Advancements in Animal Science: hay rake-type impacts ash content of hay and comparison of undergraduate student learning gains and satisfaction when enrolled in animal science courses offered in-person and online

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Dedication

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Abstract

High levels of ash are problematic in hay since ash provides no nutritional benefit to livestock. Hay raking can effect hay quality but the effect of alternative hay raking equipment on ash content is unknown. The objectives were to determine the effect of hay rake-type on ash content and forage nutritive values of alfalfa (*Medicago sativa* L.) hay. Replicated trials were conducted on two cuttings of alfalfa in Minnesota, Pennsylvania and Wisconsin. During raking, two swath rows were combined using one of the following rake-types: wheel, sidebar, rotary or merger. Samples were collected during the four phases of hay harvest: standing forage, post-cut, post-raked and post-baled or chopped and analyzed for ash and nutritive value. Ash content was different in five of the six sites-cuttings post-raking and average, for MN, PA, and WI respectively ($P \leq 0.05$). The hay merger and sidebar rake resulted in the least amount of ash (9.0-13.6% DM) while the wheel rake (10.0-15.3% DM) resulted in the greatest amount of ash post-raking. Differences in forage nutritive values were rarely observed due to hay rake-type and ranged from 20-24% DM CP, 36-48% DM NDF and 39-53% DM NDFd. First cutting alfalfa differed in RFQ with the hay merger and sidebar rake resulting in greater RFQ values (≥121) compared to the wheel rake (≤160). Using a hay merger or sidebar rake to combine swaths tended to result in less ash content and greater RFQ compared to a wheel rake.

The number of post-secondary institutions offering online courses as a component of their long-term educational strategy is increasing. A survey of public colleges and universities showed 31% of students take at least one online course during their collegiate career. However, limited data exists on learning gains and satisfaction from students enrolled in online animal science courses. The objective of this research was to evaluate student learning gains and satisfaction of animal science courses offered in-person and online at the University of Minnesota (UMN). Both courses offered in-person and online sections concurrently for two consecutive academic years. Data were collected from two introductory-level courses, Companion Animal Nutrition and Care (CANC) and Horse Management to assess undergraduate student learning gains and satisfaction of the two delivery methods. Student learning gains were assessed by comparing pre- and post-tests specific to each course and final grade with student demographics. Student satisfaction was evaluated through six questions administered through the UMN's Student Rating of Teaching. Student learning gains (12 to 41%) occurred in both delivery methods of both courses, with in-person students having greater gains in three of the four course years ($P \leq 0.0002$). Animal science majors had greater learning gains compared to non-animal science majors, but only in the first year of CANC. In both courses, final course grade was unaffected by the student's major. Freshman tended to have greater learning gains compared to more advanced students and their final course grade followed the same trend in both courses. Student satisfaction was high among both courses and delivery methods (≥ 4.8 on six-point scale), although in-person students reported higher ratings than online students ($P \leq 0.0008$) in some instances. All students would recommend both courses and delivery methods to future students. In-person and online students spent the same amount of time each week (0 to 2 hours) on homework, readings and projects with the exception of one instance, when online students devoted more time compared to in-person students.

When evaluating undergraduate, introductory-level online and in-person courses, students utilizing both delivery methods experienced learning gains and were satisfied. Based on these results, it appears online courses can be successfully used to teach undergraduate students introductory-level animal science courses.

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CHAPTER ONE: LITERATURE REVIEW

Introduction

Alfalfa (*Medicago sativa* L.) is commonly fed to livestock and represents one of the largest and most expensive dietary components of the ration (Broderick, 1995; Martinson et al., 2012). Alfalfa was grown on >17.7 million acres in 2015, producing nearly 59 million tons with a value of $8.7 billion making it one of the top four economically important crops in the contiguous 48 states (NASS, 2016a; NASS, 2016b). However, total alfalfa acreage in the United states has been declining since 2013 (NASS, 2016a), which intensifies efforts to optimize harvest management, storage efficiencies, and forage quality.

Online courses have become an additional way for animal science instructors to reach students in the 21st century. Today's undergraduate students and instructors are embracing the possibilities and challenges in pedagogy that this cultural and communication shift presents. Institutions that see online education as a critical component of their long-term strategy is increasing (Allen and Seaman, 2011). The popularity of online learning is increasing at a rate so swiftly, it's difficult to estimate the rate of growth. However, a survey of chief academic officers show 31% of higher education students take at least one course online and the rate of growth for online enrollment exceeds that of over-all higher education student enrollment (10% and <1%, respectively; Allen andSeaman, 2011).

Ash in Alfalfa Hay

Ash in livestock rations is broken down into two categories, endogenous and exogenous. Endogenous ash is defined as minerals plants normally contain while exogenous ash are minerals primarily associated with soil contamination. Exogenous ash replaces valuable nutrients and provides no calories to an animal. Undersander (2010) summarized five years of forage testing results from the University of Wisconsin Soil and Forage Testing Laboratory and found grass based forage had a mean total ash content of 10.3% with a range of 8.8 to 17.6%. Alfalfa based forage during the same time had mean total ash content of 12.3% with a greater range of 5.7 to 18%. Endogenous ash makes up approximately 8% of the plant matter, therefore, approximately 2 and 4% of the total ash in grass and alfalfa hay, respectively, is estimated to be exogenous ash.

Higher levels of ash are problematic in hay since exogenous ash provides no nutritional benefit to livestock. Total ash is a component of the non-fiber carbohydrate (NFC) calculation (NRC, 2001) used to calculate total digestible nutrients (TDN). Other nutritional values used to calculate TDN include crude protein (CP), fatty acids (FA), neutral detergent fiber (NDF) and neutral detergent fiber digestibility (NDFd). Increasing ash content negatively affects net energy (NE) for the animal and essentially equates to a 1% decrease in TDN for every 1% increase in ash (Undersander, 2010). The physiological ramifications of feeding hay with higher ash contents are not well understood, but researchers have theorized that excessive ash contents could be a barrier to maximizing production of milk and meat in bovine, ovine and caprine species. In horses, excessive ash content can lead to sand colic (Bertone J. J., Traub-Dargatz J. L., Wrigley R. W., Bennett D. G., and Williams R.J., 1988; Husted, Andersen, Borggaard, Houe, and Olsen, 2005) and may reduce absorption of nutrients and water (Ragle et a., 1989; Udenberg, 1979). For example, if a livestock producer fed 11 kg of alfalfa hay (DM basis) containing 15% ash (or approximately 7% exogenous ash), they would have fed 0.8 kg of soil to their livestock compared to only 0.4 kg of soil if the hay contained 11% ash on a daily basis.

Ash can also be problematic when purchasing hay. Using the previous values, a ton (907 kg) of hay containing 15% ash would contain approximately 66 kg of soil compared to 28 kg of soil when the ash content was reduced to 11%. At an average cost of $250 per ton, a farmer would be spending $18.25 per ton on soil contamination (15% ash hay) compared to only $7.75 per ton with lower ash hay (11%).

Hay Rake-Types

Equipment options are abundant for hay producers. Selecting an appropriate implement and understanding and using best management practices for the specific unit results in high yield and quality feedstuffs (Schuler and Shinners, 2003). There are several styles of hay rakes or a hay merger which possess unique strengths and weaknesses. However, they all have same purpose(s): 1) create a windrow narrow enough for the baler/harvester to pick up 2) merge two swath rows together 3) invert a crop allowing for faster drying and 4) move a swatch from wet to dry ground (Schuler and Shinners, 2003). There are three rake-types commonly used in the United States: wheel, rotary (gyro-rake) and parallel (sidebar or Rolabar ®). Other possible equipment used when making hay in the U. S. includes a merger, inverter or tedder.

Rake mechanisms, function and economic values differ (Schuler and Shinners, 2003). Wheel rakes have no mechanical power train, allowing them to be an inexpensive option. Some models allow a swath to be raked as wide as 11 m. The larger working width and low cost of the wheel rake make it popular with hay producers. However, with no power train, the wheel rake depends on the forward motion of the vehicle pulling it and the engagement of individual wheel tines to touch the crop or ground to turn the rake wheels. Producers have expressed that hay has a tendency to intertwine using a wheel rake, hindering the drying process.

Sidebar rakes (also known as parallel-bar or Rolabar © rakes) historically have been a popular choice among hay producers for the perception they are less aggressive with forage. They remain inexpensive, though cost more than a wheel rake because of the powertrain (wheel belts or PTO options). There are downsides to sidebar rakes including limited working width and the many moving components which need to be maintained.

Rotary rakes have a reputation for combining swaths in a manner that is well-formed while allow optimal air circulation. Developed in Europe, these rakes are well-equipped to move heavy, wet forage, whereas smaller, less substantial rakes may not be a sturdy option. Rotary rakes come in various sizes and can reach costs nearing $50,000. Implement adjustments need to be carefully set to avoid excess ground sweeping, and avoid superfluous contact with the plant leaves.

A merger is not classified as a rake, but still accomplishes the merging of swath rows into a merged row. A merger relies on placing a wide windrow atop plant stubble to dry the crop. This windrow is often too wide for modern hay makers to pick-up. For this reason, it is used more often in silage harvest than dry hay because it is better matched in size to current silage and haylage harvesters (Digman et al.,2013). This implement can be a sizeable investment, but can save time, labor and field passes by using larger working width options. Mergers are heavy-framed implements and will need a corresponding tractor to handle them.

Equipment Effects on Hay Quality

Previous research has outlined best management practices for alfalfa harvest including optimizing cutting schedules (Smith and Nelson, 1967), cutting height (Kust and Smith, 1961; Sheaffer et. al., 1988; Smith and Nelson, 1967), forage drying time (Kung Jr. et al., 2010; Shearer, Turner, Collins, and Peterson, 1992), and equipment settings. However, these works have focused on maximizing yield (Kust and Smith, 1961; Sheaffer et al., 1988; Smith and Nelson, 1967), crude protein (CP) (Kust and Smith, 1961), and digestible energy (DE), while minimizing acid detergent fiber (ADF) and neutral detergent fiber (NFD).

Hay rakes have been investigated for their contribution to crop value losses. Drying rates between sidebar and rotary rakes were found similar by (Savoie et al., 1982), though the sidebar rake produced more dry matter loss (102.3 vs 132.3 kg/ha). Sidebar rakes were used to rake wide swaths by Rotz and Abrams (1988) who assessed moisture content during the harvest process and how equipment affected future storage losses. Hoover (1996) evaluated DM losses, drying rate and rock movement from a side-rake, wheel-rake, inverter and two rotary rakes. Crude protein (CP) was impacted most by sidebar and wheel rakes Buckmaster (1993). The same study also showed slight increases in fiber in the fiber raked with the wheel rake.

Ash content can be affected by other implements during hay harvest. Digman et al. (2011) determined wide swaths (width of 2 m) resulted in forage with less ash content with a cutting height ≥ 6 cm, and angled compared to flat knives on disc mowers resulted in increased ash content. Mergers are a relatively new piece of equipment, not being used in the United States until the 1990's; providing little published research about their use. However, Digman et al. (2013) investigated ash after using a merger to combine swaths at various stubble heights, and found ash content increased as stubble height decreased. The researchers found that decreasing stubble height increased yield, resulting in the conclusion that the cost of yield loss for decreased ash was not practical.

It has been hypothesized that the type of hay rake can also impact ash content of hay. However, this hypothesis has not been tested.

Online Learning

Brick and mortar structures are losing their monopoly as the sole place of learning (Nguyen, 2015). Online learning experiences are now being offered by a greater number of organizations. Public and private colleges, universities, special interest groups, or industry may offer this mode of learning for potential students. For colleges and universities, an online course is defined as one in which at least 80% of the course content is delivered online (Allen et al., 2016). This definition has remained consistent for 13 years and is becoming widely accepted by academic leaders. A course is considered 'fully online' when all course work can be completed online with no need to meet face-to-face (Bliuc et al., 2007; Hoic-Bozic et al., 2009; Osguthorpe, 2003). Massive Open Online Courses (MOOCs, Allen et al., 2016) are an alternative for learners whom are not enrolled at an institution of higher education, and will receive no post-secondary credit for completion of the course.

For fifteen years, Allen et al. (2016) has been analyzing all active, degree-granting higher education institutions about their online learning opportunities, with data from the National Center for Educational Statistics (IPEDS, 2016). Public institution students account for 72% of online enrollments over private non-profit and private for-profit schools (Allen et al., 2016). A 7% increase in online enrollment was reported from 2012 to 2014 (Allen et al., 2016).

Effective instruction focuses on learners and instructors must continually evaluate new methods to effectively encourage the learning process (Hirumi and Bermúdez, 1996). Instructors should focus on what the students are to learn and do (Hirumi and Bermúdez, 1996). Especially for agricultural colleges, competition for a dwindling pool of students interested in the field of study is forcing programs to enhance student interest and enthusiasm for agriculture disciplines (Barnes et al., 1999), and online learning is one method to accomplish this. Complete didactic learning is a thing of the past for today's undergraduate students. They expect technology in their learning experiences and may learn and retain material to a greater extent if the material is presented in a visual and interactive format (Seels and Glasgow, 1997).

Online learning may offer other benefits when compared to traditional classroom style courses. For example, non-traditional students may have time constraints and online courses may be the most viable option for these learners (Barnes et al., 1999) and flexibility of an online course is a feature which attracts students to the format (Walker and Kelly, 2007). Lindsey and Rice (2015) suggested that students who take one online course have a higher emotional intelligence score. This is supported by an argument that online students need to put forth more effort in building interpersonal and social skills when interacting with classmates and instructors online by using technological advancements (Riffell and Sibley, 2005; Loader, 2007). Walker and Kelly (2007) state there are two ways to evaluate the success of online courses: evaluate student achievement and assess student satisfaction. Hirumi and Bermúdez (1996) suggested using assessments as learning tools rather than disposable tools to assign grades. Rather, use assessments constructively and early in the learning process so that the correct information can be learned and retained over incorrect information learned and discarded after passing an examination. However, this approach will not produce quantitative data for learning gains that some administrators may seek.

Learning Gains of Students

Learning gain is an attempt to measure the improvement in knowledge, skills, work-readiness and personal development made by students (HEFCE, 2016). Comparative learning gains between online and traditional students are difficult to find. However, Allen et al. (2016) reported perceptions of academic leaders who believe that learning outcomes of online courses are the same or superior to face-to-face teaching. Bing et al. (2011) offered online and in-person laboratories for a domestic animal anatomy class, though they were not concurrent. They indicated learning gains by students, through a pre- and post-test, in the two semesters evaluated (48.5% and 46.5%, respectively), were not different between the two delivery methods. This research could have been strengthened by offering the lab modules concurrently, rather than during different academic years.

An interesting observation reported by Zhao, et al., (2005), showed research published prior to 1998 showed favor to in-person teaching for the success of the students. However, research published after 1998 showed that online learning was as good or better in knowledge gain compared to in-person teaching.

Literature from animal science courses seems to be limited, though it does exist. There are abundant amounts of published research, analyses, and reports about online learning for undergraduate students, though it tends to be limited to courses associated with general or introductory content in natural sciences, economics, or psychology. Bing et al. (2011) explored learning gains between online and face-to-face students in a required animal anatomy laboratory over two semesters. Each laboratory module was delivered in-person and online; however, they were delivered at different years. For example, if module one was delivered face-to-face the first semester, it was delivered online the second and vice versa. Therefore, in-person and online students were not compared within the same academic session. The same teaching assistant delivered the in-person modules in both semesters, though was over-seen by a different instructor in the semesters. A benefit observed by Bing et al. (2011) for the online modules, was students could return to the content online to review or get clarification unlike the face-to-face modules.

Student engagement is a common theme that parallels student success. Learning communities have been used at the University of Connecticut in the animal science department since 2000. Though not using an online format, Zinn et al. (2015) explained there was a higher annual student retention rate for students involved in the organized learning community (LC) over student in not in an LC. Co-enrolling students in two or more classes ensures that students interact frequently and spend time engaged in common intellectual activities. Peer teaching frequently occurs in this format, increasing student learning gains and satisfaction. Facebook was used by Whittaker et al., (2014) to create a forum for a learning community. The main benefits found were effective communication, social support, and problem-solving strategies. An Australian qualitative study reported undergraduate students in veterinary science adopted a poor approach to learning with online resources. They revealed that when students used case studies through online resources, they only briefly visited the resource to complete a task, rather than have a complete and deep understanding of the case diagnosis.

In a highly thorough review of literature, (Russell, 2001) reports about 70% of published research show no significant difference between in-person or online learning. Following this suggestion, Bernard et al. (2004) completed another meta-analysis, finding effect sizes of essentially zero for learning gain, satisfaction and knowledge retention and wide variability among all three. This suggests that many applications of online learning outperform their classroom counterparts and that many perform more poorly. Ultimately, Nguyen (2015) concludes the effectiveness of online learning relative to traditional classrooms has no constant effect.

Student Satisfaction of Online Students

Student satisfaction is the perceived value of the student's education experience (Magolda and Astin, 1993). Student performance and student interaction are linked very closely to student satisfaction (Navarro and Shoemaker, 2000). To evaluate student satisfaction, The University of Minnesota uses a Student Rating of Teaching (SRT; University of Minnesota, 2016a). It states, "SRT content places additional emphasis on student learning outcomes and factors that lead to instructional excellence." Scores are used to improve instruction and assist students with future course selection. Researcher have suggested that course evaluations need to be brief and easily accessible to optimize student participation (Walker and Kelly, 2007).

As early as 1999, students agreed using enhanced computer instruction in their animal science courses was a viable method of delivery (Barnes et al., 1999). A high enrollment online statistics course (> 50 students) showed students were not as satisfied with their course outcomes, as they were with the over-all delivery (Bolliger and Wasilik, 2012). Questions related to the instructions communication skills and course requirements had a mean score of 4.62 on a five-point Likert scale. Evaluation questions such as *my interest level in the subject matter has increased because of this course* only had a mean score of 3.24 on the same Likert scale. Lawrence (1993) and Myers Briggs et al. (2003) have published the personality of a student in important in the learning process. The Myers-Briggs Type Indicator (MTBI ®) personality inventory is used to identify a person's preferences by using eight different characteristics (Myers Briggs, 2017). The MBTI ® tool consists of four dichotomous scales: 1) Extraversion – Introversion 2)

Sensing – Intuition 3) Thinking – Feeling and 4) Judging – Perceiving. A group of 72 graduate students indicated no difference in over-all satisfaction with an online course, though differences were revealed when categorized to the student's Myers-Briggs Type Indicator (Bolliger and Erichsen, 2013). The researchers report most of the 72 respondents were categorized as introverts, intuitive, feelers and judgers, which are significantly different than general population estimates published by Lawrence (1993). The study evaluated students who were already using online learning in their educational plan, suggesting the previously mentioned personality type indicators may be pre-disposed to preferring online and distance education over in-person courses. Results of this study indicate there are differences in perceived student satisfaction with certain elements in blended and online courses based on personality type. Personality and individual differences explain how individuals perceive, make judgments, and behave in certain situations (Quenk, 2009).

Although a lot a data exists, little exists on learning gains and satisfaction from students enrolled specifically in online animal science courses. This research may help guide other animal science departments when making course platform decisions.

CHAPTER TWO: HAY RAKE EFFECT ON ASH AND FORAGE NUTRITIVE VALUES OF ALFALFA HAY

Introduction

Alfalfa (*Medicago sativa* L.) is widely used in rations for livestock and can be one of the most expensive dietary components (Rotz and Muck, 1994; Broderick, 1995; Martinson et al., 2012). Alfalfa was grown on >17.7 million acres in 2015, producing nearly 59 million tons with a value of $8.7 billion, making it one of the top four economically important crops in the contiguous 48 states (NASS, 2016a; b). However, total alfalfa acreage in the United States has been declining since 2013 (NASS, 2016a), which has intensified efforts to optimize forage nutritive value through harvest management and storage efficiencies. Previous research has outlined best management practices for alfalfa harvest including optimizing cutting schedules, cutting height, forage drying time, and equipment settings (Sheaffer et al., 1988; Shearer et al., 1992; Rotz and Shinners, 2007; Kung Jr. et al., 2010). However, these efforts have focused mainly on the relationships between forage yields and forage nutritive value described by crude protein, and digestible energy (DE) and fiber fractions (Sheaffer et al., 1988; Rotz and Shinners, 2007).

Ash in livestock rations includes two categories, endogenous and exogenous. Endogenous ash is defined as minerals plants normally contain while exogenous ash is minerals primarily associated with soil contamination. The endogenous ash content of legume forages ranges from 6 to 8% dry matter (DM) with total ash content ranging from 9 to 18% DM with an average of 10% DM (Undersander, 2010). Higher levels of ash are problematic in hay since these levels are usually associated with exogenous ash due to soil contamination, which provides no nutritional benefit to livestock. Furthermore, total ash is a component of the non-fiber carbohydrate (NFC) calculation (NRC, 2001) used to calculate total digestible nutrients (TDN), which negatively impacts the net energy (NE) value of the ration. The physiological ramifications of feeding hay with higher ash contents are not well understood. Researchers have theorized that excessive ash contents could be a barrier to maximizing production performance in bovine, ovine and caprine species and could negatively impact health of equines (Bertone et al., 1988; Husted et al., 2005).

Raking hay to facilitate drying and pick-up has been identified as a phase of haymaking that can affect the yield and quality of forage (Pitt, 1990; Rotz and Shinners, 2007). Because hay rakes may come into contact with the ground, the potential to contribute ash during the raking process exists. Rake mechanisms, function and economic value differ among hay rakes types and have been summarized by Schuler and Shinners (2003). Briefly, sidebar rakes (also known as parallel-bar or Rolabar ©) are ground driven, but can be adjusted to have limited contact with the ground due to a powertrain (wheel belt or PTO options). However, a disadvantage of the sidebar rake is a limited working width. Wheel rakes are also ground driven but require contact with the ground to gather hay. These rakes are relatively inexpensive and some models allow a swath to be raked as wide as 11 m. Rotary rakes are power driven and adjustments can be made to avoid excess contact with the ground and to avoid superfluous contact with the forage leaves. A merger is not classified as a rake, but still accomplishes the merging of swath rows. Mergers are power driven and can be adjusted to avoid excess contact with the ground. Although this piece of equipment can save time and labor by merging multiple swaths at once, it tends to be more costly compared to other hay rakes.

Ash content can be affected by equipment used during hay harvest; however, most research has focused on the hay cutting phase. Digman et al. (2011) determined that wider swaths, cutting heights above 6 cm, and angled knives on hay mowers resulted in harvested forage with less ash content. Because soil disturbance is possible during hay raking, this harvest phase has a potential to affect ash content of forage; however, the effect of raking on ash content has not been evaluated. Therefore, the objectives of this research were to determine the effects of hay rake-type on ash content and nutritive values of alfalfa hay.

Materials and Methods

Replicated trials were conducted during the 2015 growing season in Minnesota (MN), Pennsylvania (PA) and Wisconsin (WI). In MN (N 45°16'47.458", W 93°36'57.676") and PA (N 40°48'45.198", W 77°52'49.1016"), research was conducted on farms with cooperating alfalfa hay producers. In Wisconsin, research was conducted at the U.S. Dairy Forage Research Center (N43°17'52.8", W 89°21'19.6"). Soil types at Minnesota, Pennsylvania and Wisconsin were loamy sand; *Entic Hapludolls* (MN), silty loam; *Typic Hapludalfs* (PA) and silty loam; *Typic Agriudolls* (WI), respectively. Targeted alfalfa maturity at cutting was 10% bloom (Kalu and Fick, 1981) with a goal of rain-free harvested hay. To examine diverse growing conditions within each location, harvest and raking occurred during the first cutting and a second or third cutting at all locations (Table 1). Hay fields had an alfalfa stand density of ≥500 stems per m^2 at all three locations.

To account for field variation, swath rows were assigned to a randomized complete block design with four replications and headland rows were excluded from the collection area. During each step of haymaking, forage was sampled to determine treatment effects on ash, CP, NDF, NDFd and RFQ. Prior to harvest, four 0.25 m^2 random samples of standing forage were hand harvested from each replicate 6 cm above the soil surface and served as the control. Alfalfa was then cut with a disc mower (MN: MoCo 835, John Deere, Moline, IL; PA, MoCo 946, John Deere, Moline, IL; WI: RD 163, Case IH, Racine, WI) using best management practices to limit ash contamination including use of a wider swath and maintaining cutting heights above 6 cm (Digman et al., 2011). Post-cutting, each of the replicates were comprised of eight swath rows. Four 0.25 m^2 random samples of cut forage were hand harvested from each replicate to determine hay mower contribution to ash content. When swaths reached approximately 60% DM, two swath rows in each replicate were combined using one of the following rakes; merger, rotary rake, sidebar rake or wheel rake (Table 2). Hay rakes were adjusted according to manufacturer recommendations and run at a standardized range of speed, operating width, power takeoff (PTO) or pounds per square inch (PSI) at each location (Table 2). Sidebar rakes were set to operate at 0.6 cm off the field surface.

Post-raking, a tarp (0.5 m^2) was positioned under a section of the combined swaths to capture ash and other plant material that could potentially be lost from the sample through handling. A 15 cm wide section was sub-sampled from four random locations of each hay rake-type swath per replicate. When the forage dried to approximately 85% DM, raked swaths were baled using either a small square-baler (MN and PA) or large round-baler (WI). Impending rainfall during first cutting in Pennsylvania resulted in forage being chopped for silage production. Random 250 g samples were collected post-baling using a hay corer (2 x 51 cm) or post-chopping by hand grab samples.

All samples were dried at 60°C for a minimum of 24 hours. After drying, samples were ground through a 6-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) followed by a 1-mm screen in a cyclone mill (UDY Corporation, Fort Collins, CO). Samples were mixed thoroughly and subsamples were analyzed for forage nutritive values using the following methods. Ash content was analyzed by igniting sample in a furnace at 600°C to oxidize all organic matter (AOAC, 1990). Ash was determined by weighing the resulting inorganic residue. Prediction equations developed for legume hay by the NIRS Forage and Feed Testing Consortium were estimated using near-infrared spectroscopy (NIRS model 6500, Foss Eden Prairie MN) to determine NDF, NDFd and CP. The standard error of cross validation was 1.97, 2.1 and 0.72, while the R^2 was 0.95, 0.89 and 0.72 for NDF, NDFd48 (NDFd) and CP, respectively (NIRS, 2016). Relative forage quality (RFQ) was calculated using NIRS predicted values of TDN x intake calculation/1.23 (Moore and Undersander, 2002). Daily air temperature and rainfall were compiled for the experimental period of the 2015 harvest season at all locations.

All parameters were analyzed using the MIXED procedure in SAS with statistical significances set at $P \leq 0.05$ (SAS, 2013). Alfalfa hay rake treatments (merger, rotary, sidebar, and wheel) and crop phases (standing, mowed, post-raked, and post-baled) and site-cuttings were modeled as fixed effects, and replicates were random effects. A combined analysis of forage nutritive value parameters across the three site-cuttings was attempted, but was prevented due to large *F*-values for interaction of site-cuttings and hay rake treatment for both first ($P < 0.01$) and subsequent alfalfa harvest ($P < 0.01$; Moore and Dixon, 2015). All forage yield and quality parameters for site-cutting, harvest phase (standing, post-cut, post-raked, and post-baled or chopped), and alfalfa harvest (first and subsequent) were analyzed separately. Change in ash percentage was calculated by subtracting ash content from standing alfalfa. Post-mowed ash content was then contrasted with the average of post-raked and post-baled ash content for each hay rake-type. All means were separated using pre-planned contrasts and Tukey's HSD at P=0.05 (Steel et al., 1996).

Results and Discussion

Weather. Mean daily air temperature at all locations were similar or slightly greater than the 30-year average (Figure 1). Rainfall during May through August of 2015 was similar to the 30-year historical average in Wisconsin. In Minnesota, greater than average rainfall was recorded in May and July while in Pennsylvania, greater than average rainfall was recorded in June compared to the 30-year historical average. Excess rainfall in Pennsylvania prohibited first cutting hay from adequately drying for haymaking, causing researchers to chop and ensilage the crop instead.

Ash Content. Ash content of standing forage ranged from 96 to 112 g kg^{-1} in Minnesota, 98 to 105 g kg^{-1} in Pennsylvania, and was 94 to 104 g kg^{-1} in Wisconsin

(Table 3). Greater rainfall, which can result in splashing of soil particles onto plants, combined with the sandy soil-type may have contributed to the higher ash content observed in first cutting in Minnesota. Ash content of post-mowed and swathed alfalfa ranged from 106 to 128 g kg^{-1} in Minnesota, 102 to 110 g kg^{-1} in Pennsylvania, and from 94 to 109 g kg^{-1} in Wisconsin (Table 3). Our results contrast with those of Kung et al. (2010) and Yoder et al. (2013) who reported an ash content of 86 and 69 g kg^{-1} in swathed alfalfa.

However, compared to the standing forage, mowing only contributed to ash content during the subsequent cutting at all three locations (Figure 2; $P \leq 0.05$). In the northern U.S. alfalfa and alfalfa-grass yields are typically greatest for spring harvest and decline at summer harvests (University of Wisconsin Forages, 2016). We hypothesized that a lesser yield resulting in greater ground exposure and drier environmental and soil conditions during subsequent cuttings could have contributed to ash accumulation. However, the small increase of ash during the hay mowing phase (≤1.6% DM) reinforced that recommended best management practices including wide swaths and cutting heights above 6 cm (Digman et al., 2011) helped to limit ash content during hay mowing.

Rake type affected ash content post-raking at all site-cuttings except for first cutting in Wisconsin ($P \leq 0.05$; Table 3). Where differences were observed, the wheel rake always resulted in the greatest ash content post-raking ($P \leq 0.05$). In contrast, the hay merger and sidebar rake resulted in the least amount of ash while the rotary rake tended to result in intermediate amounts of ash.

These results help to confirm generally accepted observations that different types of hay rakes results in different amount of ash post-raking. Because wheel rakes must contact the ground to merge windrows (Schuler and Shinners, 2003), it was anticipated that this rake type would results in a greater amount of ash due to the opportunity to introduce soil contaminants into the forage.

Post-baling, similar trends were observed as with post-raking; and rake-type effects on ash content occurred at only three of the six site-cuttings ($P \leq 0.05$; Table 3). A hay merger or sidebar rake to combine swaths again resulted in less ash content compared to a wheel rake. These results can be combined with established best management practices that reduce ash content including use of wider swaths, cutting heights ≥6 cm, and angled knives on disc mowers (Digman et al., 2011). Ash contents of alfalfa hay post-baling or chopping observed in this study are similar to ranges reported by Undersander (2010) and a commercial testing laboratory (Equi-Analytical, 2016) who reported average ash values of 123 and 107 g kg^{-1}, respectively. The current results align with the research hypothesis that ground driven rakes would result in greater amounts of ash due to contact with the ground.

The percent change in ash content in post-raked alfalfa are shown in Figure 2. Compared to the standing forage, hay rake type impacted ash content during both cuttings in Minnesota and the first cutting in Pennsylvania. When differences were observed, the wheel rake resulted in a 1 to 4% increase in ash content while the merger resulted in 0% to 1% to increase in ash content compared to the standing forage. During the subsequent cutting in Pennsylvania and both cuttings in Wisconsin, all hay rake-types resulted in a

<1% decrease in ash content compared to the standing alfalfa. Although difficult to explain, we hypothesize that as the forage dried, the soil contamination added to the forage during the other harvest phases also dried and was removed during baling. Future research should focus on the complex interaction of forage moisture and impacts of harvest phase on forage nutritive value parameters.

The ramifications of feeding livestock hay with higher ash contents are not well understood, but it is thought that excessive ash (>80 g kg^{-1}; Undersander, 2010) could be a barrier to maximizing milk and meat production. Because ash provides no calories, a 10 g kg^{-1} increase in ash results in a 1% decrease in TDN of the hay (Undersander, 2010). In horses, excessive ash content resulting in the ingestion of soil contamination can lead to sand colic (Bertone J. J. et al., 1988; Husted et al., 2005) and may reduce absorption of nutrients and water (Udenberg, 1979; Ragle et al., 1989). For example, in Minnesota first cutting hay, the wheel rake resulted in 146 g kg^{-1} ash while the hay merger resulted in the lowest amount of ash (114 g kg^{-1}) post-baling. If a livestock producer fed 11 kg of hay (DM basis) containing 146 g kg^{-1} ash (or approximately 70 g kg^{-1} exogenous ash), they would be feeding 0.8 kg of soil to their livestock compared to only 0.4 kg of soil if the hay contained 114 g kg^{-1} ash each day. Ash is also problematic when purchasing hay. Using the same values, a ton (907 kg) of hay containing 146 g kg^{-1} ash would contain approximately 66 kg of soil compared to 28 kg of soil when the ash content was reduced to 114 g kg^{-1}. At an average cost of $250 per ton, a farmer would be spending $18.25 per ton on soil contamination (146 g kg^{-1} ash hay) compared to only $7.75 per ton with lower ash hay (114 g kg^{-1}).

Crude Protein (CP). Crude protein values of standing alfalfa ranged from 209 to 233 g kg^{-1} across the three locations, while post-mowed alfalfa ranged from 207 to 248 g kg^{-1} (Table 4). No differences in CP due to hay rake-type were observed post-raking ($P \leq 0.05$). Differences in CP post-baling were only observed in Wisconsin's first cutting. Although the range of CP across hay rake-types was minimal (214 to 222 g kg^{-1}), the sidebar rake resulted in a greater amount of CP compared to the merger ($P \leq 0.05$).

Crude protein values post-baling or chopping observed in the current study are similar to those observed by Berti et al. (2012) who reported CP ranged from 20.4 to 24.1% in alfalfa hay. However, the current CP values are higher than those reported by Bosworth and Stringer (1992) who observed CP ranged from 17 to 20% in alfalfa hay when harvested at a maturity similar to the present study. Throughout the harvest process, CP remained consistent. The minimal change in CP throughout the harvest process is likely reflective of the short harvest window (3 to 5 days), lack of rainfall once cut, and best management practices that minimized leaf loss and maximized drying time.

Neutral detergent fiber (NDF) and Neutral detergent fiber digestibility (NDFd). Neutral detergent fiber of the standing alfalfa ranged from 364 to 434 g $kg^{-1}$and from 368 to 440 g kg^{-1} post-mowed across the three locations (Table 5). Differences in NDF post-raking were only observed in Wisconsin first cutting where the sidebar rake resulted in less NDF compared to the wheel rakes. No differences in NDF post-baling or chopping were observed. The NDF values observed in the current study are similar to others who have reported NDF of alfalfa cut at 10% bloom which was 420 g kg^{-1} (Bosworth and Stringer, 1992).

Although one difference in NDF based on hay-rake type was found, there were minimal changes in NDF throughout the harvest process (≤ 50 g kg^{-1}). This is likely reflective of the short harvest window (3 to 5 days), lack of rainfall once cut, and best management practices that minimized leaf loss and maximized drying time.

The NDFd of the standing forage ranged from 39 to 50% DM and from 40 to 50% DM post-mowing (Table 6). Differences in NDFd post-raking or baling were observed in three of the site-cuttings. In general, the sidebar rake resulted in greater NDFd, while the wheel rake tended to result in less. Differences in NDFd due to hay-rake type were small (≤ 2%). Since ash is not digestible, samples with high ash content likely have lower NDFd without affect on NDF. However, these numbers may differ in because of a change in leaf content, which was not evaluated in this study.

Relative Forage Quality (RFQ). Relative forage quality of the standing alfalfa ranged from 127 to 189 and from 123 to 172 post-mowed across all three locations (Table 7). Differences in RFQ post-raking were only observed in first cutting alfalfa at all three locations. In general, the wheel rake tended to result in a lower RFQ compared to the merger and sidebar rake ($P \leq 0.02$). Post-baling or chopping, differences ($P \leq 0.03$) were only observed in first cutting in Pennsylvania where the wheel rake resulted in a lower RFQ compared to the rotary rake.

The RFQ of the post-cut or baled hay observed in the current study (105 to 170) are similar to those reported by Berti et al (2012) when alfalfa was harvested at 30% bloom. Berti et al. (2012) observed RFQ means of 156 and 177. Yost et al. (2011)

observed a higher average RFQ value of 180 when alfalfa was harvested at multiple sites in Minnesota under grower management.

Relative forage quality is a calculated index that uses fiber digestibility to estimate livestock DM intake and TDN (Moore and Undersander, 2002; University of Wisconsin, 2013). Total digestible nutrients is a measure of the energy value in a feedstuff and is negatively impacted by ash content (NRC, 2001). In the current research, the wheel rake resulted in the greatest ash content, while the hay merger resulted in the least amount of ash. These results help to explain the differences observed in RFQ values between the hay rake-types.

Conclusions

Differences in ash content post-raking, post-baling or post-chopping were observed between rake-types in five of six site-cuttings. The wheel rake resulted in the greatest amount of ash content while the hay merger and sidebar rake tended to result in the least amount of ash. Throughout the harvest process, CP ranged from 200 to 241 g kg^{-1}, NDF from 368 to 482 g kg^{-1} and NDFd from 39% to 53%. However, differences due to hay-rake type were rarely observed and forage nutritive values remained consistent throughout the harvest process. Relative forage quality of first cutting hay was different post-raking and post-baling or chopping with the wheel rake tending to result in a lower RFQ value compared to the other rakes. In conclusion, using a hay merger or sidebar rake to combine swaths tended to result in less ash content and greater RFQ compared to a wheel rake.

Acknowledgements

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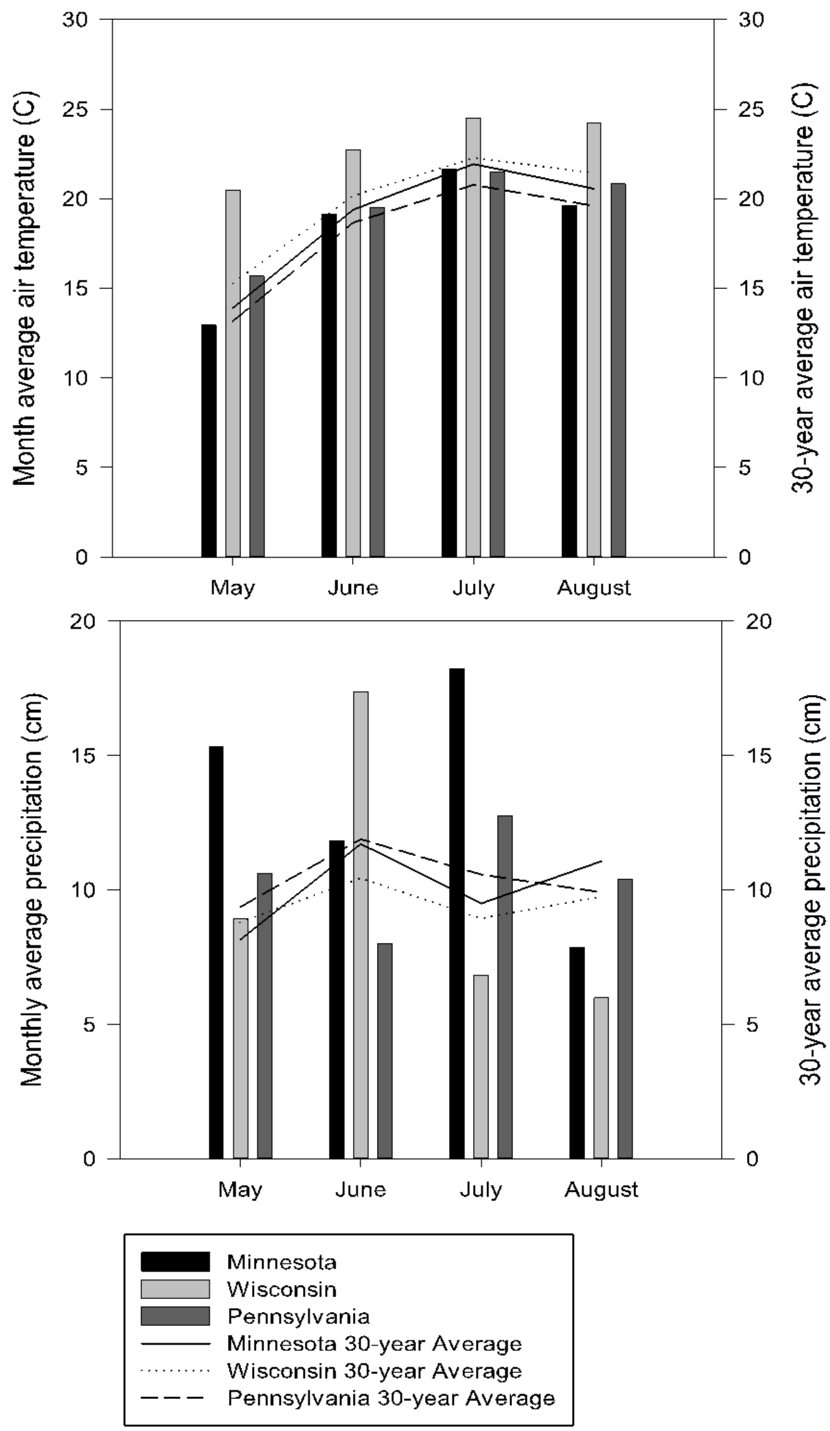

Figure 1. Monthly average temperature (°C) and average precipitation (cm) along with the 30-year average temperature and precipitation in Minnesota, Pennsylvania and Wisconsin during the 2015 hay harvest season.

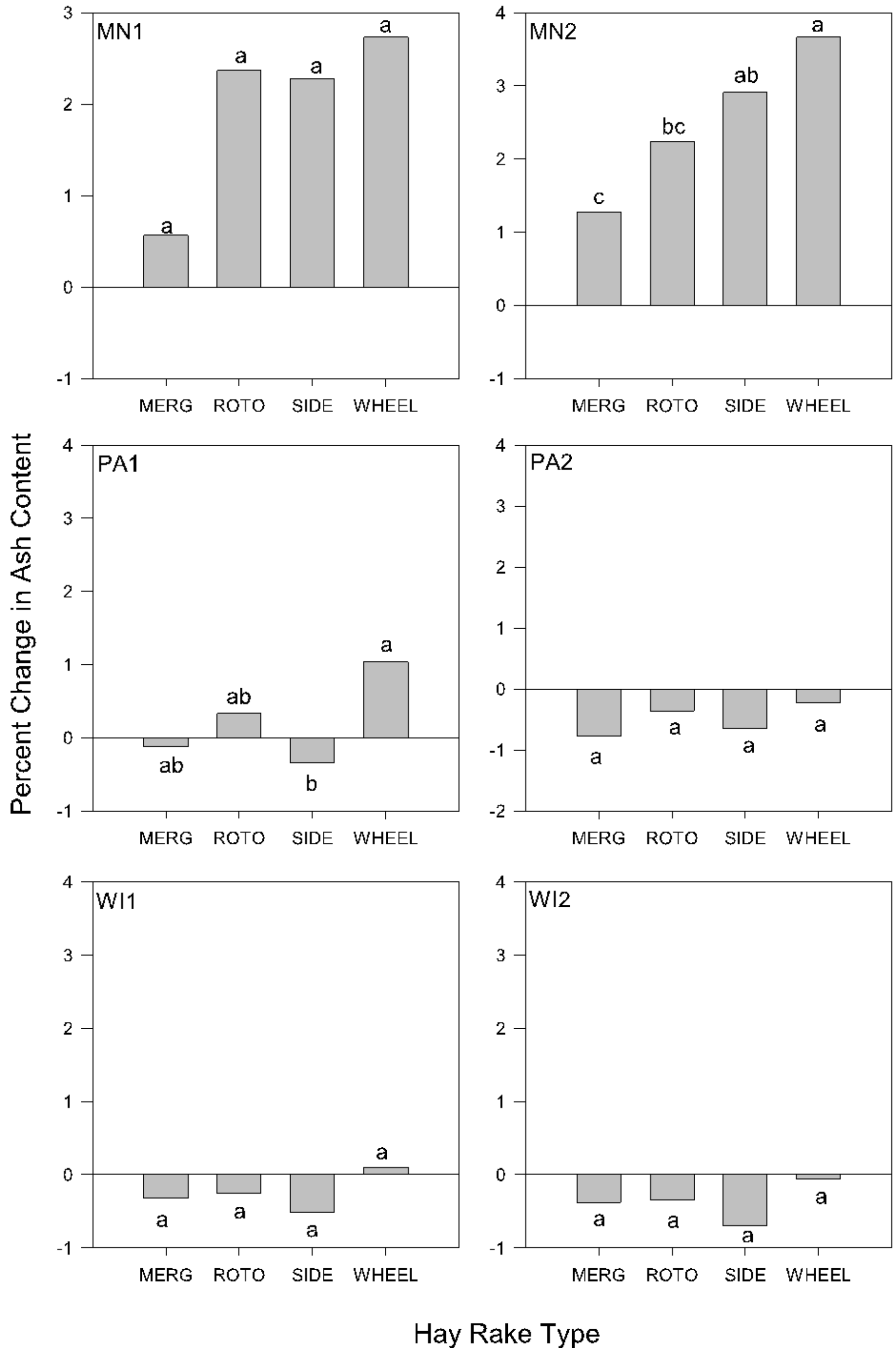

Figure 2. Change in percent Ash (DM) as a percentage of standing alfalfa post-mowing at three locations (MN: Minnesota, PA: Pennsylvania, WI: Wisconsin) and two harvests (1: First-cut, 2: Subsequent-cut) using different hay rake-types (Merger, MERG; Rotary, ROTO; Sidebar, SIDE; and Wheel-rake, WHEEL). Bars sharing the same letter are not significantly different based on Tukey HSD (α = 0.05).

Table 1. Sampling and harvest dates in Minnesota (MN), Pennsylvania (PA) and Wisconsin (WI) for standing (Stand), post-mowed (Mow), post-raked (Rake) and post-baled or chopped (Bale-Chop) alfalfa hay in 2015.

	Stand	Mow	Rake	Bale-Chop
		First Cutting		
MN	30 May	30 May	2 June	2 June
PA	3 June	3 June	5 June	5 June
WI	18 May	18 May	19 May	21 May
		Subsequent Cutting		
MN	29 July	29 July	1 August	1 August
PA	10 July	10 July	12 July	13 July
WI	30 June	30 June	3 July	4 July

Table 2. Model, working width (meters), operating speed (kilometers per hour) and power takeoff (revolutions per minute) for four rake-types used to combine alfalfa swaths in Minnesota, Pennsylvania and Wisconsin.

Rake Type	Minnesota	Pennsylvania	Wisconsin
Merger	New Holland† H5420	Miller Pro Avalanche€	H&S§ TWM-12
Working Width (m)	3.6	10.3	12.2
Operating Speed (kph)	12.9 – 16.1	12.9 – 16.1	12.9 – 16.1
PTO (rpm) or PSI	2,000 psi	1,000 rpm	1,000 rpm
Rotary Rake	Kuhn¥ GA7301	Kuhn¥ GA 4221 GTH	Kuhn¥ GA7301
Working Width (m)	7.4	3.2	7.4
Operating Speed (kph)	8	8	8
PTO (rpm)	400 - 450	400 - 450	400 - 450
Sidebar Rake	New Holland† 258	John Deere‡ 672	New Holland† 260
Working Width (m)	2.9	2.9	2.9
Operating Speed (kph)	3.2 – 11.3	3.2 – 16.1	3.2 – 11.3
Wheel Rake	New Holland† PC 1225	New Holland† 1022 - 10	H&S§ BF14 HC
Working Width (m)	7.1	6.1	8.5
Operating Speed (kph)	12.9 – 16.1	12.9 – 16.1	12.9 – 16.1

†New Holland Agriculture (New Holland, PA)
‡John Deere (Moline, IL)
¥Kuhn North America (Brodhead, WI)
§H&S Manufacturing Company, Inc. (Marshfield, WI)
€Miller Pro, Art's-Way Manufacturing Co., Inc. (Armstrong, IA).

Table 3. Ash in standing (Stand), post-mowed (Mow), post-raked (Rake) and post-baled or chopped (Bale-Chop) alfalfa hay after first and subsequent cutting in Minnesota, Pennsylvania and Wisconsin in 2015. Hay was raked with a hay merger (Merger), rotary rake (Rotary), sidebar rake (Sidebar) or wheel rake (Wheel).

		Alfalfa Harvests							
		Stand	Mow	Rake	Bale-Chop	Stand	Mow	Rake	Bale-Chop
Location		First Cutting				Subsequent Cutting			
		---------------- g kg^{-1} ----------------							
Minnesota	Merger	112†	128†	111^{b}	114^{b}	96†	106†	105^{b}	113
	Rotary			136^{a}	130^{ab}			125^{ab}	124
	Sidebar			135^{a}	132^{ab}			136^{a}	124
	Wheel			153^{a}	146^{a}			138^{a}	129
	SE	15	32	81	47	19	21	75	48
Pennsylvania	Merger	98†	102†	98^{b}	98^{b}	105†	110†	97^{ab}	99
	Rotary			99^{b}	105^{ab}			99^{ab}	100
	Sidebar			95^{b}	98^{b}			95^{b}	102
	Wheel			106^{a}	111^{a}			100^{a}	103
	SE	22	33	29	17	12	34	13	15
Wisconsin	Merger	94†	94†	90	92	104†	109†	99^{ab}	98^{ab}
	Rotary			97	93			100^{ab}	97^{ab}
	Sidebar			91	90			98^{b}	95^{b}
	Wheel			103	95			105^{a}	103^{a}
	SE	19	40	51	22	15	37	18	18

[a-b] Within each column, location and cutting, means without a common superscript differ based on a Tukey test ($P \leq 0.05$).
†Values represent the mean of samples (n=16) collected across the field area.

Table 4. Crude protein (CP) in standing (Stand), post-mowed (Mow), post-raked (Rake) and post-baled or chopped (Bale-Chop) after first and subsequent cutting of alfalfa hay harvested in Minnesota, Pennsylvania and Wisconsin in 2015. Hay was raked with a hay merger (Merger), rotary rake (Rotary), sidebar rake (Sidebar) or wheel rake (Wheel).

		First Cutting				Subsequent Cutting			
		Stand	Mow	Rake	Bale	Stand	Mow	Rake	Bale
		---------- $g\ kg^{-1}$ ----------							
Minnesota	Merger			221	221			203	216
	Rotary	227†	230†	215	223	233†	213†	208	210
	Sidebar			212	217			201	207
	Wheel			220	222			208	203
	SE	25	28	34	27	50	64	44	40
Pennsylvania	Merger			200	201			213	216
	Rotary	209†	207†	202	212	230†	229†	211	219
	Sidebar			205	208			205	216
	Wheel			203	201			208	216
	SE	33	25	39	24	17	39	30	30
Wisconsin	Merger			214	214[b]			238	240
	Rotary	223†	222†	218	215[ab]	255†	248†	235	236
	Sidebar			223	222[a]			241	232
	Wheel			213	220[ab]			241	240
	SE	20	27	16	30	39	73	50	30

[a-b]Within each column, location and cutting, means without a common superscript differ based on a Tukey test ($P \leq 0.05$).

†Values represent the mean of samples (n=16) collected across the field area.

Table 5. Neutral Detergent Fiber (NDF) in standing (Stand), post-mowed (Mow), post-raked (Rake) and post- baled or chopped (Bale-Chop) after first and subsequent cutting of alfalfa hay harvested in Minnesota, Pennsylvania and Wisconsin in 2015. Hay was raked with a hay merger (Merger), rotary rake (Rotary), sidebar rake (Sidebar) or wheel rake (Wheel).

		Stand	Mow	Rake	Bale	Stand	Mow	Rake	Bale
Location		First Cutting				Subsequent Cutting			
		---------------------------------- $g\ kg^{-1}$ ----------------------------------							
Minnesota	Merger			393	390			442	427
	Rotary	411†	440†	410	385	364†	412†	435	448
	Sidebar			412	398			449	445
	Wheel			399	389			439	458
	SE	94	72	65	76	87	109	99	82
Pennsylvania	Merger			441	458			466	459
	Rotary	427†	427†	441	455	434†	440†	468	455
	Sidebar			444	454			482	457
	Wheel			452	479			480	459
	SE	105	67	47	81	49	80	59	92
Wisconsin	Merger			422[ab]	431			384	385
	Rotary	428†	435†	415[ab]	436	371†	368†	388	385
	Sidebar			407[b]	419			374	394
	Wheel			431[a]	428			375	383
	SE	44	72	60	62	82	117	123	61

[a-b]Within a column, means without a common superscript differ based on a Tukey test ($P \leq 0.05$).

†Values represent the mean of samples (n=16) collected across the field area.

Table 6. Neutral Detergent Fiber digestibility (NDFd) in standing (Stand), post-mowed (Mow), post-raked (Rake) and post- baled or chopped (Bale-Chop) after first and subsequent cutting of alfalfa hay harvested in Minnesota, Pennsylvania and Wisconsin in 2015. Hay was raked with a hay merger (Merger), rotary rake (Rotary), sidebar rake (Sidebar) or wheel rake (Wheel).

		First Cutting				Subsequent Cutting			
		Stand	Mow	Rake	Bale	Stand	Mow	Rake	Bale
		$g\ kg^{-1}$							
Minnesota	Merger			495	501[b]			507	515
	Rotary	416†	467†	475	505[ab]	496†	504†	493	483
	Sidebar			497	519[a]			503	532
	Wheel			496	502[ab]			498	507
	SE	158	94	80	44	110	149	178	102
Pennsylvania	Merger			410[a]	411			395	399
	Rotary	414†	407†	410[a]	421	402†	397†	405	405
	Sidebar			404[ab]	402			395	406
	Wheel			393[b]	393			401	402
	SE	48	60	41	74	39	50	35	37
Wisconsin	Merger			417	412			436[b]	431
	Rotary	394†	398†	420	416	440†	457†	442[ab]	433
	Sidebar			430	415			444[ab]	426
	Wheel			403	415			456[a]	432
	SE	75	136	80	28	84	80	50	61

[a-b]Within a column, means without a common superscript differ based on a Tukey test ($P \leq 0.05$).

†Values represent the mean of samples (n=16) collected across the field area.

Table 7. Relative forage quality (RFQ) in standing (Stand), post-mowed (Mow), post-raked (Rake) and post- baled or chopped (Bale-Chop) after first and subsequent cutting of alfalfa hay harvested in Minnesota, Pennsylvania and Wisconsin in 2015. Hay was raked with a hay merger (Merger), rotary rake (Rotary), sidebar rake (Sidebar) or wheel rake (Wheel).

		First Cutting				Subsequent Cutting			
		Stand	Mow	Rake	Bale	Stand	Mow	Rake	Bale
		------------------------------------ % DM ----------------------------------							
Minnesota	Merger			165[a]	168			148	154
	Rotary	131[†]	133[†]	151[b]	170	189[†]	164[†]	146	135
	Sidebar			155[ab]	167			143	151
	Wheel			160[ab]	167			145	139
	SE	2.2	2.3	3.5	4.4	4.6	4.8	3.4	4.8
Pennsylvania	Merger			124[a]	117[ab]			111	114
	Rotary	131[†]	130[†]	124[a]	121[a]	127[†]	122[†]	113	117
	Sidebar			121[ab]	116[ab]			106	116
	Wheel			114[b]	105[b]			107	115
	SE	4.6	3.8	2.3	4.0	2.9	3.6	3.9	2.4
Wisconsin	Merger			133[ab]	128			157	159
	Rotary	125[†]	123[†]	136[ab]	127	165[†]	172[†]	156	158
	Sidebar			143[a]	135			165	154
	Wheel			125[b]	130			166	158
	SE	2.8	4.1	3.4	2.7	5.0	8.4	3.2	7.5

[a-c]Within a column, means without a common superscript differ based on a Tukey test ($P \leq 0.05$).

[†]Values represent the mean of samples (n=16) collected across the field area.

CHAPTER THREE: COMPARISON OF UNDERGRADUATE STUDENT LEARNING GAINS AND SATISFACTION WHEN ENROLLED IN ANIMAL SCIENCE COURSES OFFERED IN-PERSON AND ONLINE

Introduction

Today's undergraduate students are fluent in electronic communication (Bigelow and Kaminski, 2016). Online courses have become another method for instructors to utilize for teaching students in the 21st century, and institutions that view online education as a critical component of their long-term strategy are increasing (Allen and Seaman, 2011). Popularity of online learning is increasing at a rate so rapidly; it is difficult to estimate growth. However, a survey of chief academic officers show 31% of higher education students take at least one online course during their collegiate career and the rate of growth for online enrollment exceeds that of over-all higher education student enrollment (Allen et al., 2016).

Walker and Kelly (2007) stated that there are two ways to evaluate success of online courses, student achievement and satisfaction. Learning gains are an attempt to measure the improvement in knowledge, skills, work-readiness, and personal development made by students throughout a course (HEFCE, 2016). The University of Minnesota (UMN) uses a Student Rating of Teaching (SRT; University of Minnesota, 2016a) to evaluate student satisfaction, learning outcomes and factors that lead to instructional excellence. Prior research on undergraduate student learning gains and satisfaction is plentiful; however, research focused on animal science courses are limited. Bing et al. (2011) found student-learning gains were similar between students enrolled in online and in-person domestic animal laboratory courses. In an introductory animal and poultry science course, students were satisfied with the use of online tools for their coursework (Barnes et al., 1999).

The objective of this study was to assess undergraduate student learning gains and satisfaction of concurrent online and in-person undergraduate animal science courses with a hypothesis that students taught in-person will have greater learning gains and a higher rate of satisfaction compared with online students.

Materials and Methods

Two introductory animal science courses were evaluated, which were offered during the 2014-2015 and 2015-2016 academic years at the UMN, St. Paul Campus. Both courses included introductory content and were elective courses for Animal Science majors; both courses were open to all undergraduate students. Companion Animal Nutrition and Care (CANC; AnSc 1403) and Horse Management (HORS; AnSc 2055) were offered in-person (section 001) and fully online (section 002) concurrently for both academic years. 'Fully online' was defined as all course work was completed online with no need to meet face-to-face (Osguthorpe, 2003; Bliuc et al., 2007; Hoic-Bozic et al., 2009; University of Minnesota, 2016b). In-person sections consisted of traditional classroom style lectures that utilized PowerPoint to deliver course content and hands-on activities. In-person sections utilized the online platform Moodle (Moodle Pty. Ltd., West Perth, Australia) to host course content (i.e. copy of PowerPoint slides), the course grade book, and supplementary materials (i.e. YouTube videos, journal articles, extension factsheets). In CANC, Top Hat (Top Hat, 2016), an immediate response system, was utilized for course quizzes. Both online sections were hosted and delivered using Moodle. Both instructors utilized recorded PowerPoint slides with audio to deliver online course materials. In the CANC course, in-class guest lectures and companion animal pet visits were recorded and posted for students enrolled online. Both online courses also utilized Moodle to host online course discussions, quizzes, exams, supplementary material and the course grade book.

Companion Animal Care and Nutrition was an introductory, 3-credit, freshman-level course available to all undergraduate students interested in nutrition and care of companion animals. This course was designed for individuals who had no prior collegiate coursework in companion animal care or nutrition, but who had an interest in learning about the subject matter either personally or professionally. Animal science majors were required by the instructor to enroll in the in-person section; non-animal science majors were allowed to enroll in either section. However, exceptions were made by the instructor for Animal Science majors with extenuating circumstance to enroll online. Topics included nutrition of healthy companion animals and factors affecting companion animal nutrition including behavior, environmental conditions, and food type and availability. Three exams, two homework assignments and 10 quizzes were offered. Students enrolled in the in-person section participated in a pet visit where one student brought their pet to class. The student discussed their pet’s nutrition, care and behavior for approximately 5 to 10 minutes after which other students in the class could ask questions. When all assignments were combined, in-person students had the opportunity to earn 400 points.

Online students were also given three exams, participated in 10 discussion forums, and were given two homework projects, which resulted in 500 possible points. Students enrolled in the online section were invited to attend any in-person pet visit, although it was not a requirement nor were points awarded for attendance. The same scale for assigning final letter grades were used for both sections of the course.

Horse Management was a 2-credit, sophomore-level, introductory course that covered basic horse science topics including careers, breeds and uses, unwanted horses, estimating bodyweight and body condition score, behavior, feeding management, forage options, poisonous plants, pasture and facility management, vaccinations and deworming, colic, and basic health assessments. In-person students completed the pre- and post-assessment, three examinations, one debate, two group presentations, and five assignments. Students also earned points for attendance, participation, and completing the course evaluation. Combined, the in-person students could earn 650 points. Online students had weekly assignments that were open for multiple days including six forum discussions, six multiple-choice quizzes, and three exams. Students also received points for completing the pre- and post-assessments and the course evaluation for a total of 500 possible points. The same scale for assigning final letter grades were used for both sections of the course.

Data were collected to assess undergraduate student learning gains and satisfaction. Due to course content, each course offered a different assessment that tested students with 20 to 25 multiple choice questions that addressed major concepts the instructors expected the students to learn throughout the semester. Learning gains for individual students in each course and section were measured utilizing pre- and post-assessments that were comprised of identical questions. The pre-assessment was given on the first day of the course before any course content was delivered, while the post-assessment was given during the last week of the course. Assessments were delivered in a design consistent with the format of the section the students were registered in. For example, in-person students completed a paper-copy of the assessment during the class period, while online students completed the assessment online. Only students earning a final course grade and completing both the pre- and post-assessments were used in the data set. Learning gains were calculated by the difference in pre- and post-assessments for each individual student.

To evaluate student satisfaction of the instructor and delivery method, students completed a SRT administered by the UMN. The method of delivery of the SRT corresponded with the section (and delivery method) of the course. The standardized questionnaire included six questions. The SRT evaluations were anonymous; therefore, it was not possible to correlate SRT evaluations to student learning gains. A six-point Likert scale (Likert, 1932) was used for four of the questions while numeric values were used in the remaining two questions.

For both courses and sections (delivery methods), student demographics were collected from official university enrollment records, including declared major, academic year and final course grade (as a numerical value on a 4.0 scale) Demographics were used to help further examine student learning gains and satisfaction. Demographics of undergraduate students enrolled in both courses, sections, and academic years are presented in Table 1.

All variables were analyzed using the NPAR1WAY procedure of SAS (2013), with exception of utilizing the MIXED procedure when testing student academic year. Statistical significance was set at $P \leq 0.05$. Non-parametric test methods were necessary, which were completed using Wilcoxon rank-sum test (SAS, 2013). A combined analysis across academic years for each course was not attempted because of minor variation in course content between academic years. Course (CANC and HORS) delivery methods were also not combined because they taught unique and non-comparable subject matter. All learning gains and SRT parameters for courses, delivery methods, and academic-years were analyzed separately. Learning gains, declared major, and student academic year were modeled as fixed effects.

Results

Undergraduate student demographics are listed in Table 1. With the exception of the online section of CANC, a majority of students enrolled in both courses were ANSC majors with an even split between under-classman (freshman and sophomore) and upper-classmen (junior and senior). The percentage of students completing the SRT were consistently high among students enrolled in both in-person course sections with the expectation of the online section of CANC in both years. Fewer students enrolled in the online sections of CANC complete the SRT (29 and 35%) compared all other courses, years and delivery methods (≥ 82%). Online students in the HORS course received points for completing the SRT while students enrolled online in CANC did not. Offering points to students enrolled in online courses appears to be an effective method of encouraging student completion of the SRT.

Student learning gains occurred with both delivery methods and in both courses and academic years, although differences were observed between in-person and online delivery methods (Table 2, $P \leq 0.0002$) in three out of four course-academic year combinations. Students in both courses, delivery methods, and academic years started with a similar knowledge level with pre-assessment scores ranging between 48 and 52% correct. Post-assessment scores increased, resulting in learning gains ranging from 12 to 41%. Of the four course-academic year combinations, differences between in-person and online student learning gains were found in both academic years of CANC and in the second academic year of HORS ($P \leq 0.001$). When differences were observed between delivery methods, students enrolled in the in-person sections had greater learning gains compared with students enrolled online.

Final course grades were also evaluated and differences were observed between students enrolled in-person and online in three of the four course-academic years with final course grades ranging from 3.2 to 3.8 on a 4.0 scale (Table 2). There were differences between in-person and online final course grades in both academic years of CANC ($P \leq 0.03$) and the second academic year of HORS ($P < 0.02$). In CANC, online students earned a higher final course grade compared with in-person students. Even though students enrolled in the online sections of CANC had lower learning gains, they earned a higher final course grade compared with students enrolled in-person. Conversely, in the second academic year of HORS, in-person students earned a higher final course grade compared with online students. Students enrolled in-person also recorded higher learning gains compared with students enrolled online. However, in all three situations, the difference was less than one letter grade (i.e. A- to B+) between both delivery methods.

Demographics of the enrolled students were also used to evaluate the effect of student learning gains and final course grades on course delivery method (Table 3). No differences in student learning gains occurred between Animal Science (AnSc) and non-AnSc students in either delivery methods, courses, or academic years. Only in the first academic year of CANC did declared major affect the final grade of students enrolled in the in-person course. In this instance, the ANSC majors received a higher final grade compared with the non-ANSC students.

Some differences in student learning gains and final course grades between academic level of students and the delivery methods of each course were observed (Table 4). In the first year of CANC, differences were observed between sophomores, while in the second academic year, differences were observed between freshman, junior and senior students. In each instance, in-person students recorded greater learning gains compared with online students ($P \leq 0.05$). In the second year of HORS, differences were observed between sophomores with in-person students recording greater learning gains compared with online students ($P \leq 0.05$). No other differences between academic level and delivery methods were observed for HORS.

Only two differences in final course grade based on academic level and delivery methods were found. In year two of CANC, freshmen enrolled in the in-person course achieved a higher final course grade compared with freshmen enrolled online ($P \leq 0.02$). The same trend was observed in year two of HORS with sophomores enrolled in-person achieving a higher final course grade compared with sophomores enrolled online ($P \leq 0.01$).

Students in both courses, years and delivery methods somewhat agreed to highly agreed with the first four SRT questions indicating all students were satisfied (Table 5). Question 1 addressed the instructor's ability to present the subject matter clearly. There were no differences ($P \leq 0.08$) between courses, years or delivery methods with responses ranging from 5.4 to 6.0 on a 6.0 scale. Question 2 assessed the instructor's ability to provide feedback intended to improve the student's performance in the course. There were no differences ($P \geq 0.2$) between delivery methods in both academic years for CANC with responses ranging from 5.2 to 4.9 on a 6.0 scale. In HORS, students enrolled in-person reported greater response means ($P \leq 0.04$) compared with students enrolled online. However, ratings in both years and delivery methods in HORS showed students were satisfied with rating ≥ 4.8. Question 3 asked if students had a deeper understanding of the subject reminder as a result of the course. Differences were observed for the first academic year in both CANC and HORS courses ($P \leq 0.01$), while no differences were observed in the second academic year for both courses. When differences were observed, students enrolled online reported a higher satisfaction. However, all ratings were ≥ 5.2 indicating all students either highly agreed or agreed they had a deeper understanding of the subject matter. In the fourth question, students were asked if their interest in the subject matter was stimulated as a result of the course. When differences were observed, students enrolled in-person indicated their interest in the subject matter was stimulated more than their online peers ($P \leq 0.01$). However, all responses were ≥ 5.0 indicating all students agreed or strongly agreed their interest in the subject matter was stimulated. Although some difference was observed between students enrolled online and in-person, mean course evaluations were high (≥ 4.8) for all students, indicating an over-all satisfaction from undergraduate students enrolled in both courses, academic years, and delivery methods.

There were no differences when students were asked if they would recommend the courses to other students (question 5). Students enrolled in both courses, academic years and delivery methods indicated they would recommend the course and delivery methods to other students (Table 5). The final question (question 6) asked students approximately how many hours per week they worked on course content. Students in both courses, years and delivery methods worked between zero and two hours each week on course material. Only in the second academic year of CANC did the online students indicate they worked more hours on course material compared with their in-person peers ($P \geq 0.01$).

Discussion

Riffell and Sibley (2005) suggested that teaching large science courses online were less successful than courses with smaller enrollment. However, data from this study does not support their conclusion. CANC was a larger enrollment course with ≥ 49 students enrolled either in-person or online. However, both delivery methods resulted in student learning gains and satisfaction. Examination of even larger courses (≥100 students) is warranted to confirm student satisfaction and learning grains when enrolled in online course.

The current study agrees with findings from Zhao et al. (2005) and Bing et al. (2011) who concluded that online courses could be a successful alternative to in-person courses. Zhao et al. (2005), determined students enrolled in online courses on various subjects achieved learning gains similar to their peers enrolled in-person. This observation could be due to enhanced technology, more user friendly platforms used for online teaching, and the increased adaption of technology among college-aged students (Nguyen, 2015). Bing et al. (2011) reported positive learning gains for both in-person and online delivery methods when students were enrolled in a domestic animal laboratory, with no difference between the two delivery methods. In the current study, all students demonstrated positive learning gains throughout the semester ranging from 12 to 41%. However, differences between in-person and online sections were observed. An Australian study reported undergraduate students in veterinary science adopted a poor approach to learning with online courses because they were unsure how to use online resources (Ellis et al., 2005). The current study cannot attest to individual student's approach to learning, although the positive learning gains observed across courses, academic years and delivery methods point to the broad success of students. Ellis et al. (2005) also reported less successful students struggled with courses offered online compared to their peers enrolled in-person. Unfortunately, the current study cannot address this finding because of the inability to correlate SRT results to student learning gains and final course grades because SRT results are anonymous. This area should be investigated further as animal science departments expand their online course offerings.

In the current study, a declared AnSc major had no effect on student learning gains. Because both courses were introductory-level elective courses, it is logical that academic major did not have an impact on learning gains. It is also possible that non-AnSc majors had personal experience with horses or companion animals prior to enrolling in the courses.

Because prior student knowledge of horses and companion animals was not known or required, it is realistic to expect that academic level had a varied impact on learning gains in these introductory-level, elective courses within the AnSc major. A concrete conclusion regarding the effect of academic level on student learning gains and final course grade between in-person or online students cannot be made from data collected in the current study. Future research should focus on the interaction of academic level and student learning gains when students are enrolled in more advanced courses.

In the current study, student satisfaction was high in both courses, academic years and delivery methods. Students somewhat agreed to highly agreed that the instructors presented the subject matter clearly, the instructor provided feedback intended to improve course performance, the course resulted in a deeper understanding of the subject matter, and that their interest in the subject matter were stimulated as a result of the course. Although differences between online and in-person students were observed, all ratings were $\geq$4.8 on a six-point Likert scale or fell mostly in the “agree” area. Bradford (2011) observed that as course material difficulty increased in online courses, student satisfaction also increased. Because student satisfaction was acceptable for these introductory courses that included basic content, the same observations appear to be true when course difficulty was lower. Bolliger and Wasilik (2012) found that although students had minimal interaction with each other or with the course instructor, they were still satisfied with the delivery method of two online statistics courses. Both online courses in the current study included multiple forum discussions throughout the semester in which students could interact with one another and the instructors. These discussions may have resulted in a feeling of interaction and greater satisfaction among students. Creating ways for students enrolled in online courses to interact with one another and the instructor should be encouraged.

In the current study, mean final course grades were ≥3.2 on a 4.0 scale (or above a B-). The higher average final course grades could also have contributed to the higher student satisfaction ratings. Navarro and Shoemaker (2000) determined that student satisfaction in coursework was closely linked to student performance and student interaction.

In the current study, students spent ≤ 2 hours per week when enrolled in both the in-person and online courses. This is less than most University and instructor expectations for a 2- or 3-credit collegiate course that would traditionally require 2 hours per credit or 4 to 6 hours per week. The introductory-level of both courses may help explain why students spent less time per week than expected.

Because there is no agreed upon or standard metric for measuring student learning gains or satisfaction, it is hard to conclude which format, in-person or online, is better

(Nguyen, 2015; Allen et al., 2016). Student learning gains and student satisfaction results found in the current study align with the perceptions of a majority of academic leaders who believe online learning can result in similar student learning gains and satisfactions compared to in-person learning opportunities (Allen et al., 2016). Based on these results, it appears online courses can be successfully used to teach undergraduate students introductory-level animal science courses.

Conclusions

When evaluating undergraduate, introductory-level, online and in-person courses, students utilizing both platforms experienced positive learning gains and were satisfied. Learning gains occurred in both courses, academic years, and delivery methods, although students enrolled in in-person courses had greater learning gains compared with students enrolled online. Final average course grades ranged from 3.2 to 3.8 (on a 4.0 scale) and showed some differences between students enrolled in-person and online. However, final course grades were not always higher for students enrolled in-person, and differences within delivery methods were less than one half of a letter grade (0.5 on a 4.0 scale). Difference in student learning gains and final course grades between academic levels were found in some instances. However, all students experienced positive learning gains. Student responses to end of semester course evaluations showed that students were satisfied with both courses and delivery methods with mean evaluations ranging from 4.8 to 6.0 on a 6.0 Likert scale. However, in some cases, in-person students showed a higher level of satisfaction compared with students enrolled online. Based on these results, it appears that online courses can be successfully used in introductory-level animal science courses to teach undergraduate students.

Table 1. Demographics of undergraduate students enrolled in two animal science (AnSc) courses at the University of Minnesota during academic years 2014-2015(AY 1) and 2015-2016 (AY 2), that completed both the pre- and post-assessments and received a final grade. Demographics are separated by class delivery method: in-person (INP) or completely online (ONL).

	CANC				HORS			
	AY 1		AY 2		AY 1		AY 2	
	INP	ONL	INP	ONL	INP	ONL	INP	ONL
Total	69	49	67	94	10	23	17	20
Major[1]								
AnSc	55	0	56	8	6	10	15	15
Non-AnSc	14	49	11	86	4	13	2	5
Academic Year								
Freshman	8	5	11	2	0	2	3	1
Sophomore	25	9	25	10	2	3	10	8
Junior	21	9	14	24	3	7	2	3
[2]Senior	15	26	17	58	7	11	2	8
[3]SRT (%)	97	35	97	29	83	100	82	85

[1]Declared major according to official University records.
[2]Includes non-degree seeking and professional students.
[3]Percent of total enrollment that completed Student Rating of Teaching (SRT) evaluation.

Table 2. Mean percent correct on pre-assessment (Pre), post-assessment (Post), student learning gains (Gain; Post-Pre), and final course grade (Final Grade) for undergraduate students enrolled in Companion Animal Nutrition and Care (CANC) and Horse Management (HORS) by academic year (AY) and course delivery method (in-person or online).

	CANC				HORS			
AY 14/15	Pre (%)	Post (%)	Gain	Final Grade[1]	Pre (%)	Post (%)	Gain	Final Grade[1]
In-person	48	71	23*	3.4*	47	82	35	3.7
Online	49	65	16*	3.6*	48	80	32	3.4
AY 15/16								
In-person	52	74	22*	3.2*	50	91	41*	3.8*
Online	49	61	12*	3.5*	48	76	28*	3.4*

*Within columns indicates a difference between delivery methods (in-person and online) for each course and academic year ($P < 0.05$).
[1]Final course grade based on 4.0 grading scale (4.0 = A, 3.0 = B, 2.0 = C, 1.0 = D).

Table 3. The effect of a declared animal science (AnSc) or non-animal science (non-AnSc) major on student learning gain (%) and final course grade for undergraduate students enrolled in Companion Animal Nutrition and Care (CANC) and Horse Management (HORS) during two academic years (AY) for in-person (INP) and online (ONL) delivery methods.

	CANC				HORS			
	Learning Gains		Final Grade[1]		Learning Gains		Final Grade[1]	
AY 14/15	INP	ONL	INP	ONL	INP	ONL	INP	ONL
AnSc	24	-	3.5	-	35	34	3.7	3.3
Non-AnSc	22	16	3.2	3.6	35	31	3.5	3.5
AY 15/16								
AnSc	23	14	3.3*	3.1	42	30	3.8	3.4
Non-AnSc	20	12	2.8*	3.6	36	21	3.8	3.3

*Within columns indicates a difference between declared majors by delivery method (in-person and online) for each course and academic year ($P < 0.05$).
[1]Final course grade based on 4.0 grading scale (4.0 = A, 3.0 = B, 2.0 = C, 1.0 = D).

Table 4 Effect of student academic level on student learning gain (%) and final course grade for undergraduate students enrolled in Companion Animal Nutrition and Care (CANC) and Horse Management (HORS) during in two academic years (AY) for in-person (INP) and online (ONL) delivery methods.

	CANC				HORS			
	Learning Gains		Final Grade[1]		Learning Gains		Final Grade[1]	
AY 14/15	INP	ONL	INP	ONL	INP	ONL	INP	ONL
Freshman	23	23	3.5	3.1	-	46	-	2.5
Sophomore	25*	13*	3.4	3.6	33	35	3.4	2.9
Junior	22	12	3.5	3.6	45	25	3.7	3.6
Senior	23	16	3.3	3.7	28	33	3.9	3.6
AY 15/16								
Freshman	25*	7*	3.3*	2.1*	37	32	3.8	3.7
Sophomore	22	18	3.1	3.4	43*	27*	3.8*	3.4*
Junior	22*	12*	3.3	3.5	50	32	3.7	3.7
Senior	20*	11*	3.3	3.6	30	28	4.0	3.3

* Within rows indicates a difference between academic level by delivery method (in-person and online) for each course and academic year ($P < 0.05$).
[1]Final course grade based on 4.0 grading scale (4.0 = A, 3.0 = B, 2.0 = C, 1.0 = D).

Table 5. Mean results of student rating of teaching (SRT) [1] evaluations completed by undergraduate students enrolled in Companion Animal Nutrition and Care (CANC) and Horse Management (HORS) by academic year (AY) and course delivery method (in-person or online).

	CANC		HORS	
	AY 14/15	AY 15/16	AY 14/15	AY 15/16
Question 1[2]				
In-Person	5.5	5.6	6.0	5.8
Online	5.5	5.4	5.5	5.5
Question 2[3]				
In-Person	5.2	5.3	5.6*	5.6*
Online	4.9	5.0	5.0*	4.8*
Question 3[4]				
In-Person	5.6*	5.5	6.0*	5.6
Online	5.2*	5.5	5.3*	5.5
Question 4[5]				
In-Person	5.5*	5.3	5.9*	5.8*
Online	5.0*	5.4	5.2*	5.2*
Question 5[6]				
In-Person	1.0	1.0	1.0	1.0
Online	1.1	1.1	1.0	1.0
Question 6[7]				
In-Person	1.6	1.5*	1.5	1.7
Online	1.6	1.9*	1.4	1.4

*Differences between delivery methods (online and in-person) for each question, course and academic year ($P < 0.05$).

[1]Likert scale; 6 = highly agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, 1 = highly disagree.

[2]The instructor presented the subject matter clearly.

[3]The instructor provided feedback intended to improve my course performance.

[4]I have a deeper understanding of the subject matter as a result of this course.

[5]My interest in the subject matter was stimulated as a result of this course.

[6]I would recommend this course to other students: yes (= 1) or no (=2).

[7]Approximately how many hours per week did you spend working on homework, readings, and projects for this course: 1 = 0-2 hours, 2 = 3-5 hours, 3= 6-9 hours, 4 = 10-14 hours, 5 = 15+ hours.

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