentrate-to-forage ratio from 50:50 to 55:45. Mertens et al. (2004) observed a 5 to 6 unit change in DM for silages that were harvested in a single lot when using weekly composite samples. More recently, Weiss et al. (2012) found a much higher variability of 10.4 unit change in DM of corn silage. However, sampling error may have been the cause of the high variability as nutritionists from 50 dairy farms conducted the sampling for that study. The results from this study indicate that over a short period of time, DM changes may be unaccounted for in daily TMR mixing and could cause loss of production and health issues in dairy cattle.

The difference of the NIRu and NIRc calibrations in this trial was similar to a study by Tran et al. (2008) where they looked at the near infrared reflectance spectroscopy of fecal material to monitor diet characteristics and nutrient digestibility. Tran et al. (2008) looked at a “global,” or classic and universal calibration, versus a “local,” or models developed from a group of selected samples similar to the sample being analyzed. The data in this trial follows the same trend as the NIRu, or more global and universal calibration, was different ($P < 0.05$) from the

105°C oven. While the NIRc, or more local and specific calibration, was similar (*P* > 0.05) to the 105°C oven and provided more accuracy when determining silage DM. Similarly to more recent research, when NIR device calibration was corrected for bias, they accurately predicted DM when compared to the forced air oven lab method (*P* < 0.05), while uncalibrated NIR devices were different (*P* > 0.05) from the forced air oven lab method (Donnelly et al., 2018) which agrees with the findings in this study. However, there are limitations and risks involved with using a “local” or specific calibration. Determination of the calibration equation can be quite time consuming as a large database is needed and can be very tedious and time consuming (Shenk et al., 2001; Tran et al., 2008). Specific calibration is also limited by only being able to be used on unique groups of samples, such as an individual farm, with a specific device as equations or calibrations cannot be transferred from one device to another (Shenk et al., 2001). With improvements in NIR technology among devices being made, users expect similar results from each device.

In this trial, the KMT value for DM was similar to the 105°C oven which contradicts other research over the years that has found the KMT to inaccurately determine DM when drying for a specific time and then running for extra time until weight did not change, similar to our trial (Oetzel et al., 1993; Pino and Heinrichs, 2014; Donnelly et al., 2018). While some research has found that KMT underestimate DM (Bouraoui et al., 1993; Pino and Heinrichs, 2014; Donnelly et al., 2018), the results found in this trial were that it accurately determined DM. Operator skill required for the KMT was less than the NIR units as it could be left unattended for most of the time and be used by minimally trained workers. Oeztel et al. (1993) looked at time to complete DM determination and found that it took longer than an electronic moisture tester which was similar to this study when comparing it to the NIR devices. It is also possible to consider that researchers may be more diligent in operating a KMT during a trial when compared to commercial on farm use of this method.

Unlike the Koster Moisture Tester and calibrated NIR devices values, DM was over-estimated when using the food dehydrator method. These results differ from previous research on the use of food dehydrators for DM determination. Mertens et al. (2004) found that drying both alfalfa silage and corn silage samples in a food dehydrator was similar to the reference method when drying time exceeded 6 hours. Additionally, Mertens et al. (2004) suggested that for rapid determination of DM on-farm could be done by the use of a calibration equation from drying of a sample for 2 h, although the variation was 2.5x greater than drying for 6-8 h. In this trial, a 24 h drying period resulted in inaccurate DM values when compared to the reference method. Possible ways to improve the accuracy is to increase the drying time to exceed 24-h to see if samples can be completely dried or the development of a reliable calibration method. Advantages of the food dehydrator are that it can be left unattended, requires minimal training, and minimal maintenance. However, the long time it takes to dry a sample can be a disadvantage in an on-farm setting.

Conclusions

In the present study, once calibrated, a handheld NIR device was determined to be a reliable method of on-farm DM determination. If calibrated regularly, a handheld NIR device gives producers a method to quickly determine DM changes of corn silage on-farm and make changes to TMR mixing accordingly. However, food dehydrators in this study yielded greater DM percentages than the 105°C forced air oven. The method used for the food dehydrator in this study proves to be an inaccurate method to determine corn silage DM on-farm, but the development and use of a calibration curve may be a possible solution to improving the accuracy on-farm. However, the Koster Moisture Tester in this study proved to be a reliable method on-farm. Improvement in the calibration methods needs to be further explored to increase accuracy and repeatability of NIRS. Additionally, research on the use of a handheld NIR device on other feedstuffs to determine the accuracy on other common feeds used in the dairy industry.

Figures and Tables

Table 3.1 Dry matter (%) by method

Method[1]	DM %	SEM	*P*-Value[2]
105°C Oven	38.38	0.59	-
Food dehydrator	38.73	0.59	0.02
Koster Moisture Tester	38.22	0.59	0.28
NIRu 1	35.87	0.59	0.02
NIRu 2	32.43	0.59	< 0.01
NIRu 3	32.97	0.59	< 0.01
NIRc 1	38.40	0.74	0.91
NIRc 2	38.41	0.74	0.78
NIRc 3	38.38	0.74	0.99

[1] NIRu – factory calibration; NIRc – bias-adjusted based on average difference of 105°C oven and NIRu
[2] Comparison of methods to 105°C oven (reference method)

Figure 3.1 Gathering Sample

Figure 3.2 Scanning sample with NIR device

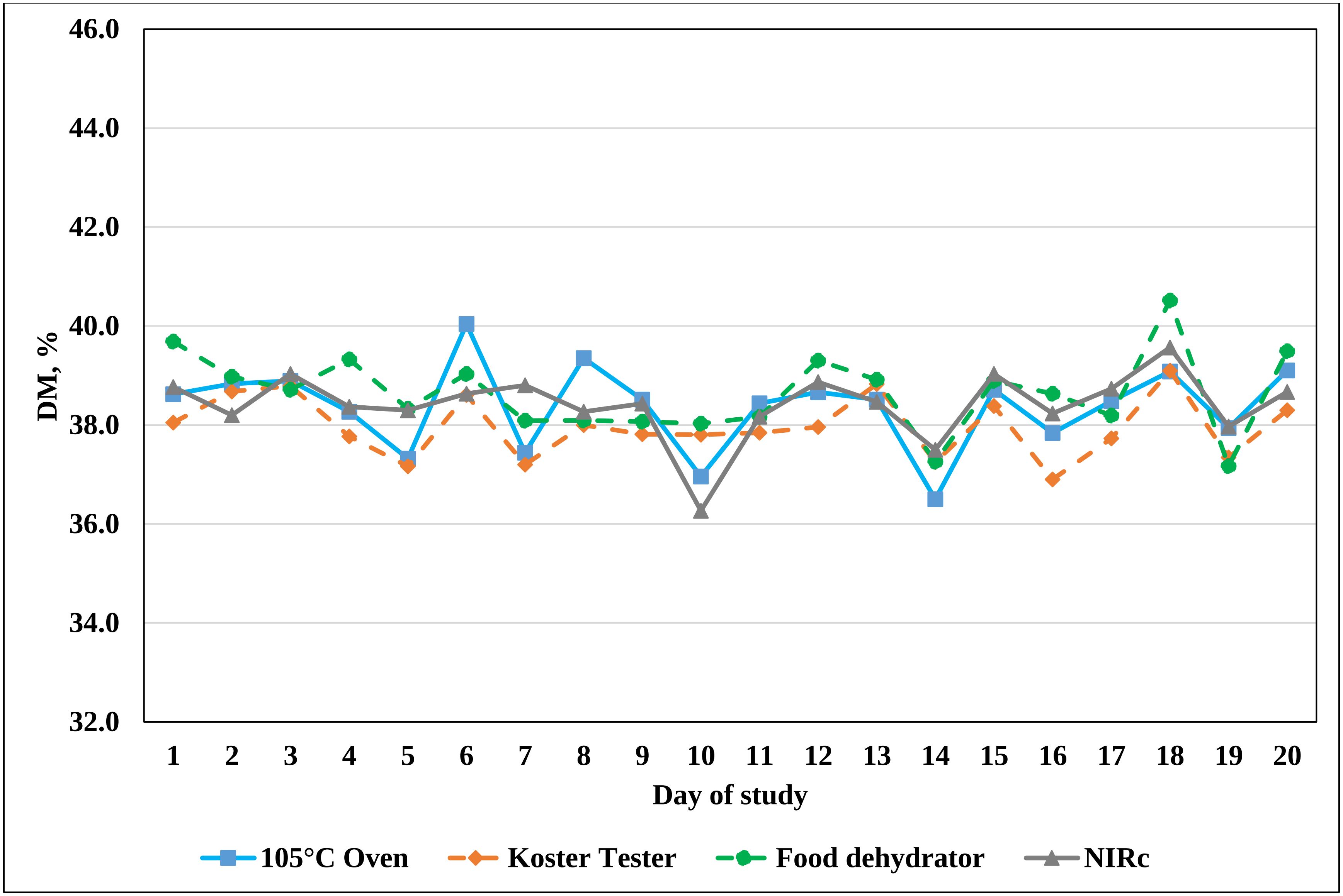

Figure 3.3 Farm 1 dry matter (%) by method over 20-d period

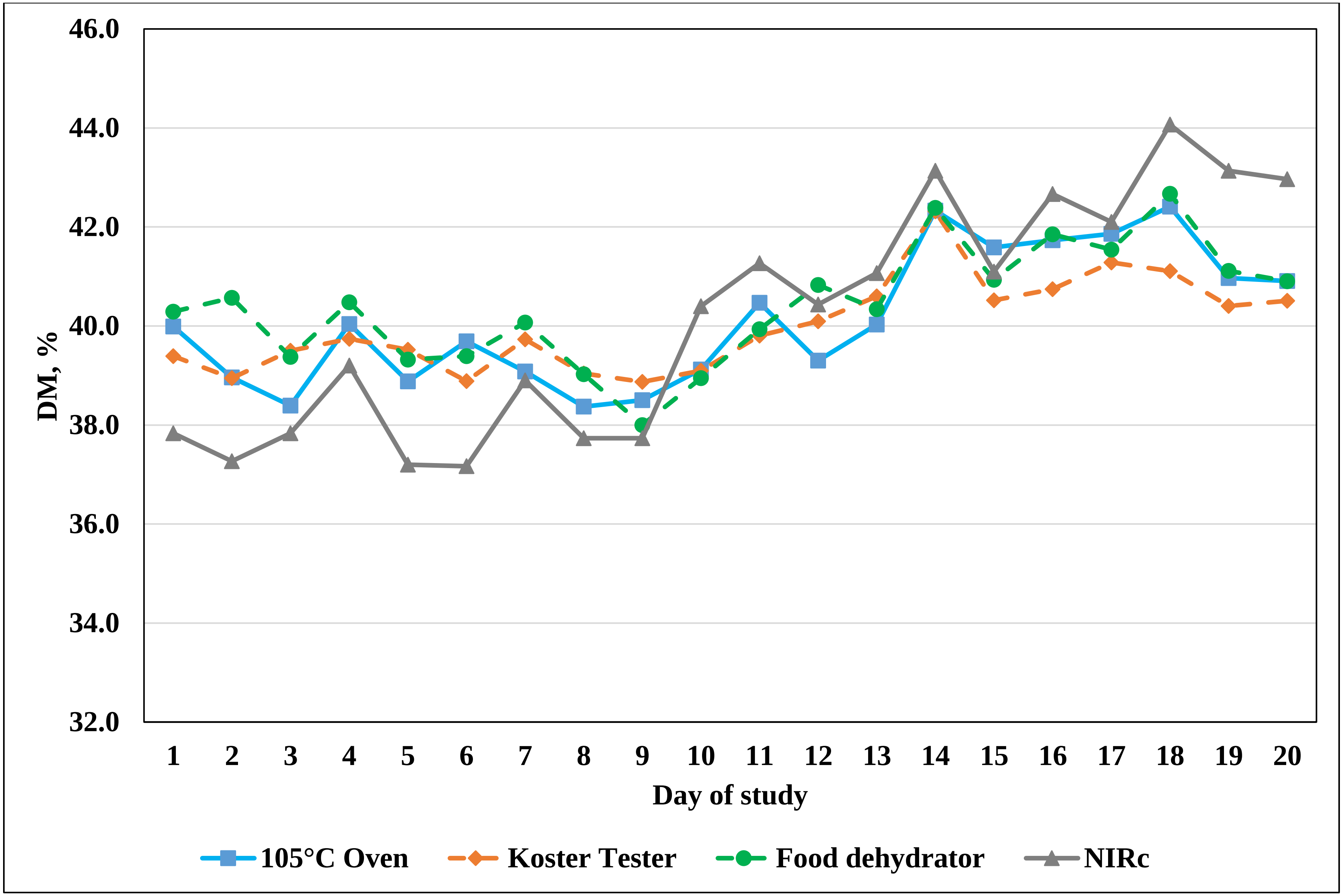

Figure 3.4 Farm 2 dry matter (%) by method over 20-d period

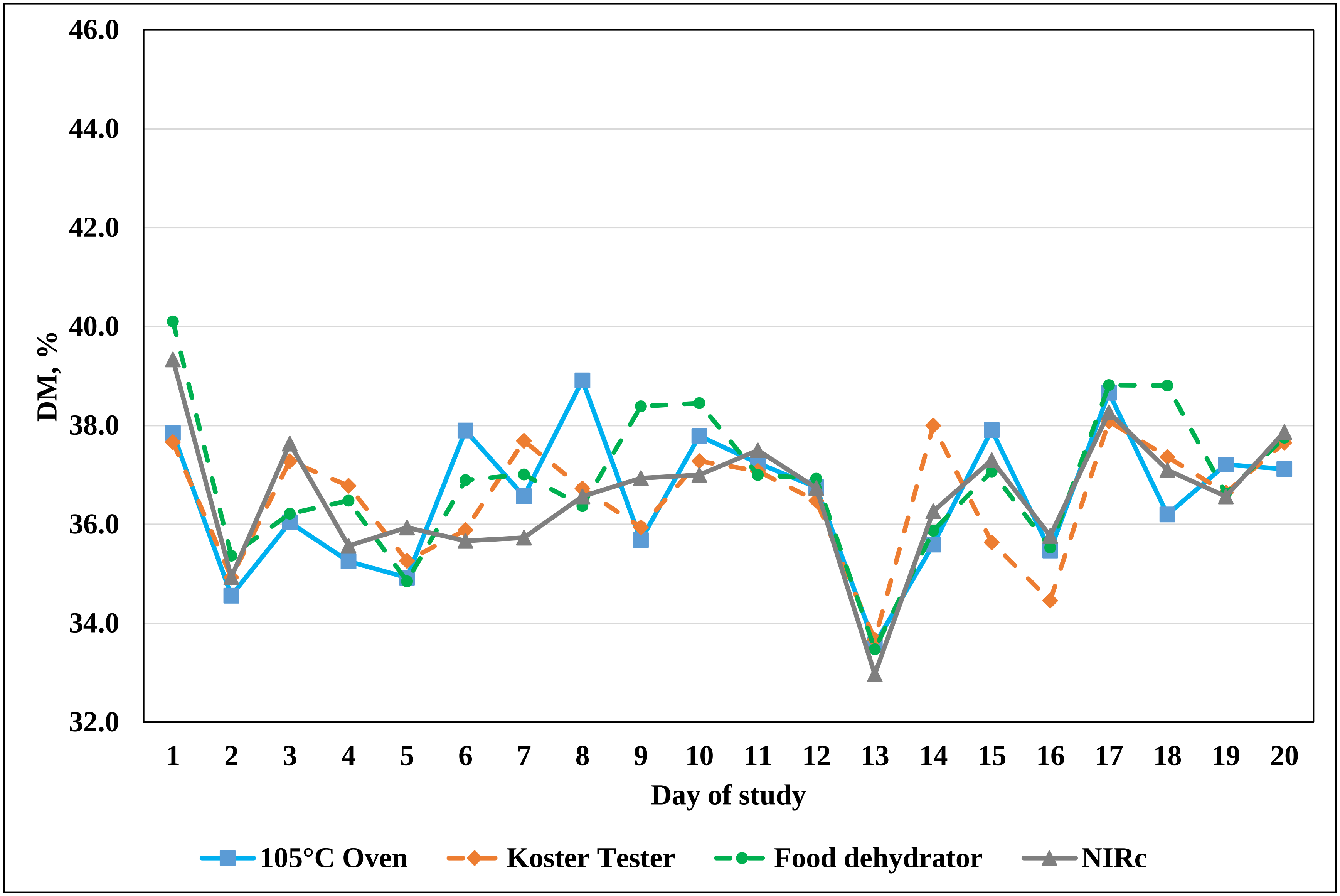

Figure 3.5 Farm 3 dry matter (%) by method over 20-d period

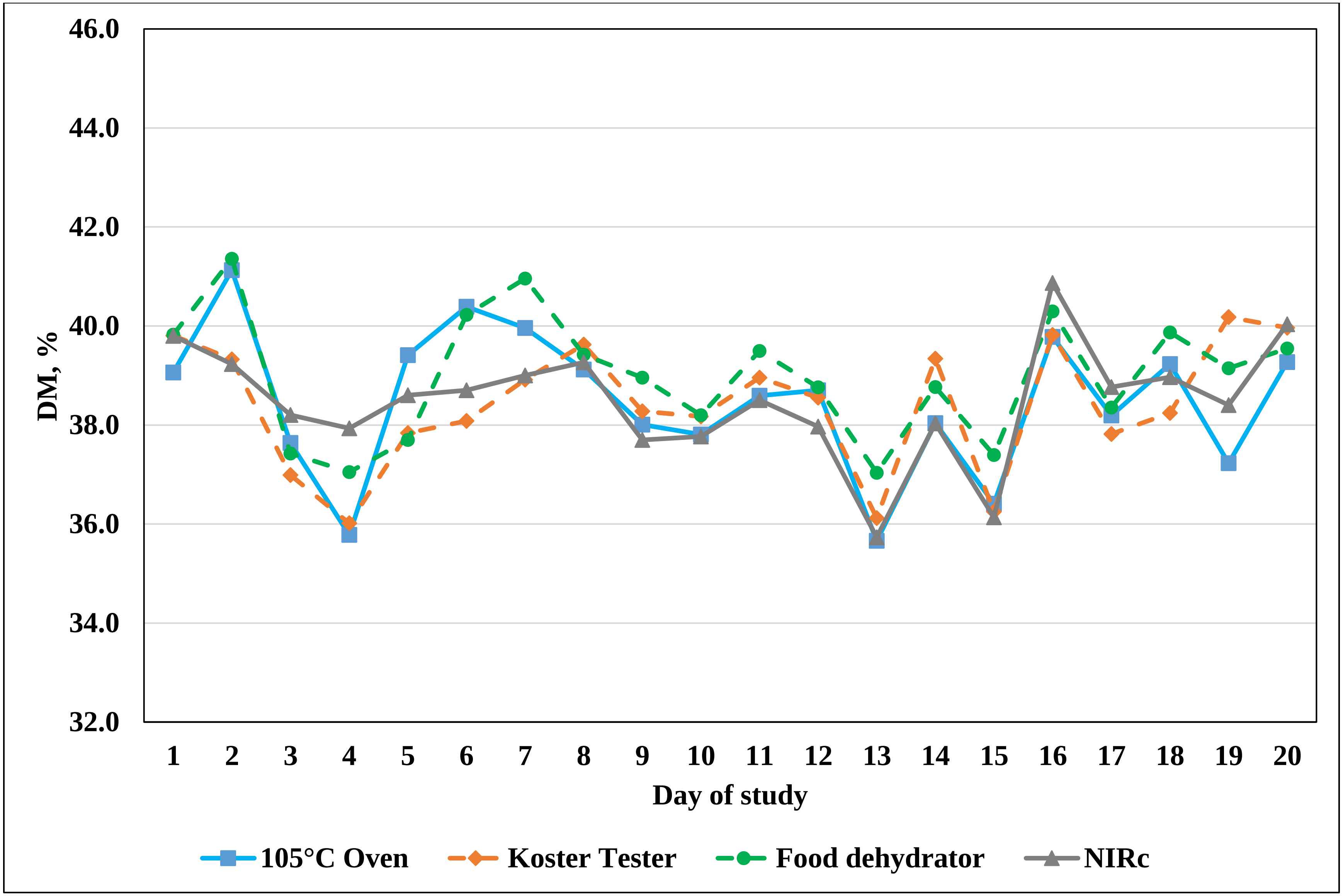

Figure 3.6 Farm 4 dry matter (%) by method over 20-d period

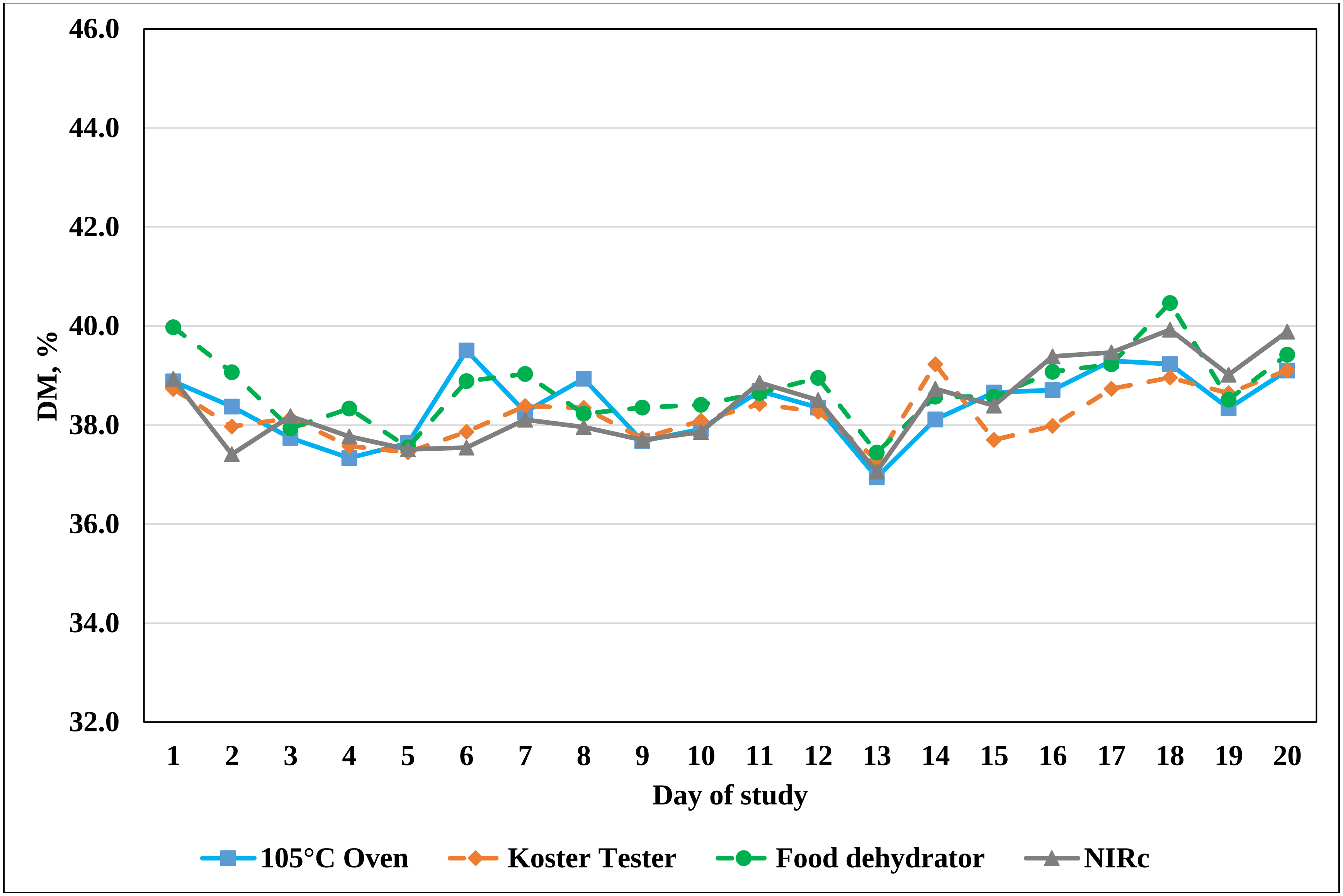

Figure 3.7 Average of all farms dry matter (%) by method over 20-d period

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Chapter 4 - Development of an integrated pest management tool for commercial dairies: feeding a pelleted supplement that is resistant to bird depredation

Abstract

An experiment was carried out to evaluate the use of a starling resistant supplement in a total mixed ration (TMR) on the lactation performance of dairy cows compared to a grain supplement in a mash form. Sixteen primi- and multiparous post-peak Holstein cows were used in a single reversal design. There were two diets formulated to be nutritionally similar: 1. TMR with the grain supplement in a mash form and 2. TMR with a grain supplement in a 0.953-cm diameter pellet. Cows were individually housed in a tie-stall barn, milked 3 times daily, and fed twice daily. Each experimental period lasted 14 days with the first 7 days for adaptation period and the last 7 days for data collection. Dry matter intake (DMI), milk production, and water intake were recorded daily. Individual feed ingredients, TMR, refusals, and milk samples were taken the last 3 d of each period. Milk samples were analyzed for components and fat-corrected milk (FCM), energy-corrected milk (ECM), and solids-corrected milk (SCM) was calculated from results. Individual feed ingredients and TMRs were analyzed for nutrient composition. TMRs and refusals were analyzed for particle size distribution using a Penn State Particle Separator. Statistical analysis was performed using PROC MIXED (SAS, version 9.4) with treatment, period, block, and all interactions as fixed effects. Particle size differed ($P < 0.05$) on the 8.0 to 19.0 mm sieve of the Penn State Particle Separator with the pelleted supplement retaining more DM as a percentage in both the TMR and refusals. This occurred as the pellet diameter did not allow it to fall through the 8 mm sieve. The results of this study showed no effect ($P > 0.05$) on DMI, feed efficiency, milk component percentage, protein yield, and solids not fat yield. However, milk production, FCM, ECM, SCM, fat yield, and lactose yield were lower significantly ($P < 0.05$) for the pelleted supplement. When feeding a 0.953-cm diameter pelleted supplement, which is resistant to starling consumption, may decrease milk production in lactating dairy cattle. However, producers must consider cost and feed loss to starling depredation when deciding on supplement form.

Keywords: pellet, mash, starling

Introduction

Nutritionists and producers formulate rations to meet the specific needs of dairy cattle to maximize production and health and any deviation could cause an economic loss. European starlings (*Sturnus vulgaris*) are an invasive species that can wreak havoc on livestock facilities, especially dairy farms. Large flocks of starlings congregate on livestock operations and exploit the large quantity of nutritious food sources (Dolbeer et al., 1978; Feare et al., 1992; Linz et al., 2007; Depenbusch et al., 2011). The loss of nutrients along with the potential for spread of harmful diseases can negatively impact performance and both cow and public health due to livestock-wildlife interactions.

Starlings are drawn to livestock operations due to the easy access to feed. They can wreak havoc to the ration presented to the animals as they have been shown to deplete the ration of the high-energy or nutrient dense feedstuffs (Feare, 1984; Depenbusch et al., 2011). Starlings have been found to eat up to 50% of their body weight per day (Forbes, 1995). The period during the early to mid-morning is when starlings primarily feed and it has been suggested that a single bird can consume up to 28.6 g per hour (Glahn and Otis, 1981). This means that a single 85 g bird could consume around 42.5 g per day and a large flock of 10,000 birds could consume about 425 kg daily. When cattle are fed diets containing steam flaked corn as the concentrate in a TMR, 44.5% of what a starling consumes is from the concentrate portion (Carlson et al., 2018).

Many studies have looked at the economic loss caused by feed depredation by starlings in both feedlots and dairy production systems. Starling depredation has been shown to cause an increase in operating expenses by $0.92/head/day in a feedlot setting (Depenbusch et al., 2011). Dairy producers in Wisconsin, New York, and Pennsylvania with ≥50 lactating cows reported losses of $9,399.14 when 1-1,000 birds were present, $22,794.26 when 1,001-10,000 birds were present, and $64,401.51 when >10,000 birds were present due to feed loss (Shwiff et al., 2012). These increase in economic losses are directly related to bird damage on farms. Major losses of nutrients can directly impact performance of the animal by decreasing weight gain (Wright, 1973; Feare and Swannack, 1978; Depenbusch et al., 2011), feed efficiency (Depenbusch et al. 2011; Carlson et al., 2018), and milk production (Carlson et al., 2018). The overall economic loss from starling depredation in the agriculture industry has been estimated over US$800 million annually (Pimental et al., 2005).

Tools preventing starling depredation have been very limited and ineffective over the years (Shwiff et al., 2012). Lethal chemical agents such as DRC-1339 (3-chloro-4-methylaniline hydrochloride) have been met with public opposition due to the slow death of infected birds and the inability to specifically target problem species (Linz et al., 2015). Nonlethal tools such as hawk kites, propane exploders, ultrasonic sounds, pyrotechnics, and others are more humane, but found to be highly ineffective in control of starling populations on livestock facilities (Linz et al., 2007). Recently, Carlson et al. (2008) looked at the use of a high-energy pellet to deter starling consumption. That study found a reduction of ≥79% in feed consumption among caged starlings when using a high-energy pellet with a diameter of 0.953-cm when compared to pellets with diameters <0.953-cm.

The objective of this study was to assess the lactation performance based on Carlson et al. (2018) findings in the use of a 0.953-cm pellet in a mid-lactation TMR to deter starling depredation.

Materials and Methods

Sixteen post-peak primi- and multiparous Holstein cows averaging 46.90 ± 4.39 kg of milk/d, 163 ± 19 DIM, 610.44 ± 19.54 kg of BW, and a BCS of 2.86 ± 0.05 were randomly assigned to one of two treatment groups using a single reversal experimental design with 8 cows per treatment group. The two treatment periods were 14 d each and included 7 d for adaptation to treatments with data and sample collection in the final 7 d of each period. Cows were housed in individual tie stalls at the Kansas State University Dairy Teaching and Research unit with free access to water, milked three times daily (0400, 1100, and 1800 h) in a double-6 milking parlor with electronic milk meter equipment. Cows were fed twice daily (1100 and 1800 h) for ad libitum intake through individual bunks located in front of each stall. Total daily feed offerings were adjusted based on previous 24-h intake so refusals were approximately 5%. Amounts fed and refused were recorded daily along with water intake. Ambient temperature and relative humidity were recorded by 2 weather stations on the farm. Barn temperature and relative humidity were recorded by 2 weather stations centrally located inside. The experimental cows were cared for according to the guidelines stipulated by Kansas State University Animal Care and Use Committee (Manhattan, KS). The health status of each animal was evaluated and recorded daily.

Diet formulation

Treatments consisted of two separate diets (Table 4.1) fed as TMR composed from a common basal mix that consisted primarily of corn silage, triticale silage, alfalfa hay, whole cottonseed, and grain mix. Treatments were as followed: Control diet (Control) – diet formulated to meet all nutrient requirements with the grain mix being in a mash form; Test diet (Test) – diet formulated to meet all nutrient requirements with the grain mix being in a pellet with a diameter of 0.953-cm. Both diets were formulated to be nutritionally similar (Table 4.1) using CPM dairy model (Cornell-Penn-Minor, Cornell University, Ithaca, NY, USA), an applied mathematical nutritional model to predict lactating dairy cow performance.

Prior to the start of the experiment, samples of forages were analyzed. Grain mix for both the control and test diets, as well as the initial diets were formulated based on the forage analysis. Ingredients of the grain mix are outlined in Table 4.2. Grain mixes were manufactured at the O. H. Kruse Feed Technology Innovation Center (Kansas State University, Manhattan, KS) in eight 1-ton batches. Whole grain ingredients were ground with a 3-high roller mill (Model 924, RMS Roller Grinder, Harrisburg, SD). Individual ingredients were weighed on certified scales and then mixed for 180 seconds at room temperature in a Hayes & Stolz – 1 ton, (Model TRDB63-0152) counterpoise mixer. Each batch was split with 47.5% kept in mash form for feeding and 52.5% to be used for pelleting in order to reduce diet variability. Mash feed was stored until feeding.

Pelleting Procedure

Pellets were produced from mash mix from grain mixing procedure. The pellets were made via steam conditioning (10” width x 55” length Wegner twin staff pre-conditioner, Model 150) and subsequently using a 1-ton 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) equipped with a 0.953-cm x 7.62-cm pellet die. Mash mix was placed into the hopper of the pellet mill and fed at a constant rate for the duration of the pelleting process. Conditioning temperature of 74.20 ± 0.40°C was achieved by adjusting steam addition using 25-30 PSI steam pressure. Conditioner retention time was held constant throughout the duration of process. Average hot pellet temperature was 83.01 ± 0.45°C throughout the duration of the process. Average production rate was 914.50 ± 2.66 kg per hour throughout the duration of the process. Pellets were then placed in a counter-flow cooler below the pellet mill and held until cool. They were then stored in totes until feeding. A sample of pellets was taken and tested for pellet durability index (PDI) using the modified version of ASAE S269.5 (2012). Pellets were sieved for fines and then 500 ± 5g was taken and placed into tumbling can device with three 1.90-cm hex nuts. The device was ran for 10 min and then sample was sieved again using same screen to obtain final weight. PDI was calculated dividing final weight by the initial weight of sample and expressed as a percentage. The PDI procedure was replicated 4 times for this study and results were averaged for an average PDI percentage.

Experimental Measures

Daily intake was calculated from feed offered and refused and recorded daily throughout experiment. Water intake and total milk production was measured and recorded daily throughout the experiment. Individual feed ingredients, basal and treatment TMR, and refusals were sampled the final 3 d of each period and were frozen (-20°C) until further analysis. Milk samples were collected during each milking on the final 3 d of each period, preserved using 2-bromo-2-nitropropane-1,3 diol, and shipped to MQT Lab Services (Kansas City, KS) to be analyzed for fat, protein, lactose, SNF, MUN, and somatic cells. Fecal grab samples were taken from the rectum of each animal on days 11, 12, and 13 every 6 h with the time advancing 2 h each successive day. Fecal samples were frozen (-20°C) and stored until further analysis. BW and BCS (1-5 scale) were measured and recorded on days 1, 2, 13, and 14 for each period after the 1100 h milking for each experimental period.

Sample Analysis

Individual feed samples for each 14 d period were thawed at room temperature and then composited by period. Two subsamples were taken and dried in a 55°C forced-air oven for 72 h for partial DM determination and the remainder was frozen (-20°C) and stored for future analysis. The two subsamples were then combined and were then ground to pass through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA).

Basal and treatment TMR samples for each 14 d period were thawed at room temperature and then composited by period. Two subsamples were taken and run through a Penn State Shaker Box and the remainder was frozen (-20°C) and stored for future analysis. These subsamples were then dried in a 55°C forced-air oven for 72 h for partial DM determination. The two subsamples were then combined and were ground to pass through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA).

Once ground, individual feed ingredients, and TMR samples were then shipped to Rock-River Laboratories (Watertown, WI) for analysis. DM content was determined by drying samples at 105°C for 3 hours in a forced-air oven. CP analysis was performed with an Elementar Rapid N Cube (Elementar Analysensysteme, Langenselbold, Germany; AOAC 990.03). Wet chemistry techniques of Goering and Van Soest (1970) were used to determine NDF (α-amylase and sodium sulfite), ADF and lignin (non-sequential). ADIA was determined after ADF determination (Goering and Van Soest, 1970; non-sequential) by placing the sample in 500°C furnace for 4 hours (AOAC 942.05). Starch content was determined by the wet chemistry techniques of Hall (2008). Macro and micro minerals were analyzed using inductively coupled plasma-optical emission spectrometer (Perkin Elmer Optima 8300, PerkinElmer, Inc., Waltham, MA; AOAC 985.01).

Refusal samples for each 14 d period were thawed at room temperature and then composited by cow within period. Two subsamples were taken and run through a Penn State Shaker Box and the remainder was frozen (-20°C) and stored for future analysis. These subsamples were then dried in a 55°C forced-air oven for 72h for partial DM determination. Subsamples were then combined and stored at room temperature for future analysis.

Milk samples were analyzed for concentrations of fat, true protein, SNF, and lactose by infrared absorbencies (B-2000 Infrared Analyzer; Bentley Instruments, Chaska, MN). Milk urea nitrogen was quantified colorimetrically (MUN spectrophotometer, Bentley Instruments) and somatic cells were counted using dual laser flow cytometry (SCC 500, Bentley Instruments; MQT Lab Services, Kansas City, KS). Energy-corrected milk yield was calculated as follows: 0.327 x milk yield + 12.95 x fat yield + 7.2 x protein yield. Solids-corrected milk production was calculated as: 12.3 x fat yield + 6.56 x SNF yield + 0.0752 x milk yield. 4% Fat corrected milk was calculated as: 0.4 x milk yield + 15 x milk fat yield. Prior to statistical analysis, milk component data was averaged from the 3 samples per day per cow so that there were 3 samples per cow per period.

Statistical Analysis

The PROC MIXED procedure of SAS (Version 9.4, SAS Institute, Inc., Cary, NC) was used for all statistical analysis. Feed intake, milk production, milk composition, milk component yield, BW and BCS data were analyzed as a single reversal design with treatment, block, period, and all interactions as fixed effects. Data for barn and ambient conditions were averaged by h and h*period prior to analysis. Average mean temperature humidity index (THI) data was calculated using the formula THI = (9/5 x Tdb + 32) – [0.55 – (0.55 x RH/100)] x [(9/5 x Tdb + 32) – 58]. Significance was declared at $P < 0.05$.

Results

Both the composition and nutrient densities of the control and test diets are outlined in Table 4.1. The mash and pellet nutrient compositions are found in Table 4.3. Ingredient composition percentages for the control and test diets differed slightly due to the mash supplement having a higher DM content than the pelleted supplement. Both diets were formulated to be high in CP for mid-lactation cows as to not be a limiting factor in this study. Pre- and post-study analysis using CPM dairy model (Cornell-Penn-Minor, Cornell University, Ithaca, NY, USA) and nutrient analysis found that both diets met nutrient requirements according to the NRC (2001). Pellet durability index results was 86.72% for the average of the four replications.

There was no difference in dry matter intake ($P = 0.186$) between the control and test diets (Table 4.4). There was no difference ($P > 0.05$) in starch, CP, NDF, or ADF intakes between the two diets. However, lignin, ADIA, and uNDF 240 intakes were greater ($P < 0.05$) for cows consuming the control diet. Additionally, Ca, P, Mg, and S intakes were higher ($P < 0.05$) in the control diet when compared to the test diet. This could be explained by higher concentrations of those minerals in the mash grain supplement.

Milk production, FCM, ECM, and SCM were significantly higher ($P < 0.05$) when cows were fed the control diet (Table 4.4). Milk component percentages, milk protein yield, and SNF yield were similar in both diets ($P \geq 0.05$), while milk fat and lactose yields were higher ($P < 0.05$) for the control diet (Table 4.5). Both treatments resulted in similar feed efficiencies ($P > 0.05$) despite the control having higher milk production, FCM, ECM, and SCM. In this trial, SCC did not differ ($P > 0.05$) between treatments. Milk urea nitrogen was similar ($P > 0.05$) between the two treatments and both levels appeared to be adequate for optimal milk production. There was no significant ($P > 0.05$) treatment effect on water intake, body weight change, or body condition score change for this trial.

There was a significant ($P < 0.05$) period effect for DMI, milk production, FCM, ECM, SCM (Table 4.4). This can be associated with decreases for each one across each period for both diets. Weather played a factor in these decreases as this study was performed during the summer months. Barn temperature, relative humidity, and THI were significantly different ($P < 0.05$) than ambient conditions across the study with temperature and THI being lower in the barn (Figures 4.1, 4.2, and 4.3). Across periods, both ambient and barn temperature and THI were higher ($P < 0.05$) for period 2, with no effect of period ($P = 0.68$) for relative humidity (Figures 4.4, 4.5, and 4.6). Additionally, all cows in this study were becoming more advanced in lactation as the study progressed. There was also a significant ($P < 0.05$) period effect for milk fat, lactose, and SNF yield, as well as milk protein percentage (Table 4.5). Milk protein percentage increased ($P < 0.05$) as milk protein yield did not differ ($P > 0.05$) between periods. Even as a period effect was seen, there were no significant ($P > 0.05$) treatment x period interactions in this study.

The pre-feeding TMR and 24h post-feeding Penn State Particle Separator results are outlined in Table 4.6. Both diets had similar ($P > 0.05$) particle size distribution on > 19.0 mm and 1.18-8.0 mm screens, however the control diet was higher ($P < 0.05$) on the < 1.18 mm screen and the test diet were higher ($P < 0.05$) on the 8.0-19.0 mm screen. The difference in particle size distribution was seen as the 0.953-cm diameter of the pellet did not allow them to pass through the 8 mm screen. The results for the refusals followed the same pattern as the pre-feeding TMR with the > 19 mm and the 1.18-8.0 mm screens being similar ($P > 0.05$), and the control diet being higher ($P < 0.05$) on the < 1.18 mm screen and the test diet being higher ($P < 0.05$) on the 1.18-8.0 mm screen.

Discussion

With the push to be more environmentally and economically conscientious in recent years, the exploration for a humane control of European starlings has been increasing. Carlson et al. (2018) studied the use of a 0.953-cm diameter pelleted supplement to decrease bird depredation of rations and found a ≥79% reduction in bird consumption of that diet. Our study was designed to test the efficacy of that pellet in post-peak Holstein cows. The use of pellets in total mixed rations has not been extensively researched over the years. Much of the research available has been dedicated to determining the efficacy of a pelleted grain supplement to a mash grain supplement. These studies have focused on the impacts of a pelleted supplement on milk and milk component production in lactating cows.

The main impact found in this study was the effect of milk production, FCM, ECM, and SCM yields. Previous research has found an increase in milk production when feeding a pelleted supplement, however physical form of the supplement had no effect on SCM or FCM (Titgemeyer and Shirley, 1997; Keyserlingk et al., 1998). However, in the current study we found a decrease ($P < 0.05$) in milk production, FCM, ECM, and SCM in cows that were fed a pelleted supplement.

Producers are paid based on components in milk, so they receive high importance when selecting diets to optimize cow performance. As early as 1956, Adams and Ward found that when feeding a pelleted supplement, milk fat yield decreased. This finding has been supported in more recent literature (Hawkins et al., 1963; Haelein et al., 1968) and in this current study where we observed a significant ($P < 0.05$) 0.07 kg decrease in milk fat yield. Keyserlingk et al. (1998) found that milk protein yield was affected by physical form of a grain supplement in favor of pellets, which is supported by past literature (Haelein et al., 1968; Titgemeyer and Shirley, 1997). In the current study, while we did not find a significant difference, there was a tendency ($P < 0.10$) for milk protein yield to be lower when cows were fed the pelleted supplement. The lower milk fat yield and lower milk production, along with similar milk protein yield, may help explains the lesser FCM, ECM, and SCM yields observed in this trial.

When cows select for or against longer particles in a TMR it is described as sorting behavior (Gonzalez et al., 2015). Leonardi and Armentano (2003) found that cows typically will sort for the grain component of the TMR, leaving the longer or coarser components behind. This behavior could possibly lead to subacute ruminal acidosis which can cause lower feed intake and decreased milk fat (Heinrichs and Kononoff, 2002; Kononoff et al., 2003; Schroeder et al., 2003). In the current study, the mash supplement offered an increased proportion of fine particles and a lesser proportion of medium particles than the pellet supplement. This could be found as the diameter of the pellets did not allow for them to pass through the 8.0 mm screen. Cows from both diets ate a larger proportion of longer particle sizes seen by the decrease in DM retained on the > 19 mm screen. However, the middle screen (8.0 to 19.0 mm) in the control diet did not change from pre- to 24h post-feeding, but the test diet decreased by almost 18% on a DM basis. Heinrichs and Kononoff (2002) suggested that if particle size distribution of feed in the bunk over time differs more than 3 to 5% from the original TMR distribution, sorting may be occurring. This data suggest cows were sorting for particles held on the middle screen, which consisted of the pelleted supplement. However, when looking at the PDI of the pellets it is possible that pellets were broken down in the bunk and created more fines. The action of pellets breaking down to finer particles could explain the decrease of DM retained on the 8.0 – 19.0 mm screen and the increase of DM on the < 1.18 mm screen for the test diet. The PDI of 86.72% was fairly low, which would result in more fines after transport and mixing. One thing to note is that both diets in this study did not fall under the recommended guidelines outlined by Heinrichs and Kononoff (2002) for particle size distribution in TMR’s. Both the control and test diet are higher than the recommended distribution of 2-8% on the > 19 mm screen at 12.50 and 16.57%, respectively. Heinrichs and Kononoff (2002) recommend a particle distribution of 30-50% on the

8.0 – 19.0 mm screen. The control diet is in this range at 39.63%, while the test diet is outside of this range at 61.22%. The recommended distribution on the 1.18 – 8.0 mm screen is 30-50% and both the control and test diet are well below that range at 7.70 and 6.79%, respectively. The particle size distribution of 15.43% for the test diet on the < 1.18 mm screen fits inside the recommended range of ≤ 20%, while the control diet was higher than the range at 40.21%.

In this current study, milk production was lower when feeding a pelleted grain supplement to post-peak lactating dairy cows when compared to the supplement in mash form. However, this was without starlings present to consume feed. Carlson et al. (2018) looked at an NRC (2001) dairy production model to estimate the loss of performance by starling depredation. They found that after starlings had consumed feed, there was a 3.9 Mcal/d decrease in TMR presented to lactating cows. The Mcal/d for this study was 34.6 Mcal/d for the control diet and 32.9 Mcal/d for the test diet. When using a 3.9 Mcal/d decrease for starling consumption on the control diet, that isn't resistant to starling depredation, the control diet supplies cows with 30.7 Mcal/d. This is 2.1 Mcal/d lower than the test diet. This decrease in Mcal/d supplied in the control diet would negatively impact performance in cows fed that diet. According to the NRC (2001), 0.749 Mcal is needed to produce 1 kg of 4% FCM. When looking at the decrease of 3.9 Mcal/d due to starling consumption, this would decrease milk production by 5.2 kg of 4% FCM. Producers should talk with nutritionists and feed mill representatives to determine cost efficiency of using a pelleted supplement vs. mash supplement when formulating rations.

Conclusion

The use of a pelleted grain supplement in the test diet resulted in lower milk production, FCM, ECM, and SCM to the mash grain supplement in the control diet with a similar DMI and feed efficiencies. However, when using the NRC (2001) prediction model by Carlson et al.

(2018) the energy content of the test diet would be more suitable to maintain milk production than the control diet when starlings are present on dairy farms. Another benefit of the pelleted supplement would be the reduction of excretions from starlings on feed and the effect they have on palatability and/or DMI. Producers should weigh options of cost and feed loss when considering using a pelleted supplement as a starling deterrent. Future cost analysis research needs to be conducted the pelleted supplement as a starling resistant supplement on dairy production facilities.

Figures and tables

Table 4.1 Ingredient and nutritional composition of both basal and treatment diets

	Control	Test
Ingredient, % of DM		
Corn silage	23.92	24.01
Triticale silage	7.18	7.21
Alfalfa hay	19.31	19.39
Whole cotton seed	4.09	4.11
Mash	45.49	-
Pellet	-	45.28
Nutrient, % of DM		
DM, % as-fed	52.84	52.63
CP	19.96	19.73
ADF	20.87	20.80
NDF	31.47	32.32
Starch	19.01	20.51
Ash	7.23	7.07
ADIA	4.19	3.11
Lignin	4.92	4.93
uNDF 240	14.96	13.52
Ca	1.08	0.85
P	0.55	0.47
Mg	0.48	0.38
K	1.66	1.63
S	0.26	0.23

Table 4.2 Ingredient (%) composition of mash and pellet mix

Ingredient	Amount (%)
Dry-rolled corn	39.14
Corn dried distiller’s grain	21.26
Soybean meal (dehulled)	10.70
Cotton seed meal	9.93
Ground wheat	9.61
Soybean Oil	0.53
Limestone	0.53
Mono Calcium Phosphate	0.35
Sodium selenite	0.06
Salt	0.35
Copper sulfate	0.01
Zinc Sulfate	0.02
Sodium bentonite	3.55
Vitamin A 66,138 IU/kg	0.03
Vitamin D 66,138 IU/kg	0.01
Vitamin E 44,092 IU/kg	0.02
Min-AD[1]	3.72

[1] Magnesium limestone (Papillon Agricultural Company, Easton, Maryland)

Table 4.3 Nutrient composition (% of DM) of mash and pellet

Nutrient, % of DM	Mash	Pellet
DM, % as-fed	89.36	88.60
CP	22.80	22.30
ADF	6.23	5.97
NDF	16.20	17.99
Starch	30.53	33.97
Ash	7.28	7.32
ADIA	4.34	1.96
uNDF 240	9.85	6.93
Ca	1.61	1.11
P	0.78	0.61
Mg	0.82	0.64
K	0.92	0.85
S	0.36	0.29

Table 4.4 Effects of treatment on performance of lactating cows

	Control	Test	SEM	*P* Treat	*P* Period	*P* Treat*Period
DMI, kg/d	26.77	25.90	0.60	0.186	0.008	0.885
Milk, kg/d	38.54	36.23	1.18	0.037	0.013	0.422
FCM[1]	36.61	34.64	1.20	0.031	0.014	0.706
ECM[2]	39.04	36.95	1.20	0.040	0.024	0.688
SCM[3]	42.98	40.56	1.30	0.039	0.024	0.682

[1] Fat Corrected Milk = (0.4 x kg of milk) + (15 x kg of milk fat).
[2] Energy Corrected Milk = (0.327 x kg of milk) + (12.95 x kg of milk fat) + (7.2 x kg of milk protein).
[3] Solid Corrected Milk = (0.0752 x kg of milk) + (12.3 x kg of milk fat) + (6.56 x kg of SNF).

Table 4.5 Effects of treatments on milk components and other measures

	Control	Test	SEM	*P* Treatment	*P* Period	*P* Treat*Period
<u>%</u>						
Fat	3.67	3.71	0.08	0.578	0.243	0.343
Protein	2.94	2.95	0.03	0.600	0.008	0.433
Lactose	4.89	4.85	0.04	0.318	0.057	0.555
SNF[1]	8.99	8.96	0.06	0.539	0.250	0.350
<u>kg/d</u>						
Fat	1.41	1.34	0.05	0.048	0.030	0.944
Protein	1.13	1.07	0.04	0.092	0.129	0.611
Lactose	1.88	1.76	0.06	0.048	0.012	0.464
SNF[1]	3.46	3.25	0.12	0.055	0.036	0.531
<u>Other measures</u>						
SCC x 1,000, cells/ ml	279	261	141	0.750	0.593	0.427
MUN, mg/dL	16.55	16.13	0.52	0.154	0.100	0.493
Starting body weight, kg	609.93	610.95	19.54	0.863	0.506	0.676
Body weight change, kg	44.15	8.27	27.18	0.356	0.522	0.658
Body condition score change[2]	0.07	-0.01	0.03	0.094	0.055	0.458
Water intake, L/d	107.55	105.51	3.13	0.493	0.402	0.450

[1] Solids not fat.

[2] Five point scale where 1 = very thin and 5 = very fat

Table 4.6 Effect of diet on particle size determination of total mixed ration pre- and 24h post-feeding

	Pre-feeding				24h post-feeding			
	Control	Test	SEM	P Diet	Control	Test	SEM	P Diet
DM retained, %								
> 19.0 mm	12.50	16.57	1.44	0.198	7.41	7.72	0.09	0.787
8.0 to 19.0 mm	39.63	61.22	2.11	0.019	35.03	43.45	1.28	< 0.001
1.18 to 8.0 mm	7.70	6.79	0.85	0.546	11.85	11.46	0.22	0.099
< 1.18 mm	40.21	15.43	0.70	0.022	45.71	37.37	1.92	0.005

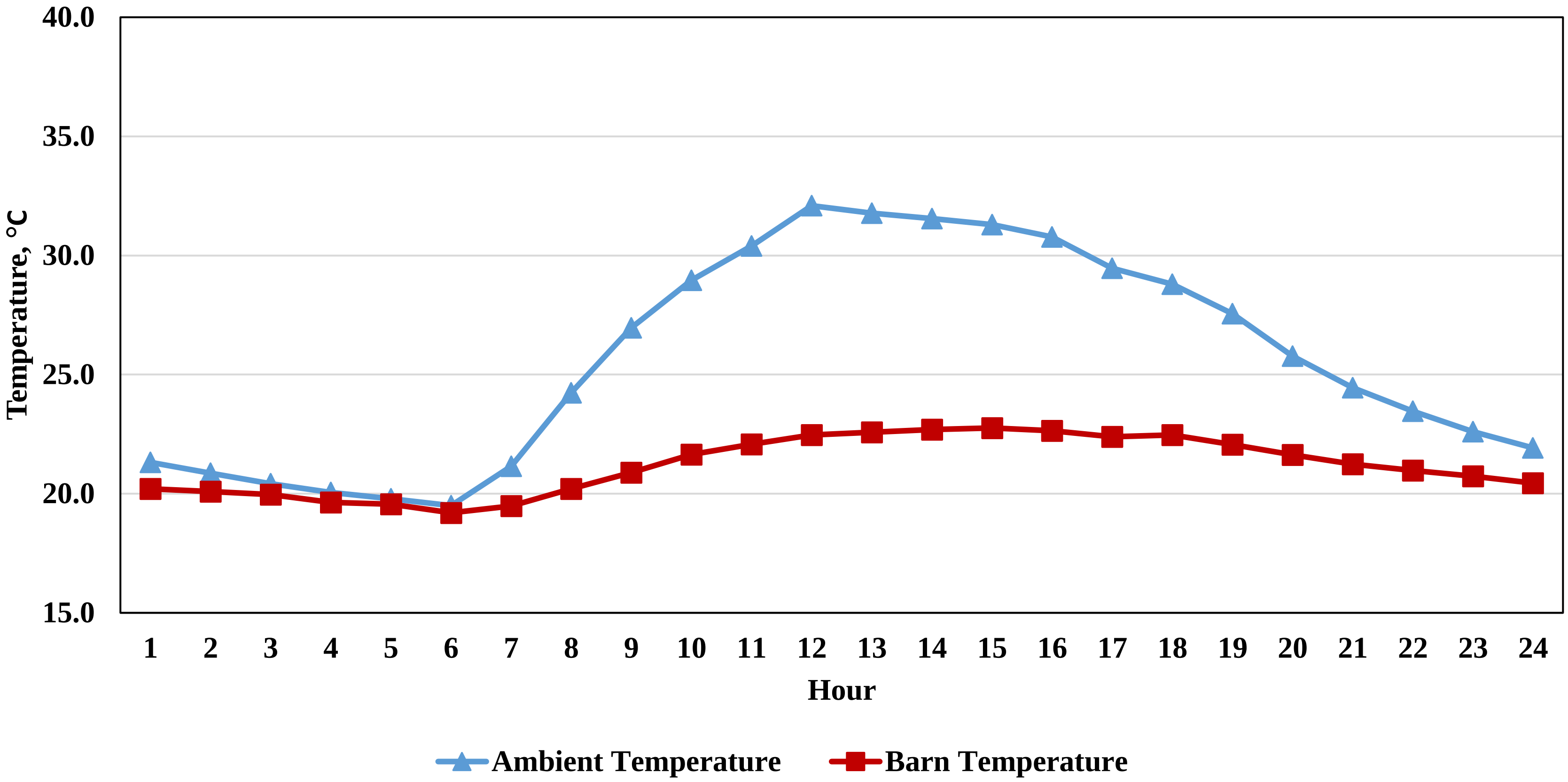

Figure 4.1 Average ambient and barn temperature (°C) by hour over both periods

SEM = 0.41
Location effect: P < 0.001
Location*h effect: P < 0.001

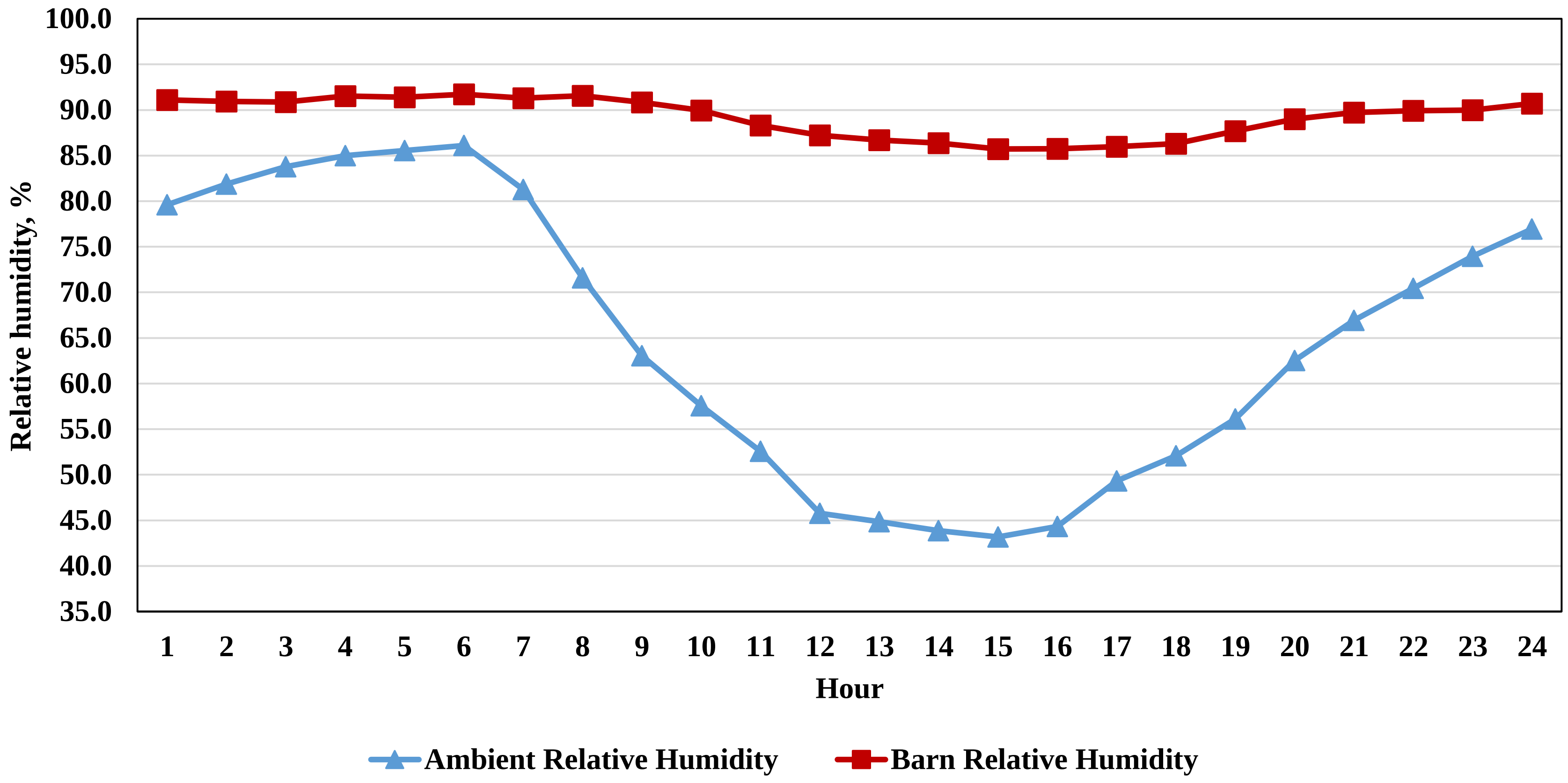

Figure 4.2 Average ambient and barn relative humidity (%) by h over both periods.

SEM = 1.80
Location effect: P < 0.001
Location*h effect: P < 0.001

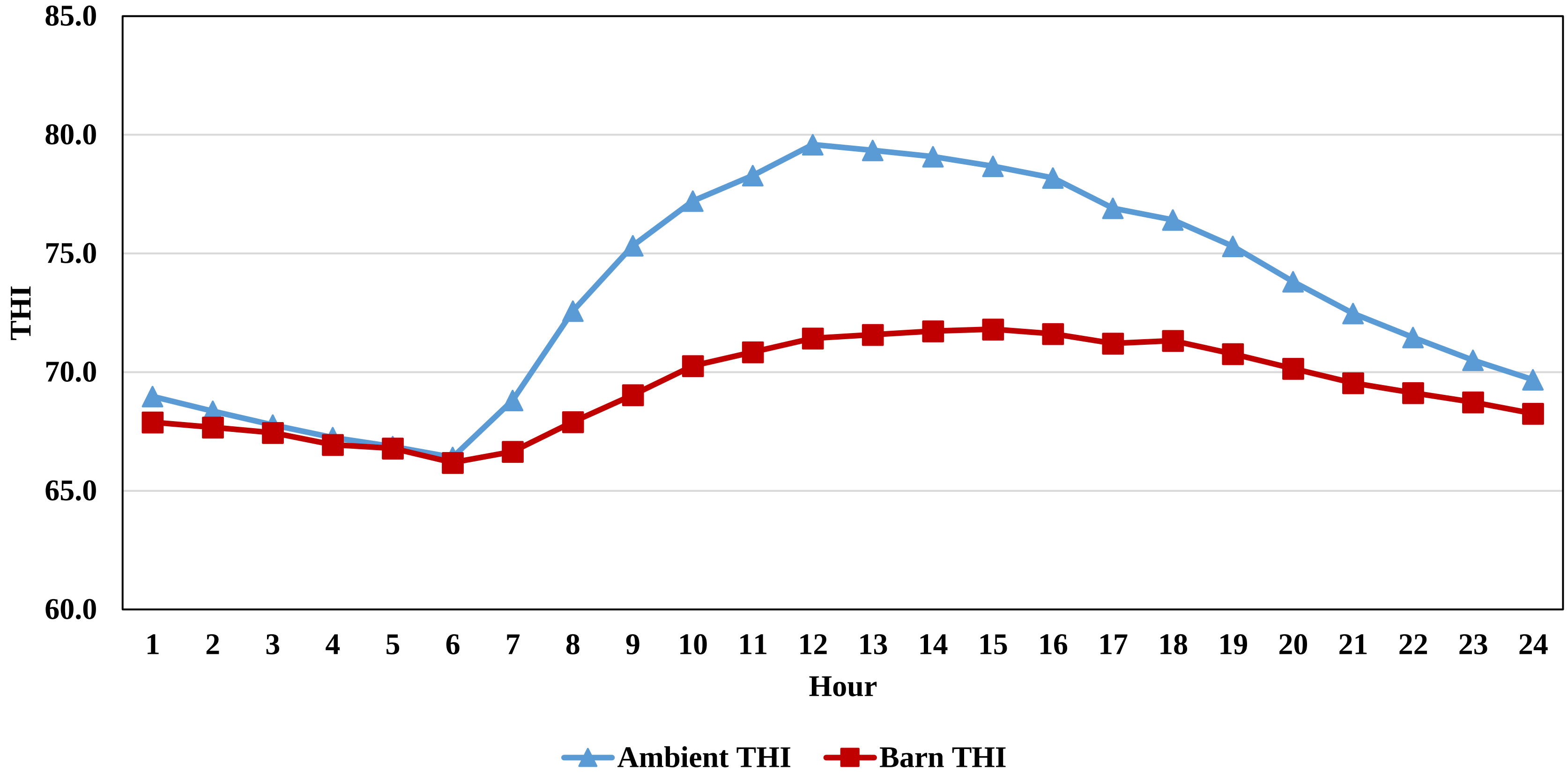

Figure 4.3 Average ambient and barn THI by h over both periods.

SEM = 0.47
Location effect: P < 0.001
Location*h effect: P < 0.001

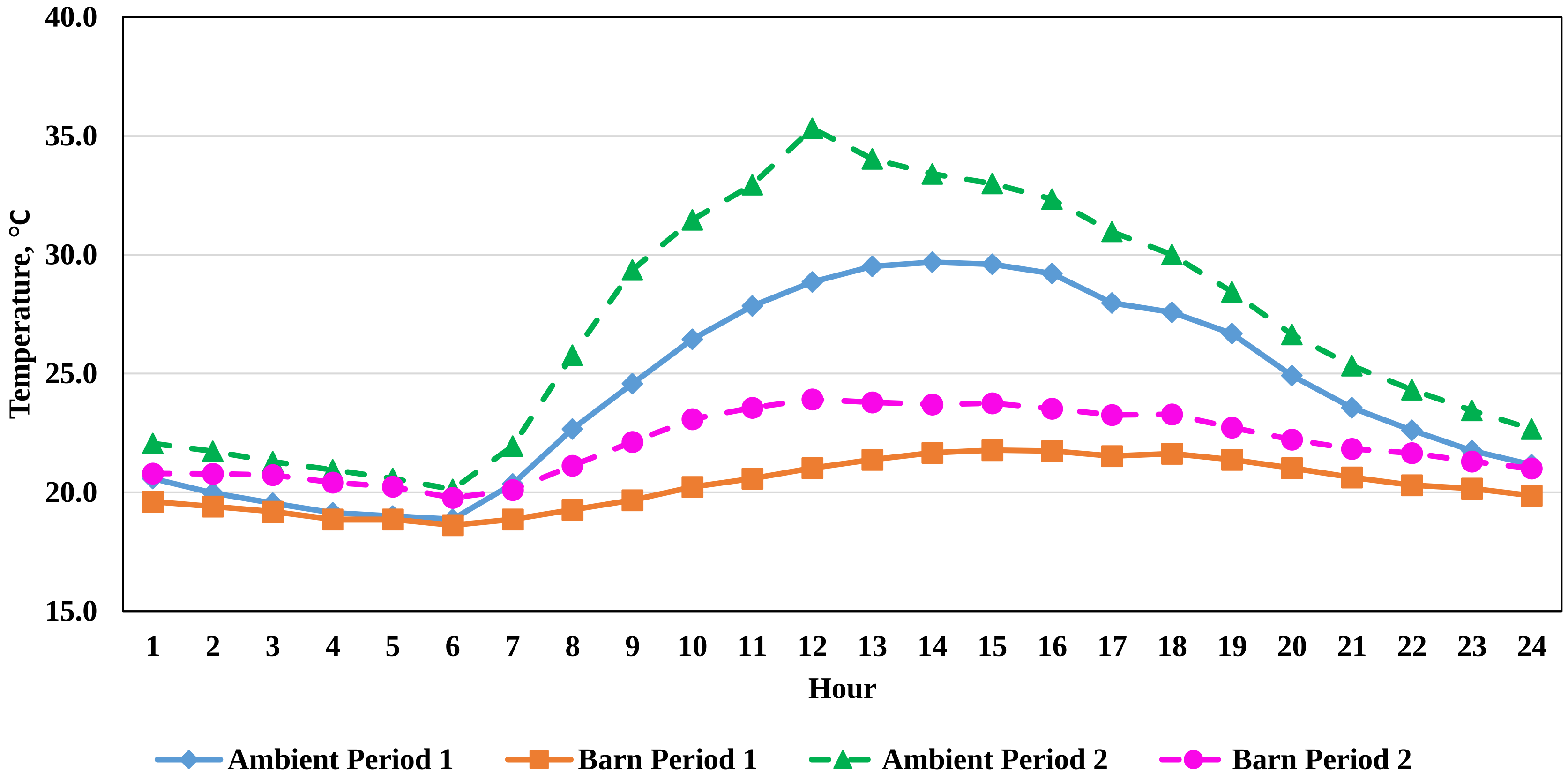

Figure 4.4 Ambient and barn temperature (°C) by period

SEM = 0.55
Period effect: $P < 0.001$
Period*h effect: $P < 0.001$
Location*period*h effect: $P < 0.05$

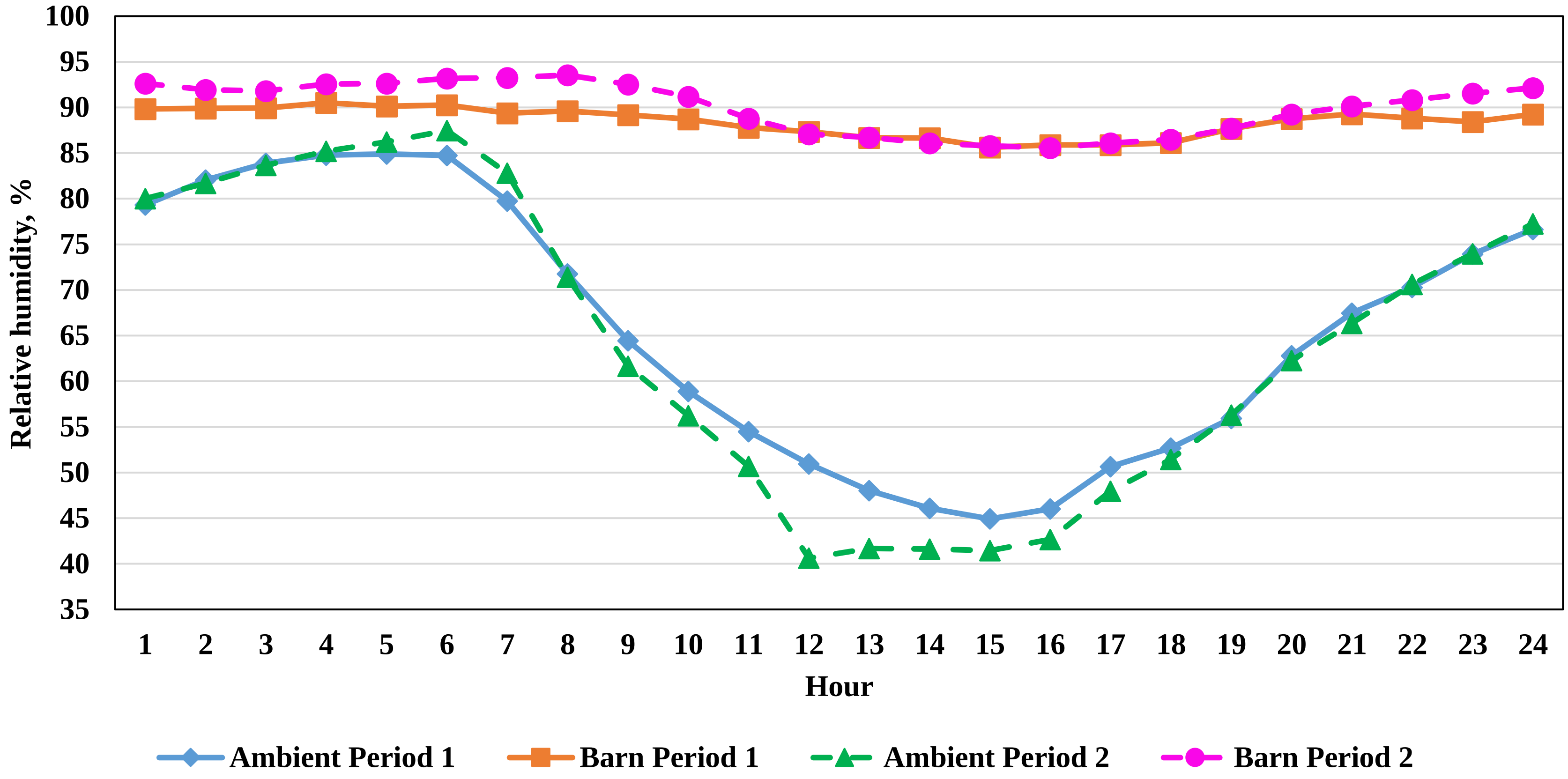

Figure 4.5 Ambient and barn relative humidity (%) by period

SEM = 2.30
Period effect: P = 0.86
Period*h effect: 0.48
Location*period*h effect: P = 0.68

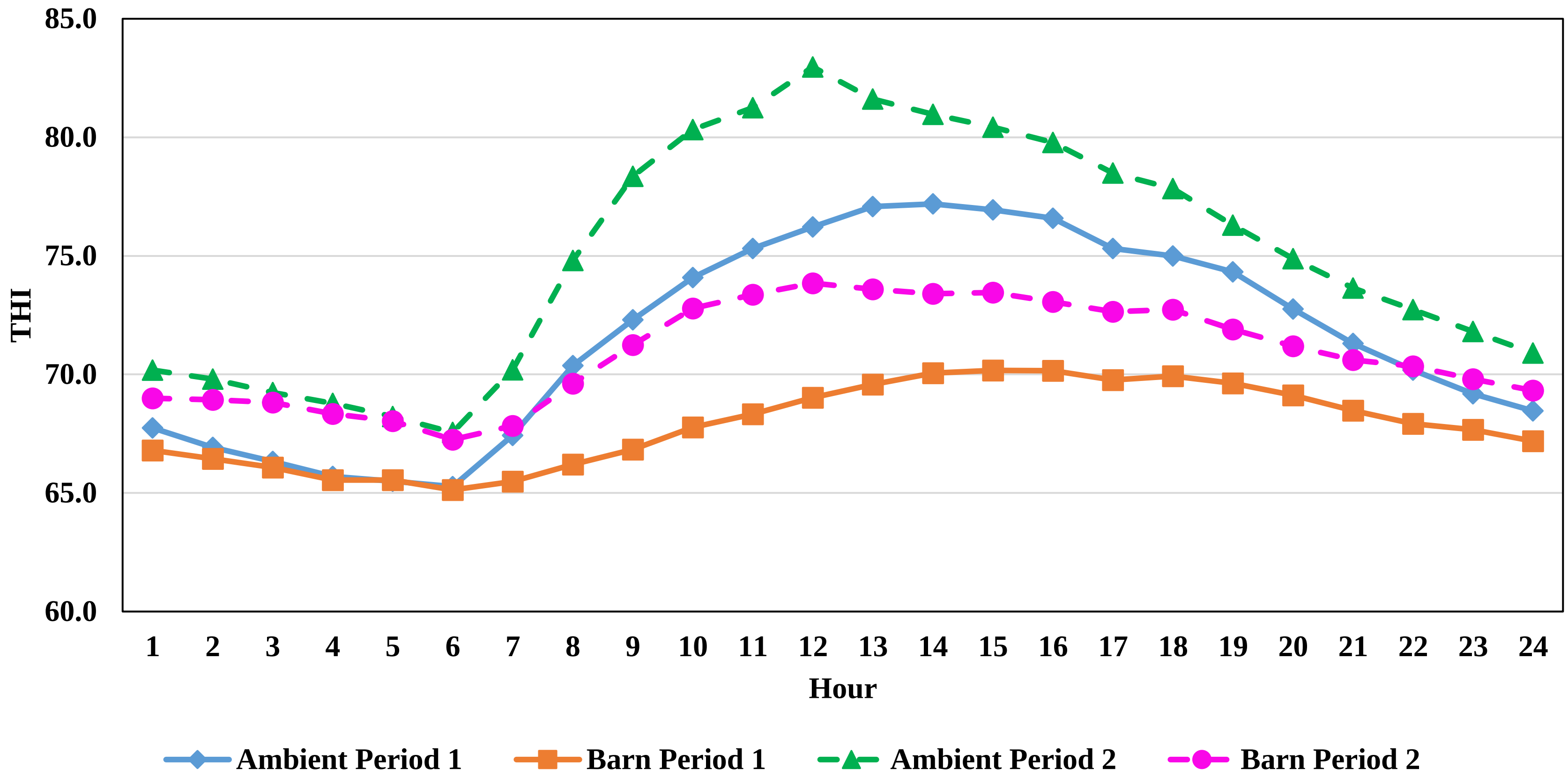

Figure 4.6 Ambient and barn THI by period

SEM = 0.65
Period effect: P < 0.001
Period*h effect: P < 0.001
Location*period*h effect: P = 0.99

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