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BEEF CATTLE GRAZING PREFERENCE OF TALL FESCUE AS AFFECTED BY ENDOPHYTE

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ABSTRACT OF THESIS

BEEF CATTLE GRAZING PREFERENCE OF TALL FESCUE AS AFFECTED BY ENDOPHYTE

Many factors control, contribute to, stimulate and limit forage selection. It is apparent that cattle prefer certain cultivars compared to others. This study sought to test if cattle displayed preferences for certain cultivars over a two-year period in 2008 and 2009. Determining the effect of endophyte status on preference was another objective. Previous research showed rapid increase in the selection of preferred cultivars, i.e., diet learning. We attempted to replicate those results. Forty cultivars (34 tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.) cultivars), two festuloliums (Festuca pratensis x Lolium perenne), two meadow fescue (*Lolium pratense*) and one meadow brome (*Bromus biebersteinii*), and one orchard grass (*Dactylis glomerta* L.)) were used to determine preference and to investigate factors contributing to preference. From this two-year study, we observed that cattle preferred certain cultivars compared to others, e.g. KYFA9819 > Latar-OG > Barfest-FL and AU-Triumph < 97TF1-EF < Seine, the most and least preferred cultivars, respectively. During drought conditions, both novel and toxic endophyte cultivars were preferred significantly ($P < 0.05$) to endophyte free counterparts. The cattle showed rejection of unpalatable grasses but did not clearly show learning to increase selection of desired cultivars.

KEYWORDS: tall fescue, grazing preference, forage selection, palatability, grazing behavior

Herbert Troye Owens III

February 8, 2011

BEEF CATTLE GRAZING PREFERENCE OF TALL FESCUE AS AFFECTED BY ENDOPHYTE

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THESIS

Herbert Troye Owens III

The Graduate School

University of Kentucky

2011

BEEF CATTLE GRAZING PREFERENCE OF TALL FESCUE AS AFFECTED BY ENDOPHYTE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture
at the University of Kentucky

By

Herbert Troye Owens III

Lexington, Kentucky

Director: Dr. Timothy D. Phillips, Associate Professor

Lexington, Kentucky

2011

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Chapter 1: Literature Review

Introduction

When given the opportunity to graze without restriction herbivores display selective tendencies. The degree of selectivity varies between different herbivores (Hardison et al., 1954). Many factors control, contribute to, stimulate and limit selection (Aderibigbe et al., 1982; Mayland and Shewmaker, 1999; Provenza, 1995). A non-exhaustive list of factors that control selection includes physical attributes, chemical factors, postingestive controls and environmental factors (Provenza, 1995).

Provenza (1995) outlines four models for food selection. They include euphagia, hedyphagia, body morphophysiology and learning from forage consequences. Euphagia is considered a ruminant's instinctive ability to sense factors in their feed. It combines the use of the senses to select food based on a nutritional basis; also, it allows the animal to shun foods that are injurious to them because of toxic factors.

Hedyphagia is defined as selection of foodstuffs that are found "immediately 'pleasing'" to the senses, while simultaneously not selecting those that are displeasing (Provenza, 1995). Provenza contrasts euphagic selection with hedyphagic selection by indicating that the animal is choosing based on qualities present in the food that may not directly be related to a nutritional or toxic make up. Evolution is implicated in aligning taste perception of plants so that plants with a bad taste are also toxic and the inverse is true that nutritious plants are good tasting (Provenza, 1995).

Body-morphophysiology model supporters, according to Provenza, believe that the evolutionary history of a ruminant dictates its ingestion habits. Through generations of evolution in varied environments, each ruminant would have had its diet honed to its specific corporal needs. In this model, each ruminant is principally directed by its evolutionary past (Provenza, 1995).

The forth model is an amalgamation of the other three models. It is learning through foraging consequences. This learning through consequences model provides the animal with dietary latitude to choose foods from a mixture of possibilities, and in that, the animal would receive feedback (Provenza and Balph, 1990). The feedback, which is negative or positive, dictates future selection by the animal. The impact of toxic or nutritive foods on the animal's body would contain a facet of the body morphophysiological model. Chemical messages in the brain from the senses cause positive or negative hedonistic responses that exemplify the hedyphagia model. The final aspect of the model relates to the euphagia model in which "feedback from nutrients and toxins can enable animals to select nutritious foods and limit intake of toxic foods" (Provenza, 1995).

Overall, considering the complexity of animal behavior and the lack of complete knowledge for selection in animals, learning through consequence seems to be the most reasonable model for describing herbivorous food selection. There is definite overlap between the models, and at different times, different models can explain a given grazing situation. Focusing on one possible model to explain all grazing does not accurately cover the all inputs into the animals system but the learning model covers the greatest aspects of animal selection (Provenza and Balph, 1990).

Selection and Preference

Selection, preference and palatability are terms that some may use synonymously or interchangeably; however there are differences between the terms. Selection is simply an observation of how an animal chooses between different types of feed. Preference is selection, however, the distinction between preference and selection is a "proportional choice among two or more foods" (Heady, 1964). Meaning the animal is not merely grazing at random but, for a number of reasons, is selecting one species or cultivar more than another. It is possible that there is an evolutionary distinction between the terms, preference is hard wired into the brain stem and limbic system while selection is under cortical control (Provenza, 1996). Accordingly, it is this more recent evolutionary development that allows the cortex to override preference (brain stem) and respond to changes (Provenza, 1996).

Palatability

The term that describes the factors that influence or direct preference is palatability. Palatability can be described as a quality or state of a plant that increases the likelihood of its selection (Heady, 1964). So rather than being synonymous terms palatability is a factor that can drive preference. Palatability has been defined as how readily a food is "selected and eaten" (Jones, 1952). Provenza and Balph (1990) describe a situation where palatability is dependent upon internal feedback from the rumen after food consumption. Palatability has the connotation of pleasure in some instances, as sweet flavors are considered more palatable than bitter ones. However, this can be subverted when bitter flavor is paired with positive feedback from the rumen, preference increases and when sweet is paired with negative feedback preference decreases (Provenza and Balph, 1990). The previous example shows how preference can change in response to feedback; maintaining a good internal environment is more important than selecting the most palatable food.

Preference is rarely a result of one plant characteristic but rather is the combined effect of a suite of characteristics of which palatability is one (Mayland and Shewmaker, 1999). Palatability itself has many factors that can make forages more or less palatable. Affecting the palatability can alter intake rates leading to a possible change in preference. It is possible to alter preference by changing the palatability of a grass. A less preferred tall fescue with unpalatable sulfur-based compounds was made to have its preference increased with the application of juice from a preferred Italian ryegrass species (Scehovic et al., 1985). Presumably, this occurred because the juice from the ryegrass masked the unpalatable favors thus illustrating how one of many different plant characteristics can affect palatability and preference.

Animals interact with their environment through their senses. Plants possess many characteristics that animals perceive. A foraging animal uses the senses of taste, sight, touch and smell to select food in the environment; simultaneously impairing all four of these senses results in reduced selection of preferred species (Krueger et al., 1974). Taste and smell are mediated through chemical interactions while sight and touch are physical. Studying the plant/animal interface can help show how sensory inputs and the following reactions support different aspects of the models of food selection; euphagia, hedyphagia, body morphophysiological and learning through consequence (Provenza, 1995).

Physical Perception

Tactility

As a means of deterring predation for an array of herbivores, grasses and other plants have developed morphological defenses (Provenza and Balph, 1990). Pubescence or the presence of hair-like structures on the plant is a common antigrazing strategy employed by plants (Mayland and Shewmaker, 1999). As a result, some animals find plants with hair unpleasant (Hardison et al., 1954). Cattle (*Bos taurus*) have been observed using their muzzle to presumably “feel” forages (Mayland et al., 1997). Contradistinctively, a study in sheep revealed that sheep preferred trichome dense globemallow leaves when compared to less dense ones (Rumbaugh et al., 1993). Other methods of deterrence by plants that directly target the sense of touch these would include thorns, spines, and stickiness (Baumont, 1996).

Tough grass is harder to masticate thus harder to reduce the particle size resulting in more time spent chewing and a decreased intake rate. There is a positive correlation between intake rate and preference, implying that grasses with higher tensile strength, i.e. tougher, would be negatively correlated with preference (MacAdam and Mayland, 2003). MacAdam (2003) found that the strongest leaves were the least preferred while the weakest were the most preferred. She also reports that increased distance between leaf vascular bundles, i.e. leaf width, is positively correlated with preference (MacAdam and Mayland, 2003). Krueger et al., 1974, found that when controlling the senses for touch animals generally selected plants with minimal coarseness.

Visual Perception

Sight is readily used by grazing animals. It seems intuitive that sight played an important role in animal food selection however early studies of vision and preference revealed that there was little difference between blinded sheep and sighted ones (Arnold, 1966). Arnold found that blinded sheep altered their grazing behavior but not their preference. He concluded that sight mainly functioned as a means by which the animal oriented itself in space. In Arnold's study the animals' vision was not completely blocked, meaning the animal had a slight ability to discern plants (Krueger et al., 1974). Rumbaugh (1993) tested the palatability of globemallow, crested wheatgrass and alfalfa by planting 85%, 14% and 4%, respectively, in a pasture. Sheep were allowed to graze freely. Between the three species, alfalfa was the most desired; the sheep were observed, "stretching their necks and scanning" for more alfalfa plants (Mayland and Shewmaker, 1999; Rumbaugh et al., 1993). Rumbaugh's results strengthen greatly the link between sight and selection; however, it does not explore the ability of an animal to distinguish between more similar species as in a pasture of different grasses. Krueger found that when controlling smell, taste and touch sheep were able to reject unpalatable plants using sight only (Krueger et al., 1974). This is an example of the importance of the learning model of feeding; the sheep recognized that a certain plant was unpalatable and rejected it. MacAdam (2003) found that leaf width was correlated with preference, this can attributed to sight or postingestive factors or degrees of both; a blind study in cattle with the same cultivars could be helpful to tease out the differences (MacAdam and Mayland, 2003).

Chemical Perception

Plants produce a large number of chemicals for a large variety of uses. Some of these chemicals are volatile in nature. Over fifty volatile compounds were found in common between eight entries of endophyte-free tall fescue cultivars (Mayland et al., 1997). The particular sensitivity animals have to these chemicals is not truly known but animals possess a sense of smell and taste that may allow them to acknowledge the presence of any or some of those and other compounds.

Olfaction

Observation of cattle behavior has been used to bolster claims that olfaction plays an important role in selection. Cattle have been observed moving the muzzle over the "canopy" of a sward and passing by certain forages while stopping to eat another (Shewmaker et al., 1997b). When different cultivars were planted next to one another, a border effect was noticed. The border area between two adjacent plots can send mixed olfactory signals to the animal causing it to graze in the middle of the plot at a greater degree than on the border (Shewmaker et al., 1997a). The close proximity causes the aromatic signals to alter the perception of palatability.

Mayland et al. (1997) found a significant correlation between grazing preference and the presence of 6-methyl-5-hepten-2-one, (Z)-3-hexenyl propionate and acetic acid. These chemicals *could* convey a pleasurable quality to the animal; but only a correlation was shown. More study would be needed to show if the application of the chemicals affected their palatability. Those results might explain the results of Scehovic's study where the application of juice from a palatable cultivar onto an unpalatable one increased selection of the unpalatable cultivar and the reverse application (unpalatable juice onto palatable plant) reduced selection. It could be assumed that spraying a substance on a plant will affect the taste of the plant but the effect was limited in time. This means the responsible chemicals were probably volatiles sensed by the animals (Scehovic et al., 1985).

Gustation

Among the four senses animals use for grazing, taste is of primary importance (Krueger et al., 1974). The other senses are present to complement taste (Mayland and Shewmaker, 1999). Garcia (1989) unambiguously states, "taste is the arbiter of what is fit to eat." Taste gives the animals the ability to differentiate between foods and stimulates hedonistic sensations (Provenza, 1996). The immediate pleasing or displeasing response to taste is the basis of the hedyphagia grazing model, where grazing is strongly mediated by pleasure; evolution has taught the animal that toxic plants taste bad and nutritious plants taste good (Provenza, 1995). Some plants exploit this evolutionary learning to their advantage by producing compounds that taste bad thus reducing the incidences of herbivory.

Grazing animals can recognize bitter, sweet, sour and salty tastes (Goatcher and Church, 1970). Researchers have identified the chemoreceptors associated with those tastes on sheep's tongue (Grovum, 1988). Goatcher and Church (1979) tested the sensitivity of goats (*Capra aegagrus hircus)*, pygmy goats, sheep (*Ovis aries)* and cattle (*Bos taurus)* to the low concentration of chemical solutions representing bitter, sweet, sour and salty tastes; they reported the following results:

Sweet: Cattle > Normals[1] > Pygmies > Sheep
Salty: Cattle > Pygmies > Normals> Sheep
Sour: Cattle > Pygmies = Sheep > Normal Goats
Bitter: Pygmies = Normals > Sheep > Cattle

Additionally they tested the rejection rate at high concentrations of the same chemicals; resulting in the following:

Salty: Cattle > Sheep > Normals > Pygmies
Sour: Cattle > Sheep > Normals and Pygmies
Bitter: Sheep = Cattle > Normals = Pygmies
Sweet: No rejection found

It has been shown that cattle prefer hay cut at sundown versus sunrise. This is probably because of the taste conveyed by nonstructural carbohydrates (Fisher et al., 1999). As the day progresses the levels of water-soluble carbohydrates increases, and these compounds, including sucrose, are sweet tasting to the cattle (Smith, 1973). Sweet taste is very desirable to cattle, which prefer sweet tastes and flavors (Nombekela et al., 1994). Gilbertson et al. (1997) found that in rats (*Rattus norvegicus*) malate and citrate intensified sweet flavors, and if a grass had a higher concentration of either of the two, it would probably be more palatable. However, in tests with cattle there was only a weak correlation between the organic acids and preference (Mayland et al., 2000b).

Growth promoted by the application of fertilizer may affect the taste of forages. The acceptability of orchard grass declined with an increase in nitrogen fertilization (Reid et al., 1966). The effect may be attributed to the increase in growth that a fertilized plant experiences thus reducing the concentration of nonstructural carbohydrates, altering the carbohydrate-nitrogen balance and reducing sweetness (Smith, 1973). The alteration of this balance has digestive consequences in that correlations between carbohydrates may also show evidence of digestive feedback in the cattle. Taste initiates the feedback loop, which is continued by

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[1] Normals refers to normal goats
[2] Represents an advanced stage of maturity

information from the rumen that controls the rest of the meal (Early and Provenza, 1998; Mayland et al., 2000a).

To determine palatability, animals use cues from primary sensory stimulation. Invoking a strong response to one or more of the senses can result in rejection and aversion or acceptance and preference (Provenza and Balph, 1990). Euphagia assumes ruminants have the ability to directly sense toxins and nutrients; researchers doubt the likelihood of that ability (Provenza, 1995; Provenza and Balph, 1990). Purely hedonistic or hedyphagia approach only explains palatability as an immediate pleasurable sensation, it does not explain why the most pleasurable choice may not always be the preferred. There are other factors involved. The fourth model of food selection, learning based on feeding consequences, helps enumerate the other factors that condition an animal's food selection. The senses (e.g. taste, sight) work in concert with feedback mechanisms; many of an animal's choices that appear to be solely based on taste, may be further stimulated by feedback from the viscera (Provenza, 1995). The animal receives internal feedback after ingestion thus garnering the name postingestive feedback.

Postingestive Feedback

Processing feedback and the resulting behavioral changes validate the learning model. Without considering the learning model, it seems paradoxical that a foraging animal does not always select the food of highest nutritional quality but when including previous experience into the situation it becomes less illogical (Provenza and Cincotta, 1993). Consuming forage containing excesses of nutrients, like rapidly digestible protein, causes ammonia production in the rumen; this causes malaise and decreases intake (Provenza, 1995). Malaise is the internal feedback message that limits feeding, which is often observed as decreased preference. The same is true with the ingestion of toxins; there is a threshold upon which once reached a grazer will cease the meal because of malaise. Most signals are carried in ruminal blood flow to the brain. Once grazing commences blood flow increases, it takes about 15 minutes to reach peak flow. Traveling through the blood are chemical signatures of both toxins and nutrients (Provenza, 1995). Once those signals reach the brain there will be a consequence, either acceptance or aversion.

There are different candidate molecules that carry postingestive messages to the brain. Presumably, the byproducts of fermentation by gut microbes are responsible for most of the chemical production; chemicals like volatile fatty acids, propionate, ammonia or amino acids amongst others (Provenza, 1995). The viscera has a rich supply of afferent receptors signaling the brain work in concert with microbial metabolite molecules along with insulin, which allows for a rapid response as to the condition of the meal. If an animal receives a dearth of feedback or negative feedback intake is reduce while the opposite case is also true. The lack of nutrients and presence of toxins adversely affects rumen microbes and causes a reduction in the very chemical byproducts to which the brain is conditioned to respond (Provenza, 1995; Van Soest, 1994).

Postingestive signals may operate as ways to maintain proper rumen function; in this way, preference would show selection of forages with the proper nutritional constituents to achieve or sustain equilibrium (Faverdin, 1999). Nutrients can affect "osmotic pressure equilibrium, rumen distension, homoeothermic and acid-base equilibrium in the blood and rumen [,]" altering one or more of these may affect learning and have a sustained impact on intake (Faverdin, 1999; Villalba et al., 2009). A rumen becomes toxic when there is too much protein production and absorption. The remedy for this is to reduce intake (Faverdin, 1999). Ruminants have the ability to modify and alter their selection as a means of malady mitigation (Provenza, 1995). This puts preference on a continuum that shifts with the internal state of the rumen and causes the selection of species that were normally considered unpalatable if they offer relief from malaise. Provenza (1995) parallels this to a person consuming medicine, the medicine's flavor is displeasing but its soothing effect is the impetus behind its consumption. Similarly, when an unpleasing flavor is paired with caloric content it is selected preferentially to a pleasing flavor with no caloric value.

Cognition

The brain has different ways to separate the messages it receives from the viscera and the sense organs. It is possible to form a dichotomy determined by the mental processes used by the animal, cognitive or noncognitive (affective). Noncognitive responses are controlled by the lower brain, primary brain stem and limbic system (Provenza, 1995). Taste becomes linked to postingestive consequences (good or bad) which alter the "incentives" for consuming certain foods; this is a "neurally mediated interaction" between taste and the body. The cognitive process uses the other senses are to choose foods that cause satiation while shunning those who cause malaise (Provenza, 1995). Different portions of the brain control cognitive and affective processing; they work together on internal environment and that internal environment is where directs food preference.

Anatomy elucidates possible reasons for the affective versus cognitive model. Taste neurons and visceral neurons terminate in a primitive portion of the brain; olfactory neuron rest near the amygdala (limbic system), the area of the brain responsible for emotions, motivation and fear (Provenza, 1995). Evolutionarily this links olfaction to the ability to avoid predators and toxins. As messages enter the brain they first encounter the brainstem then travel to the limbic system followed by the cortex (Provenza, 1996). Timing is another factor that causes separation between olfaction and taste-feedback. For a novel olfactory aversion to arise the postingestive feedback has to occur immediately, taste, however, can take many hours as digestion ferries the messages to the brain (Provenza, 1995; Provenza, 1996).

The affected area of the brain plays an important role in forming an aversion. When an emetic system (brainstem) response is triggered, an immediate aversion is formed to the agent that is perceived to have caused the insult (Ginane and Dumont, 2006; Provenza, 1995). Ruminants have trouble forming aversions to toxins that do not activate an emetic response; drugs such as strychnine and cyanide do not form aversions because they affect the metabolism and the nervous system (Provenza and Balph, 1990). Gastrointestinal (GI) distress causes two possible effects, lower GI discomfort (cramps, diarrhea and flatulence) generally does not cause a lasting aversion however when the emetic system is affected (upper GI discomfort) causes an aversion to form (Provenza, 1995). An emetic response is hardwired into the brainstem to cause aversions and avoidance.

Conscience memory (cognition) does not necessarily convey aversion. It is presupposed that memory is the process of actively recalling past experiences; however, there is a form of emotional (non-cognitive) memory (LeDoux, 1992). The hippocampus and the cortex control conscious memory while non-cognitive is operated by the thalamus, amygdala and the cortex and functions independent of conscience awareness (Provenza, 1995). The emotional memory information could be stored with the conscience memory and retrieved as if it were consciously collected and fit perfectly with the flow of memory (LeDoux, 1992). This storage overlap helps explain why an anesthetized animal could develop an aversion to food consumed prior to the anesthesia (Provenza, 1995; Provenza et al., 1994). Provenza (1994) shows this when sheep were feed a familiar food and then put under anesthesia, while anesthetized they were administered an “intraruminal injection of LiCl,” the sheep later developed an aversion for the food. The same principal was shown in studies of non-ruminates.

Learning

Postingestive information would have little importance long term if the animal were incapable of recalling and associating novel sensory input with a catalog of past events. Animals remember what they learn; if not, everything would be viewed as novel and met with hesitance (Provenza and Cincotta, 1993). Evidence that animal do indeed remember can be seen when they discriminate between familiar and novel foods, they are cautious when sampling novel foods (Provenza and Cincotta, 1993). According to Provenza and Cincotta (1993), an herbivore can remember a positive or negative event for up to 1-3 years. Range managers report increased incidences of death in new cattle that are unfamiliar with the plants as opposed to cattle that were raised with those same plant species (Launchbaugh and Provenza, 1991). Launchbaugh (1991) reckons cattle can remember all the species of plants encountered on a range citing the ability of a particular "seed-caching" bird to remember the location of 9000 seed storage sites.

Learning from Others

Some factors that influence grazing are beyond the control of the GI tract. These elements come from maternal interaction and social behavior. Cattle are very social animals; they have complex forms of communication and a social hierarchy structure, which invariably controls grazing behavior (Phillips, 2002). Herds have dominant and subordinate members; dominant cattle generally consume more forage than do their subordinate counterparts. Subordinate cattle may have to select less preferred forage in a heterogeneous environment because dominant members begin foraging earlier in the day; thus, the forage available to the subordinate members is less nutritious (Dumont et al., 2002; Phillips, 2002). Spatial distribution can also effect selection because cattle have a desire for personal space, if a dominant member is grazing in a certain area less dominate cattle have to seek a patch that is outside the personal space of them in avoidance of eye contact (Phillips, 2002).

Social interaction can also alter an acquired food aversions. Ralphs and Provenza (1999) report that aversions can be broken by social facilitation followed by trial sampling. The influencing of one animal on another is social facilitation (Ralphs and Provenza, 1999). When an animal with an aversion to a particular food observes other animals selecting that food it will resample the food, if no adverse consequences result, continued grazing will occur, ending the aversion (Ralphs and Provenza, 1999). In sheep raised together, it was noted that the desire to remain together was greater than the desire to forage on preferred patches (Scott et al., 1995).

The maternal bond is another strong factor determining selection and preference (Roguet et al., 1998). Post-partum bonding between mother and calf occurs almost immediately. The mother bonds chemically with the fetus while *in utero.* There are plant molecules present in the placenta that pass through to the fetus. It is possible that the fetus learns about flavor prior to birth through that connection (Provenza and Balph, 1990). The fetus is able to associate the flavors with gastrointestinal consequences (Provenza et al., 1992). If a pregnant cow is deprived sodium, her calf is likely to have an increased desire for sodium (Phillips, 2002). In lambs the gustatory system is operational during the final trimester meaning that the brain is probably receptive to the chemical cues it receives (Provenza and Balph, 1990). After birth it is likely that the flavor messaging is transmitted through the mother's milk, this reinforces the signals the fetus received *in utero* conditioning them to prefer certain flavors to other prior to their first grazing event (Provenza and Balph, 1990). Lambs raised on flavored milk preferred foods that possessed the same flavor as the milk (Launchbaugh and Provenza, 1991). Thus, the developing brain retains much information on the composition of foods. The mother cow is the primary instructor once the calf is ready to begin grazing. The young calf closely follows its mother selecting foods she selects. Avoidance from the mother yields avoidance in the progeny (Launchbaugh and Provenza, 1991). Orphan lambs exhibit different grazing behavior than lambs accompanied by their mothers' (Thorhallsdottir et al., 1987). Post weaning lamb's preference mirrored their mother's preference between two species, one of which the mother had been conditioned to avoid (Mirza and Provenza, 1994).

Incorporating New Information

As young ruminants begin grazing, they must sample cautiously as they build their library of tastes and consequences. Plants vary widely in levels of nutrients and toxins throughout the year and selection is mediated on the basis of those levels (Provenza and Balph, 1990). The goal of successful grazing is to select nutritious plants at a higher rate than toxic ones (Provenza, 1995). Ruminants continually sample different things in the environment; they freely sample familiar foods while cautiously sample novel ones. Novel foods may be rejected despite being nutritious, if the animal does not perceive them as having desirable characteristics (Provenza and Balph, 1990). Sampling allows the animals to gain knowledge about available plants. When cattle are moved to a new environment, they continue to sample, a negative consequence that may result is the over consumption of novel toxic plants. New cattle may consume toxic plants in excess prior to receiving negative feedback whereas cattle familiar with that environment avoid those plants (Launchbaugh and Provenza, 1991; Phillips, 2002; Provenza, 1995).

Ruminants dealing with new information need to be able to apply information from past feeding events in order to select safely. The application of knowledge in this situation is referred to as generalization. Generalization, further defined, is a strategic way for an animal to respond adaptively to “novel stimuli” based on similarity to prior experiences (Ginane and Dumont, 2006). Conditioned sheep have shown the ability to generalize and avoid negative postingestive qualities to a greater degree than their unconditioned counterparts (Favreau et al., 2010). Lambs use flavor cues as tools of generalization. These flavor cues direct the selection of novel foods; postingestive feedback dictates the degree to which the novel food will be added to the diet (Villalba and Provenza, 2000).

Spatial Memory

Herbivores rapidly incorporate the locations of preferred species in heterogeneous environments (Dumont et al., 2002). Herbivores use this information to make informed energy balance decisions while grazing. Rather than wondering around aimlessly, spatial memory allows the animal to encounter their preferred food more often, thus reducing the amount of time needed searching during grazing (Edwards et al., 1996). Edward et al. (1996) found that when a preferred species was associated with a visual clue spatial memory was enhanced. Irrespective of the visual cue the sheep where able to remember the location of their preferred food, when the food was moved and the sheep were released they returned to the previous location of the food (Edwards et al., 1996). Spatial memory also helps guide animals to relative food abundances (Dumont and Petit, 1998). This utilization is another energy-time saver to the grazer; when the animal is able to stay at an area of abundance they can spend more time grazing versus searching.

Other Factors Influencing Selection

Non-alimentary factors also influence selection, environmental, spatial and temporal; these factors are generally abiotic. Many times the influence of the aforementioned factors are short-term and not subject to ruminal feedback. Things as varied as paddock size, presence of flies and fear of predation all have varying effects on selection; decreasing and sometimes halting grazing in the cases of flies and predation fear, while paddock size affects where within an enclosure the animals will graze (Phillips, 2002). Other factors include the location of water, topography and weather (Roguet et al., 1998; Vecellio et al., 1995).

Sward Structure

The structure of the canopy has profound effects on the manner in which herbivores select forage. At times in an effort to economize the cost/benefit ratio of foraging herbivores will select the sward that offers the maximum "per bite" amount of forage. When cattle were presented the choice between tall-dense, short-dense, tall-sparse and short-sparse patches the predominately chose the tall-dense and the short-dense patches (Distel et al., 1995). These results indicate an ability to select from the patch that will provide the greatest amount of forage per bite. A study of horses also indicates that sward height is a factor that can lead to increased selection; presumably, the speed with which forage procurement can occur necessitates the choice (Edouard et al., 2009). Results such, as these seem to be clear indications of the optimal foraging theory (OFT); animals selecting foods that will maximize intake. A problem with the optimal foraging theory is that it does not offer any mechanistic explanations for its predictions (Provenza and Balph, 1990). Offering cattle the choice between a mature[2] tall reproductive and a short vegetative sward, the cattle selected the short vegetative sward; they chose to spend more time grazing rather than graze the tall sward (Ginane et al., 2003). That result is counter to the prediction of OFT; the cattle were able to consume the reproductive sward at a faster rate yet they chose the vegetative sward (Ginane et al., 2003).

Alkaloids in endophyte-infected grasses

Toxic factors in plants act as an evolutionary defense against predation. Immobility affords plants minimal opportunity to evade herbivores; some plants developed physical deterrents while others developed chemical ones. The chemical deterrent must be sensible to the animal and elicit a behavioral response to some degree; it does not behoove a plant community to be grazed completely before any action from the secondary chemicals occurs. In that way, some plant chemicals, caffeine, nicotine and digitalis, induce a dose response where low doses induce satiety and high doses produce more serious consequences (Garcia, 1989; Provenza, 1995). Sheep and goat will select palatable plants containing LiCl, an emetic agent, but they modulate their intake in order to keep the level of LiCl below the response threshold (Dutoit et al., 1991). This shows an ability to manage the dose of toxin while foraging a known palatable species. When LiCl is consumed at a high dose with novel palatable forage, it only requires one meal to produce an aversion (Dutoit et al., 1991).

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[2] Represents an advanced stage of maturity

Many secondary compounds in plants are alkaloids, which are responsible for bitter flavors in some plants. Bitterness is a feeding deterrent unless the bitter flavor is paired with positive postingestive cues (Provenza and Balph, 1990). Herbivores sampling novel forages may be disinclined to continue feeding on plants with bitter flavors; this risk averse behavior is what some refer to as the "rule of thumb," or the avoidance of strong flavors in forage (Augner et al., 1998). Villalba and Provenza (2000) showed that this "rule" could be overcome by positive postingestive factors. This indicts that strong and bitter flavors are not exclusively associated with toxins and that the avoidance based on flavor intensity could be a vestige of evolutionary learning to avoid poisoning (Augner et al., 1998; Villalba and Provenza, 2000).

Tall Fescue Toxins

Tall fescue, *Lolium arundinaceum (Schreb.) Darbysh,* is the predominant cool-season grass in the United States, it is the major grass from New England to Kansas and dominants the area known as the 'transition zone' where cool, temperate climates meet the subtropical climates (Sleper and Buckner, 1995). Tall fescue's greatest genetic diversity is found in Western Europe but the plant's ability to survive a vast array of normally limiting conditions has seen it adapted throughout Europe and portions of North Africa and successfully introduced to North and South America, Australia, Japan , and South and East Africa (Burns and Chamblee, 1979; Terrell, 1979).

In 1931, an ecotype tall fescue was discovered by E. N. Fergus. After a 12 year evaluation period the University of Kentucky released 'Kentucky 31' (Buckner et al., 1979). Tall fescue's total acreage increased dramatically in the decades to follow, along with research and release of new cultivars (Buckner et al., 1979). Many of these cultivars varied differently both physically and chemically with one of the major chemical differences a reduction in alkaloid concentration (Asay et al., 1979; Hill et al., 2002). It was believed that these intrinsic alkaloids were the cause of tall-fescue toxicosis.

So-called tall-fescue toxicosis is not caused by a toxic factor produced by tall fescue but in fact is caused by compounds produced by a fungal endosymbiont, *Neotyphodium coenophialum*. This association has many beneficial consequences for the plant, such as conferring pest resistance, drought tolerance and increased soil nutrient utilization (Malinowski and Belesky, 1999; Schardl et al., 2007; Sullivan et al., 2007).

The negative consequences of this association are borne out when infected plants are grazed by ruminants and toxicosis occurs. Some symptoms of tall fescue toxicosis manifest as photosensitization, decreased heat tolerance, increased respiration and decreased weight-gain (Joost, 1995; Thompson and Stuedemann, 1993). Two other conditions, fescue foot and fat necrosis, are possible results of over ingestion of these toxic factors, these conditions cause physical abnormalities, such as the loss of ears, tail and hooves (Hemken et al., 1984) (Mayland and Cheeke, 1995). One alkaloid produced by *N. coenophialum*, ergovaline, is responsible for these effects in cattle (Browning and LeiteBrowning, 1997; Fahey Jr and Berger, 1988; Schardl et al., 2007). Ergovaline is an ergopeptide alkaloid and is the chemical toxin that causes the major homeostatic disruptions (Peters et al., 1992). Shardl et al. (2007) states, "ergot alkaloids are extremely potent, and their known toxicities in livestock strongly suggest that they are the primary or sole cause of fescue toxicosis." Ingestion such a toxic chemical invariably affects grazing behavior as infected cattle increase their shade seeking tendencies in an attempt to evade the heat (Hemken et al., 1984). Selection and intake are very reduced by animals seeking to alleviate heat stress.

Perloline, a plant-produced alkaloid, can be responsible for some decreased weight gain. Perloline has an inhibitory effect on rumen microorganisms, that inhibition means decreased cellulose breakdown (Van Soest, 1994) (Boling et al., 1975). Volatile fatty acid production is limited further decreasing the available energy (Fahey Jr and Berger, 1988). The simple fact that less cellulose is being digested more slowly means the passage rate is reduced which causes intake to decrease.

Novel endophyte

It is possible to infect endophyte free tall fescue with a strain of fungus that does not produce the toxic ergot alkaloids associated with tall fescue toxicosis. The non-toxic endophyte strains are often referred to as novel endophytes. Removal of the toxic endophyte followed by reinfection with a non-toxic variant is important because it confers the benefits of drought and heat tolerance while simultaneously reducing common indicators of tall fescue toxicosis (Bouton et al., 2002; Parish et al., 2003).

Near-Infrared reflectance Spectroscopy (NIRS)

Near-Infrared reflectance Spectroscopy, NIRS, is a fast and efficient way to analyze forage quality (Shenk and Westerhaus, 1991). Norris et al. (1976) found NIRS predictions within an acceptable sample error range and concluded that NIRS could be a useful tool for evaluating forage quality. Leaps in the technology occurred between the late 1980s and the mid 2000s. Clark et al. (1987) concluded that NIRS was not a useful tool to determine levels of macrominerals, Ca, P, K, and Mg. More recently, however, Halgerson et al. (2004) were able to produce accurate predictive equations for calibration making it possible to predict some macromineral levels; they were not able to accurately predict Mg. Nie et al. (2009) was able to predict cell constituents, neutral detergent-soluble carbohydrates (NDSC), with NIRS, but they were unable to predict organic acids. The predictive quality and capability of NIRS continues to increase with time, making it an invaluable tool for researchers studying forage quality. The NIRS becomes a good tool for breeders by giving them the ability to test things like fiber content new breeding lines.

Breeding for palatability

Breeding is one tool that can be used to increase palatability. Plant breeding is attempts to identify a desired trait and disseminate it through subsequent generations. This occurs when the breeder selects plants, choosing which plants will pass their genes to the next generation. Charles Darwin identified three different types of selection: natural, unconscious and methodical(Darwin, 1909). Through history, forage crops have undergone each of each of these evolutionary processes (Casler, 2001). The clearest example of natural selection is the interaction between grazing animals and plants (Casler, 2001). Early Plant domestication was facilitated by unconscious human selection (Zohary, 2004). Modern breeders use methodical selection, searching for a “definite object” in the hopes of directing and accelerating the evolutionary process (Darwin, 1909). The difficulty in breeding forages is that there is not one “definite object,” breeders are generally attempting to advance a suite of traits into successive generations.

The particular genetics of a plant can cause added difficulty, as is the case with tall fescue due to the fact that it is an obligate outcrossing species (Pedersen and Sleper, 1993). Additionally it is an allohexaploid species complex comprised of three morphotypes, Mediterranean, Continental and rhizomatous (Hand et al., 2010). Improving forage quality is a major desire of breeders, acid and neutral detergent fiber (ADF and NDF), protein tend to be the prominent targets (Annicchiarico and Romani, 2005). As technology has progressed, it has changed the ways tall fescue and other forage crops were bred.

The 1960s saw the first shift towards identifying the nutritional quality of the forage as a selection criterion (Casler, 2001). Digestibility became an important characteristic as it measured the amount of available energy to the animal; protein and antiquality measures also became targets for breeders (Casler, 2001).

Given tall fescue's obligate outcrossing nature, early researchers used recurrent or mass selection where only a small percentage of a population of plants are used to form the next generation (Pedersen and Sleper, 1993). Selection was heavily based on phenotypic appearance. This method of breeding is accompanied with problems such as decreased forage and seed yield, and possible loss of lodging resistance (Casler, 2001).

Breeders now have the potential for substantial breakthroughs with the new tools available to them. Whereas improvements from formerly used breeding techniques have met a wall, new technology will be able to scale and surpass previous impediments (Wang and Spangenberg, 2007). These new technologies include genomics, transgenics, and molecular markers (Hopkins, 2005; Saha et al., 2005; Wang and Spangenberg, 2007). These new gene based techniques allow the breeder to work on the DNA level. Transgenics allows the transfer of discrete genetic information for plant to plant, some even across species (Casler, 2001; Wang and Spangenberg, 2007). If breeders were able to identify a gene linked with palatability, they possibly would have the ability to transfer that into other species, theoretically conferring palatability.

Chapter 2: BEEF CATTLE GRAZING PREFERENCE OF TALL FESCUE AS AFFECTED BY ENDOPHYTE STATUS

Introduction

Tall fescue, [*Lolium arundinaceum* (Schreb.) Darbysh.], is the predominant cool-season grass in the United States. It is the major grass from New England to Kansas and dominates the area known as the transition zone where cool, temperate climates meet subtropical climates (Sleper and Buckner, 1995). In 1931, researchers at the University of Kentucky discovered an ecotype tall fescue, which led to the release of "Kentucky 31" (Buckner 1979). The total acreage of tall fescue increased dramatically in the decades following (Buckner et al., 1979). Improvement through breeding research and release of new cultivars has created many options for grassland managers. Advances in technology have allowed for the removal of the toxicosis inducing fungal endophyte while replacing it with a novel endophyte that can be a viable replacement option (Parish et al., 2003).

Each cultivar presents an animal with a suite of different characteristics that either increase or decrease selection. Depending on the location, time and space cattle are known to select certain forages in deference to others (Provenza, 1995; Roguet et al., 1998). This study has five main objectives, determining if cattle have preferences, determining whether any preference is based on leaf physical properties and assessing the affect of endophyte status on preference. Additionally this study will test if cattle can become conditioned to select preferred increasingly as time proceeds.

Materials & Methods

Planting Setup

Forty cool-season cultivars or experimental lines, comprising of 34 tall fescue cultivars, two festuloliums (Festuca x Lolium), two meadow fescue (*Lolium pretense* L.) and one meadow brome (*Bromus biebersteinii* Roem. & Schult.), and one orchard grass (*Dactylis glomerta* L.), were seeded during fall 2006 at the Spindletop Research Farm, Lexington, KY. Three tall fescue entries were toxic- endophyte infected, nine were infected with either AR584 or AR542 novel endophyte; the remainder were endophyte free (Table 1).

Experimental Design

The field site was divided into four pastures each containing three randomized complete block replications of the 40 entries. The entries were arranged in three of the four pastures as follows: 10 entries by twelve entries in space; the twelve ranges ran west to east with the 10 columns north to south. The fourth pasture was planted 20 entries north to south and six entries west to east because of constraints in field dimensions (Figure 1). The entries were spatially separated by a single row of grass between plots. The seeding rate was approximately 10 g per plot, and plots were seeded with an Almaco forage drill as seven rows at 15.24cm spacing, with plot length at 2.74m. The borders between plots and the ends of each plot were mowed to a 5 cm stubble height prior to grazing periods with a lawn mower. Areas outside the test plots were seeded with a mixture of tall fescue and orchardgrass and were also mowed prior to grazing periods.

In June of 2008, the spring growth was removed and fertilizer was applied in the form of ammonium nitrite at a rate of 25lbs N/acre. After six-weeks of regrowth, the field was prepared for the cattle. The orchardgrass buffers were removed with a 22-inch Sears Craftsman lawn mower. A Hege 212 harvester was used for the first trial to remove the border around the plots; for the subsequent trials, the lawn mower was used for all harvests, as it was more efficient. To distinguish the rows the end of each entry was mowed out. This created a "checkerboard" like pattern in each plot. Electric fence was erected around the entire study (all 4 plots); with partition separating the individual plots. In a deviation from normal protocol, senesced crabgrass seed heads were removed prior to the beginning of the second grazing period by mowing with a Hege212 forage harvester at a height of 40 cm. Each of the two grazing periods in 2009 was prepared in a similar fashion as 2008.

Animals

Each 2008 grazing period used 15 months old beef cattle steers; in 2009, 15 months old beef heifers were used. In the 2008 study, four steers were used on both trials; in 2009, five heifers were used. In 2008 the steers used were selected randomly from a heard of around twenty; the first 2009 trial proceeded in the same fashion with random selection, however, the second trial used the five smallest animals from the heard of heifers.

The animals used during the two years of the study were acclimated to human interaction.

Endophyte Status

Endophyte status was tested by tissue print immunoblot. Ten non-reproductive tillers were removed per plot, one replication per each pasture. These were clipped flush at their base. After a flush surface was produced the tiller was applied to a piece of nitrocellulose paper, this paper has a grid that represents the pasture. After 40 samples per entry were collected, the nitrocellulose paper is developed. The test results in blots of varying shades of red, controls of known positive and negatives are on the paper as a means of comparison. Only tall fescue, meadow fescue, and festulolium entries were tested for endophyte infection.

Grazing Protocol

The cattle began grazing on pasture one. They were allowed 24 hours of grazing on an individual pasture (three replications) before being move to the next pasture. Each day they were moved to the next pasture and allowed to graze for the same 24-hour period. They were provided minerals and water located at the west end of each plot.

Forage Data

A pre-grazing sample was collected using a lawn mower set 5 cm off the ground. A 55 cm swath was removed and collected in a paper bag. This was used for fresh and dry weight analysis. The initial weight was recorded after which the sample was placed in a dryer until completely dry. Once dry the sample was reweighed. This step was repeated for each plot.

After the cattle were removed from a particular pasture, post-grazing samples were taken. During the first trial of this experiment, the entire remaining plot was removed with a Hege 212 harvester. Considering the time constraints and labor required, and size of harvest, the Hege was replaced by the lawn mower used for the pre-grazing for the following three trials; it removed approximately 1/3 of the plot area. Post-grazing samples were collected, bagged, weighed and dried using the same procedure as with the pre-grazing samples.

At the conclusion of each trial, the entire field was clipped to a 5 cm stubble height and fertilizer was applied in order to encourage new growth for the following grazing trial with different animals. Prior to the second trial, irrigation was used due to a lack of precipitation; this was the only trial for which irrigation was used.

Forage Quality Analysis

Dried herbage samples were ground to a 1mm particle size using one of or both a Wiley Mill and a Udy Cyclone Mill. After grinding, the samples were placed in 53mm clear plastic containers. The Foss NIRSystems 5000 determined forage quality components, acid detergent fiber (ADF), neutral detergent fiber (NDF), protein, relative feed value (RFV), and minerals. The Foss ISIscan software was calibrated using a standard grass hay equation developed by FOSS and the NIRS Consortium (NIRS Forage & Feed Testing Consortium, 2011). The NIRS system computes quality components for each plot, which were then pooled across twelve replications per grazing period for statistical analysis.

Visual Ratings

The preference rating was based on a 1-5 visual rating; one represented little to no grazing and five represented an entry that was reduced to stubble. One technician was used to assign all the preference ratings for the entire study period. Visual subjective ratings were also used to grade the forage stand cover and rate the crab grass percentage. Stand cover was based on a 1-5 scale with five being of greatest cover and one being the least cover. An entry dominated by crabgrass received a score of five while those with little presence of crabgrass received a one; the crabgrass score was only taken during the first grazing trial due to the large amount of crabgrass that had infested the study area.

Statistical Analysis

The experimental units were entries, pasture, and grazing period. Analysis of variance (ANOVA) was determined for: pre and post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein, Calcium (CA), potassium (K), phosphorus (P) and magnesium (MG) using the PROC GLM procedure (SAS Institute, 2008). Traits were pooled from twelve replications in each grazing period and analyzed across and within grazing period. Least square means (LSMEANS) were determined and compared for entries by grazing period ($P < 0.05$).

The plant based method of determining preference was a percentage based on the amount of forage left behind on each plot on a dry weight basis, the term was called refusal dry weight or refusaldw. The refusal percentage was based on the pregrazing and postgrazing totals; the formula is below.

$$\text{Refusaldw percentage } = \left(\frac{PREGRAZE - POSTGRAZE}{PREGRAZE}\right)(100)$$

Graze score was a visual score used as another determiner of preference. Pearson correlation coefficient analysis, PROC CORR procedure, was used with these two preference measures with selected forage quality components ($P < 0.05$).

Orthogonal contrasts were used to compare rough-leaved versus soft-leaved plants, festulolium versus meadow fescue, orchard grass versus meadow brome, and tall fescue versus non-tall fescue plants. Contrast were also used to test differences between different classes of lines with endophyte (toxic, novel and endophyte free) these contrast were: toxic endophyte infected versus endophyte free fescue, novel endophyte versus endophyte free fescues, KY31 endophyte infected versus KY31 endophyte free, and AR542 versus AR584 novel endophytes.

Conditioning trends were analyzed using a generalized linear model dry weight refusal percentage was tested by pasture, time, and time by entry. The time effect was partitioned into linear, quadratic and higher orders (lack of fit term) three parts to for the model.

Results & Discussion

Weather

The first year of this study, 2008, was not a particularly hot year, but it was a dry year. At the time of the first grazing period, the area was experiencing an 8 cm rain deficit; by the arrival of the second grazing period, that deficit was in excess of 15 cm. The study area was noticeably dry and irrigation was used. Conditions for the third and fourth grazing periods were much more favorable. Increased rainfall led to cooler temperatures ruling out the need for irrigation as in the previous year. Precipitation fell during each grazing period, as much 7 cm in graze 1 and around 4 cm for the other three periods (Table 2.1).

Endophyte status

All endophyte-free tall fescue entries had infection frequencies lower than 15%, while all infected entries had infection greater than 86% except for Jesup MaxQ at 78% (data not shown; personal communication, Tim Phillips).

The analysis of variance (ANOVA) for yield statistics is represented in Tables 2.12 and 2.13. The variables are pre- and post-grazing measurements of fresh weight, pre-and post- dry weight, pre-and post- and moisture content (premoist and postmoist). Also included are the refusal percentage as based on dry and fresh weight (refusaldw and refusalfw), a stand cover rating (SC), and a graze rating (GS).

The sources used for the ANOVA were replications and entries, which were pooled by grazing period. A highly significant effect was shown during each of the four grazing periods for the replications ($P\leq 0.01$) (Tables 2.12 and 2.13). For the first grazing period the only effect that failed to show significance was pre grazing moisture content and species. Of the four grazing periods, the second had the least significant effects. During the second grazing period the post grazing moisture content, both fresh and dry weight refusal and graze rating were significant at the $P\leq 0.05$ level (Table 2.12). Only pre grazing moisture content was not significant in the third grazing session while all other effects in the fourth were significant. Pre grazing moisture content was only significant during the last (4th) grazing session. This could be due to the date at which this grazing session took place as it occurred much later than the other periods, with less drought stress and after crabgrass had died.

The important variables considered were based on yield, forage quality or subjective scoring. The yield components was prefresh, it was the available forage before grazing. The refusal percentage on a dry-weight basis (refusaldw) was calculated based on the amount of forage removed; (pre-graze dry-weight (dw) - post-graze dw)/pre-graze dw. Graze score (GS) and stand cover rating (SCR) were both subjectively scored by a trained technician while ADF, Protein, NDF, RFV were determined by NIR. Both simple means and least square means (LSMEANS) were determined from the original dataset.

Yield

Pre-grazing fresh weight

Pre-grazing fresh weight (prefresh) is the forage removed prior to the introduction of the cattle onto the plot. Replications comprised a significant source of variation for prefresh in each of the four grazing periods (Table 2.12). There were significant differences between the species in each grazing period with the exception of the second (Table 2.12). During the regrowth period, there was less than average rainfall, possibly accounting for the lack of variation. Across the four grazing sessions TFsoft-HY-C3, TuscanyII and AU-Triumph were the higher prefresh yielding cultivars. The lowest yielding entries were Jesup-MaxQ and KYTF2. Maximum yields in the first three periods varied less between each other than did each with the fourth period. The difference between the three was nearly 150 kg ha^{-1} while the fourth session produced nearly 400 kg ha^{-1} more than the highest of the three. The overall averages ranged from 670.2 kg ha^{-1} to 1151.8 kg ha^{-1}(Figure 2.47).

During the third and fourth grazing period, there was a significant positive correlation between prefresh and SCR, 0.45 and 0.78 respectively (Tables 2.15 and 2.16). There was a negative correlation between prefresh and protein during graze one, two and three, correlation coefficients were -0.67, -0.49 and -0.77 respectively (Tables 2.14, 2.16 and 2.17). This indicates that higher yielding plots had lower values of protein, and higher levels of protein tended to be seen in entries with lower yields. For each of the grazing periods, excluding the second, contrast analysis showed a significant ($P<0.05$) difference between the pregrazing yields of the tall fescue entries and the non-tall fescue entries.

Pre-grazing moisture content

Pre-grazing moisture content (premoist) is moisture content as derived from the fresh and dry weights of the forage samples. Premoist can serve as an analog of plant succulence. A significant difference among entries ($P<0.05$) was seen only in the fourth grazing session (Table 2.12). Bariane, Barfest-FL, Fawn and TuscanyII were the entries with the highest moisture content across the grazing sessions. Cache-MB had low moisture content throughout the study. During the fourth grazing period premoist was positively correlated with SCR, indicating that better plots had higher moisture content.

Refusal percent

Dry weight refusal percent or refusaldw is the proportion of the forage not grazed; it was determined arithmetically using the pre- and post-grazing harvest yields on a dry matter basis. There were significant differences between species in each grazing session (Table 2.12). The lowest refusaldw was during the first grazing period and was 32% refusal for Bartura while the highest was during the third grazing session at 89% for both AU-Triumph and Cache-MB (Tables 2.4 and 2.6). The means of the first three grazing periods were within five percentage points (between 73% and 68%); the fourth was 61% refused. During the first grazing session, there was a positive correlation between refusaldw and post grazing moisture content. In the fourth session, the refusaldw is negatively correlated with protein (Table 2.17). This correlation shows that as protein increased the cattle consumed more forage. This correlation was also negative during the second and third grazing sessions but to a lesser extent (Tables 2.15 and 2.16). It also correlated negatively with GS over all grazing periods, the correlation coefficients range from -0.85 to -0.72 across the four grazing periods (Tables 2.14-17). This helps validate the strength of the visual scoring method as a means of determining grazing preference. Vast differences between the two would confound the assigning of preference. Bartura-MF was among lowest four entries in terms of refusaldw percentage across the four grazing periods. Four other entries had similar performance among three of the four grazing periods; they were Barfest-FL, Cache-MB, KYFA9819-FL and Latar-OG, all of the non-tall fescue entries. AU-Triumph and 97TF-EF were highly refused across the study (Figure 2.57).

Contrasts show significant differences between festuloliums (KYFA9819 and Barfest) and meadow fescues (Bartura and KYFP9801) for all four grazing periods. The meadow fescues were refused more than the festuloliums during the first, third and fourth periods. During the second grazing period, the festulolium was more refused compared to meadow fescue. The second grazing period failed to yield many significant differences as seen in the other three periods in which the tall fescue entries were significantly differed from the non-tall fescue entries. The climate during the second grazing period factored heavily into these results, possibly causing the forages not to be perceived differently by the cattle. During the second grazing period endophyte free strains, 97TF1-EF/+, KY31-EF/+ and PDF-EF/+, were refused to a greater degree and endophyte infected, 74.05% and 58.5% respectively. This is likely due to the endophyte infected plants surviving the drought conditions better than the endophyte free strains; during this period, the only time during the study, the endophyte infected plants had significantly ($P<0.05$) higher protein levels and significantly ($P<0.05$) lower ADF and NDF than non-infected.

Contrast between novel endophyte and endophyte free plants showed a similar result as between endophyte infected and endophyte free plants. The novel endophyte plants were selected at a significantly ($P <0.05$) higher percentage than endophyte free plants.

Refusaldw data was used in conjunction with GS data to determine preference. There exists some uncertainty with the refusal data because of the method of collection. The lawn mower used for harvesting remained the same but the operator often changed. In addition, a particular plot was not necessarily uniformly covered with the same quantity of herbage. If the pregrazing or postgrazing sample came from parts that were not of the same initial height the refusal figure for that plot would be less than true; the number of replications should be sufficient in accounting any aberrations caused by that occurrence. Another problem could be similarly caused by asymmetrical grazing. The swaths were cut in a north-south direction, if the cattle grazed asymmetrically in the same direction it would be difficult to retrieve a sample representative of the actual grazing that occurred. Fecal depositions produced minor challenges on some plots; the fecal matter depressed the forage making it unharvestable in that area. Some plots reported a higher weight for postgrazing than the pregrazing total. Shewmaker, 1995, in a similar study observed the same effect concluding regrowth during the time between pre and postgrazing was sufficient to cause that response. Other studies indicate that utilization is generally underestimated and regrowth should not be assumed to have a negligible effect (Moisey et al., 2005).

Stand cover rating

Stand cover rating or SCR is a visual assessment of forage availability based on stand cover and weed prevalence. A score of five indicates 100% cover by the entry and a score of one is a plot mostly populated by weeds or has a poor stand of the expected entry. The second grazing period was the only non-significant period for the effect of entries on SCR (Table 2.12). PDF-AR584 and Latar-OG proved to have the best stand cover rating across the grazing trials. Three of the worst were Fawn, KYFA9819-FL and Barfest-FL, which were exceptionally poor due to weak stands of the seeded entries and high crabgrass foxtail infestations. SCR was negatively correlated to NDF in the first grazing session.

SCR was important to identify because of the effects of sward structure and composition. Sward structure and composition can both affect grazing behavior. A high SCR score represents a plot that is homogeneous and dense, while plots receiving low scores either were infested with crabgrass or lacked density. Research shows that stand density affects the bite mass in cattle (Soder et al., 2009). Optimal foraging theory would suggest that the densest plots would be grazed at high rates because they allow for maximum intake(Distel et al., 1995). This could have been the effect seen during the fourth grazing period. Plots were all at their densest and there was a positive correlation between SCR and refusaldw. Ganskopp, 1997, did not find optimal grazing rather; found that cattle grazed out the preferred species prior to consuming the other forage. Another study found that short vegetative grass swards, of high quality, were preferred to tall reproductive swards despite the fact that intake could be maximized on the tall swards (Ginane et al., 2003). This explains why Barfest-FL and KYFA9818 were grazed away three of the four study periods, even though they had very thin stands.

Graze score

Graze score was also determined by visual assessment. After the cattle exit the pasture, the amount of forage removed was assessed. A plot received a score of five if it was grazed completely and a score of one for minimal selection. GS was significant throughout the entire experiment (Table 2.13). The highest mean was during the first session, 4.8, and the lowest was during the third, 1.3. The averages across grazing periods ranged from 3.0-3.4. During the second grazing period, GS was negatively correlated with NDF and positively correlated with protein (Table 2.15). During grazing period 3 and 4 GS was correlated positively with protein (Table 2.16 and 2.17). Across the entire study, GS and refusaldw were correlated; they are two different representations of the same effect. The most grazed were Bartura-MF, Latar-OG, Bariane and KYFA9819-FL. The most consistently rejected was AU-Triumph.

Refusaldw is considered a type of section ratio while GS is a preference score. Preference scores are more sensitive than are selection ratios (Moisey et al., 2005; Shewmaker et al., 1997b). Producing the refusaldw figure is a very labor-intensive endeavor, requiring multiple man-hours and fuel consumption during the harvesting and drying process not to mention the amount of time needed to weigh samples and the waste production. A technician can be trained in less than an hour to visually assess plots. This study employed only one person to produce the visual ratings; other studies have used up to four technicians to score entries (Shewmaker et al., 1997b). In addition, the scale in this study was from 1-5. Using a wider ranging scale would have provided more precision; 10-point scales are commonly employed in other studies (Shewmaker et al., 1997b).

Leaf Physical Properties

During both grazing periods of 2009 there was a significant difference in refusal percentage ($P<0.05$). The varieties categorized as soft were selected at a higher rate. The graze score shows similar significances in 2009. The first graze period graze score was also significant ($P<0.05$). Soft leaved plants being selected at a higher rate is the expected result, operating with the assumption that soft leaved cultivars allow for easier mastication and a higher digestion rate.

Forage Quality

Two samples were collected from each plot in each grazing period, one prior to the introduction of cattle and the second after the removal of the cattle. The variables of interest are Acid detergent fiber (ADF), Neutral Detergent Fiber (NDF), Relative Feed Value (RFV) and protein. There were significant differences in both entries and replications in all grazing periods for these traits, $P\leq0.01$ (Table 2.13).

ADF

Acid detergent fiber (ADF) is made up of the lignin and cellulose portion of the cell wall. Increased levels of ADF are generally correlated with decreased intake. Barfest-FL, Cache-MB, KYFA9819-FL and Latar-OG were the species with the highest amounts of ADF through the course of each of the four grazing periods (Table 2.2-5). Jesup-MaxQ and endophyte free KYFA9301 produced the most consistently low ADF percentages (Table 2.2-5). The standard deviation for all for grazing periods never exceeded 2 units; the means ranged from 29.4 to 36.4. Grazing sessions one and two were the lowest and highest, respectively. The mean ADF levels for all entries increased after the cattle were removed during the second and fourth grazing periods while the opposite was true for the first and third (Tables 2.8-11). ADF levels during the fourth grazing period were not significantly correlated with any pertinent measures (Table 2.17). ADF and prefresh were positively correlated during the first and third grazing period (Table 2.14 and 2.16). This indicates that the structural components (fiber) increased as yield increased.

NDF

Across the two years of study AU-Triumph, Latar-OG, Seine and Cache-MB produced the greatest quantity of NDF. All entries during the second grazing period possessed high percentages of NDF. The average NDF from graze 2 was greater than the maximum of any entry during grazes 1 and 4. Grasses that tend to be lower in NDF were Bartura-MF, KY31-E+, KYFA0006 and KYFA9301-EF. The high and low mean range was similar to what was seen with ADF; graze 1 and 3 were the low and high, respectively. During the first and third grazing sessions, NDF was generally greater before the introduction of cattle than after they were removed; the reverse was true for the second and fourth periods (Table 2.8-11). NDF correlated positively with prefresh during the first and third grazes while correlating negatively with GS during those same grazing periods (Table 2.14 and 2.16).

RFV

No non-tall fescue cultivar had a high RFV while three of them were among the lowest, Barfest-FL, Cache-MB, and Latar-OG along with two tall fescue cultivars, AU-Triumph and Seine. Grasses with high RFVs were KY31-E+, KYFA9301-AR584 and KYFA9301-E-. RFV was greater after the removal of cattle during the first and third grazing sessions and greater before cattle grazed during the second and fourth periods. Overall graze 2 produced the lowest mean RFV and graze 1 the highest. The RFV of the second period was the only mean not to exceed 100. RFV means during the second and third grazing period both correlated positively. There was a negative correlation in the first and third grazing period between RFV and prefresh (Table 2.14 and 2.16).

It is widely known that intake decreases as fiber content increases. Fiber limits energy availability by taking up space and not digesting completely (Buxton and Redfearn, 1997). Despite this fact Latar-OG, which was among the highest in fiber, was also one of the preferred cultivars; Cache displayed similar results. This indicates the action of another agent directing selection. The correlations between fiber and selection data are not strong enough to explain possible preference (Tables 2.14-17).

Protein

Protein levels were typically consistent between the entries during the last three grazing periods; they were elevated during the first grazing period (Figures 2.53-56). AU-Triumph was near the bottom of all entries during each of the four grazing periods. Bartura-MF and Bariane were the only two with high protein levels in each grazing session. Interestingly two grasses, Cache-MB and Latar-OG went from being the two worst in graze 1 to being the two best in the second grazing period, which they repeated exactly in the subsequent two grazing sessions (Figures 2.53-56). Protein correlated negatively with SCR during grazes 3 and 4, -0.64 and -0.57 respectively. There was a positive correlation between protein and GS in each grazing period with the exception of the first (Tables 2.14-17).

Forage Preference Conditioning Analysis

When offered a choice of forage, herbivores generally begin a meal by cautiously sampling new items prior to incorporating them into their diet. If the animal perceives the forage as having a particular quality that is positive, the animal will increase its selection of that forage. The reverse of is also true, if an herbivore encounters forage that produces a negative feedback response, selection decreases. When offered a variety of choices over a period of days this effect should be visible: increased selection of certain grasses and a decrease in others. Two different methods were used to determine to measure this response: visual score and a physical measurement based on the amount of forage left or refused. Graphs of the refusal percentages segregate loosely into five groups: positive slopes, negative slopes, flat, zigzagged and parabolic.

Positive Slope

A positive slope indicates a decreased consumption over time; varieties include Tfsoft-HY-C3, TuscanyII, and Stockman (Figures 2.44-46).

Negative Slope

Negative slope depicts the situation where selection increases over time, Latar-OG, and KYFA9819-FL (Figures 2.28 and 2.38).

Flat

A flat or level slope shows a selection rate that did not change much over time, Jesup-MaxQ, AU-Triumph and KY31-E+ (Figures 2.11, 2.18-19). These grasses maintained relatively the same status through the study period.

Zigzag

This pattern means the cattle's preference for these entries did not follow a trend over time. Some zigzags were more subtle than others were. Some of the more, subtle ones could be placed in the flat group, Seine, KYFA0006 (Figures 2.21, 2.26 and 2.43) and KYFA9611 are among the more typical zigzag layout.

Parabolic

This shape exemplifies high initial selection followed by a two-day decrease rounded out by increased selection on the final day. Cultivars representative of parabolic trend are PDF-E+, KYFA9301-AR542 and KYFA9908 (Figures 2.22, 2.33 and 2.42).

Graph position

It is important to note that there is information contained in these graphs irrespective of the graph shape based on the general position on the y-axis. If there is an entry that produced a flat graph low on the y-axis and another positioned higher, the first entry is preferred in comparison to the second entry. This is more likely to occur with the flat and zigzag shaped graphs. In the flat group, this is evident with Fawn, high refusal, and Barfest-FL, which is nearly 20 percent lower on each day, Figure 2.17 and 2.12 respectively.

Graze Score

The GS is also represented on these graphs using a secondary axis. These data do not fit as snuggly into discrete categories. However, there are certain graphs wherein the GS is an exact reflection of the refusaldw percentage data. Those occurrences support the idea of using the visual rating alone. The fact that GS and refusal are inversely related is why they reflect, as the GS increases the refusaldw is expected to decreases. The graph for 97TF1-AR584 is an excellent example of this effect (Figure 2.8).

MAPS

The visual grazing score data is also displayed in the form of choropleth map overlaid on a satellite image of the study area. These choropleth map s help identify any spatial or topographical effects that may be affecting selection. On the maps the highest level of grazing is a 5 shaded in dark blue and the lowest or least grazing activity is 1 and colored red.

Graze 1 (Figure 2.3)

Day 1 appears to have border effect on the south and west sides where the cattle grazed heavily. After being separated from the main herd the cattle involved in the study spent a up to a half hour fixated on the cattle for which they had just been separated; after the other animals moved to another portion of their field, the cattle in the study area began to graze about the study area. Day 2 is free of any strongly pronounced border effect; it also contains less highly grazed plots. The eastern border of day 3 has a clear border effect. The grazing pattern on the fourth day is distributed evenly.

Graze 2 (Figure 2.4)

The border effect is very evident in this grazing session. All of the western sides were heavily grazed. The southern border and eastern border of day one were grazed hard along with the eastern border of day three. The majority of the pasture on day four was grazed very heavily. The weather possibly caused the border effect. The dry nature of the herbage may have caused the cattle to consume more water, which is known to effect spatial grazing behavior (Phillips, 2002; Roguet et al., 1998).

Table 2.1. Average temperature and rainfall totals during the four grazing periods.

graze		date	avg max air temperature (°C)	avg min air temperature (°C)	total precipitation (cm)
1	2008	30 Jul- 2 Aug	27.2	18.3	7.03
2		9-12 Sept	28.3	16.7	1.09
3	2009	13-18 July	26.7	17.2	1.14
4		16-20 Nov	12.8	5.56	1.35

Table 2.2. Study entries listed by entry number including place origin and endophyte status.

entry	name	status	origin (of cultivar or population)	notes
1	PDF-EF	x	Noble Foundation	tall fescue
2	PDF-E+	x	Noble Foundation	tall fescue
3	PDF-AR542	x	Noble Foundation	tall fescue
4	PDF-AR584	cv	Noble Foundation	tall fescue
5	Stockman	cv	FFR	tall fescue
6	KYFA0006	x	University of KY	tall fescue
7	97TF1-E+	x	Noble Foundation	tall fescue
8	97TF1-EF	x	Noble Foundation	tall fescue
9	97TF1-AR542	x	Noble Foundation	tall fescue
10	97TF1-AR584	x	Noble Foundation	tall fescue
11	KY31-EF	x	University of KY	tall fescue
12	KY31-E+	cv	University of KY	tall fescue
13	KYFA9301-EF	x	University of KY	tall fescue
14	KYFA9301-AR542	x	University of KY	tall fescue
15	KYFA9301-AR584	x	University of KY	tall fescue
16	KYFA9821-EF	x	University of KY	tall fescue
17	KYFA9821-AR542	x	University of KY	tall fescue
18	KYFA9821-AR584	x	University of KY	tall fescue
19	KYFA9819-FL	x	University of KY	festulolium
20	Barfest-FL	cv	Barenbrug	festulolium
21	Jesup-MaxQ	cv	Univ. of GA/AgResearch/Pennington	tall fescue
22	Bartura	cv	Barenbrug	meadow fescue
23	TFsoft-HY-C3	x	USDA-ARS-FRRL	tall fescue
24	KYFA9304	x	University of KY	tall fescue
25	Bariane	cv	Barenbrug	soft-leaved tall fescue
26	Barolex	cv	Barenbrug	soft-leaved tall fescue
27	Seine	cv	DLF-Trifolium	tall fescue
28	Kenhy	cv	University of KY (Buckner)	tall fescue (hybrid derivative)
29	AU-Triumph	cv	Alabama AES (Auburn Univ., 1981)	tall fescue
30	KYFA9908	x	University of KY	tall fescue
31	KYFA9905	x	University of KY	tall fescue
32	Fawn	cv	Oregon AES, 1964	tall fescue
33	TuscanyII	cv	FFR	tall fescue
34	Latar-OG	cv	USDA-SCS, WSUAES, IAES, 1957	orchardgrass
35	Cache-MB	cv	USDA-ARS-FRRL	meadow bromegrass
36	KYTF2	x	University of KY	tall fescue
37	KYFA9732	x	University of KY	tall fescue
38	KYFA9611	x	University of KY	tall fescue
39	KYFA9913	x	University of KY	tall fescue
40	KYFP9801-MF	x	University of KY	meadow fescue

x=experimental population
cv=released (commercial) cultivar

Table 2.3. Orthogonal contrasts used to comparing rough-leaved versus soft-leaved plants (I), festulolium versus meadow fescue (G), orchard grass versus meadow brome (H), and tall fescue versus non tall fescue plants (C). Contrast were also used to test differences between different classes of lines with endophyte (toxic, novel and endophyte free) these contrast were: toxic endophyte infected versus endophyte free fescue (B), novel endophyte versus endophyte free fescues (D), KY31 endophyte infected versus KY31 endophyte free (E), and AR542 versus AR584 novel endophytes (F). (P< 0.05)

	Pre-fresh	Pre-dry	Pre-moist	Post-fresh	Post-dry	Post-moist	refusal dw	SC	GS	ADF	NDF	Protein
graze 1	C H	C G	H	C G H	C G H	C D G	C G H	C D G	C D H I	C G	C G	B C E H
graze 2	G	(ns)	C G	B	B	C	B D G	(ns)	G	B C D H	B G	B C H
graze 3	C	C	G H	C G H	C G H	C	C D G H I	C F G	C G H I	C G	C G	C F
graze 4	B C G H	C G	B C G H	B C D G H	C G H	C D	C G H I	C G H	C I	C	(ns)	C H

(ns) = no significance found in any group

Groups

(B) PDF-AR542, KYFA9821-AR542, KYFA9301-AR542, 97TF1-AR542 **vs**. PDF-AR584, KYFA9821-AR584, KYFA9301-AR584, 97TF1-AR584

(C) Bariane, Barolex, 97TF1-AR542, 97TF1-AR584, 97TF1-E+, 97TF1-EF, AU-Triumph, Fawn, Jesup-MaxQ, KY31-E+, KY31-EF, KYFA0006, KYFA9301-AR542, KYFA9301-AR584, KYFA9301-EF, KYFA9304, KYFA9611, KYFA9732, KYFA9821-AR542, KYFA9821-AR584, KYFA9821-EF, KYFA9905, KYFA9908, KYFA9913, KYTF2, PDF-AR542, PDF-AR584, PDF-E+, PDF-EF, Seine, Stockman, TFsoft-HY-C3, TuscanyII, Kenhy **vs**. Barfest-FL, KYFA9819-FL, Cache-MB, Bartura, KYFP9801-MF, Latar-OG

(D) 97TF1-AR542, 97TF1-AR584, Jesup-MaxQ, KYFA9301-AR542, KYFA9301-AR584, KYFA9821-AR542, KYFA9821-AR584, PDF-AR542, PDF-AR584 **vs**. 97TF1-EF, KY31-EF, KYFA9301-EF, KYFA9821-EF, PDF-EF

(E) KY31-EF **vs**. KY31-E+

(F) 97TF1-AR542, KYFA9301-AR542, KYFA9821-AR542, PDF-AR542, Jesup-MaxQ **vs**. 97TF1-AR584, KYFA9301-AR584, KYFA9821-AR584, PDF-AR584

(G) Bartura, KYFP9801-MF **vs**. Barfest-FL, KYFA9819-FL

(H) Latar-OG **vs**. Cache-MB

(I) AU-Triumph, Fawn, KY31-E+, KY31-EF, Seine **vs**. KYFA9304, Bariane, Barolex, Kenhy, TFsoft-HY-C3

Table 2.4. Graze 1 least square means of pre/post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein, Calcium (CA), potassium (K), phosphorus (P) and magnesium (MG).

					LSMEANS					
		pre			post					
name	**fresh^3**	**dry^3**	**moist^4**	**fresh^3**	**dry^3**	**moist^4**	**refusalfw^4**	**refusaldw^4**	**SCR**	**GS**
97TF1-AR542	662.62	166.18	73.41	459.28	124.82	66.78	69.98	76.70	2.7	2.8
97TF1-AR584	540.13	147.09	72.00	453.98	127.15	67.73	74.83	83.29	3.0	3.0
97TF1-E+	596.12	157.91	72.92	445.62	123.49	69.61	73.98	78.01	2.8	3.2
97TF1-EF	616.67	161.33	73.42	457.91	128.03	70.84	74.50	81.96	2.9	2.8
AU-Triumph	758.41	191.42	74.56	555.54	149.10	71.10	73.19	76.65	2.6	2.3
Bariane	637.22	162.46	73.83	106.99	43.78	54.99	68.34	73.22	2.6	3.4
Barolex	728.48	169.58	75.44	422.53	114.06	72.42	57.42	64.81	2.9	3.8
Fawn	717.96	182.69	73.91	395.38	107.71	70.83	80.07	86.84	1.8	2.1
Jesup-MaxQ	613.43	165.37	71.30	209.36	72.30	62.47	69.07	74.91	2.3	2.8
KY31-E+	755.66	195.47	72.69	476.22	139.32	68.98	72.87	79.28	2.1	2.7
KY31-EF	742.56	191.42	73.58	610.08	160.08	72.30	65.88	68.76	2.3	2.5
KYFA0006	592.56	167.31	70.44	418.71	121.00	64.63	66.86	71.86	2.2	2.8
KYFA9301-AR542	592.07	168.61	72.23	544.70	155.31	70.05	61.41	66.93	2.6	3.5
KYFA9301-AR584	638.51	173.79	72.89	465.66	129.04	70.83	70.44	77.46	2.6	3.0
KYFA9301-EF	597.09	161.49	72.18	418.35	120.08	63.88	70.20	76.20	2.9	3.0
KYFA9304	692.07	176.05	73.09	367.79	107.15	63.39	67.10	73.68	2.8	2.8
KYFA9611	627.35	169.42	72.85	452.41	128.00	69.86	67.74	74.26	2.2	2.7
KYFA9732	616.34	160.03	73.08	411.12	121.12	69.13	72.31	80.17	2.3	3.1
KYFA9821-AR542	624.27	166.34	72.57	446.59	128.03	70.91	73.81	81.35	2.9	2.6
KYFA9821-AR584	702.10	173.46	74.25	442.77	126.02	68.08	73.23	80.00	2.6	2.6
KYFA9821-EF	683.82	178.32	73.03	461.08	130.24	66.58	66.81	68.49	2.8	3.1
KYFA9905	673.30	173.62	73.65	139.52	51.73	52.73	75.63	81.18	2.5	2.6
KYFA9908	639.00	177.73	71.17	490.12	136.75	67.74	75.34	74.47	2.4	2.4
KYFA9913	581.39	155.83	71.92	481.16	138.88	70.52	56.89	64.80	3.2	2.9
KYTF2	553.72	145.63	72.52	477.84	120.28	71.02	66.09	74.93	3.1	3.2
Kenhy	677.99	181.72	73.26	520.72	144.82	71.58	72.46	75.55	2.8	2.5
PDF-AR542	623.79	167.80	71.70	513.78	137.35	69.88	61.95	66.34	2.5	3.2
PDF-AR584	645.47	180.91	71.52	360.24	103.02	66.17	65.86	70.63	2.5	2.6
PDF-E+	785.11	196.44	73.68	314.62	95.66	65.42	72.10	77.47	2.7	2.5
PDF-EF	636.08	168.45	73.17	365.22	108.43	66.35	69.24	75.30	2.8	2.9
Seine	689.16	175.24	72.96	475.14	130.12	70.33	69.78	77.21	2.4	2.8
Stockman	726.70	179.13	74.53	268.31	82.05	64.04	69.56	75.46	3.3	3.0
TFsoft-HY-C3	778.64	190.94	74.41	386.06	114.45	68.76	72.08	78.33	2.3	2.3
TuscanyII	734.47	184.14	74.31	425.14	127.47	66.78	69.22	74.61	2.8	2.7
Bartura	608.58	147.25	73.26	556.71	149.00	71.59	38.73	48.23	3.4	4.8
Barfest-FL	566.67	133.82	74.45	467.31	128.55	68.85	19.73	31.98	2.4	4.8
KYFP9801-MF	645.95	172.65	72.28	519.36	136.09	69.16	51.88	57.67	2.8	3.4
KYFA9819-FL	639.64	150.00	73.62	528.84	135.06	71.84	20.97	34.17	2.8	4.7
Latar-OG	1014.24	244.82	74.61	546.39	147.35	71.63	29.33	34.17	1.0	4.3
Cache-MB	851.78	236.08	71.60	515.38	136.71	72.01	57.41	60.63	1.0	3.1

[3] kg ha^{-1}

[4] percent content

Table 2.4. (continued)

	LSMEANS							
Name	**ADF[3]**	**NDF[3]**	**RFV[3]**	**Protein[3]**	**CA[3]**	**K[3]**	**P[3]**	**Mg[3]**
97TF1-AR542	29.4	55.81	110.25	18.77	0.78	2.25	0.43	0.34
97TF1-AR584	29.1	55.50	111.54	18.33	0.76	2.33	0.43	0.33
97TF1-E+	29.2	55.58	111.14	18.65	0.78	2.39	0.43	0.32
97TF1-EF	29.2	55.73	110.69	18.78	0.78	2.25	0.43	0.33
AU-Triumph	30.2	57.22	106.73	18.01	0.77	2.22	0.43	0.31
Bariane	28.7	54.95	113.05	19.41	0.78	2.40	0.45	0.34
Barolex	29.7	56.95	107.62	18.49	0.75	2.34	0.44	0.33
Fawn	29.5	56.89	108.27	18.81	0.75	2.32	0.44	0.31
Jesup-MaxQ	28.1	53.78	116.06	18.80	0.80	2.23	0.44	0.34
KY31-E+	29.0	55.09	112.17	17.55	0.77	2.27	0.43	0.33
KY31-EF	28.8	55.43	111.81	18.71	0.77	2.39	0.44	0.33
KYFA0006	28.4	54.60	114.01	18.60	0.81	2.30	0.43	0.35
KYFA9301-AR542	28.6	54.98	112.95	18.48	0.77	2.23	0.43	0.34
KYFA9301-AR584	27.6	53.09	118.88	19.46	0.86	2.22	0.43	0.35
KYFA9301-EF	28.0	53.88	116.17	18.64	0.79	2.23	0.43	0.34
KYFA9304	28.4	54.48	114.24	18.81	0.77	2.35	0.44	0.32
KYFA9611	28.3	53.68	116.46	18.96	0.79	2.16	0.44	0.35
KYFA9732	28.9	54.89	112.71	18.48	0.79	2.15	0.43	0.35
KYFA9821-AR542	28.6	54.40	114.16	18.61	0.77	2.26	0.44	0.33
KYFA9821-AR584	28.5	54.39	114.59	18.41	0.78	2.24	0.43	0.34
KYFA9821-EF	29.8	56.56	108.55	17.81	0.76	2.29	0.42	0.33
KYFA9905	28.6	54.92	113.26	18.20	0.79	2.20	0.43	0.34
KYFA9908	28.2	54.14	115.76	18.79	0.79	2.32	0.44	0.34
KYFA9913	29.0	54.90	112.62	18.53	0.76	2.27	0.43	0.34
KYTF2	29.0	54.59	113.64	18.07	0.77	2.23	0.43	0.33
Kenhy	28.8	54.23	114.05	18.42	0.79	2.25	0.43	0.33
PDF-AR542	28.7	55.36	112.42	18.61	0.78	2.20	0.43	0.34
PDF-AR584	28.8	55.19	112.36	18.16	0.77	2.17	0.43	0.33
PDF-E+	29.1	56.35	109.45	18.05	0.72	2.44	0.43	0.31
PDF-EF	28.1	54.27	115.43	18.90	0.80	2.31	0.43	0.34
Seine	30.9	59.15	102.34	17.85	0.66	2.33	0.43	0.31
Stockman	29.6	56.03	109.85	17.44	0.71	2.41	0.43	0.31
TFsoft-HY-C3	28.9	55.85	110.95	18.38	0.73	2.41	0.44	0.32
TuscanyII	29.1	55.75	110.69	18.28	0.75	2.38	0.43	0.33
Bartura	31.3	56.07	107.44	18.73	0.74	2.39	0.44	0.30
Barfest-FL	31.2	56.45	107.02	18.26	0.78	2.24	0.42	0.33
KYFP9801-MF	29.1	54.73	112.92	18.70	0.81	2.15	0.42	0.33
KYFA9819-FL	31.2	57.09	105.68	18.06	0.77	2.22	0.42	0.32
Latar-OG	36.1	65.26	86.92	15.83	0.53	2.30	0.43	0.28
Cache-MB	35.7	63.55	89.59	17.38	0.34	2.61	0.46	0.28

Table 2.4. (continued)

	LSMEANS							
name	**ADFa***	**RFVa**	**NDFa**	**Proteina**	**Caa**	**Ka**	**Pa**	**Mga**
97TF1-AR542	29.80	116.80	52.85	19.83	0.90	2.03	0.43	0.38
97TF1-AR584	28.83	119.85	51.67	19.85	0.91	2.04	0.43	0.37
97TF1-E+	29.23	118.10	52.18	19.69	0.89	2.14	0.42	0.36
97TF1-EF	28.79	120.24	51.52	20.46	0.95	2.00	0.42	0.39
AU-Triumph	30.93	110.34	54.87	19.22	0.86	1.99	0.43	0.34
Bariane	28.37	121.02	51.47	21.05	0.92	2.17	0.45	0.38
Barolex	29.61	115.04	53.46	20.16	0.87	2.13	0.44	0.38
Fawn	29.80	112.84	54.37	20.01	0.88	2.01	0.43	0.36
Jesup-MaxQ	28.94	118.47	52.35	19.60	0.89	2.09	0.43	0.38
KY31-E+	30.05	114.39	53.61	19.34	0.94	1.91	0.42	0.38
KY31-EF	29.68	115.77	53.15	19.53	0.88	2.10	0.43	0.37
KYFA0006	28.77	119.10	52.04	20.29	0.93	1.96	0.43	0.39
KYFA9301-AR542	29.35	117.05	52.86	19.71	0.89	1.96	0.43	0.37
KYFA9301-AR584	29.09	118.60	52.28	19.95	0.90	2.02	0.43	0.38
KYFA9301-EF	28.80	120.15	51.74	19.75	0.88	2.04	0.43	0.37
KYFA9304	29.73	115.50	53.15	19.73	0.89	2.11	0.43	0.37
KYFA9611	28.85	120.34	51.52	20.15	0.93	1.98	0.43	0.39
KYFA9732	28.85	120.55	51.44	20.36	0.94	1.91	0.43	0.40
KYFA9821-AR542	29.25	118.40	52.12	20.07	0.95	1.90	0.42	0.38
KYFA9821-AR584	29.32	117.98	52.18	19.73	0.91	2.07	0.43	0.39
KYFA9821-EF	29.15	117.68	52.45	19.36	0.85	2.08	0.43	0.36
KYFA9905	29.24	117.13	52.63	19.94	0.91	1.99	0.43	0.39
KYFA9908	28.41	121.23	51.36	19.99	0.90	2.02	0.44	0.38
KYFA9913	28.86	119.67	51.75	19.71	0.88	2.08	0.43	0.37
KYTF2	29.33	118.36	52.06	19.34	0.86	2.10	0.42	0.38
Kenhy	29.97	115.64	53.00	19.29	0.90	2.03	0.42	0.37
PDF-AR542	28.87	118.38	52.49	19.88	0.91	1.92	0.43	0.39
PDF-AR584	29.56	116.48	52.99	19.57	0.91	1.96	0.43	0.38
PDF-E+	28.86	120.06	51.61	20.24	0.95	2.10	0.43	0.39
PDF-EF	28.55	121.49	51.27	20.23	0.92	1.97	0.43	0.38
Seine	30.06	111.80	54.58	19.74	0.84	2.04	0.44	0.36
Stockman	28.83	119.65	51.92	19.78	0.87	2.11	0.43	0.37
TFsoft-HY-C3	29.75	113.57	54.01	19.87	0.87	2.03	0.44	0.37
TuscanyII	29.94	114.98	53.30	19.53	0.89	2.06	0.43	0.37
Bartura	31.24	113.80	53.16	20.54	0.95	2.07	0.42	0.37
Barfest-FL	29.70	119.61	51.50	21.33	0.92	2.02	0.45	0.41
KYFP9801-MF	30.11	115.35	52.97	20.02	0.90	1.94	0.43	0.36
KYFA9819-FL	30.67	113.87	53.51	20.39	0.91	1.96	0.43	0.38
Latar-OG	34.28	96.01	60.39	20.01	0.69	2.21	0.47	0.36
Cache-MB	35.28	93.98	60.74	20.53	0.47	2.38	0.46	0.36

*a denotes postgrazing forage quality

Table 2.5. Graze 2 least square means of pre/post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein, Calcium (CA), potassium (K), phosphorus (P) and magnesium (MG).

					LSMEANS					
		pre			**post**					
Name	**fresh**	**dry**	**moist**	**fresh**	**dry**	**moist**	**refusalfw**	**refusaldw**	**SCR**	**GS**
97TF1-AR542	915.06	318.22	63.91	587.92	229.00	55.95	60.33	71.32	3.3	3.5
97TF1-AR584	1008.46	345.74	63.54	561.72	231.47	56.71	55.66	66.29	3.2	3.2
97TF1-E+	944.06	336.71	63.12	506.32	226.19	52.66	53.75	65.69	3.2	3.0
97TF1-EF	922.01	329.40	63.70	565.79	248.36	54.50	63.62	76.68	2.8	3.2
AU-Triumph	949.40	343.27	63.45	545.82	233.71	55.40	59.20	71.10	3.1	3.1
Bariane	959.42	315.18	64.68	538.18	230.15	54.18	51.09	65.65	3.5	3.0
Barolex	1042.61	340.32	66.47	469.55	200.27	54.56	56.22	62.00	3.3	3.3
Fawn	1006.46	333.58	65.51	603.45	213.83	62.27	53.01	66.89	3.5	3.2
Jesup-MaxQ	959.14	326.62	63.61	530.17	224.62	53.27	56.94	66.34	3.2	3.3
KY31-E+	902.90	311.20	63.95	407.20	183.65	50.62	46.68	57.43	3.9	3.4
KY31-EF	904.06	309.48	64.15	522.94	213.81	55.48	57.78	68.87	3.7	3.1
KYFA0006	733.82	248.91	63.42	546.74	213.80	56.74	44.50	57.34	4.0	3.3
KYFA9301-AR542	990.19	326.87	65.94	418.97	176.52	55.27	64.66	76.97	3.1	3.4
KYFA9301-AR584	934.87	325.36	64.25	485.85	207.56	55.05	55.62	68.90	3.0	3.3
KYFA9301-EF	921.00	308.58	64.43	362.35	150.42	52.67	66.49	78.45	3.2	3.3
KYFA9304	964.13	320.87	64.30	638.14	245.48	58.19	59.84	66.61	3.3	3.2
KYFA9611	958.22	332.94	65.15	536.91	223.45	55.91	54.82	68.71	2.8	3.3
KYFA9732	927.46	321.95	64.63	586.54	233.04	57.31	59.39	74.18	3.2	3.4
KYFA9821-AR542	813.61	291.80	63.21	580.76	213.84	58.87	55.67	69.78	3.5	3.4
KYFA9821-AR584	820.68	295.94	63.00	520.83	209.90	56.68	55.10	68.03	3.6	2.8
KYFA9821-EF	1080.16	362.69	63.52	552.80	230.79	53.98	57.94	65.93	3.4	3.5
KYFA9905	1012.83	349.64	64.14	509.73	215.80	53.83	58.10	65.95	3.2	3.5
KYFA9908	996.55	326.85	65.33	433.05	182.83	54.76	65.02	74.26	3.4	3.6
KYFA9913	853.82	293.98	64.25	446.46	195.34	54.12	55.69	67.92	3.2	3.4
KYTF2	802.94	295.65	63.32	656.43	242.48	59.12	56.66	69.27	3.3	3.2
Kenhy	957.57	336.49	63.23	569.49	224.76	59.44	61.76	73.19	2.9	3.2
PDF-AR542	1002.82	334.55	63.45	667.20	250.07	58.25	47.95	59.07	3.6	3.1
PDF-AR584	988.16	331.85	64.52	489.75	202.13	55.28	55.88	67.25	3.3	3.6
PDF-E+	859.13	300.72	63.18	669.23	256.68	59.09	43.88	52.33	3.6	3.3
PDF-EF	997.59	334.43	64.87	460.54	198.57	54.49	67.52	76.61	3.3	3.6
Seine	1046.84	345.42	61.38	573.25	238.45	55.03	53.78	60.00	3.4	3.3
Stockman	1072.64	350.30	66.02	385.67	179.88	52.36	63.51	73.85	2.8	3.3
TFsoft-HY-C3	1066.81	346.42	65.89	515.52	207.31	54.33	48.97	61.25	3.5	3.4
TuscanyII	1054.21	341.67	64.66	574.34	231.88	55.99	54.67	64.90	3.3	3.3
Bartura	1019.77	347.63	64.49	410.64	177.68	52.26	49.93	59.59	3.6	3.3
Barfest-FL	822.49	309.76	60.95	682.35	255.43	59.30	66.97	76.13	2.8	3.1
KYFP9801-MF	980.45	341.41	63.48	531.28	194.21	59.14	68.56	76.86	2.9	3.3
KYFA9819-FL	770.70	298.12	58.79	645.51	250.50	59.14	69.52	78.68	2.8	3.1
Latar-OG	866.88	319.53	61.31	538.66	215.52	57.29	47.06	58.29	3.9	3.8
Cache-MB	867.93	339.57	60.21	565.56	223.32	57.94	44.98	55.67	4.2	3.3

Table 2.5. (continued)

	LSMEANS							
Name	**ADF**	**NDF**	**RFV**	**Protein**	**CA**	**K**	**P**	**MG**
97TF1-AR542	36.17	64.98	87.22	13.92	0.70	1.63	0.38	0.41
97TF1-AR584	36.71	65.97	85.24	13.95	0.71	1.57	0.37	0.43
97TF1-E+	36.36	65.10	86.94	14.15	0.70	1.67	0.38	0.41
97TF1-EF	37.76	67.12	82.51	13.34	0.71	1.46	0.38	0.42
AU-Triumph	36.83	66.30	84.60	13.31	0.70	1.59	0.37	0.41
Bariane	35.39	63.27	90.40	14.96	0.77	1.62	0.39	0.43
Barolex	36.04	64.57	88.00	14.41	0.71	1.73	0.39	0.41
Fawn	36.07	64.74	87.56	14.96	0.73	1.70	0.39	0.40
Jesup-MaxQ	35.73	64.76	87.83	14.43	0.71	1.66	0.38	0.41
KY31-E+	34.83	63.22	91.15	14.70	0.77	1.59	0.38	0.43
KY31-EF	35.82	64.13	88.72	14.23	0.70	1.65	0.39	0.41
KYFA0006	35.39	63.58	89.99	14.36	0.73	1.48	0.38	0.42
KYFA9301-AR542	37.00	65.92	84.97	14.05	0.74	1.53	0.38	0.42
KYFA9301-AR584	36.67	65.38	86.09	14.30	0.74	1.61	0.38	0.44
KYFA9301-EF	36.54	65.47	86.00	13.79	0.72	1.53	0.38	0.42
KYFA9304	36.71	65.46	85.88	13.95	0.73	1.62	0.38	0.42
KYFA9611	36.06	64.44	87.97	14.11	0.78	1.42	0.38	0.44
KYFA9732	36.28	64.87	87.10	14.60	0.73	1.54	0.39	0.44
KYFA9821-AR542	35.82	64.51	88.21	14.03	0.72	1.53	0.38	0.43
KYFA9821-AR584	35.40	63.82	89.46	14.34	0.66	1.67	0.39	0.39
KYFA9821-EF	37.27	66.47	84.10	14.17	0.71	1.58	0.38	0.43
KYFA9905	35.89	64.33	88.30	14.46	0.81	1.54	0.38	0.45
KYFA9908	36.49	65.23	86.36	14.24	0.71	1.64	0.38	0.41
KYFA9913	36.31	65.27	86.51	13.47	0.73	1.56	0.38	0.42
KYTF2	37.42	66.96	83.21	12.72	0.64	1.55	0.37	0.40
Kenhy	36.52	65.93	85.55	13.66	0.76	1.48	0.37	0.45
PDF-AR542	36.36	65.29	86.54	13.75	0.69	1.57	0.38	0.42
PDF-AR584	36.13	65.11	87.06	14.57	0.77	1.45	0.38	0.45
PDF-E+	35.06	63.66	90.38	14.22	0.71	1.66	0.38	0.43
PDF-EF	36.67	65.63	85.68	13.82	0.67	1.67	0.38	0.41
Seine	36.31	65.22	86.61	14.34	0.67	1.72	0.39	0.39
Stockman	36.50	65.34	86.25	13.89	0.73	1.59	0.38	0.44
TFsoft-HY-C3	35.34	64.11	89.37	14.41	0.69	1.76	0.39	0.40
TuscanyII	36.58	65.40	86.01	13.97	0.72	1.59	0.39	0.42
Bartura	36.81	64.90	86.52	14.65	0.74	1.57	0.38	0.43
Barfest-FL	38.19	67.69	81.50	13.57	0.74	1.44	0.37	0.44
KYFP9801-MF	37.24	65.91	84.70	13.85	0.72	1.55	0.38	0.42
KYFA9819-FL	37.51	66.41	83.75	13.90	0.77	1.41	0.37	0.44
Latar-OG	36.23	64.13	88.13	16.85	0.64	1.88	0.44	0.41
Cache-MB	37.70	64.23	86.39	15.45	0.56	1.81	0.43	0.39

Table 2.5. (continued)

LSMEANS

name	**ADFa**	**NDFa**	**RFVa**	**Proteina**	**Caa**	**Pa**	**Ka**	**Mga**
97TF1-AR542	36.70	65.45	85.90	14.01	0.89	0.38	1.22	0.50
97TF1-AR584	37.63	66.49	83.42	13.66	0.76	0.38	1.37	0.45
97TF1-E+	36.98	65.10	86.02	13.37	0.72	0.38	1.43	0.44
97TF1-EF	37.58	66.58	83.46	13.24	0.82	0.37	1.21	0.48
AU-Triumph	37.13	65.89	84.79	13.25	0.73	0.38	1.36	0.43
Bariane	36.49	64.36	87.46	14.32	0.82	0.38	1.30	0.47
Barolex	37.04	65.34	85.63	13.57	0.73	0.39	1.47	0.44
Fawn	36.39	64.89	86.97	14.17	0.77	0.38	1.37	0.43
Jesup-MaxQ	36.87	65.86	85.10	13.57	0.74	0.38	1.44	0.43
KY31-E+	35.49	63.73	89.58	14.10	0.86	0.37	1.29	0.47
KY31-EF	36.58	64.53	87.18	14.14	0.83	0.38	1.23	0.46
KYFA0006	36.38	64.66	87.20	13.34	0.84	0.37	1.22	0.47
KYFA9301-AR542	36.99	65.45	85.52	13.86	0.82	0.38	1.25	0.47
KYFA9301-AR584	36.97	65.51	85.52	13.91	0.78	0.37	1.33	0.46
KYFA9301-EF	37.46	66.22	84.02	13.46	0.75	0.38	1.35	0.45
KYFA9304	36.32	64.55	87.37	13.58	0.76	0.38	1.40	0.44
KYFA9611	37.41	66.17	84.07	12.93	0.81	0.37	1.26	0.48
KYFA9732	37.30	66.05	84.36	13.81	0.85	0.38	1.16	0.50
KYFA9821-AR542	36.14	64.40	87.91	13.96	0.77	0.38	1.31	0.44
KYFA9821-AR584	36.56	64.99	86.63	13.98	0.80	0.37	1.41	0.45
KYFA9821-EF	37.21	66.00	84.69	13.66	0.83	0.38	1.29	0.47
KYFA9905	36.45	64.93	86.82	13.99	0.86	0.37	1.22	0.48
KYFA9908	37.74	66.11	83.83	13.71	0.79	0.38	1.33	0.46
KYFA9913	37.67	66.88	83.02	13.03	0.76	0.37	1.34	0.45
KYTF2	38.43	67.58	81.26	12.93	0.77	0.38	1.20	0.46
Kenhy	37.18	65.80	84.85	13.76	0.89	0.37	1.09	0.50
PDF-AR542	36.31	64.99	86.83	13.62	0.84	0.38	1.25	0.47
PDF-AR584	36.46	64.91	86.85	13.79	0.81	0.38	1.35	0.48
PDF-E+	35.97	64.02	88.69	13.91	0.77	0.38	1.37	0.45
PDF-EF	36.32	64.67	87.36	13.86	0.81	0.38	1.34	0.47
Seine	37.55	66.30	83.79	13.68	0.70	0.39	1.47	0.40
Stockman	37.36	65.82	84.69	13.02	0.78	0.37	1.36	0.46
TFsoft-HY-C3	37.44	66.15	84.15	13.66	0.74	0.38	1.37	0.43
TuscanyII	38.41	67.28	81.65	12.63	0.72	0.38	1.41	0.43
Bartura	38.63	66.72	82.17	13.62	0.80	0.39	1.30	0.47
Barfest-FL	38.81	67.63	80.79	13.31	0.79	0.37	1.25	0.47
KYFP9801-MF	37.71	66.27	83.69	13.60	0.80	0.38	1.26	0.46
KYFA9819-FL	39.29	68.17	79.75	13.26	0.77	0.37	1.26	0.45
Latar-OG	38.20	65.86	83.66	15.77	0.74	0.43	1.55	0.44
Cache-MB	38.95	65.55	83.24	13.96	0.60	0.42	1.57	0.42

*a denotes postgrazing forage quality

Table 2.6. Graze 3 least square means of pre/post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein, Calcium (CA), potassium (K), phosphorus (P) and magnesium (MG).

				LSMEANS						
	pre			post						
name	**fresh**	**dry**	**moist**	**fresh**	**dry**	**moist**	**Refusalfw**	**refusal dw**	**SCR**	**GS**
97TF1-AR542	703.56	176.86	74.54	527.68	133.39	74.51	78.83	79.38	3.0	3.0
97TF1-AR584	670.39	180.10	72.15	458.47	122.90	72.78	74.08	73.66	3.2	3.2
97TF1-E+	698.71	175.24	74.42	510.21	127.01	74.80	75.49	74.50	3.1	3.0
97TF1-EF	740.78	185.76	73.48	495.53	129.19	73.43	71.53	74.83	2.9	2.8
AU-Triumph	740.78	193.04	70.48	633.95	166.95	73.44	85.28	88.82	2.3	3.6
Bariane	709.22	167.15	75.99	285.10	74.66	71.89	61.43	65.11	3.5	2.8
Barolex	598.38	165.53	71.06	410.93	104.03	73.88	85.48	76.60	3.5	3.0
Fawn	731.88	180.10	75.05	468.26	120.14	74.87	79.29	80.88	2.8	2.8
Jesup-MaxQ	739.97	189.00	74.39	271.11	81.66	68.43	70.35	65.09	3.4	3.0
KY31-E+	729.45	187.38	73.71	719.24	215.04	69.95	73.08	70.85	3.3	3.4
KY31-EF	758.58	188.19	74.57	550.06	138.98	74.07	75.37	74.68	3.2	3.4
KYFA0006	702.75	165.53	76.20	489.23	118.50	76.33	63.51	73.34	3.4	2.6
KYFA9301-AR542	636.41	157.44	74.97	496.22	124.30	74.57	67.93	74.07	3.3	2.9
KYFA9301-AR584	659.87	175.24	72.85	506.01	128.50	74.50	83.34	80.09	3.3	3.2
KYFA9301-EF	777.99	197.90	74.61	425.76	111.02	72.38	59.58	61.73	3.7	3.0
KYFA9304	647.73	167.96	72.79	434.70	116.61	71.63	79.58	76.86	3.4	2.8
KYFA9611	711.65	180.91	73.49	549.36	134.79	75.12	76.48	76.08	3.0	2.8
KYFA9732	619.42	160.68	73.10	430.51	111.72	73.51	67.38	69.53	3.6	2.8
KYFA9821-AR542	756.96	204.37	73.69	496.92	124.30	74.48	72.27	68.87	3.0	3.2
KYFA9821-AR584	739.16	195.24	74.28	522.79	129.19	75.17	75.32	74.01	3.0	3.6
KYFA9821-EF	743.20	184.14	74.19	395.55	104.73	72.98	74.64	72.79	3.1	3.2
KYFA9905	754.53	191.42	74.66	295.58	75.36	72.61	69.13	67.05	3.6	2.9
KYFA9908	686.57	177.67	73.88	509.51	125.70	74.93	73.82	71.99	3.3	2.8
KYFA9913	738.35	176.05	76.12	520.69	135.49	73.46	72.81	75.53	3.6	2.5
KYTF2	692.23	171.20	75.08	510.91	127.80	74.38	68.94	69.87	3.4	2.8
Kenhy	673.62	164.72	75.47	495.53	120.81	75.30	69.45	72.32	3.5	2.7
PDF-AR542	633.98	166.34	73.45	477.35	120.11	74.37	87.20	87.54	2.8	3.0
PDF-AR584	709.22	176.05	74.67	505.31	127.10	74.53	79.97	80.87	3.0	3.4
PDF-E+	759.39	199.51	73.02	493.43	126.40	73.84	79.25	78.03	3.1	3.3
PDF-EF	737.54	198.71	72.88	452.88	112.42	75.03	66.76	66.38	3.2	2.8
Seine	689.00	176.05	74.40	443.79	111.02	74.46	86.29	86.17	2.4	3.4
Stockman	706.80	181.72	73.57	430.51	125.70	71.19	78.75	76.68	3.2	3.0
TFsoft-HY-C3	815.21	210.84	73.22	554.25	141.78	73.61	80.20	76.56	2.3	3.7
TuscanyII	803.88	188.19	76.02	536.07	134.42	74.20	76.98	80.13	3.0	3.0
Bartura	575.73	139.64	74.82	557.75	145.97	73.54	51.34	63.35	4.4	2.3
Barfest-FL	688.19	159.87	76.08	447.99	115.91	72.98	48.68	53.95	4.2	1.3
KYFP9801-MF	727.02	189.00	70.71	619.97	157.16	74.31	72.59	73.33	3.4	2.3
KYFA9819-FL	795.79	181.72	76.07	528.38	131.29	74.90	38.73	44.41	4.4	1.3
Latar-OG	934.95	260.19	71.89	615.77	150.44	74.84	49.33	50.89	3.3	4.5
Cache-MB	870.23	256.15	67.08	578.02	144.57	74.78	86.24	88.74	1.8	4.5

Table 2.6. (continued)

	LSMEANS							
name	**ADF**	**NDF**	**RFV**	**Protein**	**K**	**CA**	**P**	**MG**
97TF1-AR542	33.09	58.72	100.26	15.43	1.81	0.81	0.38	0.33
97TF1-AR584	32.94	58.11	101.48	14.95	1.90	0.78	0.37	0.31
97TF1-E+	33.04	57.56	103.10	15.70	2.05	0.85	0.38	0.32
97TF1-EF	33.37	58.71	99.98	15.45	1.67	0.84	0.38	0.34
AU-Triumph	34.72	61.08	94.45	14.44	1.90	0.74	0.38	0.30
Bariane	33.18	58.39	100.90	16.32	1.98	0.85	0.40	0.34
Barolex	31.55	56.43	106.43	16.05	2.00	0.81	0.40	0.32
Fawn	33.44	60.38	97.04	15.61	1.89	0.81	0.39	0.31
Jesup-MaxQ	32.38	57.98	102.26	15.95	2.11	0.77	0.39	0.33
KY31-E+	32.31	57.51	103.46	15.35	1.99	0.79	0.39	0.32
KY31-EF	32.48	57.95	102.37	15.42	1.93	0.77	0.39	0.32
KYFA0006	32.85	57.64	102.35	16.18	1.86	0.88	0.38	0.36
KYFA9301-AR542	32.28	57.45	103.40	15.75	1.94	0.81	0.39	0.33
KYFA9301-AR584	31.53	56.63	105.93	15.69	1.97	0.81	0.39	0.33
KYFA9301-EF	31.82	57.05	104.93	15.71	1.93	0.84	0.38	0.32
KYFA9304	32.93	57.91	102.18	15.26	1.97	0.77	0.39	0.32
KYFA9611	32.00	56.86	104.89	15.38	1.80	0.82	0.38	0.34
KYFA9732	32.52	57.56	103.08	15.45	1.79	0.82	0.39	0.33
KYFA9821-AR542	33.13	58.36	101.15	16.06	1.60	0.85	0.37	0.33
KYFA9821-AR584	33.22	58.84	99.76	15.34	1.95	0.77	0.39	0.32
KYFA9821-EF	32.06	57.28	103.97	15.17	1.85	0.80	0.39	0.33
KYFA9905	32.24	57.93	102.95	15.70	1.75	0.85	0.39	0.34
KYFA9908	32.44	57.80	102.77	15.19	1.74	0.79	0.39	0.33
KYFA9913	32.82	57.80	102.12	15.47	1.91	0.84	0.38	0.33
KYTF2	32.62	56.87	104.19	15.84	1.73	0.89	0.38	0.34
Kenhy	32.74	57.21	103.45	15.75	1.78	0.86	0.38	0.33
PDF-AR542	31.84	57.39	104.17	14.98	1.76	0.80	0.38	0.33
PDF-AR584	32.93	59.01	99.97	14.97	1.95	0.77	0.38	0.32
PDF-E+	32.49	58.08	102.21	15.12	2.08	0.78	0.38	0.31
PDF-EF	32.16	57.59	103.34	15.15	1.83	0.82	0.38	0.32
Seine	33.43	60.20	97.41	15.22	2.00	0.73	0.40	0.30
Stockman	32.52	57.42	103.66	15.29	1.82	0.81	0.39	0.31
TFsoft-HY-C3	33.72	60.14	96.99	14.86	1.90	0.78	0.38	0.31
TuscanyII	32.27	56.86	104.53	15.56	1.97	0.86	0.38	0.34
Bartura	31.34	54.84	109.86	16.45	2.12	0.83	0.40	0.32
Barfest-FL	34.72	60.25	95.89	15.35	2.04	0.87	0.39	0.34
KYFP9801-MF	32.84	58.09	101.82	15.52	1.80	0.81	0.38	0.33
KYFA9819-FL	33.49	57.60	101.96	16.02	1.91	0.92	0.39	0.34
Latar-OG	38.92	66.72	81.81	14.32	1.95	0.57	0.43	0.29
Cache-MB	39.73	66.28	81.59	13.81	1.81	0.51	0.41	0.28

Table 2.6. (continued)

LSMEANS

name	ADFa*	NDFa	RFVa	Proteina	Caa	Ka	Pa	Mga
97TF1-AR542	31.79	56.75	105.25	14.25	0.75	1.88	0.38	0.31
97TF1-AR584	32.02	56.62	105.27	14.15	0.75	1.81	0.37	0.30
97TF1-E+	32.77	57.17	103.38	14.54	0.75	2.01	0.38	0.30
97TF1-EF	31.21	55.57	108.19	14.65	0.80	1.56	0.37	0.33
AU-Triumph	33.87	59.44	98.10	13.85	0.73	1.81	0.37	0.30
Bariane	31.39	55.66	107.93	15.19	0.83	1.93	0.39	0.33
Barolex	31.88	56.30	106.08	15.43	0.81	1.87	0.39	0.32
Fawn	32.71	58.40	101.14	14.92	0.77	1.94	0.39	0.29
Jesup-MaxQ	31.76	56.46	105.98	15.20	0.75	1.89	0.38	0.31
KY31-E+	30.91	54.90	110.16	14.31	0.74	1.90	0.38	0.30
KY31-EF	31.51	55.59	107.84	14.51	0.74	1.85	0.38	0.30
KYFA0006	31.33	55.71	108.12	15.27	0.82	1.78	0.38	0.33
KYFA9301-AR542	31.23	55.07	109.27	14.85	0.78	1.81	0.38	0.31
KYFA9301-AR584	30.71	54.88	110.37	14.75	0.75	1.88	0.39	0.31
KYFA9301-EF	31.35	55.77	108.12	14.43	0.72	1.78	0.37	0.33
KYFA9304	31.56	55.96	107.23	14.39	0.77	1.85	0.38	0.32
KYFA9611	31.44	55.36	108.52	14.71	0.79	1.65	0.37	0.34
KYFA9732	31.60	55.77	107.29	14.25	0.76	1.63	0.37	0.33
KYFA9821-AR542	31.51	55.98	107.03	14.43	0.73	1.89	0.38	0.30
KYFA9821-AR584	31.05	55.66	108.37	14.15	0.72	1.94	0.38	0.31
KYFA9821-EF	31.41	55.60	108.37	14.72	0.77	1.72	0.38	0.33
KYFA9905	31.10	55.67	108.13	14.60	0.76	1.77	0.38	0.32
KYFA9908	32.20	56.75	104.78	14.27	0.74	1.74	0.38	0.32
KYFA9913	31.57	55.70	107.70	14.70	0.79	1.71	0.37	0.32
KYTF2	32.01	56.18	105.97	14.88	0.81	1.70	0.37	0.32
Kenhy	31.41	55.12	108.95	14.62	0.79	1.71	0.38	0.32
PDF-AR542	31.25	55.70	107.97	14.62	0.76	1.72	0.37	0.32
PDF-AR584	31.58	56.21	106.57	14.41	0.73	1.80	0.38	0.31
PDF-E+	31.63	56.39	106.11	14.05	0.74	1.98	0.37	0.30
PDF-EF	30.83	54.86	110.17	14.65	0.78	1.69	0.37	0.32
Seine	33.05	59.22	99.35	14.66	0.70	1.98	0.39	0.29
Stockman	31.73	56.54	105.66	13.77	0.72	1.73	0.37	0.31
TFsoft-HY-C3	32.88	59.13	99.60	13.91	0.71	1.93	0.38	0.29
TuscanyII	32.54	57.66	102.85	14.41	0.77	1.89	0.37	0.31
Bartura	32.65	55.46	106.65	15.39	0.86	1.77	0.37	0.34
Barfest-FL	33.51	57.54	101.68	14.96	0.82	1.72	0.38	0.34
KYFP9801-MF	31.51	55.56	108.16	14.78	0.77	1.67	0.37	0.33
KYFA9819-FL	32.58	54.60	109.70	15.55	0.97	1.67	0.37	0.37
Latar-OG	40.09	67.45	79.64	12.00	0.52	1.72	0.40	0.28
Cache-MB	38.21	63.51	86.66	14.12	0.47	1.80	0.42	0.28

*a denotes postgrazing forage quality

Table 2.7. Graze 4 least square means of pre/post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein, Calcium (CA), potassium (K), phosphorus (P) and magnesium (MG).

					LSMEANS					
		pre			**post**					
name	**fresh**	**dry**	**moist**	**fresh**	**dry**	**moist**	**refusalfw**	**refusaldw**	**SCR**	**GS**
97TF1-AR542	1283.17	508.09	59.65	791.39	279.64	64.28	67.02	59.00	3.6	3.3
97TF1-AR584	1260.52	514.56	58.58	857.10	310.40	63.45	72.48	63.96	3.3	3.4
97TF1-E+	1254.05	519.42	58.33	848.71	310.40	63.20	72.33	63.43	2.9	3.3
97TF1-EF	1101.94	478.96	56.13	798.38	311.80	60.80	76.68	68.91	3.1	3.3
AU-Triumph	1252.43	498.38	59.68	964.77	352.35	62.87	80.88	74.58	2.7	3.3
Bariane	865.70	370.55	55.88	406.88	167.79	57.91	50.00	47.30	3.8	3.4
Barolex	1279.94	493.53	60.88	769.02	271.25	64.44	63.96	58.03	3.8	3.2
Fawn	1207.12	500.00	58.82	799.78	289.43	63.63	70.60	62.87	3.0	3.2
Jesup-MaxQ	847.90	378.64	54.29	485.18	192.95	60.45	61.82	53.58	3.3	3.8
KY31-E+	846.28	398.06	52.25	460.01	167.79	57.70	52.58	45.06	3.3	3.4
KY31-EF	1228.16	506.47	58.31	827.74	283.84	65.48	71.92	59.18	3.6	3.7
KYFA0006	1307.44	543.69	58.08	851.51	304.81	63.89	69.82	59.67	3.8	3.3
KYFA9301-AR542	1292.88	500.00	61.04	865.49	317.39	63.36	71.28	66.97	3.8	3.0
KYFA9301-AR584	1257.28	514.56	58.79	802.57	286.63	63.77	67.57	58.66	3.6	3.3
KYFA9301-EF	1116.50	457.93	58.13	713.09	278.24	60.73	67.78	64.47	3.5	3.3
KYFA9304	1126.21	478.96	56.48	727.07	267.06	62.68	68.93	58.43	3.3	2.9
KYFA9611	1168.28	508.09	56.29	769.02	278.24	63.25	69.82	59.87	3.1	3.5
KYFA9732	1139.16	493.53	56.03	707.49	269.85	61.61	66.83	58.33	3.3	3.1
KYFA9821-AR542	1111.65	488.67	55.59	764.82	297.82	60.91	73.28	64.08	3.5	3.3
KYFA9821-AR584	1142.39	490.29	56.45	742.45	288.03	61.13	70.53	62.40	3.3	3.1
KYFA9821-EF	1064.72	470.87	55.39	662.75	255.87	60.48	64.97	57.46	2.9	3.0
KYFA9905	737.86	373.79	47.58	363.53	149.61	58.92	53.83	42.88	3.5	3.5
KYFA9908	1158.58	487.06	57.39	791.39	290.83	62.73	72.27	63.52	3.7	3.3
KYFA9913	1160.19	491.91	57.24	727.07	269.85	62.68	67.28	58.50	3.8	3.1
KYTF2	1051.78	449.84	56.06	731.26	274.05	62.43	75.60	64.80	3.6	2.8
Kenhy	1199.03	493.53	58.28	847.32	316.00	62.29	73.27	67.74	3.6	3.3
PDF-AR542	1182.85	498.38	57.20	809.56	302.01	62.28	72.13	63.52	2.9	3.8
PDF-AR584	1030.74	457.93	55.39	721.48	281.04	60.89	74.74	65.96	2.9	3.7
PDF-E+	1058.25	475.73	54.48	697.71	279.64	59.87	70.38	62.38	3.3	3.8
PDF-EF	1021.04	448.22	55.78	611.02	239.09	60.88	64.34	56.72	3.4	3.3
Seine	1056.63	475.73	54.37	647.37	267.06	58.68	65.76	59.25	2.8	3.7
Stockman	1014.56	448.22	55.79	631.99	247.48	59.45	66.15	59.75	3.1	3.3
TFsoft-HY-C3	1313.92	546.93	57.73	869.69	316.00	63.71	69.95	61.28	3.2	3.5
TuscanyII	1338.19	555.02	57.96	906.04	339.77	62.53	73.23	65.22	3.3	3.2
Bartura	1364.08	532.36	60.63	929.81	331.38	63.58	72.17	66.20	4.1	2.7
Barfest-FL	1132.69	491.91	56.18	746.64	295.02	60.22	70.87	64.04	3.9	1.9
KYFP9801-MF	1462.78	580.91	59.84	1132.55	384.51	65.76	81.08	70.85	3.5	3.1
KYFA9819-FL	1218.45	530.74	55.94	836.13	318.79	61.70	73.03	64.15	4.3	1.8
Latar-OG	1257.28	548.54	56.24	887.86	320.19	63.31	75.20	64.38	3.8	4.3
Cache-MB	1160.34	481.25	58.39	806.77	296.42	63.09	74.32	66.99	4.2	2.3

Table 2.7. (continued)

	LSMEANS							
name	**ADF**	**NDF**	**RFV**	**Protein**	**CA**	**K**	**P**	**MG**
97TF1-AR542	30.27	56.45	108.01	13.30	0.81	1.58	0.33	0.32
97TF1-AR584	30.67	56.83	106.80	13.26	0.80	1.50	0.33	0.31
97TF1-E+	30.84	56.36	107.37	13.41	0.80	1.58	0.33	0.30
97TF1-EF	30.47	55.81	109.20	13.83	0.83	1.37	0.33	0.31
AU-Triumph	31.08	57.43	105.07	13.37	0.79	1.46	0.32	0.29
Bariane	29.90	55.25	111.05	14.31	0.86	1.55	0.34	0.32
Barolex	31.14	57.18	105.66	14.23	0.83	1.48	0.34	0.30
Fawn	31.21	57.95	104.01	14.01	0.82	1.59	0.33	0.29
Jesup-MaxQ	29.74	55.86	109.71	14.01	0.81	1.65	0.34	0.31
KY31-E+	29.09	54.24	113.83	13.74	0.84	1.46	0.33	0.31
KY31-EF	30.30	56.05	108.72	13.67	0.80	1.49	0.33	0.31
KYFA0006	30.27	55.51	109.73	14.22	0.87	1.46	0.33	0.32
KYFA9301-AR542	29.46	54.48	113.06	14.80	0.85	1.51	0.34	0.31
KYFA9301-AR584	29.69	54.82	111.89	14.29	0.86	1.45	0.34	0.32
KYFA9301-EF	29.44	54.66	112.53	14.46	0.84	1.43	0.34	0.31
KYFA9304	30.21	55.41	110.19	13.92	0.86	1.52	0.33	0.32
KYFA9611	30.93	56.63	106.65	13.30	0.84	1.38	0.32	0.33
KYFA9732	30.42	55.43	110.02	13.62	0.88	1.28	0.32	0.34
KYFA9821-AR542	29.03	54.27	114.02	14.53	0.85	1.57	0.33	0.30
KYFA9821-AR584	29.94	55.22	110.90	14.15	0.81	1.58	0.34	0.29
KYFA9821-EF	30.32	55.83	109.22	14.51	0.85	1.41	0.34	0.31
KYFA9905	30.74	56.67	107.04	14.35	0.86	1.45	0.33	0.32
KYFA9908	30.36	55.95	108.81	13.81	0.84	1.49	0.33	0.32
KYFA9913	29.59	54.56	112.76	14.79	0.92	1.49	0.33	0.32
KYTF2	30.66	56.17	108.19	14.30	0.86	1.52	0.34	0.32
Kenhy	30.85	56.09	107.98	14.74	0.88	1.48	0.34	0.30
PDF-AR542	30.82	56.75	106.49	13.66	0.82	1.44	0.33	0.32
PDF-AR584	30.70	56.72	106.99	13.23	0.76	1.43	0.33	0.32
PDF-E+	29.43	54.90	112.08	13.37	0.78	1.60	0.33	0.31
PDF-EF	30.33	56.12	108.73	13.53	0.78	1.45	0.33	0.31
Seine	31.71	59.40	100.79	12.94	0.72	1.60	0.34	0.29
Stockman	30.14	55.86	109.41	13.83	0.84	1.43	0.33	0.31
TFsoft-HY-C3	31.46	57.37	104.99	14.59	0.83	1.38	0.33	0.29
TuscanyII	30.24	55.96	108.83	13.87	0.89	1.41	0.33	0.31
Bartura	30.65	54.19	112.18	15.65	0.97	1.51	0.34	0.32
Barfest-FL	30.68	55.58	109.14	15.35	0.89	1.56	0.35	0.31
KYFP9801-MF	30.59	55.75	108.77	14.24	0.84	1.36	0.33	0.31
KYFA9819-FL	31.48	56.89	107.44	14.95	0.87	1.45	0.35	0.30
Latar-OG	33.25	59.30	99.19	15.21	0.83	1.46	0.35	0.29
Cache-MB	32.23	57.74	103.30	17.20	0.94	1.35	0.37	0.28

Table 2.7. (continued)

			LSMEANS					
name	**ADFa**	**NDFa**	**RFVa**	**Proteina**	**Caa**	**Ka**	**Pa**	**Mga**
97TF1-AR542	33.41	61.60	95.39	14.60	0.84	1.57	0.32	0.29
97TF1-AR584	33.92	61.97	94.01	14.12	0.77	1.69	0.33	0.27
97TF1-E+	34.29	62.35	92.94	13.98	0.77	1.72	0.33	0.27
97TF1-EF	34.22	62.27	93.42	14.70	0.85	1.49	0.32	0.28
AU-Triumph	35.03	63.86	90.09	14.40	0.82	1.33	0.31	0.26
Bariane	33.84	61.80	94.39	14.15	0.79	1.72	0.33	0.28
Barolex	33.42	61.67	95.07	15.73	0.93	1.50	0.32	0.27
Fawn	34.28	62.84	92.46	15.47	0.86	1.58	0.33	0.26
Jesup-MaxQ	33.21	61.72	95.20	14.35	0.77	1.69	0.33	0.28
KY31-E+	32.65	60.05	98.73	14.05	0.83	1.56	0.32	0.27
KY31-EF	32.48	59.91	98.94	13.91	0.77	1.58	0.33	0.28
KYFA0006	33.64	61.11	95.93	14.91	0.93	1.46	0.31	0.31
KYFA9301-AR542	33.13	61.23	96.21	15.70	0.92	1.53	0.33	0.29
KYFA9301-AR584	33.41	61.45	95.43	14.96	0.82	1.65	0.34	0.28
KYFA9301-EF	33.03	60.79	97.42	14.81	0.83	1.60	0.33	0.28
KYFA9304	34.39	62.34	93.01	14.36	0.87	1.45	0.31	0.28
KYFA9611	34.21	62.48	92.77	14.77	0.86	1.39	0.32	0.30
KYFA9732	33.44	60.86	96.43	14.52	0.90	1.37	0.31	0.30
KYFA9821-AR542	33.32	61.31	95.68	15.15	0.86	1.58	0.33	0.27
KYFA9821-AR584	33.71	61.39	95.21	14.56	0.84	1.54	0.33	0.27
KYFA9821-EF	33.11	61.10	97.44	15.06	0.88	1.56	0.32	0.27
KYFA9905	33.90	62.22	93.99	14.82	0.85	1.58	0.33	0.28
KYFA9908	33.46	60.77	96.35	14.36	0.85	1.54	0.32	0.29
KYFA9913	34.42	62.55	92.59	15.49	0.91	1.47	0.32	0.28
KYTF2	34.30	62.47	92.88	15.19	0.95	1.42	0.31	0.29
Kenhy	34.53	62.63	92.48	15.40	0.87	1.56	0.33	0.27
PDF-AR542	34.33	62.68	92.59	14.53	0.87	1.30	0.31	0.29
PDF-AR584	33.50	62.27	94.40	15.07	0.88	1.41	0.32	0.29
PDF-E+	32.93	60.85	97.01	13.74	0.79	1.68	0.32	0.29
PDF-EF	34.00	61.92	94.27	14.05	0.80	1.52	0.32	0.28
Seine	34.79	64.48	89.33	13.60	0.71	1.70	0.33	0.25
Stockman	33.45	61.80	94.99	14.52	0.86	1.44	0.31	0.29
TFsoft-HY-C3	34.48	63.27	91.79	14.78	0.81	1.63	0.32	0.27
TuscanyII	33.94	62.12	93.98	14.91	0.85	1.52	0.32	0.28
Bartura	34.06	60.30	96.70	15.94	0.96	1.49	0.33	0.29
Barfest-FL	36.06	64.06	88.88	16.24	0.93	1.37	0.32	0.27
KYFP9801-MF	34.33	62.76	92.38	14.93	0.85	1.46	0.32	0.28
KYFA9819-FL	34.07	61.14	96.59	16.64	1.00	1.41	0.32	0.27
Latar-OG	37.31	65.90	84.64	15.93	0.86	1.45	0.34	0.27
Cache-MB	35.09	63.17	91.11	18.44	0.99	1.28	0.33	0.26

*a denotes postgrazing forage quality

Table 2.8. Graze 1 forage quality least squares means differences (pregarzing – postgrazing) for Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and protein.

	LSMEANs			
name	**ADFd**	**NDFd**	**RFVd**	**PROTEINd**
97TF1-AR542	-0.43	2.95	-6.55	-1.06
97TF1-AR584	0.31	3.83	-8.31	-1.52
97TF1-E+	0.03	3.45	-7.32	-1.14
97TF1-EF	0.40	4.21	-9.55	-1.68
AU-Triumph	-0.69	2.35	-3.61	-1.21
Bariane	0.32	3.47	-7.98	-1.64
Barolex	0.05	3.49	-7.42	-1.67
Fawn	-0.31	2.52	-4.56	-1.20
Jesup-MaxQ	-0.79	1.47	-2.45	-0.77
KY31-E+	-1.03	1.47	-2.21	-1.79
KY31-EF	-0.87	2.06	-3.52	-0.95
KYFA0006	-0.36	2.66	-5.37	-1.74
KYFA9301-AR542	-0.75	2.22	-4.33	-1.24
KYFA9301-AR584	-1.48	0.80	0.28	-0.49
KYFA9301-EF	-0.83	2.15	-3.97	-1.12
KYFA9304	-1.28	1.33	-1.26	-0.92
KYFA9611	-0.51	2.06	-3.63	-1.17
KYFA9732	0.26	3.77	-8.82	-1.91
KYFA9821-AR542	-0.61	2.28	-4.24	-1.46
KYFA9821-AR584	-0.56	2.78	-5.12	-1.72
KYFA9821-EF	0.70	4.04	-8.93	-1.59
KYFA9905	-0.60	2.29	-3.87	-1.74
KYFA9908	-0.22	2.77	-5.48	-1.20
KYFA9913	0.14	3.15	-7.05	-1.18
KYTF2	-0.38	2.47	-4.59	-1.36
Kenhy	-1.17	1.17	-1.41	-0.83
PDF-AR542	-0.07	3.13	-6.76	-1.55
PDF-AR584	-0.29	3.05	-6.17	-1.72
PDF-E+	0.35	4.88	-10.97	-2.22
PDF-EF	-0.52	3.02	-5.97	-1.24
Seine	0.86	4.57	-9.46	-1.89
Stockman	0.82	4.11	-9.80	-2.34
TFsoft-HY-C3	-0.89	1.84	-2.61	-1.49
TuscanyII	-1.08	2.02	-3.14	-1.24
Barfest-FL	1.51	4.87	-12.48	-3.07
Bartura	0.02	2.90	-6.37	-1.82
Cache-MB	0.78	3.31	-5.63	-3.42
KYFA9819-FL	0.48	3.61	-8.20	-2.16
KYFP9801-MF	-0.74	2.14	-3.80	-1.35
Latar-OG	1.85	4.87	-9.09	-4.19

Table 2.9. Graze 2 forage quality least squares means differences (pregarzing – postgrazing) for Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and protein

	LSMEANs			
name	**ADFd**	**NDFd**	**RFVd**	**PROTEINd**
97TF1-AR542	-0.71	-0.65	1.75	0.03
97TF1-AR584	-0.92	-0.51	1.82	0.28
97TF1-E+	-0.62	0.00	0.92	0.78
97TF1-EF	0.18	0.54	-0.95	0.10
AU-Triumph	-0.30	0.41	-0.18	0.06
Bariane	-1.10	-1.09	2.94	0.65
Barolex	-1.00	-0.77	2.37	0.83
Fawn	-0.32	-0.15	0.60	0.78
Jesup-MaxQ	-1.25	-1.22	3.03	0.90
KY31-E+	-0.68	-0.66	1.81	0.70
KY31-EF	-0.81	-0.46	1.69	0.00
KYFA0006	-1.15	-1.30	3.27	1.01
KYFA9301-AR542	-0.18	0.27	-0.07	0.50
KYFA9301-AR584	-0.41	-0.33	0.98	0.60
KYFA9301-EF	-0.92	-0.75	1.98	0.34
KYFA9304	0.38	0.91	-1.49	0.37
KYFA9611	-1.17	-1.36	3.16	1.14
KYFA9732	-1.02	-1.19	2.74	0.79
KYFA9821-AR542	-0.33	0.02	0.45	0.07
KYFA9821-AR584	-0.87	-0.89	2.11	0.35
KYFA9821-EF	0.06	0.47	-0.58	0.51
KYFA9905	-0.56	-0.61	1.49	0.47
KYFA9908	-1.23	-0.84	2.46	0.54
KYFA9913	-1.36	-1.65	3.57	0.40
KYTF2	-0.77	-0.37	1.40	-0.35
Kenhy	-0.57	0.25	0.43	-0.22
PDF-AR542	0.05	0.30	-0.29	0.13
PDF-AR584	-0.33	0.20	0.20	0.78
PDF-E+	-0.81	-0.24	1.40	0.22
PDF-EF	0.54	1.14	-2.11	0.03
Seine	-1.24	-1.08	2.82	0.66
Stockman	-0.86	-0.48	1.57	0.86
TFsoft-HY-C3	-1.88	-1.67	4.54	0.60
TuscanyII	-1.68	-1.74	4.03	1.10
Barfest-FL	-0.62	0.06	0.71	0.26
Bartura	-1.82	-1.88	4.46	0.96
Cache-MB	-1.25	-1.32	3.15	1.49
KYFA9819-FL	-1.78	-1.76	4.00	0.64
KYFP9801-MF	-0.37	-0.25	0.77	0.27
Latar-OG	-1.97	-1.73	4.47	1.08

Table 2.10. Graze 3 forage quality least squares means differences (pregarzing – postgrazing) for Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and protein

	LSMEANs			
name	**ADFd**	**NDFd**	**RFVd**	**PROTEINd**
97TF1-AR542	1.30	1.97	-4.99	1.19
97TF1-AR584	0.92	1.48	-3.79	0.80
97TF1-E+	-0.09	-0.12	1.11	1.14
97TF1-EF	2.16	3.15	-8.21	0.80
AU-Triumph	0.85	1.64	-3.64	0.60
Bariane	1.79	2.73	-7.03	1.14
Barolex	-0.42	0.00	0.77	0.58
Fawn	0.73	1.98	-4.10	0.68
Jesup-MaxQ	0.63	1.52	-3.72	0.75
KY31-E+	1.46	2.70	-6.98	0.99
KY31-EF	0.97	2.37	-5.47	0.91
KYFA0006	1.53	1.93	-5.77	0.90
KYFA9301-AR542	1.04	2.38	-5.87	0.90
KYFA9301-AR584	0.75	1.53	-3.97	1.00
KYFA9301-EF	0.34	1.05	-2.61	1.41
KYFA9304	1.37	1.95	-5.05	0.87
KYFA9611	0.52	1.28	-3.11	0.70
KYFA9732	0.93	1.79	-4.21	1.19
KYFA9821-AR542	1.60	2.33	-5.75	1.62
KYFA9821-AR584	2.07	3.18	-8.54	1.26
KYFA9821-EF	0.64	1.68	-4.40	0.46
KYFA9905	1.14	2.26	-5.18	1.10
KYFA9908	0.24	1.05	-2.01	0.92
KYFA9913	1.25	2.10	-5.58	0.76
KYTF2	0.62	0.69	-1.78	0.95
Kenhy	1.33	2.08	-5.49	1.13
PDF-AR542	0.43	1.63	-3.48	0.37
PDF-AR584	1.35	2.79	-6.60	0.56
PDF-E+	0.84	1.64	-3.78	1.15
PDF-EF	1.33	2.74	-6.83	0.50
Seine	0.38	0.99	-1.93	0.56
Stockman	0.71	0.85	-1.85	1.57
TFsoft-HY-C3	0.84	1.01	-2.61	0.95
TuscanyII	-0.37	-0.93	2.04	1.17
Barfest-FL	1.21	2.71	-5.79	0.39
Bartura	-1.30	-0.62	3.21	1.06
Cache-MB	1.52	2.77	-5.06	-0.31
KYFA9819-FL	0.91	3.00	-7.75	0.47
KYFP9801-MF	1.32	2.53	-6.34	0.74
Latar-OG	-1.17	-0.73	2.17	2.31

Table 2.11. Graze 4 forage quality least squares means differences (pregarzing – postgrazing) for Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and protein

	LSMEANs			
name	**ADFd**	**NDFd**	**RFVd**	**PROTEINd**
97TF1-AR542	-3.14	-5.14	12.61	-1.30
97TF1-AR584	-3.24	-5.14	12.79	-0.86
97TF1-E+	-3.45	-5.99	14.43	-0.57
97TF1-EF	-3.75	-6.46	15.77	-0.87
AU-Triumph	-3.74	-6.13	14.26	-0.99
Bariane	-3.94	-6.55	16.65	0.16
Barolex	-2.28	-4.49	10.59	-1.50
Fawn	-3.07	-4.89	11.54	-1.46
Jesup-MaxQ	-3.47	-5.87	14.51	-0.34
KY31-E+	-3.57	-5.81	15.10	-0.31
KY31-EF	-2.18	-3.85	9.78	-0.23
KYFA0006	-3.37	-5.60	13.80	-0.69
KYFA9301-AR542	-3.67	-6.75	16.85	-0.90
KYFA9301-AR584	-3.72	-6.63	16.46	-0.67
KYFA9301-EF	-3.59	-6.13	15.11	-0.36
KYFA9304	-4.19	-6.92	17.18	-0.44
KYFA9611	-3.28	-5.85	13.88	-1.47
KYFA9732	-3.02	-5.43	13.59	-0.91
KYFA9821-AR542	-4.29	-7.04	18.34	-0.62
KYFA9821-AR584	-3.77	-6.17	15.70	-0.40
KYFA9821-EF	-2.79	-5.27	11.78	-0.56
KYFA9905	-3.16	-5.55	13.05	-0.47
KYFA9908	-3.10	-4.82	12.45	-0.55
KYFA9913	-4.83	-7.99	20.17	-0.70
KYTF2	-3.64	-6.30	15.31	-0.88
Kenhy	-3.69	-6.54	15.51	-0.66
PDF-AR542	-3.51	-5.93	13.90	-0.87
PDF-AR584	-2.67	-5.34	11.94	-2.01
PDF-E+	-3.50	-5.95	15.07	-0.37
PDF-EF	-3.57	-5.73	14.25	-0.34
Seine	-3.09	-5.08	11.46	-0.66
Stockman	-3.30	-5.94	14.42	-0.69
TFsoft-HY-C3	-3.02	-5.90	13.20	-0.20
TuscanyII	-3.70	-6.16	14.85	-1.04
Barfest-FL	-5.38	-8.48	20.27	-0.89
Bartura	-3.41	-6.11	15.47	-0.29
Cache-MB	-2.86	-5.43	12.20	-1.24
KYFA9819-FL	-2.59	-4.25	10.84	-1.69
KYFP9801-MF	-3.73	-7.01	16.39	-0.70
Latar-OG	-4.06	-6.59	14.55	-0.71

Table 2.12. Analysis of variance for yield components and graze score for replications and entries. Pre/post fresh weight (fresh), dry weight (dry), moisture content (moist), percent refusal on a fresh and dry weight basis (refusalfw & refusaldw), stand cover rating (SCR), graze score (GS)

			prefresh	predry	premoist	postfresh	postdry	postmoist	refusalfw	refusaldw	SCR	GS
2008	Graze 1	Rep	**	**	**	**	**	**	**	**	**	**
		Entries	**	**	ns	**	**	**	**	**	**	**
	Graze 2	Rep	**	**	**	**	**	**	**	**	**	**
		Entries	ns	ns	ns	ns	ns	*	**	**	ns	**
2009	Graze 3	Rep	**	**	**	**	**	**	**	**	**	**
		Entries	**	**	ns	**	**	**	**	**	**	**
	Graze 4	Rep	**	**	**	**	**	**	**	**	**	**
		Entries	**	**	**	**	**	**	**	**	**	**

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

Table 2.13. Forage Quality Analysis of variance for replications and entries. Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and protein, before grazing and after grazing.

			ADF	NDF	RFV	PROTEIN	ADFa	NDFa	RFVa	PROTEINa
2008	Graze 1	Rep	**	**	**	**	**	**	**	**
		Entries	**	**	**	**	**	**	**	**
	Graze 2	Rep	**	**	**	**	**	**	**	**
		Entries	**	**	**	**	**	**	**	**
2009	Graze 3	Rep	**	**	**	**	**	**	**	**
		Entries	**	**	**	**	**	**	**	**
	Graze 4	Rep	**	**	**	**	**	**	**	**
		Entries	**	**	**	**	**	**	**	**

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

Table 2.14. Graze 1 Pearson correlation coefficient analysis pregrazing moisture content (premoist), percent refusal dry weight basis (refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein.

	premoist	**refusaldw**	**SCR**	**GS**	**ADF**	**NDF**	**RFV**	**PROTEIN**
prefresh	0.467	-0.192	-0.629	-0.087	0.631	0.738	-0.701	-0.668
	**	ns	**	ns	**	**	**	**
premoist		-0.157	0.059	0.174	0.217	0.256	-0.264	-0.205
		ns	ns	ns	ns	ns	ns	ns
refusaldw			0.192	-0.853	-0.633	-0.486	0.539	0.399
			ns	**	**	**	**	*
SCR				0.087	-0.568	-0.632	0.589	0.431
				ns	**	**	**	**
GS					0.480	0.313	-0.376	-0.205
					**	*	*	ns
ADF						0.957	-0.977	-0.747
						**	**	**
NDF							-0.993	-0.775
							**	**
RFV								0.769
								**

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

Table 2.15. Graze 2 Pearson correlation coefficient analysis pregrazing moisture content (premoist), percent refusal dry weight basis (refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein.

	premoist	**refusaldw**	**SCR**	**GS**	**ADF**	**NDF**	**RFV**	**PROTEIN**
prefresh	0.55457	-0.06285	0.20894	-0.1881	-0.0363	0.04523	-0.0197	0.04002
	**	ns	ns	ns	ns	ns	ns	ns
premoist		0.08988	0.17977	-0.1231	-0.3846	-0.1936	0.27362	-0.16105
		ns	ns	ns	*	ns	ns	ns
refusaldw			-0.0993	-0.747	0.50513	0.63767	-0.6154	-0.53754
			ns	**	**	**	**	**
SCR				0.18396	-0.0764	-0.1388	0.11115	0.38875
				ns	ns	ns	ns	*
GS					-0.4541	-0.6738	0.61221	0.60121
					**	**	**	**
ADF						0.86905	-0.9497	-0.36279
						**	**	*
NDF							-0.9789	-0.6447
							**	**
RFV								0.54872
								**

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

Table 2.16. Graze 3 Pearson correlation coefficient analysis pregrazing moisture content (premoist), percent refusal dry weight basis (refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein.

	premoist	refusaldw	SCR	GS	ADF	NDF	RFV	PROTEIN
prefresh	-0.20127	-0.18406	0.45525	-0.3462	0.66474	0.68396	-0.6863	-0.49263
	ns	ns	**	*	**	**	**	**
premoist		-0.36966	-0.5724	0.54243	-0.495	-0.5038	0.48817	0.65315
		*	**	**	**	**	**	**
refusaldw			0.46816	-0.7775	-0.0501	0.04701	-0.029	-0.37515
			**	**	ns	ns	ns	*
SCR				-0.745	0.47412	0.57465	-0.5381	-0.636
				**	**	**	**	**
GS					-0.3968	-0.5112	0.49467	0.66666
					*	**	**	**
ADF						0.9599	-0.9737	-0.66371
						**	**	**
NDF							-0.9966	-0.7325
							**	**
RFV								0.72146
								**

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

Table 2.17. Graze 4 Pearson correlation coefficient analysis pregrazing moisture content (premoist), percent refusal dry weight basis (refusaldw), stand cover rating (SCR), graze score (GS), Acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), protein.

	premoist	**refusaldw**	**SCR**	**GS**	**ADF**	**NDF**	**RFV**	**PROTEIN**
prefresh	0.85017	0.69699	0.7757	-0.7001	-0.2435	0.15263	-0.0813	-0.76527
	**	**	**	**	ns	ns	ns	**
premoist		0.64445	0.6591	-0.5084	-0.3118	-0.0038	0.0424	-0.61124
		**	**	**	0.0501	ns	ns	**
refusaldw			0.677	-0.7186	-0.1999	0.06673	-0.031	-0.67441
			**	**	ns	ns	ns	**
SCR				-0.5282	-0.0229	0.21992	-0.1949	-0.56515
				**	ns	ns	ns	**
GS					0.05669	-0.2404	0.20083	0.73152
					ns	ns	ns	**
ADF						0.88348	-0.929	0.25586
						**	**	ns
NDF							-0.989	-0.07939
							**	ns
RFV								0.00907
								ns

ns - not significant
* - (0.011 to 0.05)
** - (≤0.01)

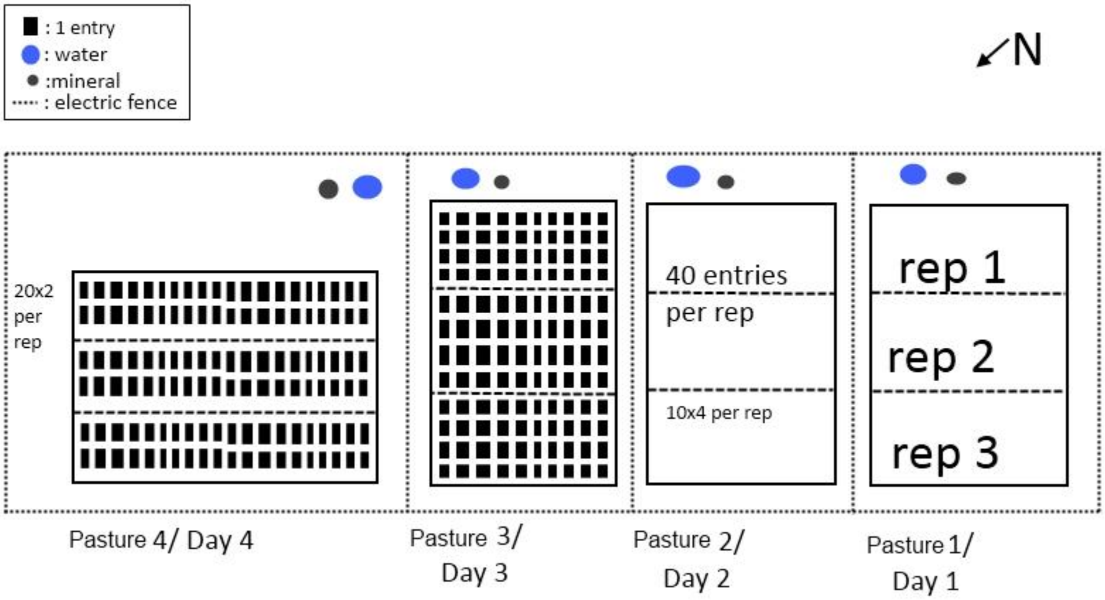

Figure 2.1. A schematic representation of the area in Lexington, KY. Dashed line within the plot does not indicate a physical border or separation. Diagram not to scale.

Figure 2.2. Google Earth Satellite view of research area, 2002

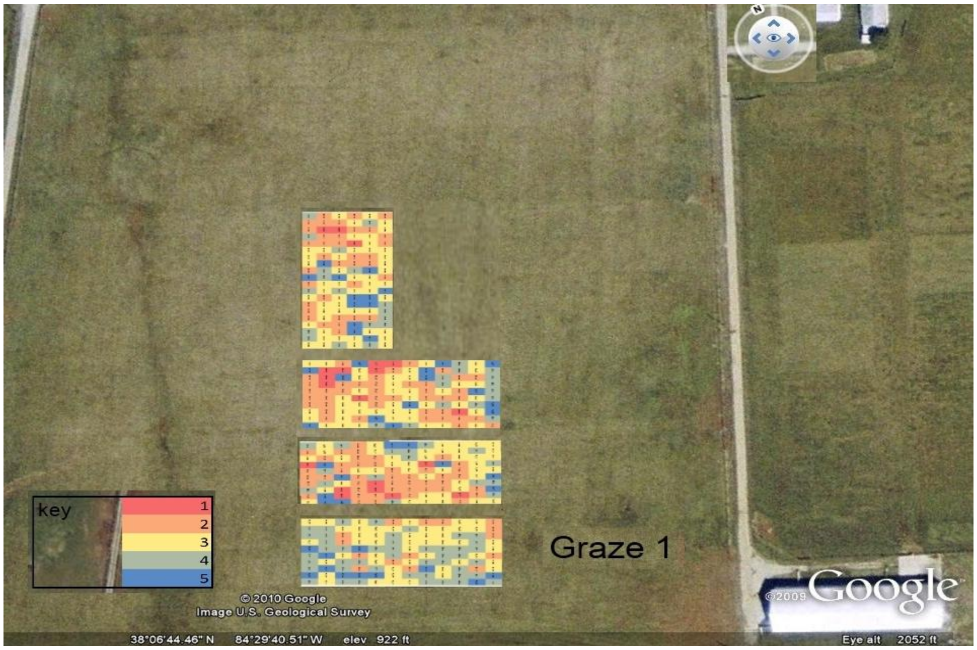

Figure 2.3. Choropleth map of the grazing area with a representation of the amount of forage removed based on a visual rating. A score of 1 indicates minimal grazing, 5 maximal.

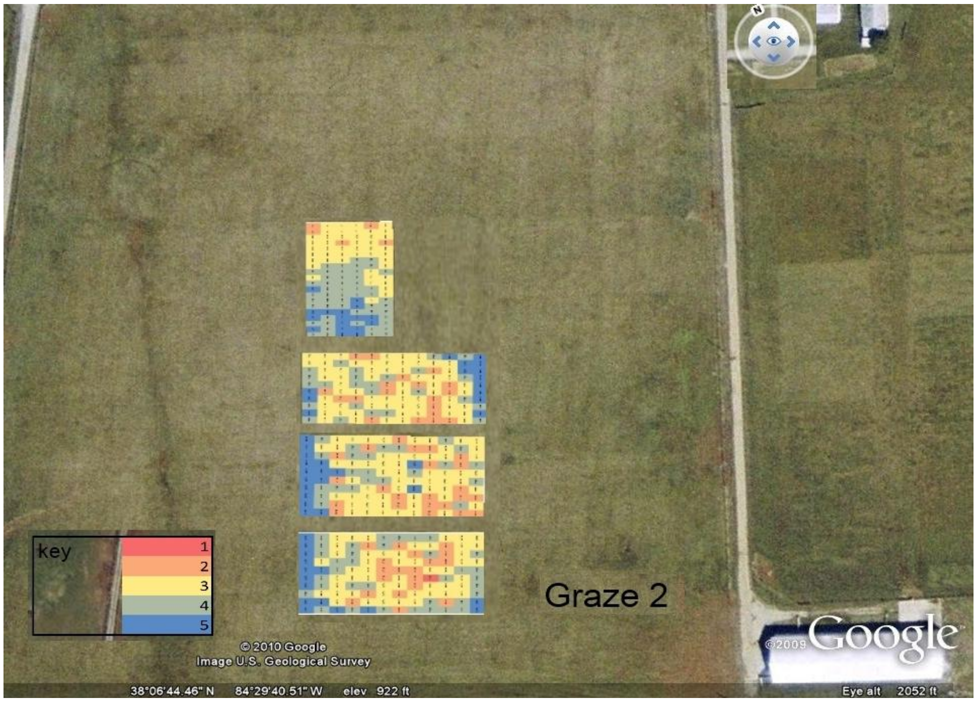

Figure 2.4**.** Choropleth map of the grazing area with a representation of the amount of forage removed based on a visual rating. A score of 1 indicates minimal grazing, 5 maximal.

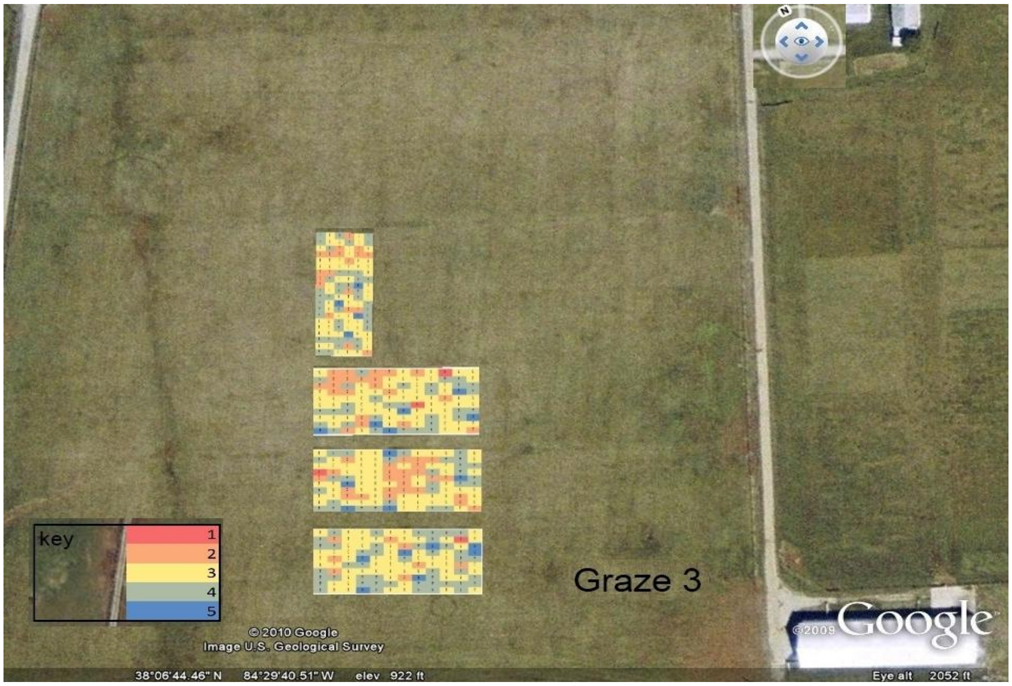

Figure 2.5. Choropleth map of the grazing area with a representation of the amount of forage removed based on a visual rating. A score of 1 indicates minimal grazing, 5 maximal.

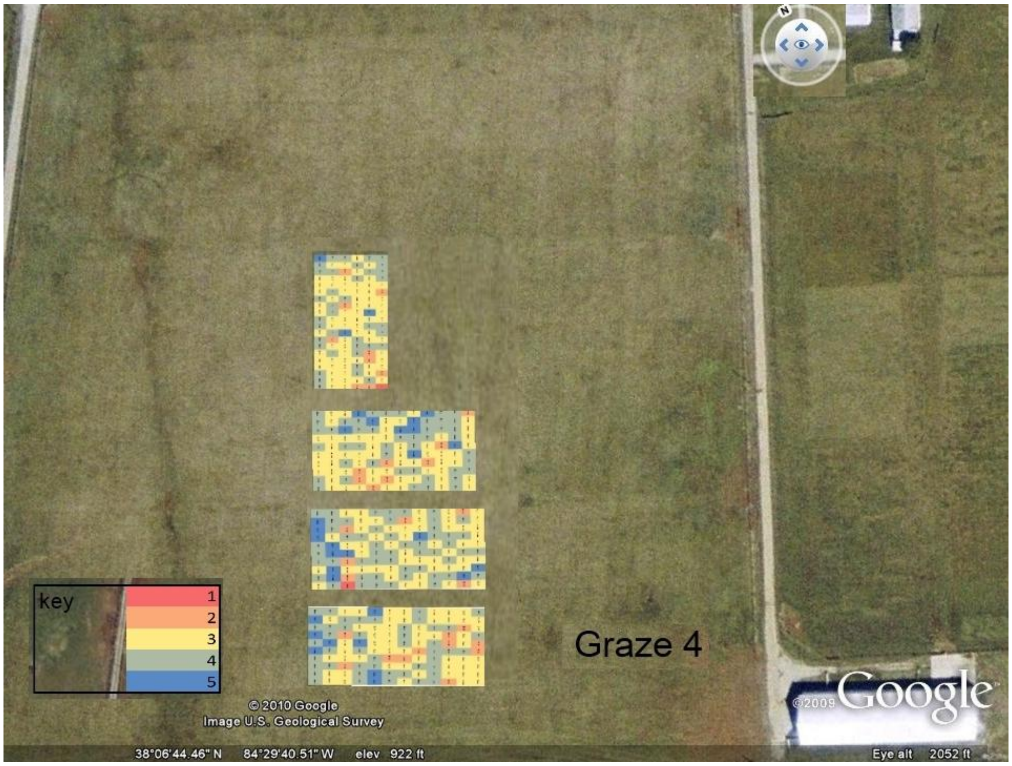

Figure 2.6. Choropleth map of the grazing area with a representation of the amount of forage removed based on a visual rating. A score of 1 indicates minimal grazing, 5 maximal.

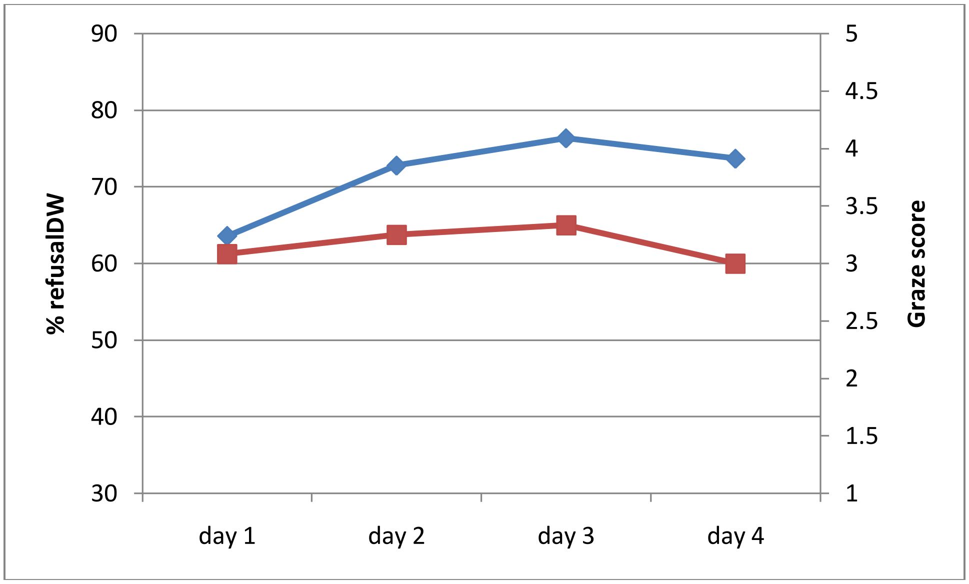

Figure 2.7. Conditioning trend 97TF1-AR542. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

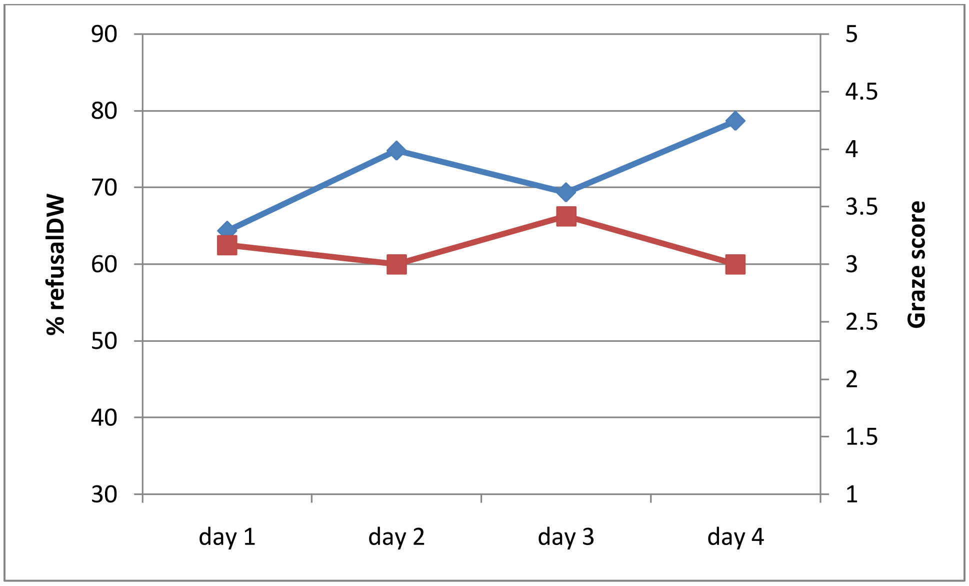

Figure 2.8. Conditioning trend 97TF1-AR584. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

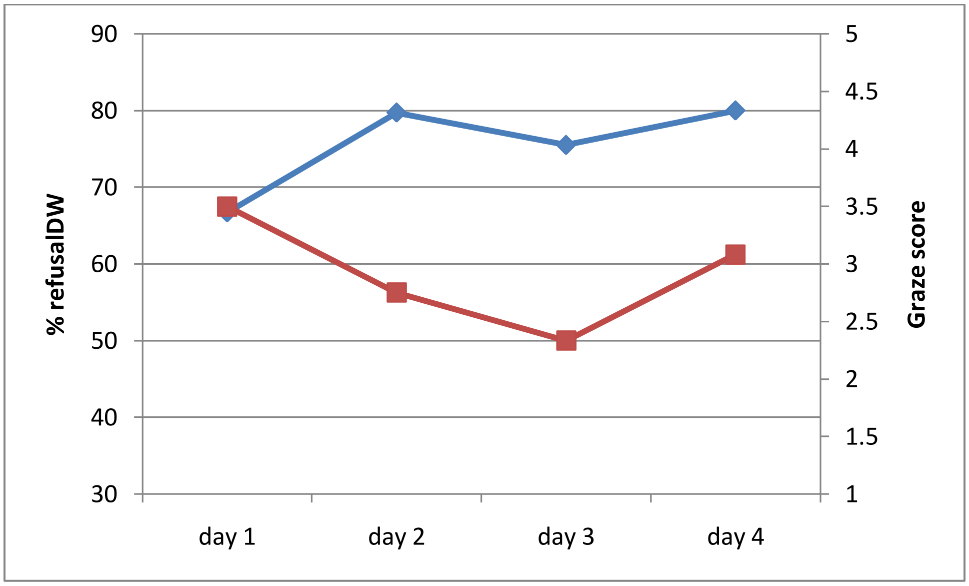

Figure 2.9. Conditioning trend 97TF1-EF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

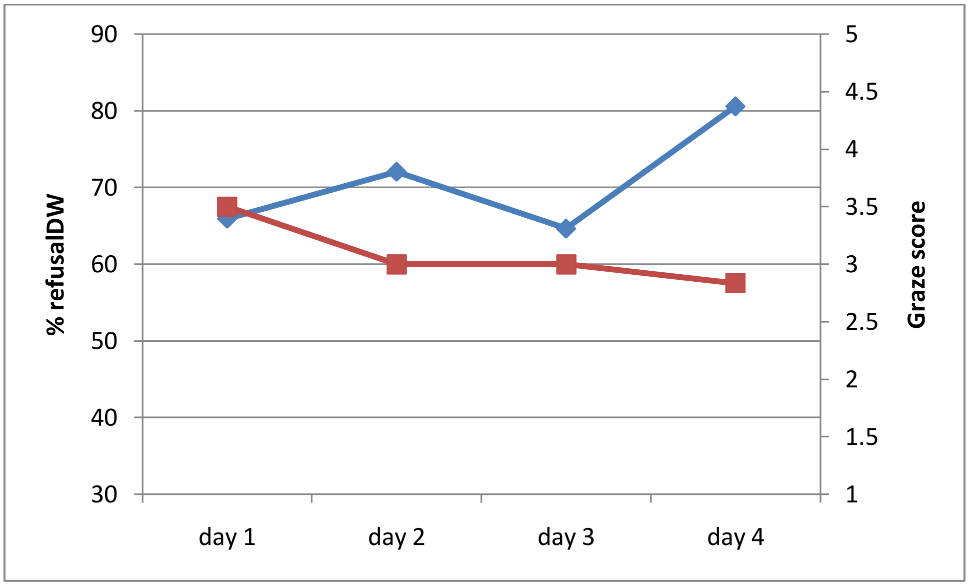

Figure 2.10. Conditioning trend 97TF1-E+. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

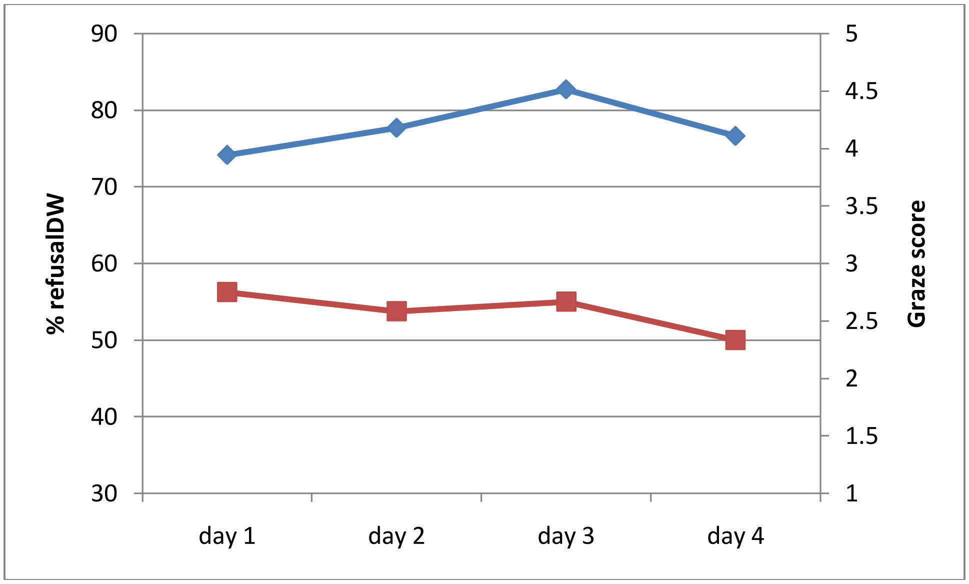

Figure 2.11. Conditioning trend AU-Triumph. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

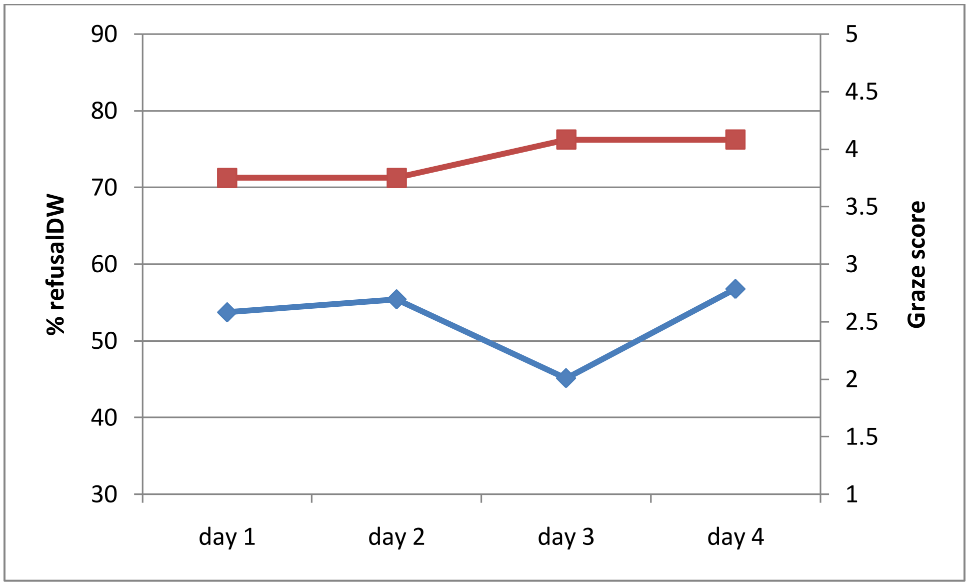

Figure 2.12. Conditioning trend Barfest-FL. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

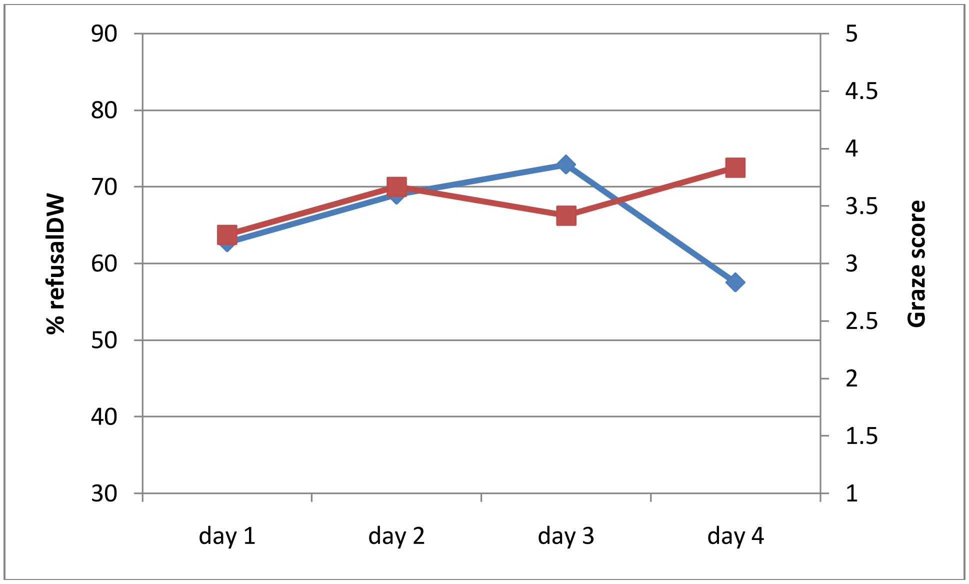

Figure 2.13. Conditioning trend Bariane. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

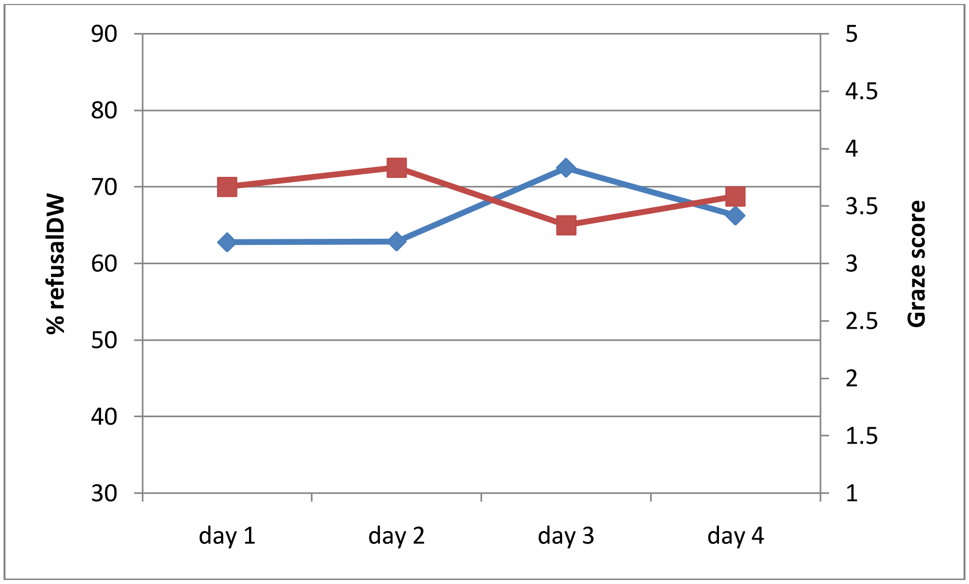

Figure 2.14. Conditioning trend Barolex. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

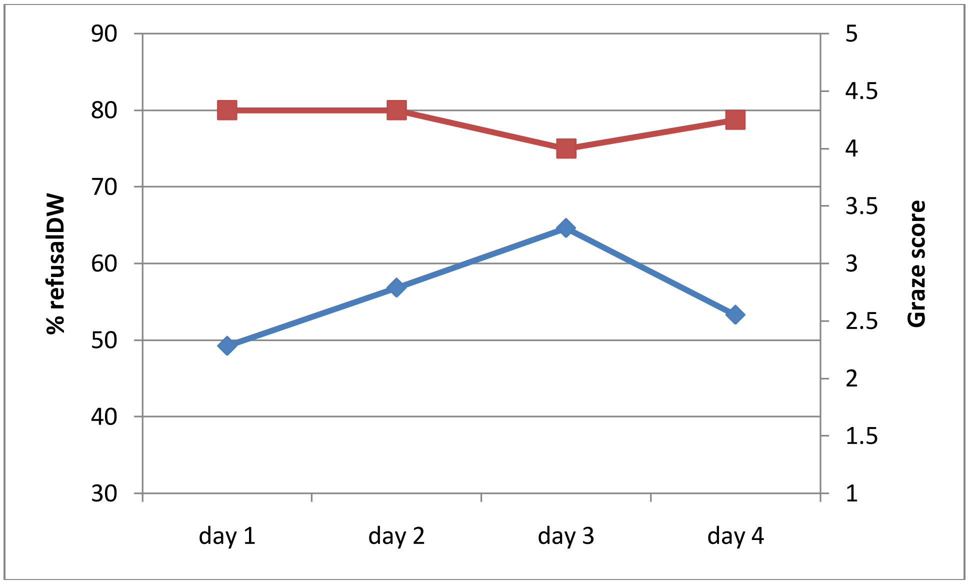

Figure 2.15. Conditioning trend Bartura-MF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

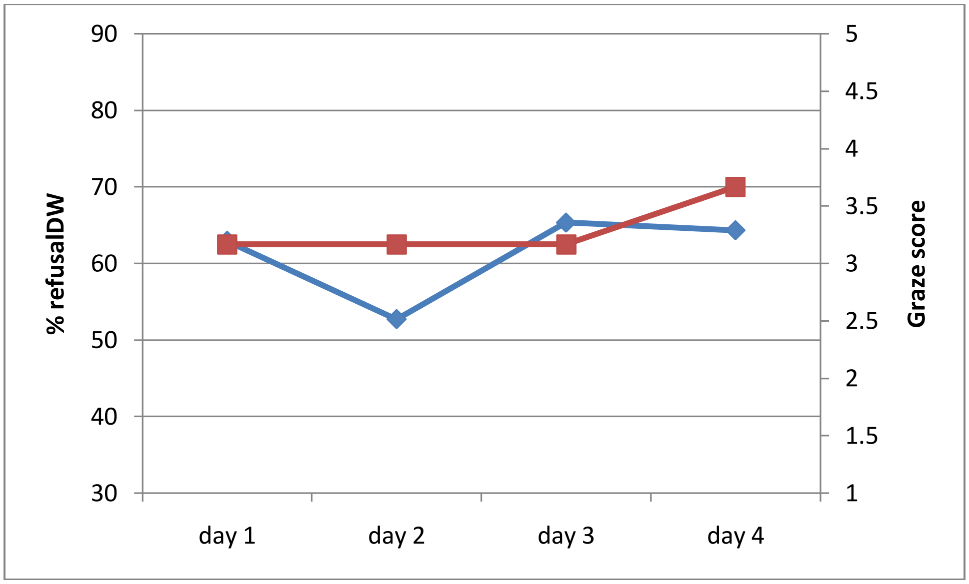

Figure 2.16. Conditioning trend Cache-MB. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

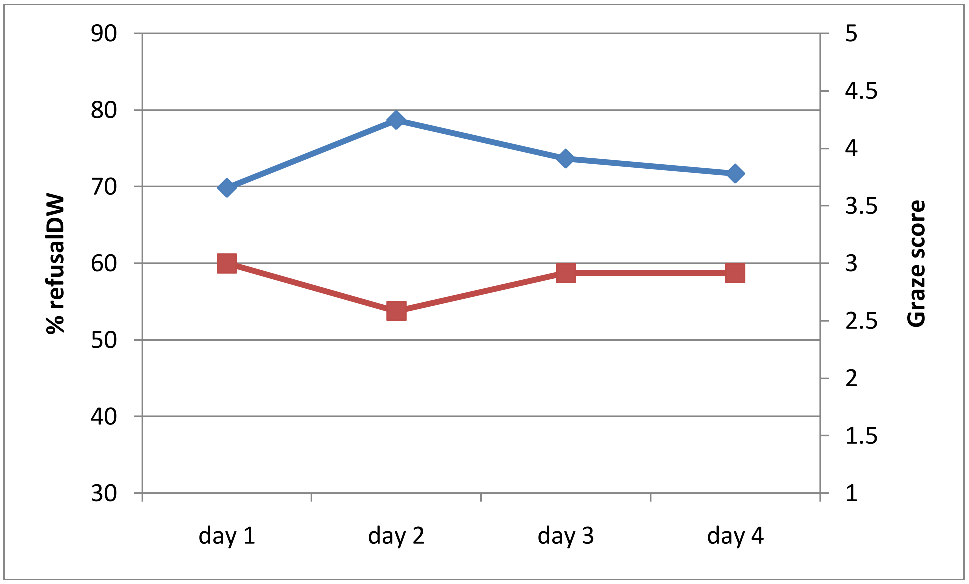

Figure 2.17. Conditioning trend Fawn. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

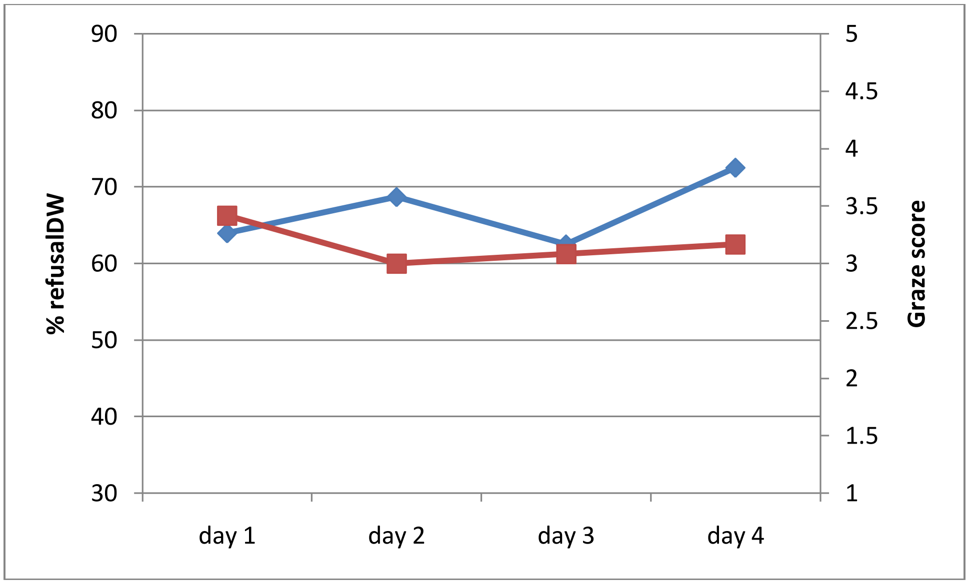

Figure 2.18. Conditioning trend Jesup-MaxQ. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

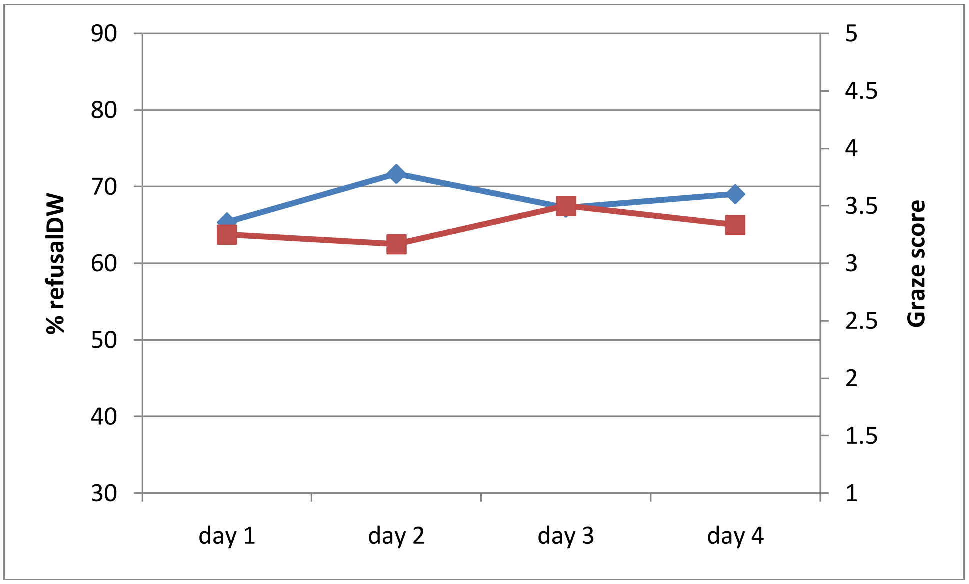

Figure 2.19. Conditioning trend KY31-E+. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

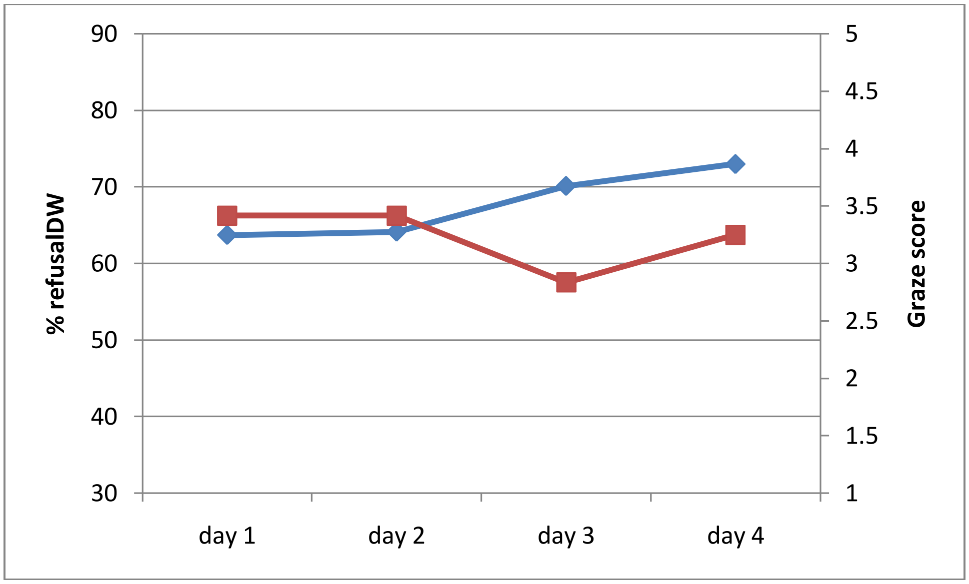

Figure 2.20. Conditioning trend KY31-EF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

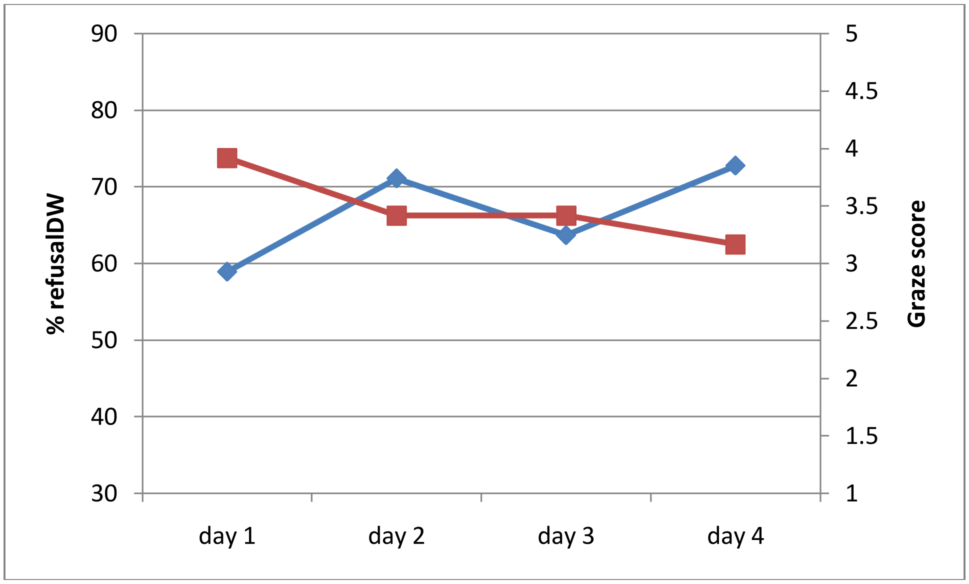

Figure 2.21. Conditioning trend KYFA0006. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

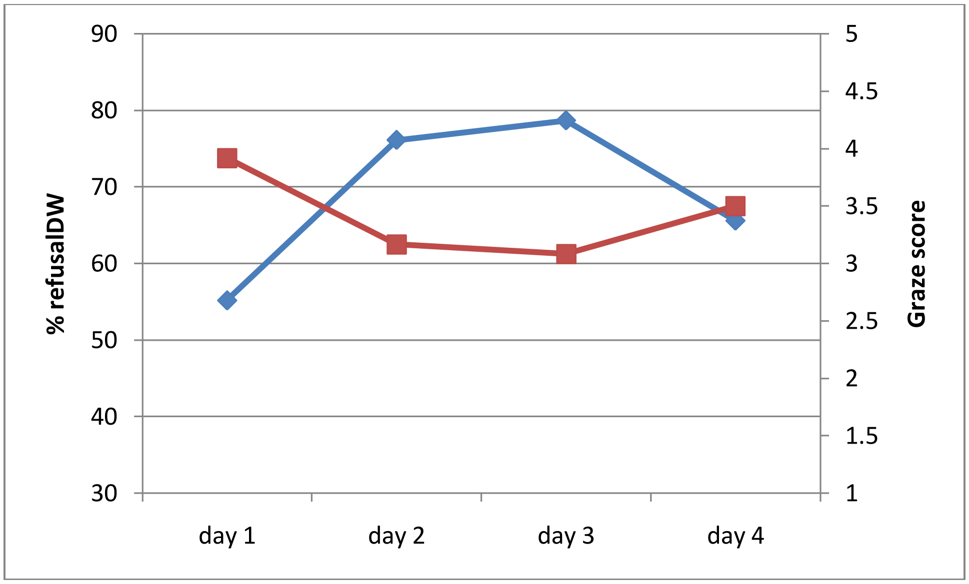

Figure 2.22. Conditioning trend KYFA9301-AR542. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

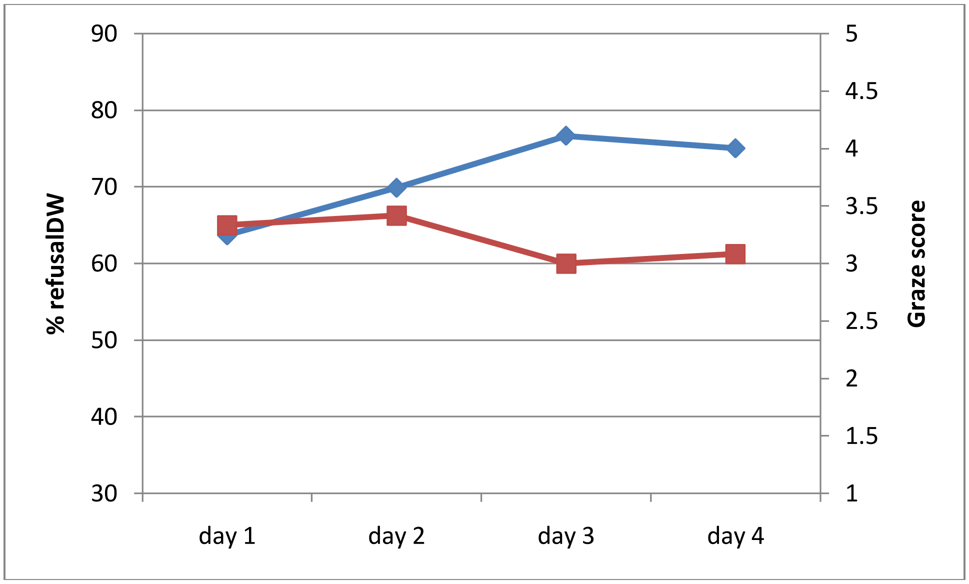

Figure 2.23. Conditioning trend KYFA9301-AR584. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

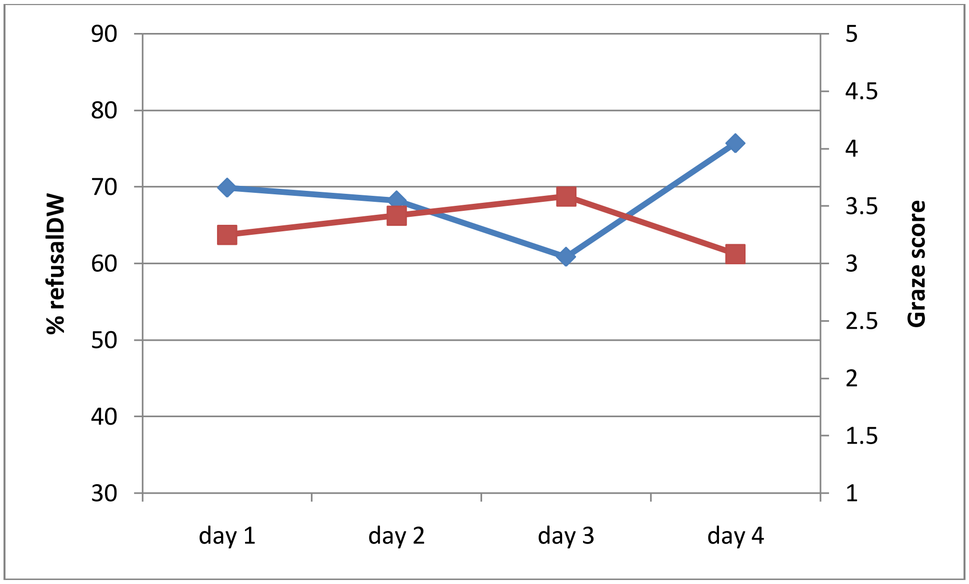

Figure 2.24. Conditioning trend KYFA9301-EF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

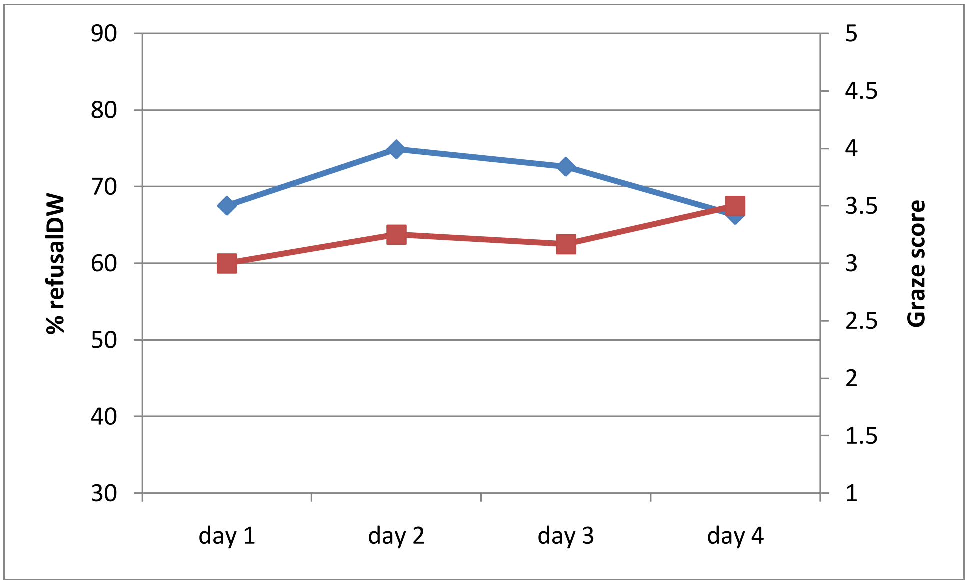

Figure 2.25. Conditioning trend KYFA9304. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

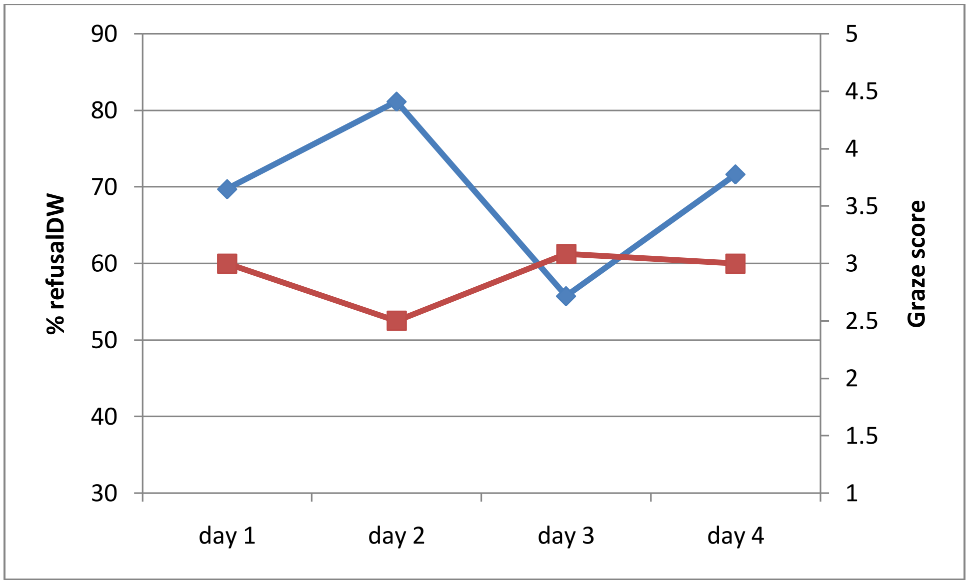

Figure 2.26. Conditioning trend KYFA9611. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

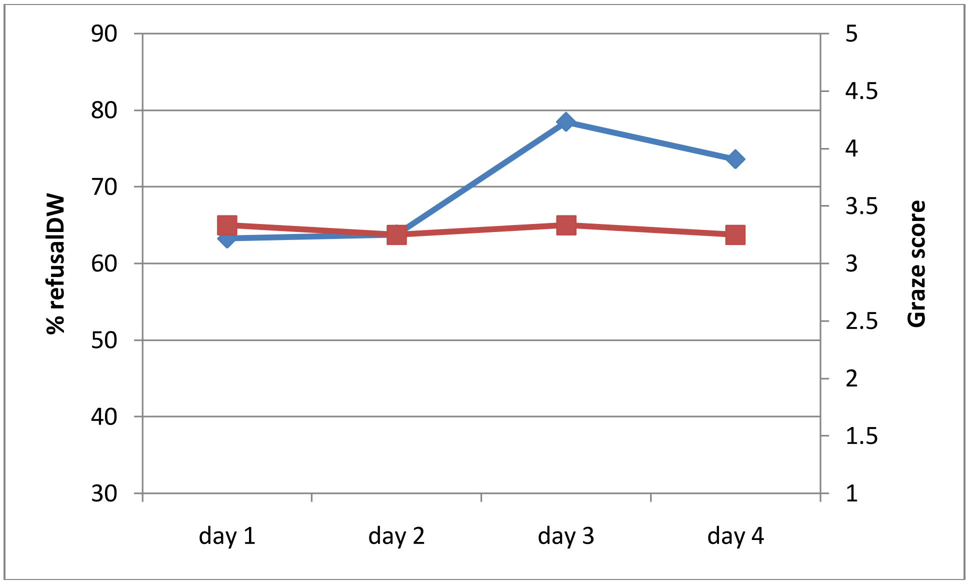

Figure 2.27. Conditioning trend KYFA9732. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

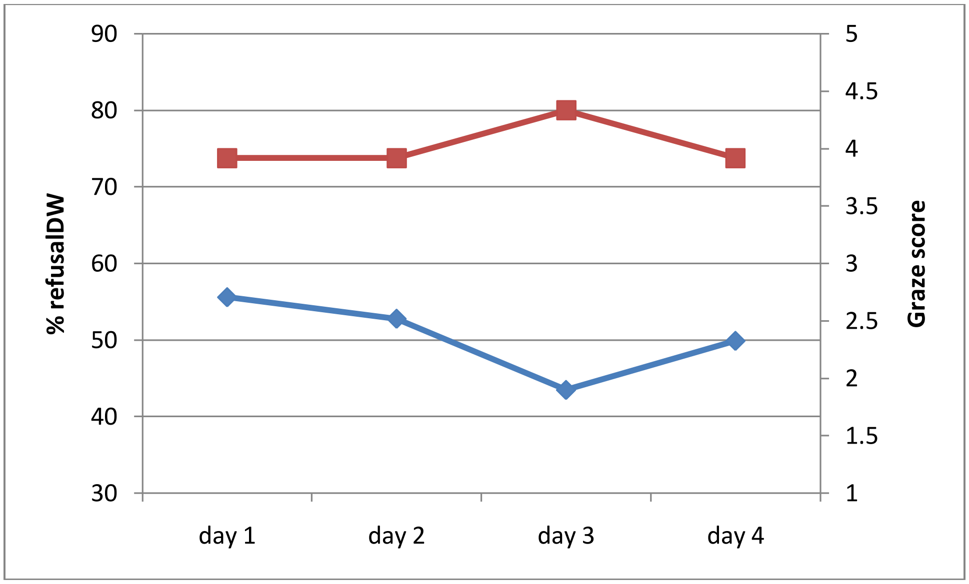

Figure 2.28. Conditioning trend KYFA9819-FL. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

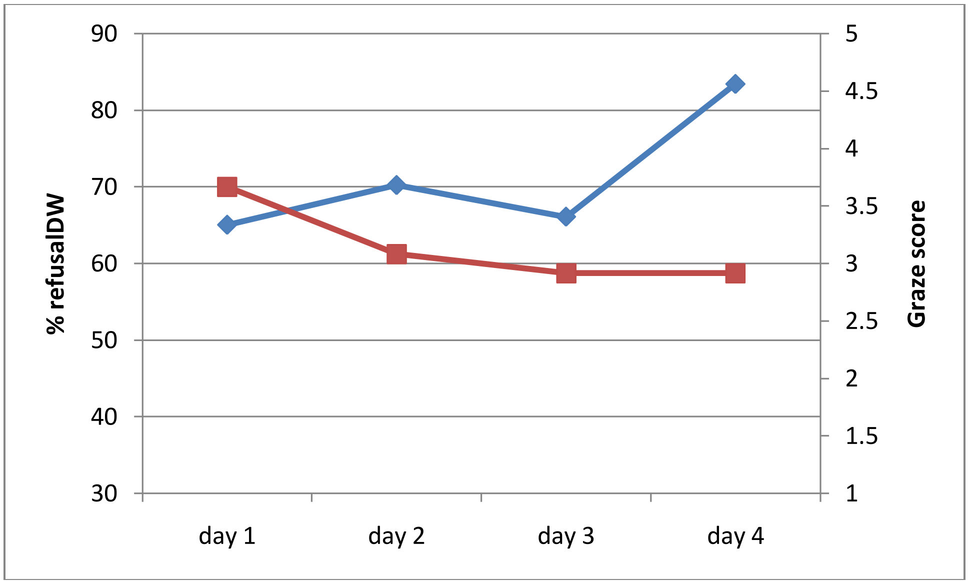

Figure 2.29. Conditioning trend KYFA9821-AR542. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

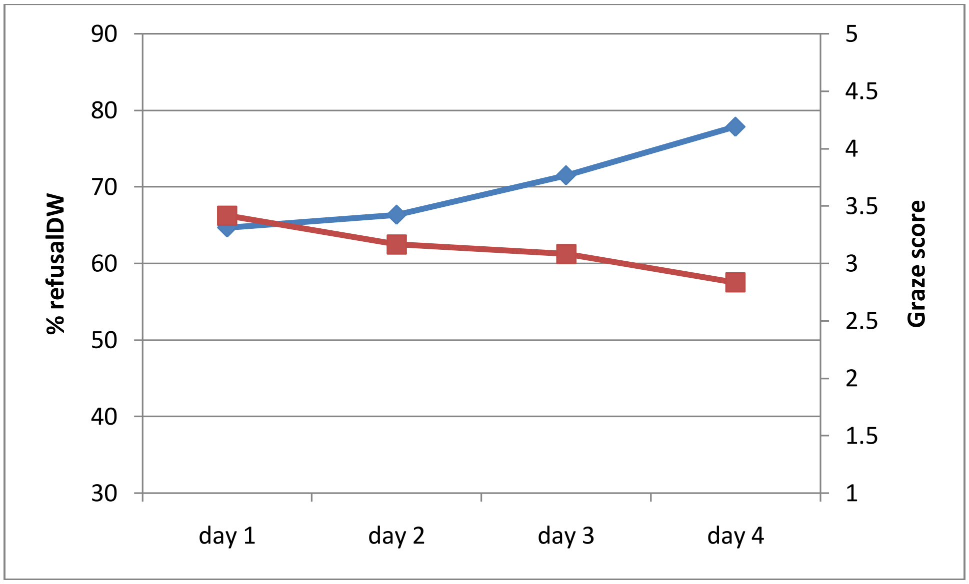

Figure 2.30. Conditioning trend KYFA9821-AR584. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

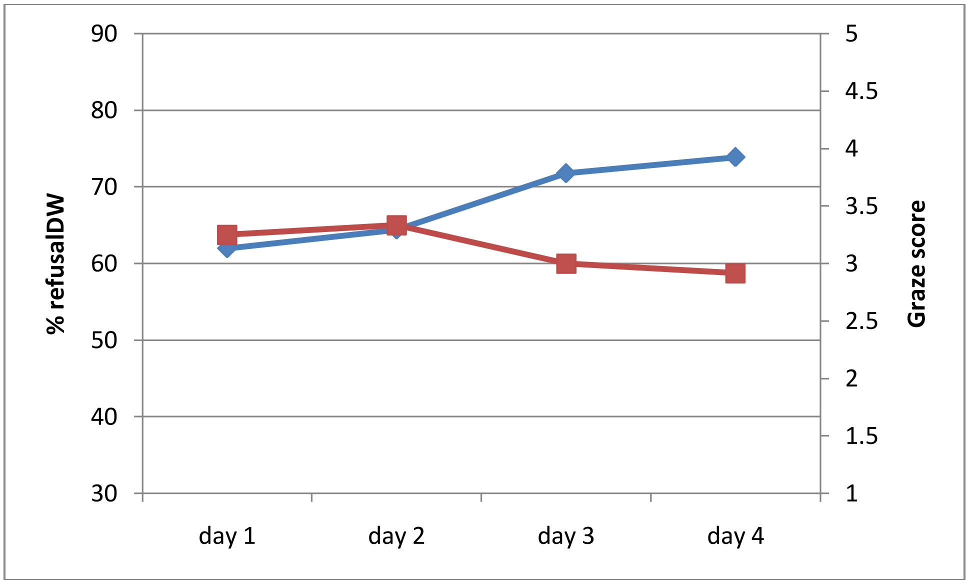

Figure 2.31. Conditioning trend KYFA9821-EF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

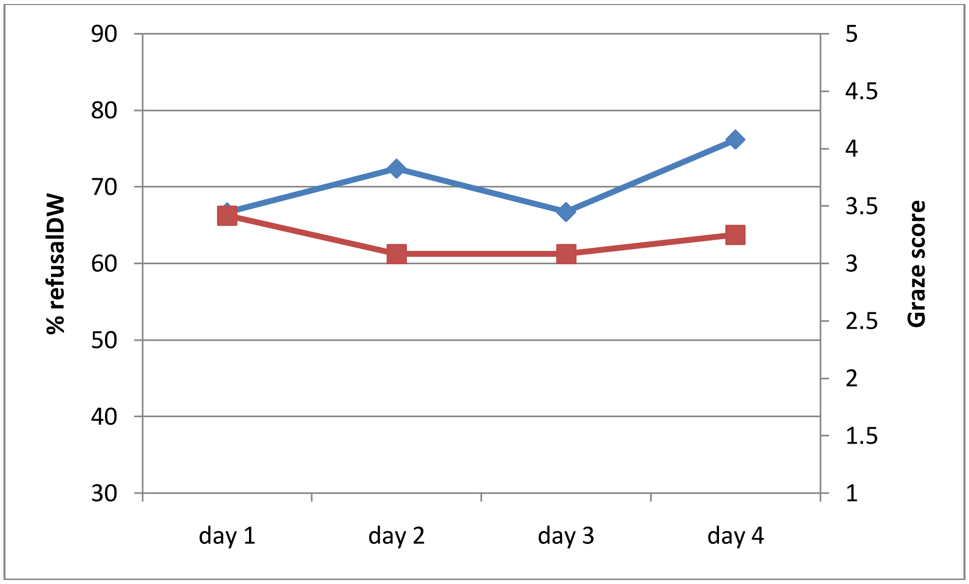

Figure 2.32. Conditioning trend KYFA9905. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

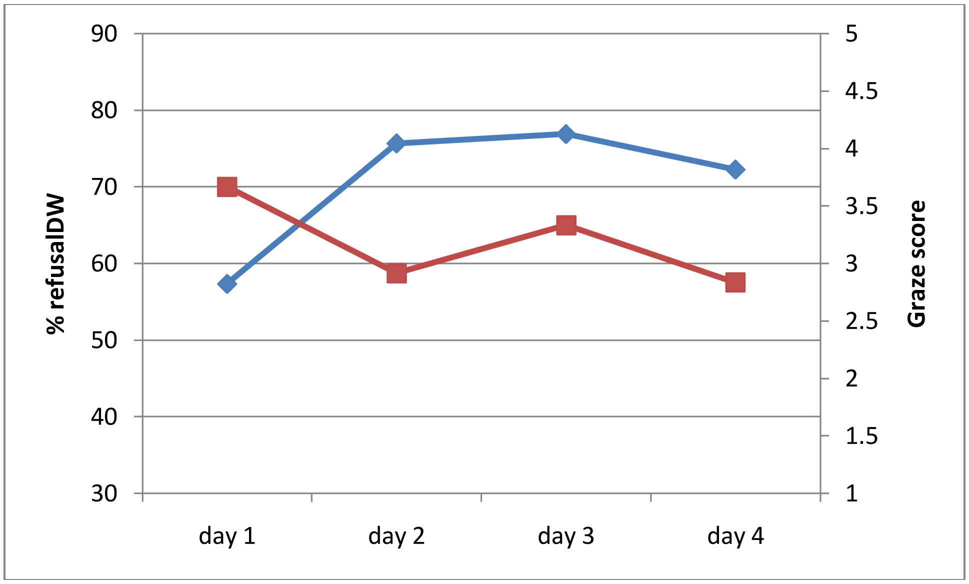

Figure 2.33. Conditioning trend KYFA9908. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

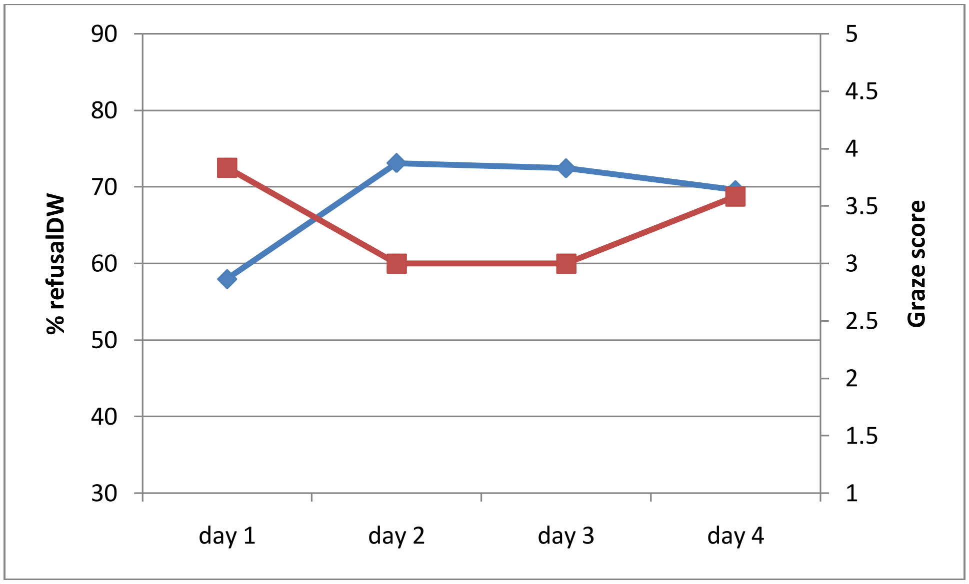

Figure 2.34. Conditioning trend KYFA9913. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

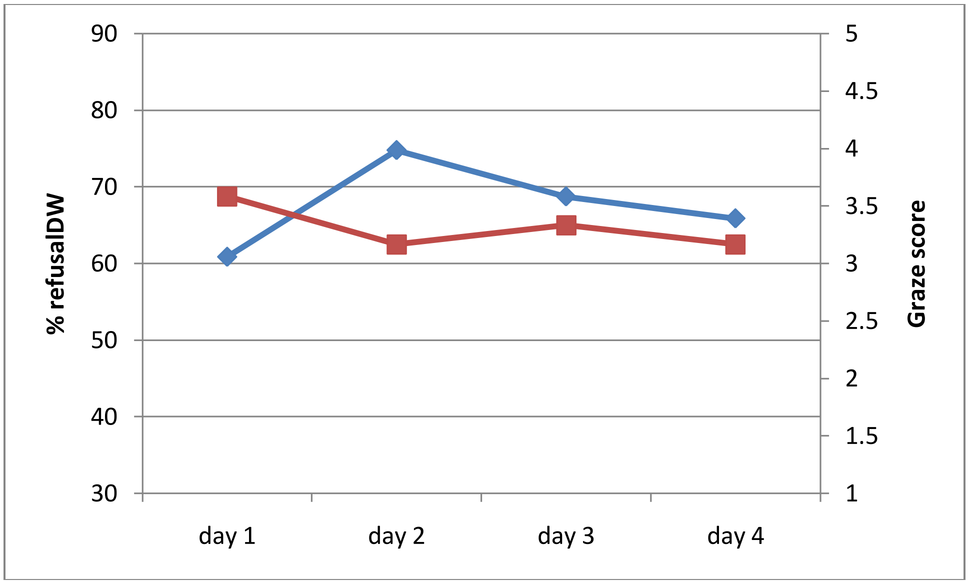

Figure 2.35. Conditioning trend KYFP9801. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

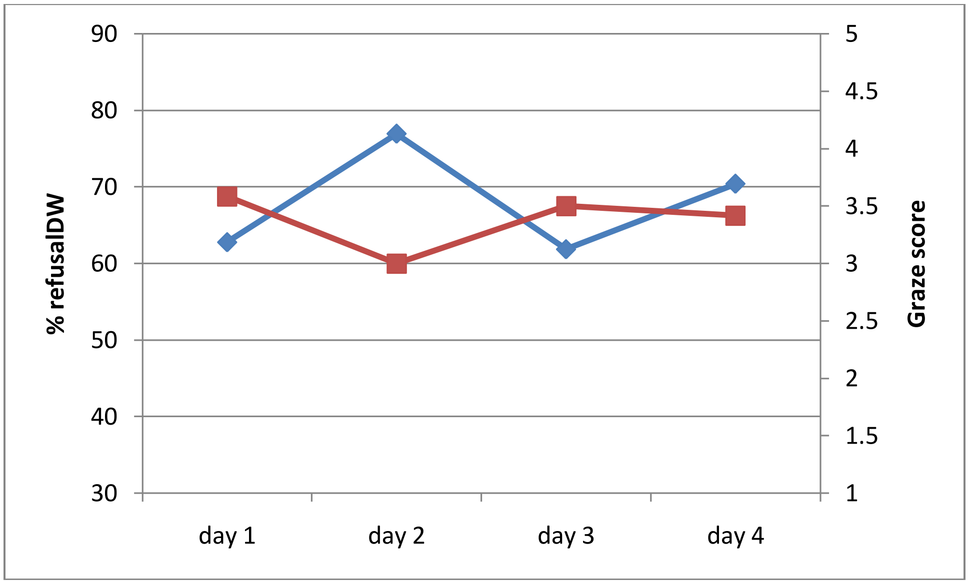

Figure 2.36. Conditioning trend KYTF2. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

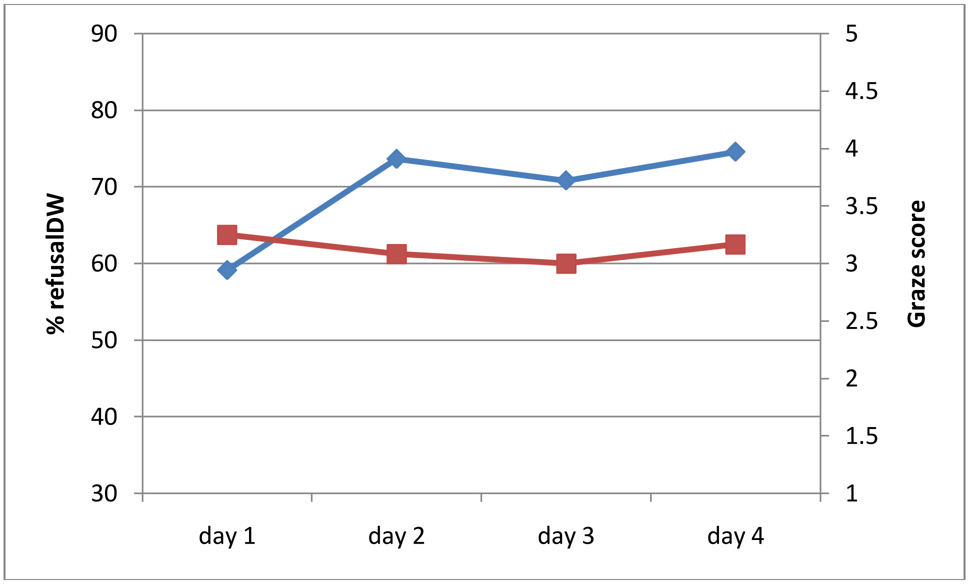

Figure 2.37. Conditioning trend Kenhy. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

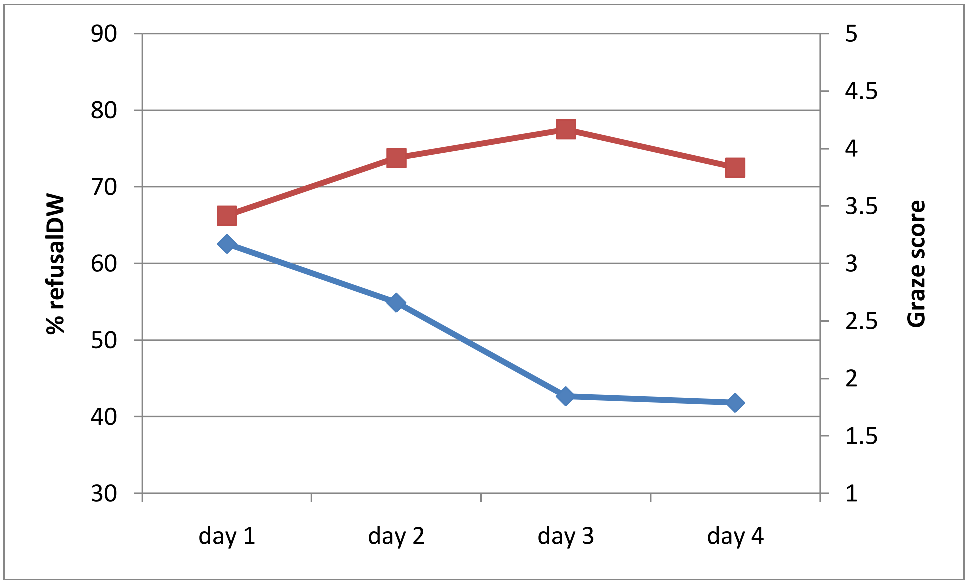

Figure 2.38. Conditioning trend Latar-OG. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

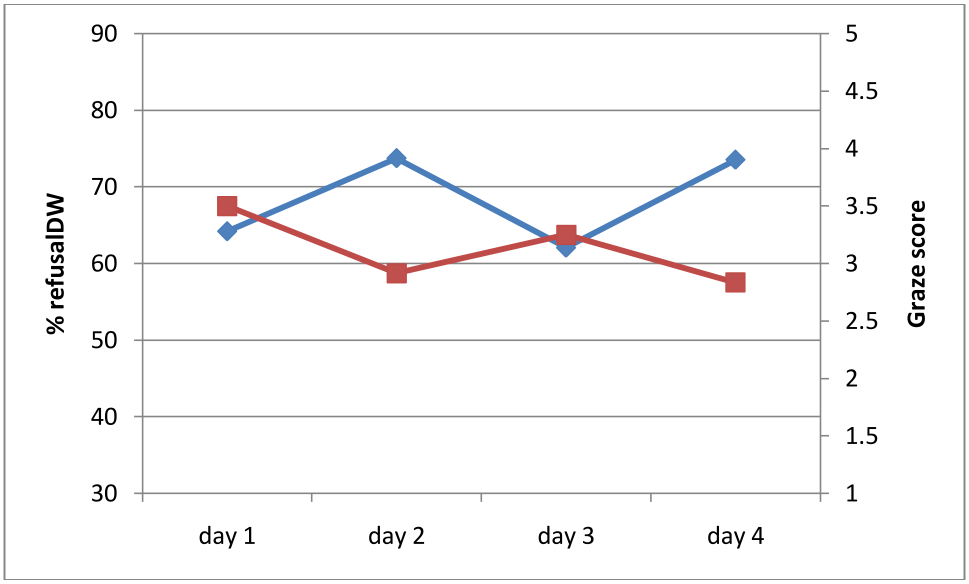

Figure 2.39. Conditioning trend PDF-AR542. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

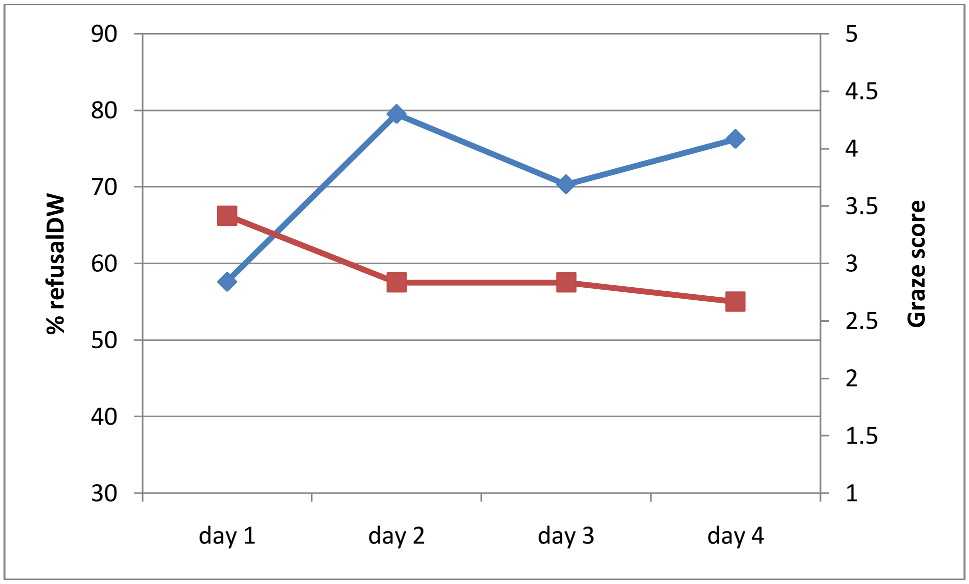

Figure 2.40. Conditioning trend PDF-AR584. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

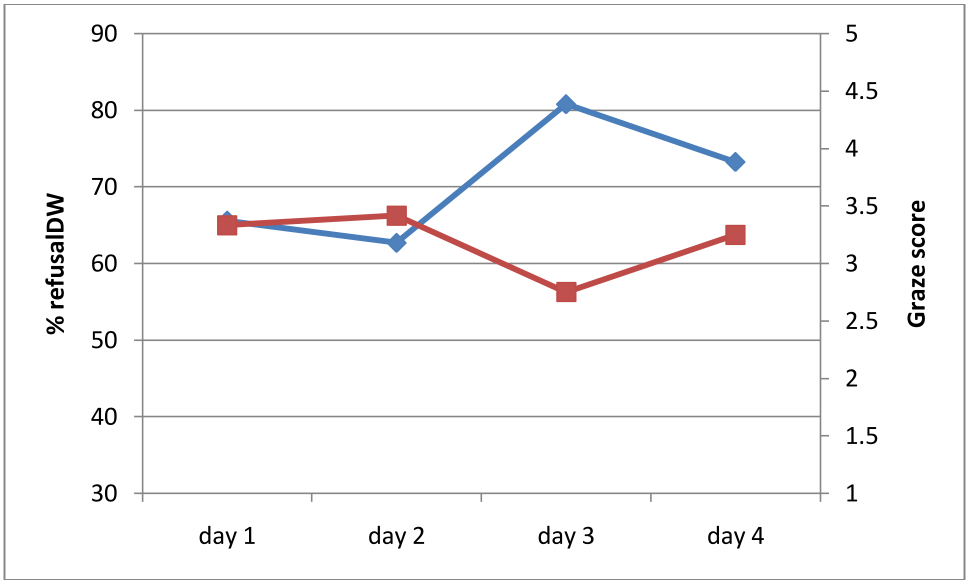

Figure 2.41. Conditioning trend PDF-EF. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

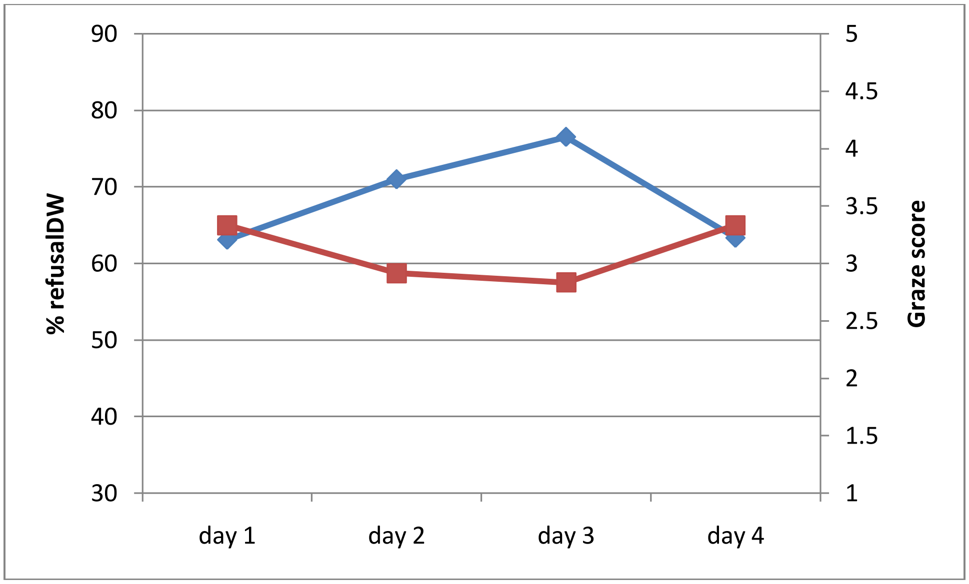

Figure 2.42. Conditioning trend PDF-E+. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

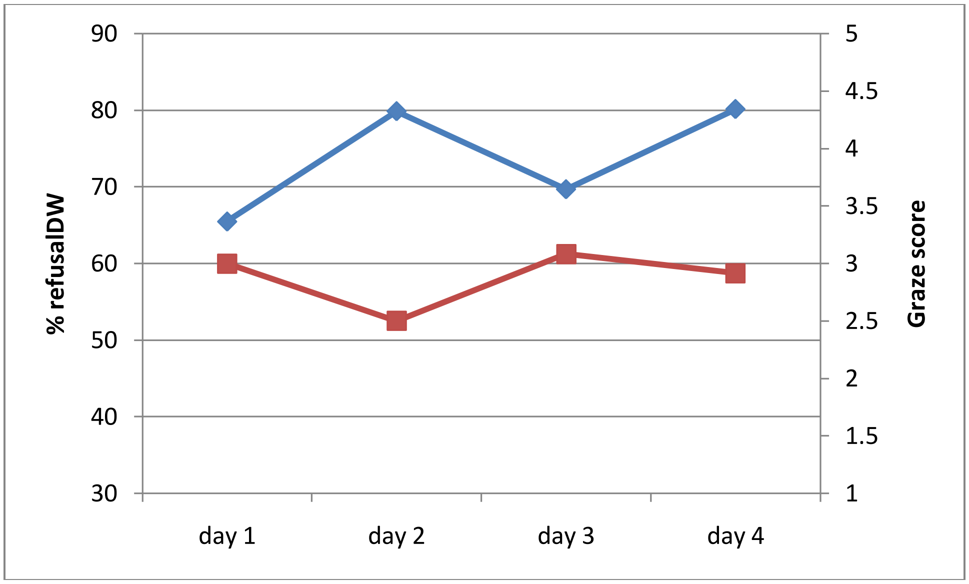

Figure 2.43. Conditioning trend Seine. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

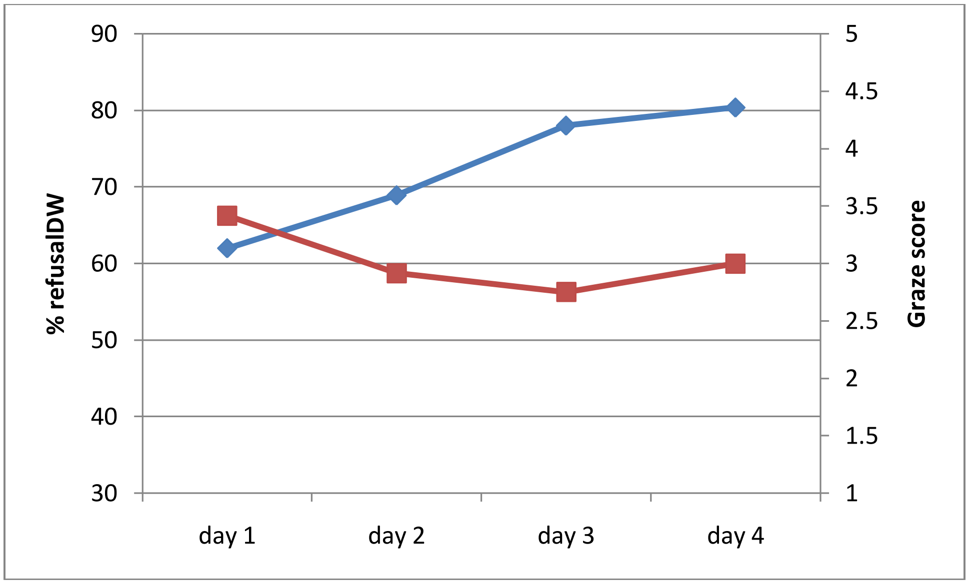

Figure 2.44. Conditioning trend Stockman. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

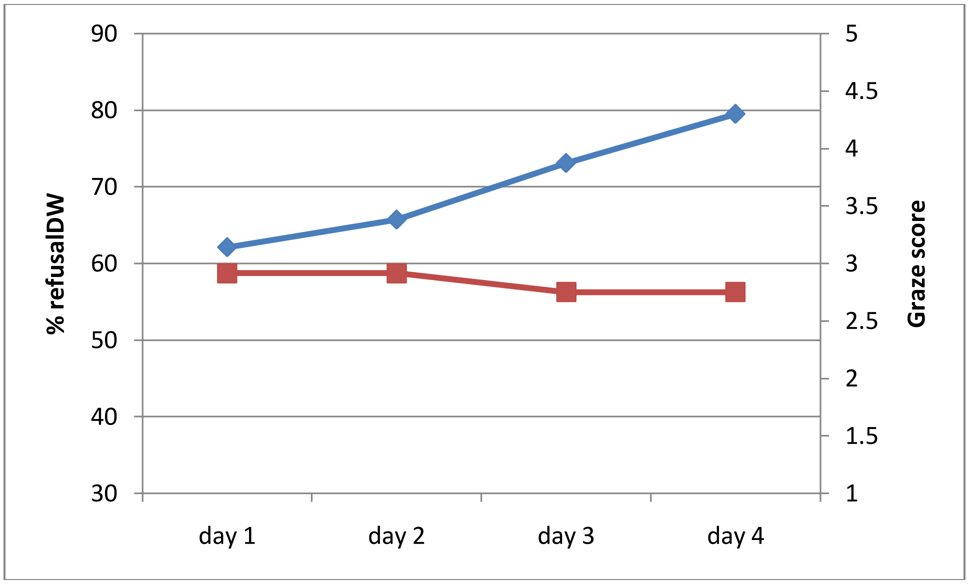

Figure 2.45. Conditioning trend Tfsoft-HY-C3. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

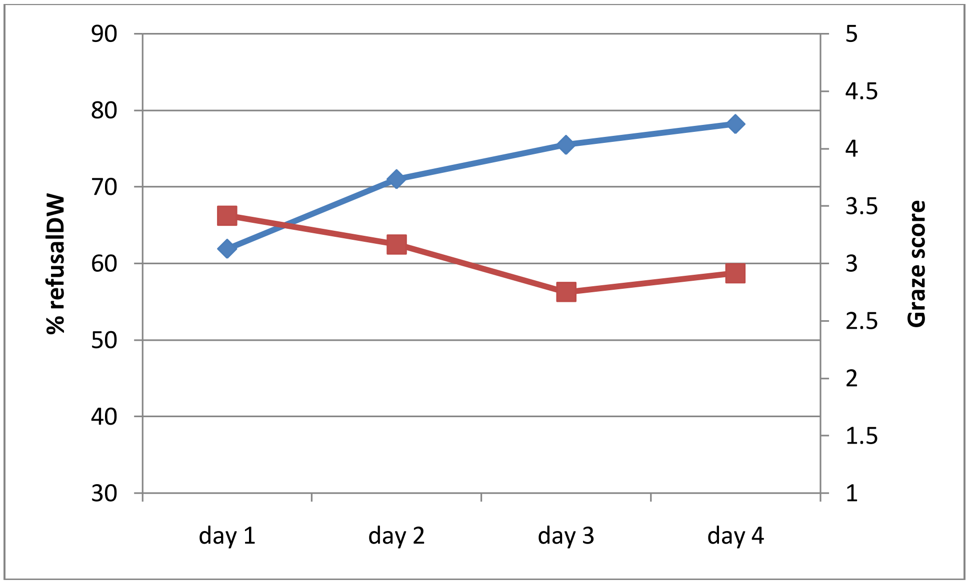

Figure 2.46. Conditioning trend TuscanyII. Percent refusal on dry weight basis (diamond) scaled on the left axis. Graze score (box) scaled on right axis.

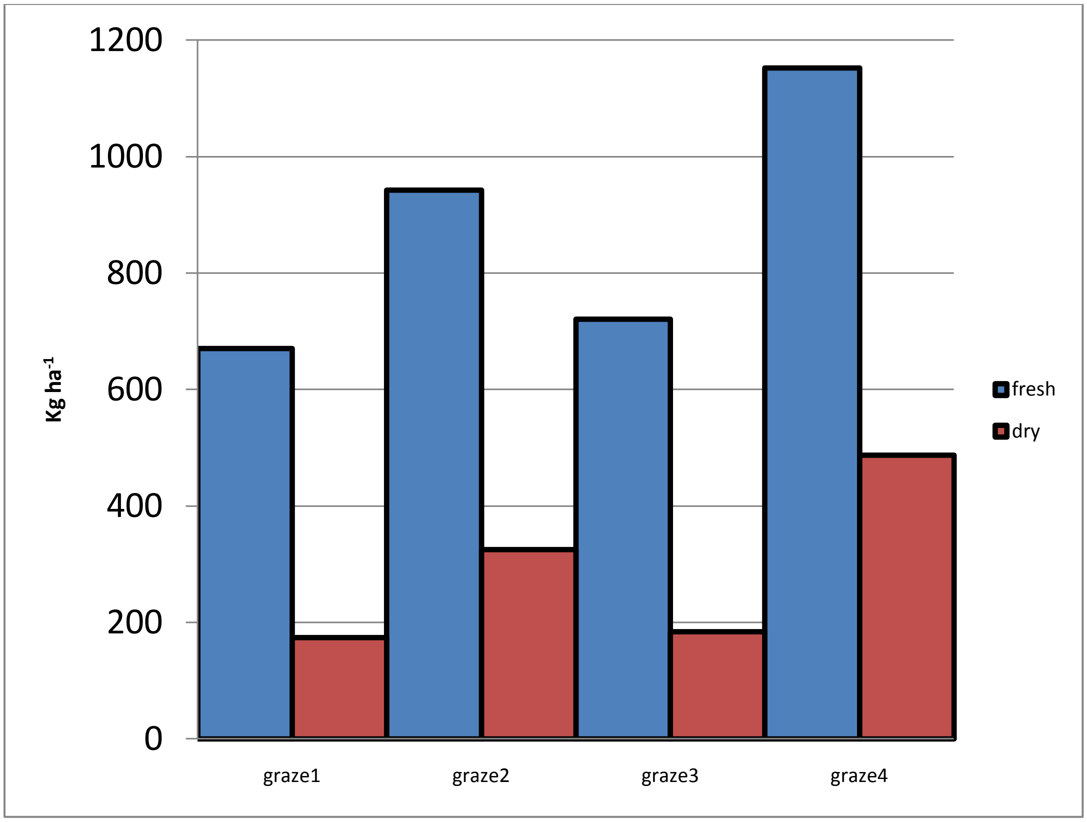

Figure 2.47. Average fresh and dry weight yields for all entries grouped by grazing periods.

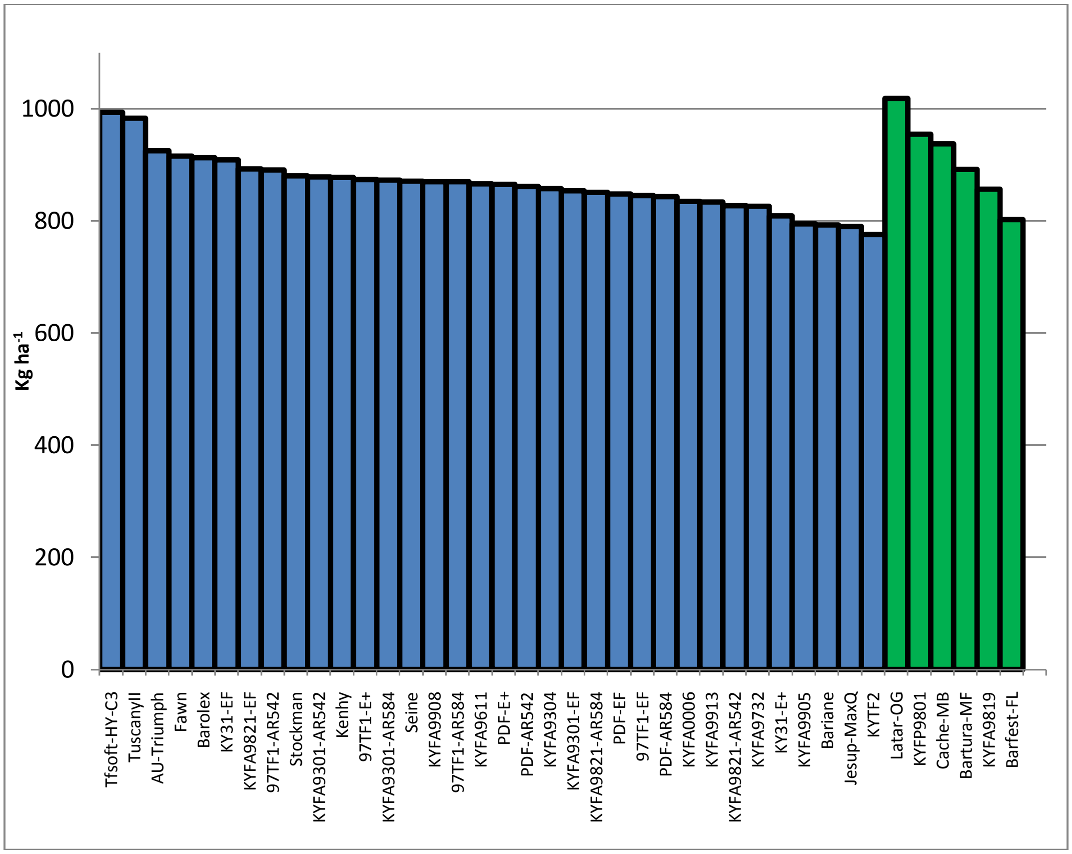

Figure 2.48. Average entry yield pooled over all four grazing periods. Plotted in descending order. (Tall Fescue – blue; non Tall Fescue – green)

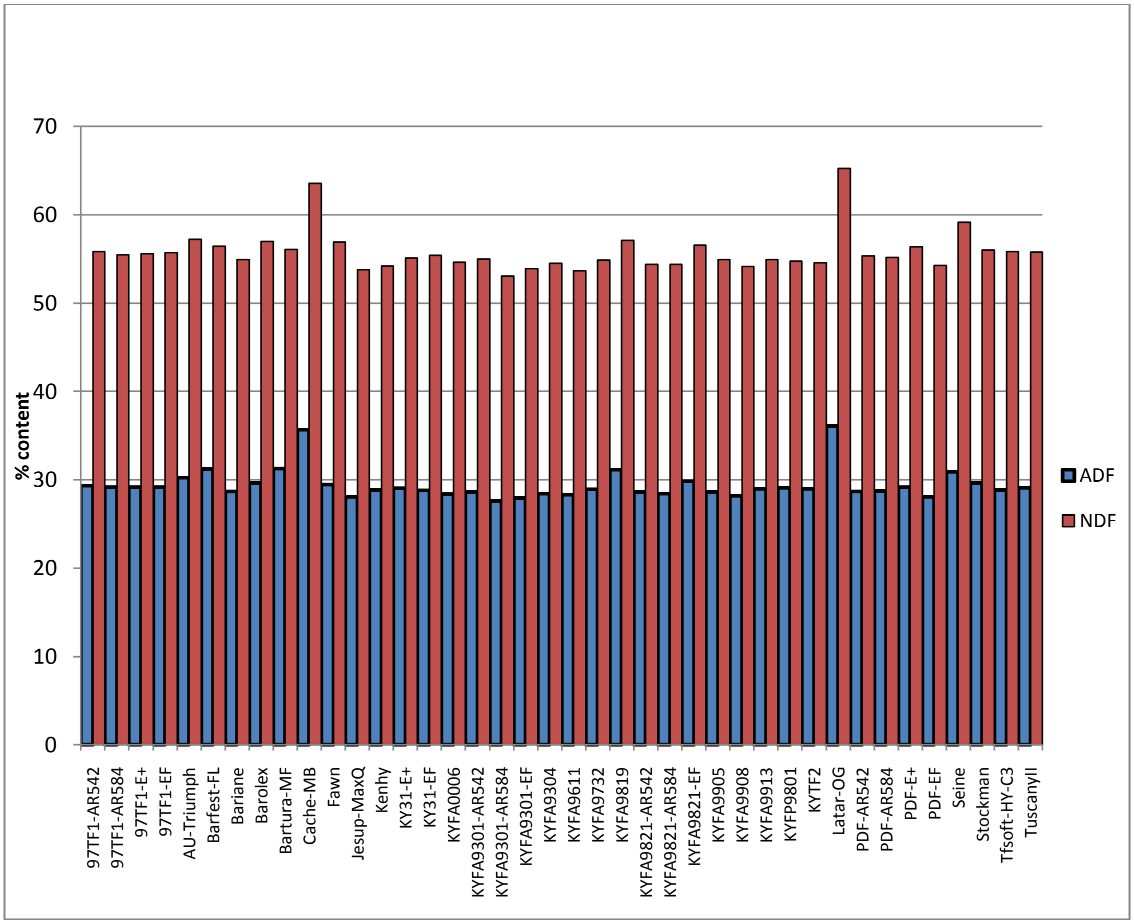

Figure 2.49. Graze 1 fiber percent content means as measured in the form of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) with a near infrared scanner.

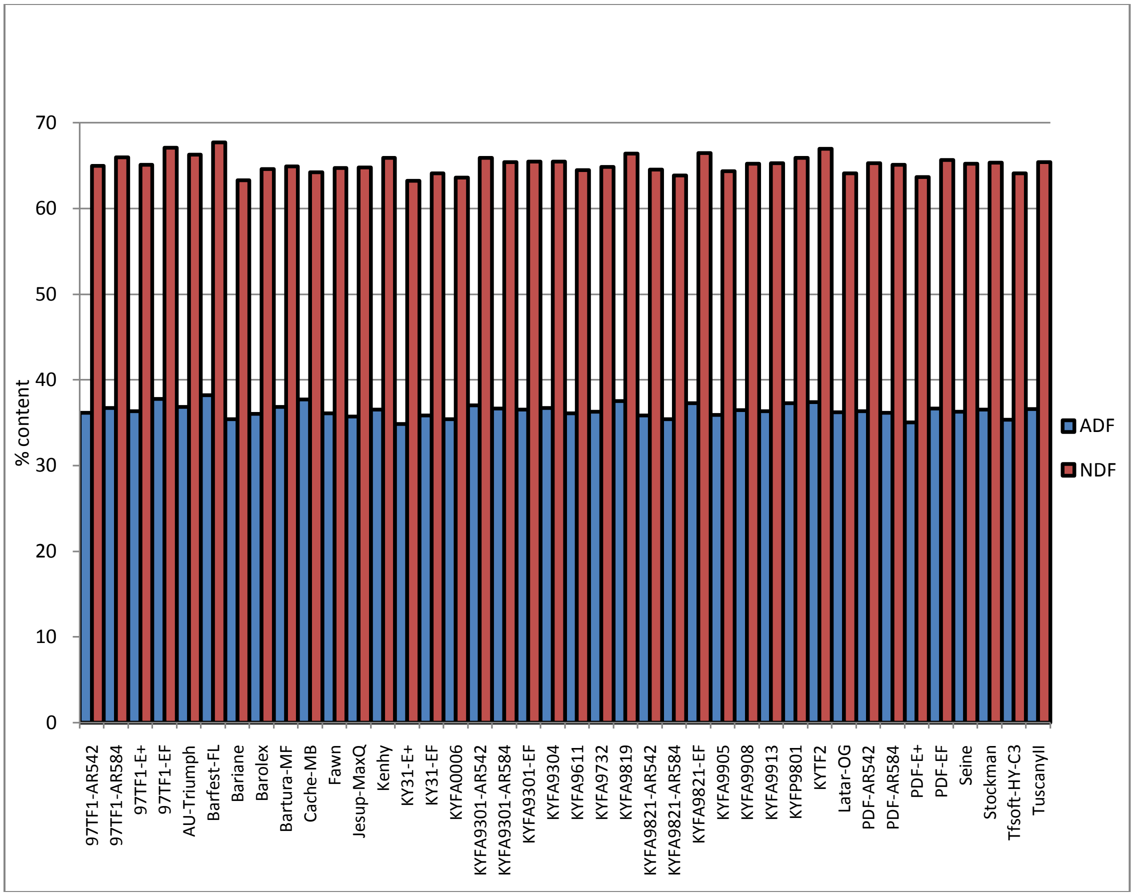

Figure 2.50. Graze 2 fiber percent content means as measured in the form of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) with a near infrared scanner.

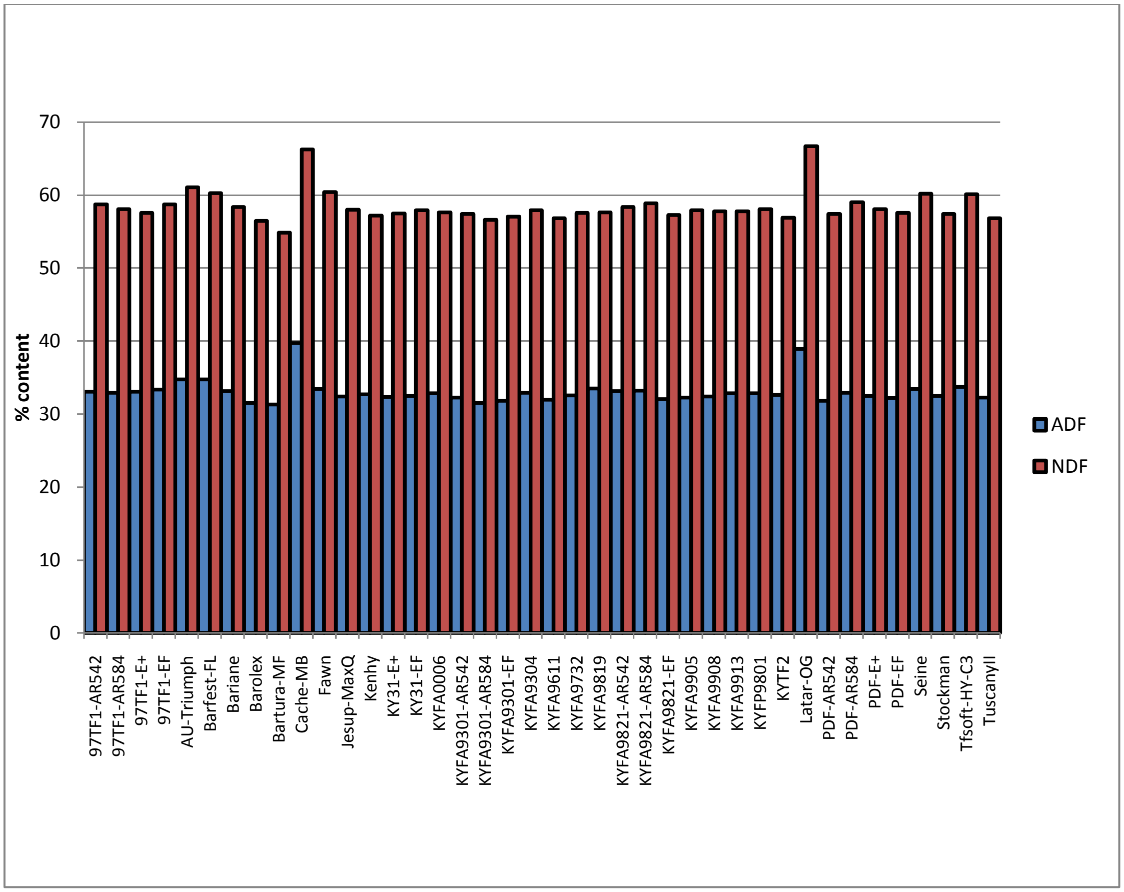

Figure 2.51. Graze 3 fiber percent content means as measured in the form of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) with a near infrared scanner.

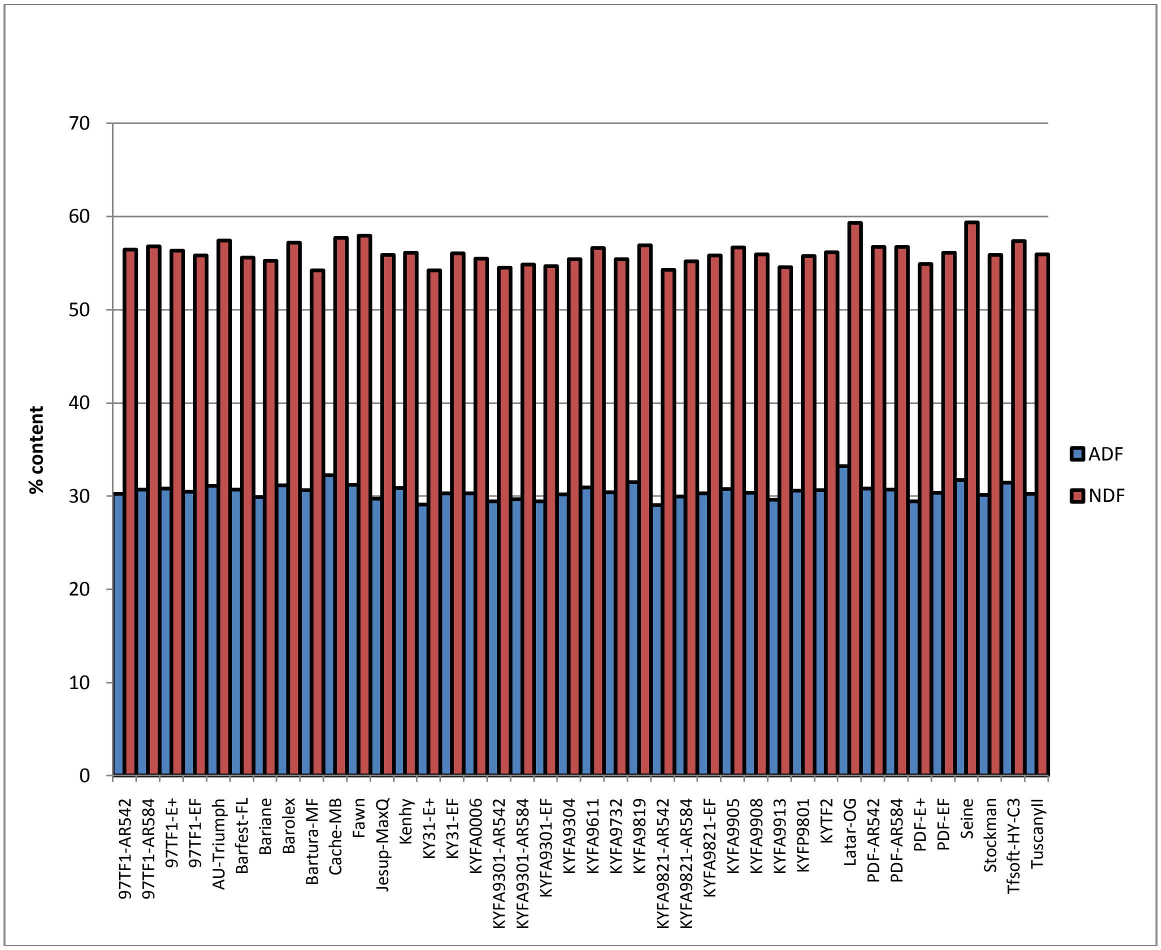

Figure 2.52. Graze 4 fiber percent content means as measured in the form of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) with a near infrared scanner.

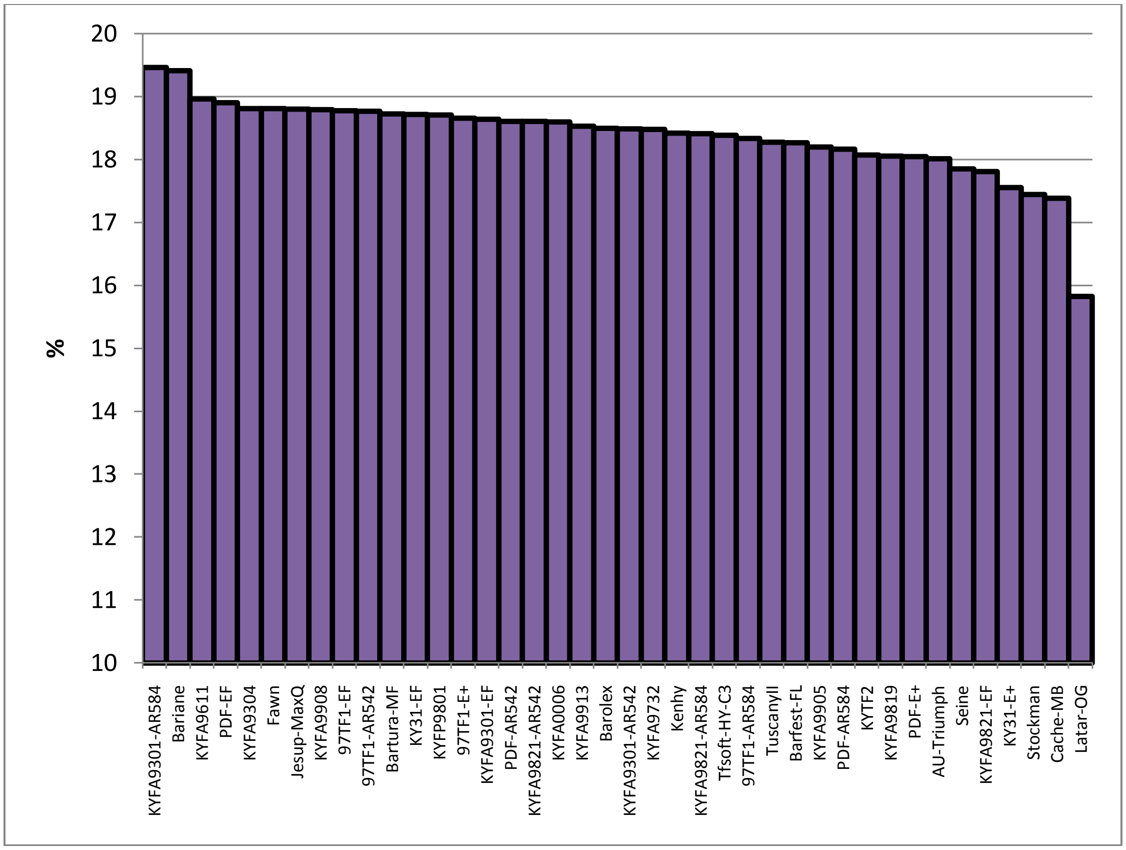

Figure 2.53. Graze 1 protein percentage for entries graphed in descending order.

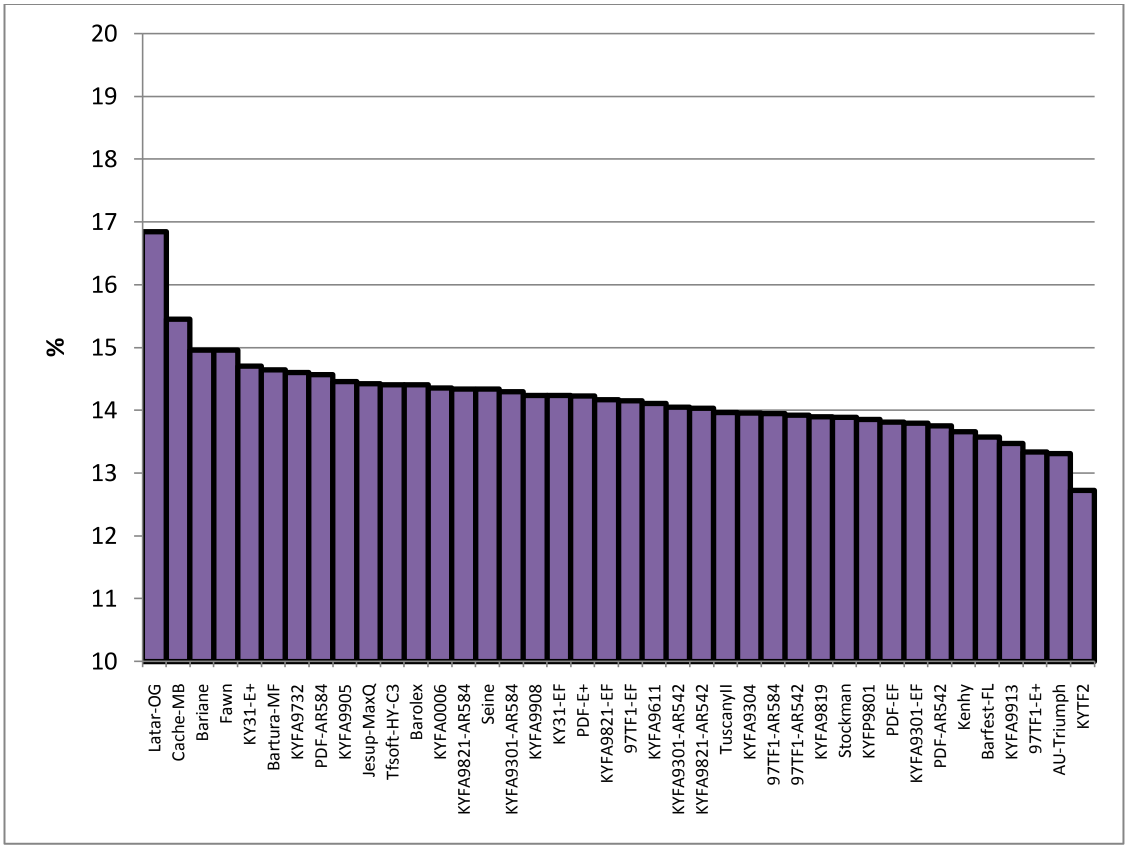

Figure 2.54. Graze 2 protein percentage for entries graphed in descending order.

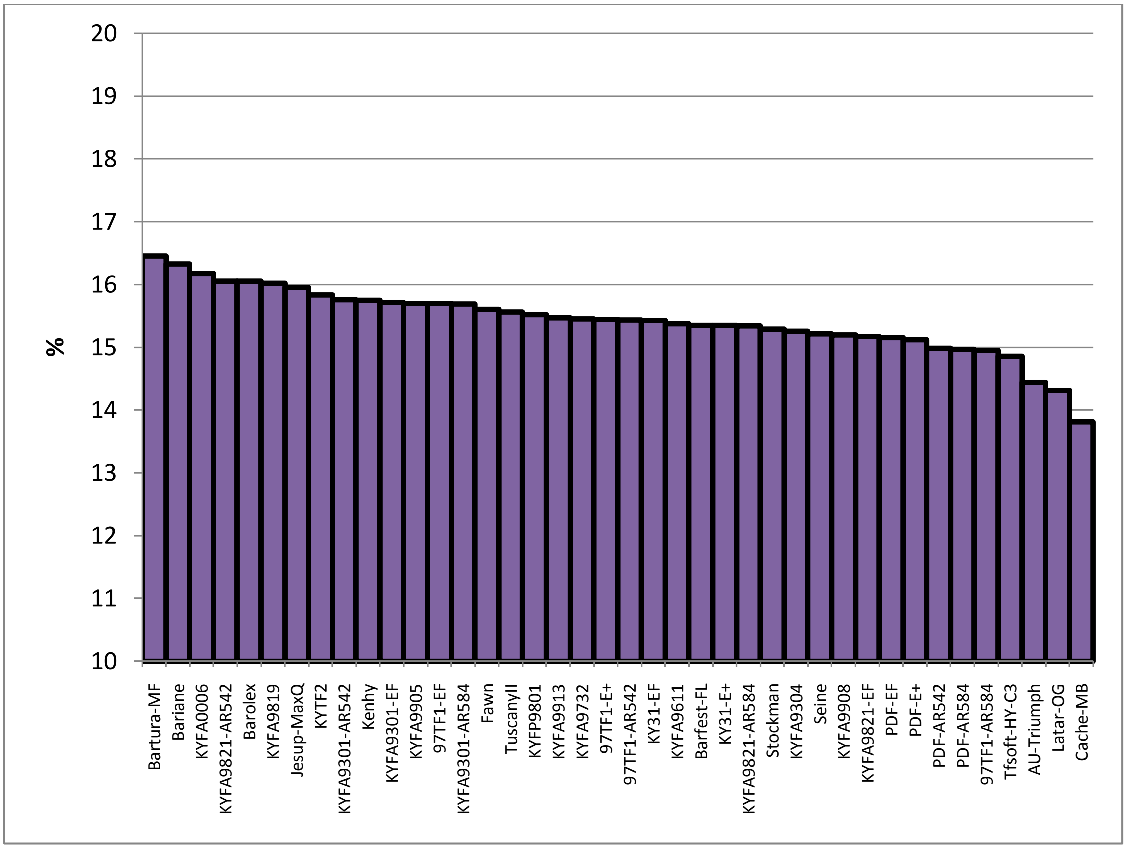

Figure 2.55. Graze 3 protein percentage for entries graphed in descending order.

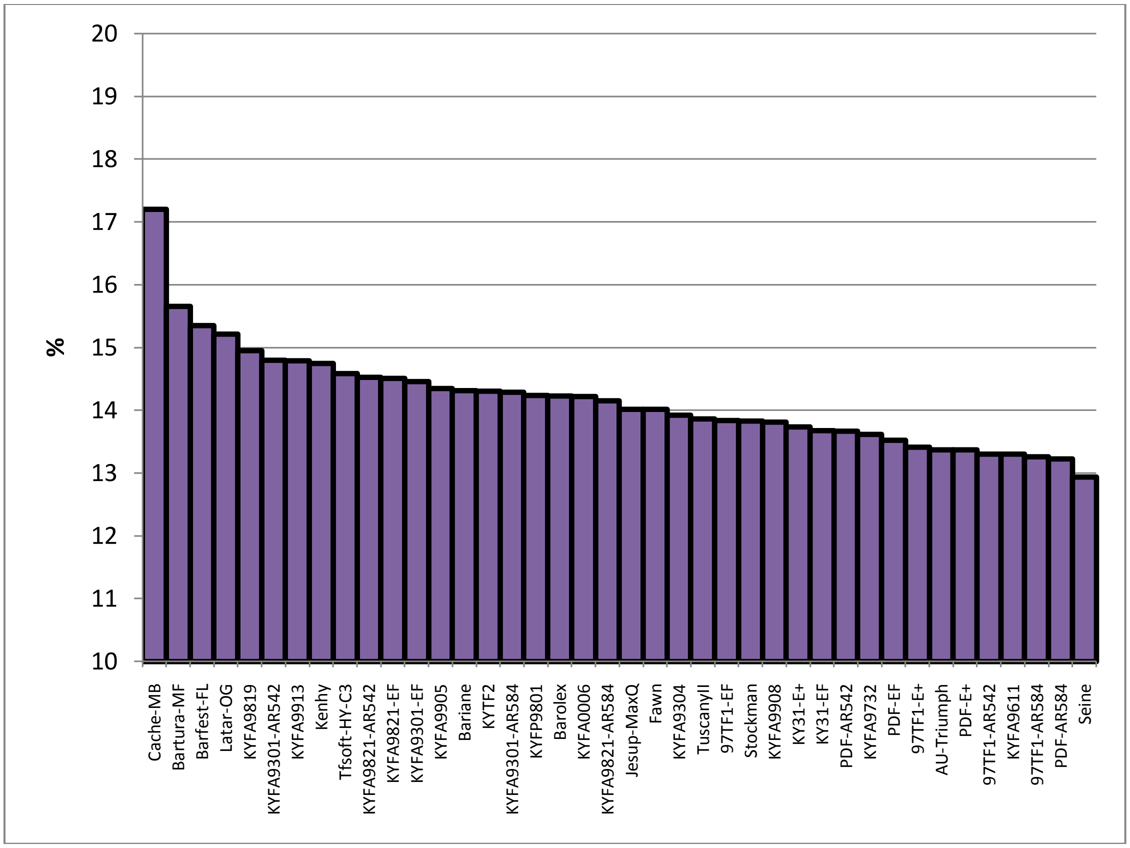

Figure 2.56. Graze 4 protein percentage for entries graphed in descending order.

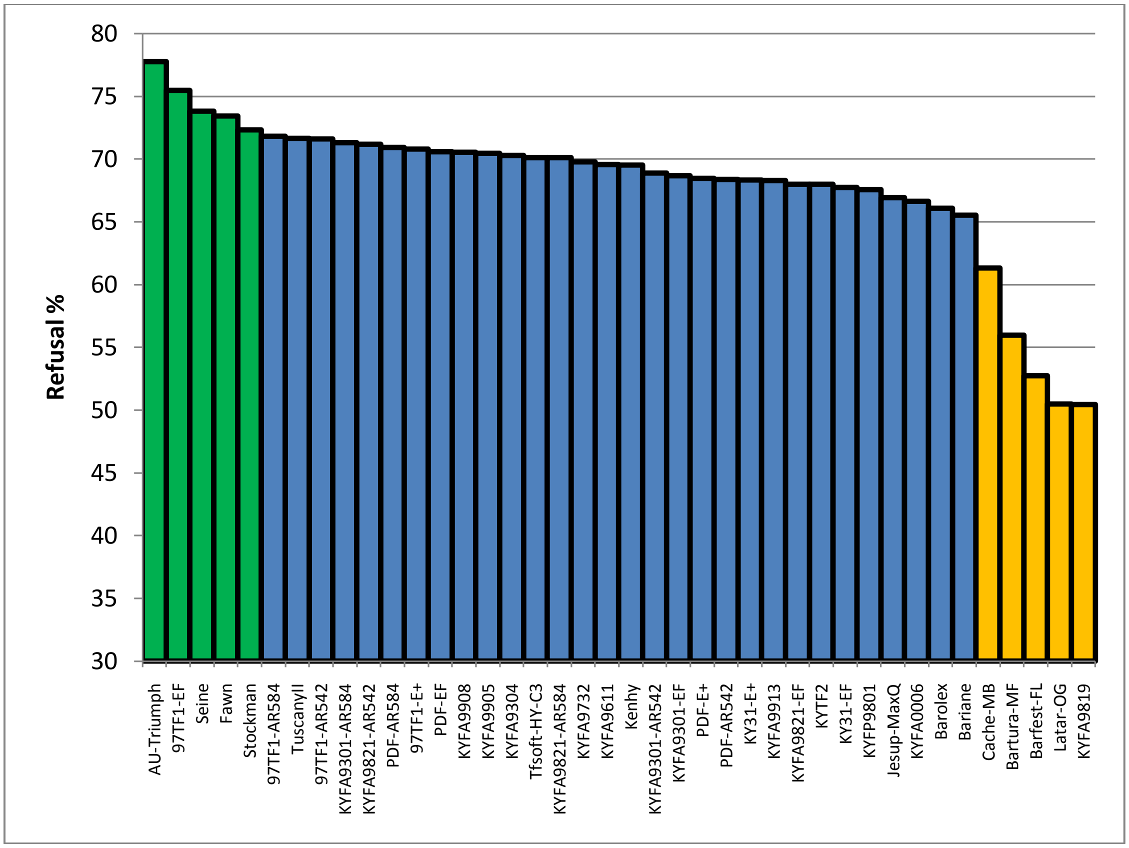

Figure 2.57. Average refusal percentage by entry across all four grazing periods graphed in decreasing order. Green shows the top five most refused while yellow indicates the five least refused.

Chapter 3: CONCLUSION

General Discussion

Climate effects

It is possible that the weather played a role in forage quality during portions of this study. The most obvious factor is the lack of precipitation. Warm season grasses like crabgrass are favored in situations like this, which was evident during the second grazing period. In an attempt to mitigate these effects, irrigation was used. The second grazing period had a refusal dry weight of 56% making it 8% lower than the next closest grazing period. Cattle find crabgrass palatable and the fact that it existed in some of the plots could explain why some grasses were selected in a larger quantity during the second day of grazing (Bosworth et al., 1986).

It is possible the dry weather could have had during the second grazing period caused the cattle to seek water at a higher rate, which resulted in them spending more time grazing in the sections of the field near the water. This is indicated by the border effect seen on the east side of the plot, which is very strong on the third and fourth days. This effect is shown on the second choropleth map. The border effect confounds interpretation of preference, with location becoming the more important selection factor for the cattle.

The second year of this study was a wetter than normal year. This was evident in the yield totals for the fourth grazing period. Producing 1151 kg ha^{-1} the mean across the fourth grazing period was over 200 kg ha^{-1} greater than the next closest period. Conditions that cause plants to grow at faster rates, clouds and less sun light, lower forage quality (Vecellio et al., 1995).

Spatial Implications

The shape and size of the plots might have affected the cattle's grazing behavior. Each plot was small relative to a real-world grazing system. After the depletion of preferred cultivars, less favorable ones are consumed (Ganskopp et al., 1997). This happens more rapidly than if the plots had been larger meaning that more of the less favorable cultivar is consumed making it harder to get a true estimation of forage preference. Other research has shown that as patch size decreases, patch utilization increases (Clarke et al., 1995). Some cultivars may have not been grazed to the degree to which they were if there was not complete depletion of any cultivar. During a tolerance trial, free ranging cattle were observed grazing the preferred cultivar to depletion resulting in a stark difference between adjacent plots. One distinction between that milieu and the current study is the possible effects of plant maturity; plant maturity is less of a factor due to the procedures used to prepare the grazing area.

Spatial memory possibly confounds attempts to identify a trend over the four grazing days. The first three pastures were oriented in the same fashion while the fourth pasture layout was different because of limitations in available land. If it is assumed the cattle were able to perceive the patch location in the pasture on the first day of the grazing, it is possible that when moved to the next identical pasture, they searched with an expectation to find the same cultivars in the same relative locations, using the water and electric fence as a points of reference (Phillips, 2002; Roguet et al., 1998). Edwards et al. (1996) found that sheep returned to the same location in a pasture where a preferred species had previously been located. Their study found that it took only one exposure; they used visual cues to bolster the effect but the same effect was seen in experimentation without visual cues (Dumont and Petit, 1998). This effect could explain the heavy border grazing seen during the second grazing and to a lesser degree during the fourth grazing period. The border effect seen could indicate the practical application of spatial memory, as it is not to pinpoint an exact location but to direct the animal to the general area considering that in nature the species would not be situated as discretely as in this study. If this memory had any effect, it would become negligible during the fourth grazing period because of its orientation.

Other studies have shown that distributing forage over a range causes increased grazing of less preferred species (Roguet et al., 1998). As relative depletion within eyesight increases, the adjacent species are more likely to be grazed (Dumont et al., 2002). The adjacent forage factor seem to be why, generally, whenever a plot was grazed completely the next plot was usually highly consumed but not to the same degree. Dumont et al. (2002), found that fescue between 1 and 5 m from ryegrass (more preferred) was never grazed more than fescue within 1 m by heifers and ewes.

Social Effects

Cattle are social animals and these social interactions affect their behavior. Preference is based on the selection of each individual; each animal has different motivations for selecting what it selects but the group can alter these factors (Scott and Provenza, 1999). The cattle used in this study for the first three trials were initially grazing on an adjacent paddock; four and five were separated from a group of twenty and introduced to the study area. On the first day of the first grazing period, the animals had a strong desire to remain with the original herd, which was visible across the border of the study area. This possibly affected how the animals selected forage on that day.

Under normal circumstances in a familiar environment herbivores forage in a group and maintain their individual preferences but in an unfamiliar setting, this changes (Scott et al., 1995; Scott et al., 1996; Scott and Provenza, 1999). It is likely that the study area was viewed as an unfamiliar environment, which would indicate a larger group grazing effect. This was observed to some degree. The animals usually appeared to form couples or one or two lone animals would break away and graze separately from the remaining animals. Their generalized movements were also somewhat synchronized; they normally sought water and rested in the fields synchronously. The size of the group has a strong effect on the locations are grazed by that group, as the size increases they traverse more area (WallisDeVries, 1996).

Conclusion

It is obvious that cattle prefer certain cultivars compared to others. Their preferential grazing was evident after visual inspection and by forage utilization. Their preference seemed to be less varied within the tall fescues as a group than with the non-tall fescue cultivars, which were generally consumed at a higher level. Similar studies found that cattle would select certain cultivar preferentially; none of those studies used the same number of entries (Figure 3.2). It is a possibility that the number of entries played a role in how the animals perceive their choices.

Leaf physical properties probably played a role in forage selection and preference. Three of the least preferred entries were coarse leaved varieties while two of the most preferred tall fescues were specifically bred for softness. Physical properties were significant ($P < 0.05$) in two of the four grazing periods (Figure 3.3). Testing leaf tensile strength could indicate other correlations with preference as other studies have shown an inverse correlation between preference and leaf tensile strength (MacAdam and Mayland, 2003).

A clear determination on the effect had by the endophyte cannot be had based on this study's results. Differences were seen between the three endophyte status classes, endophyte free, toxic-endophyte infected and novel-endophyte infected, but there was no consistent trend between the three (Figure 3.1). It is possible that due to how the endophyte works in cattle's system, that the necessary exposure threshold to induce a negative reaction was not met. Postingestive cues may have not had the normal effect because of the time constraint placed on the animal by being moved after only 24 hours. When climate was a factor, the endophyte status clearly affected grazing behavior. During the grazing period that experienced drought conditions both toxic and novel endophyte infected plants were consumed preferred to their endophyte free counterparts.

Previous research showed rapid increase in the selection of preferred cultivars; however, this result was not repeated in this study. Certain varieties were consumed at a higher rate compared to others but only Latar-OG showed strong signs that it was being consumed at a higher level with each passing day. Certain cultivars were selected less and less with each passing day. The cattle learned to increase rejection of unpalatable grasses and did not necessarily learn to increase selection of desired cultivars.

Of the five most grazed cultivars, none was tall fescue. This could be due to the novelty of the non-tall fescue cultivars or intrinsic qualities not accounted for during the study. If the animals did not perceive all the tall fescues as different from each other, a relative negative experience could cause grazing depression of the other tall fescues and increase consumption of the non-tall fescues. Only after depletion of non-tall fescue, entries would the cattle return to the tall fescues.

A few modifications could improve outcomes and increase the facility of future research on this subject. The first two of these are linked: decrease the number of cultivars and increase the plot size. Having too many similar cultivars decreases the sensitivity of the data, if there is more difference in the grasses it is likely to have a stronger affect on the cattle. Larger plots create a more realistic grazing scenario while also increase the likelihood of true postingestive feedback occurring and being acted upon.

Both of the aforementioned outcomes could also be achieved by increasing the amount of time the cattle remain in each paddock or increasing the number of animals. The goal was to have the cattle remove 50% of the available forage, which was not reached during any of the grazing periods. With smaller plots, increasing the time alone could cause a slight loss of data at the high utilization end; it could cause cultivars to appear more preferred than they actually were.

Palatability is based complex intrinsic traits in forages. Breeding that focuses on only one trait may cause an undesirable effect in another trait. This interplay means that preference testing of new lines will always be necessary. Breeding strictly for palatability has its pitfalls in lack of persistence, evident in this study. Therefore future breeding efforts most always monitor and maintain persistence, as a cultivar lacking persistence will not be economically viable.

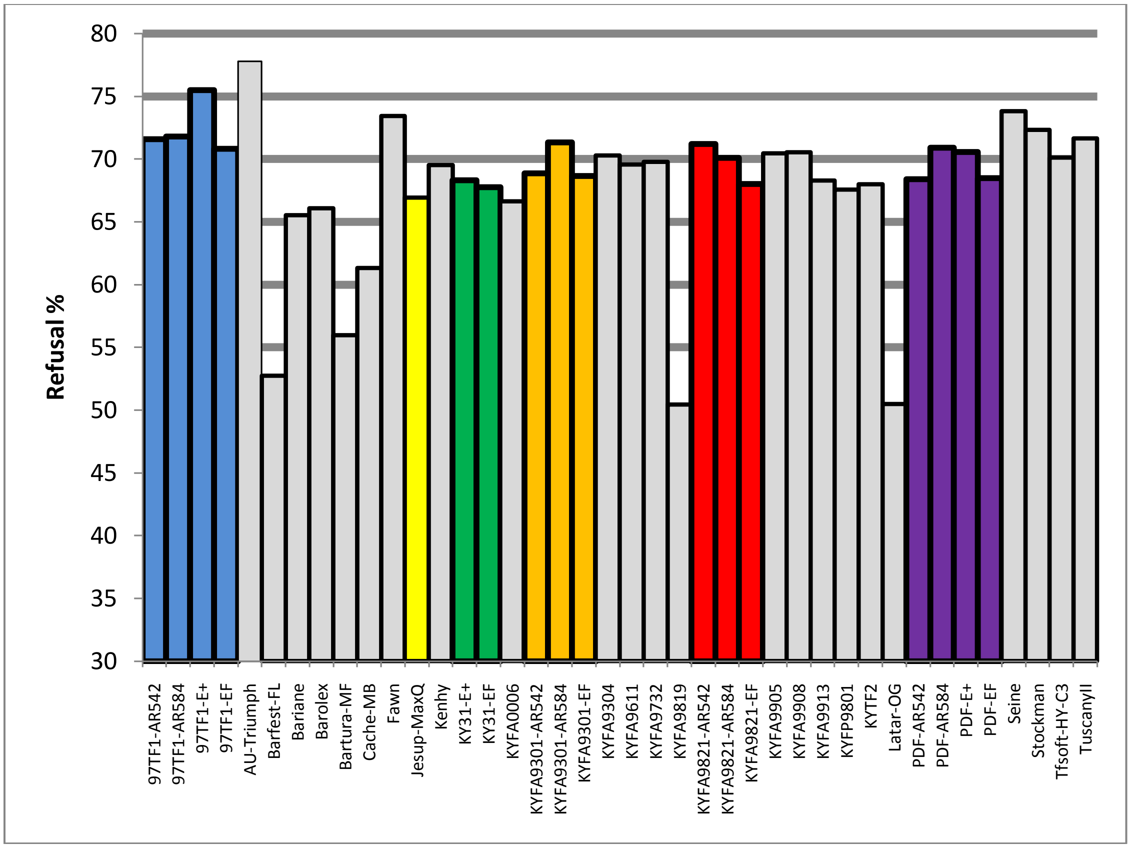

Figure 3.1. Endophyte status. Refusal dry weight percentages by entry across all four grazing periods. Novel endophyte (AR584 and AR542) and endophyte-infected strains are highlighted in color. Each color represents a different line or entry: 97TF1 (blue), Jesup-MaxQ (yellow), KY31 (green), KYFA9301 (orange), KYFA9821 (red) and PDF (purple).

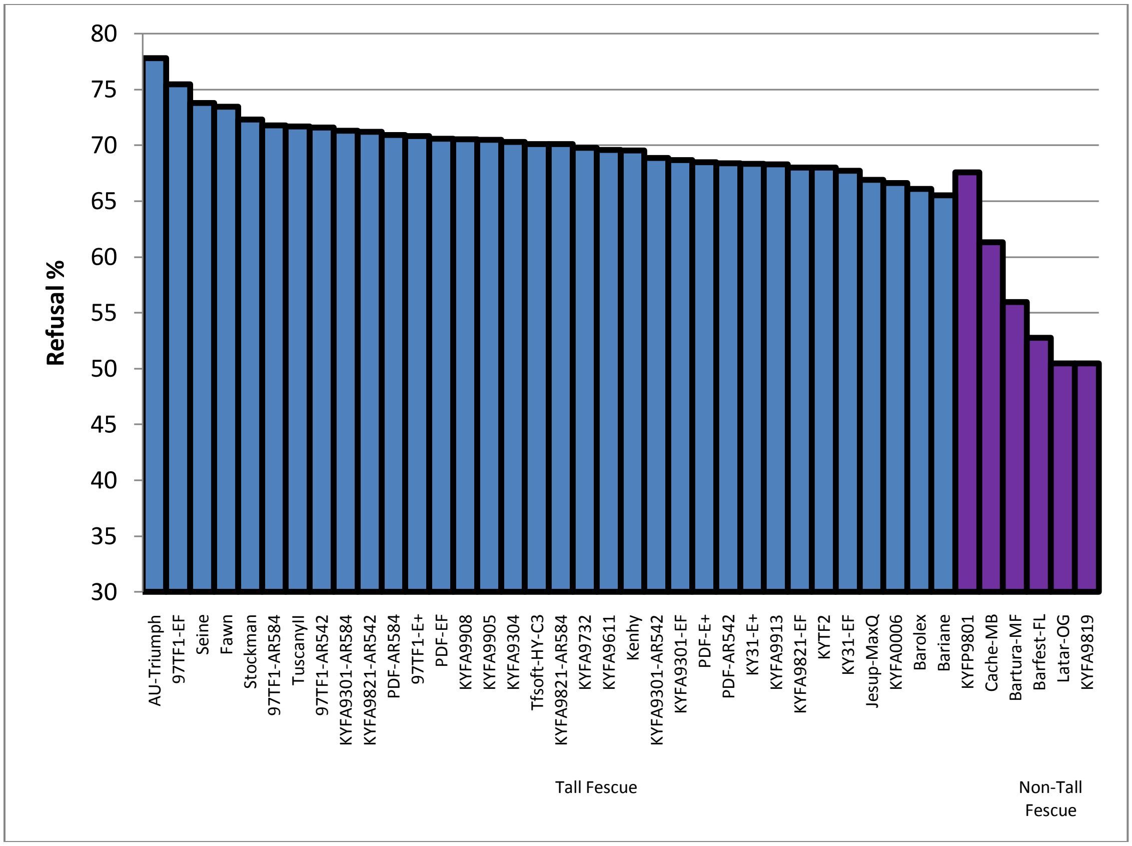

Figure 3.2. Refusal dry weight percentages by entry across all four grazing periods. Tall fescue and non-Tall fescue are separate. Tall fescues are represented in blue and non-tall fescue are purple.

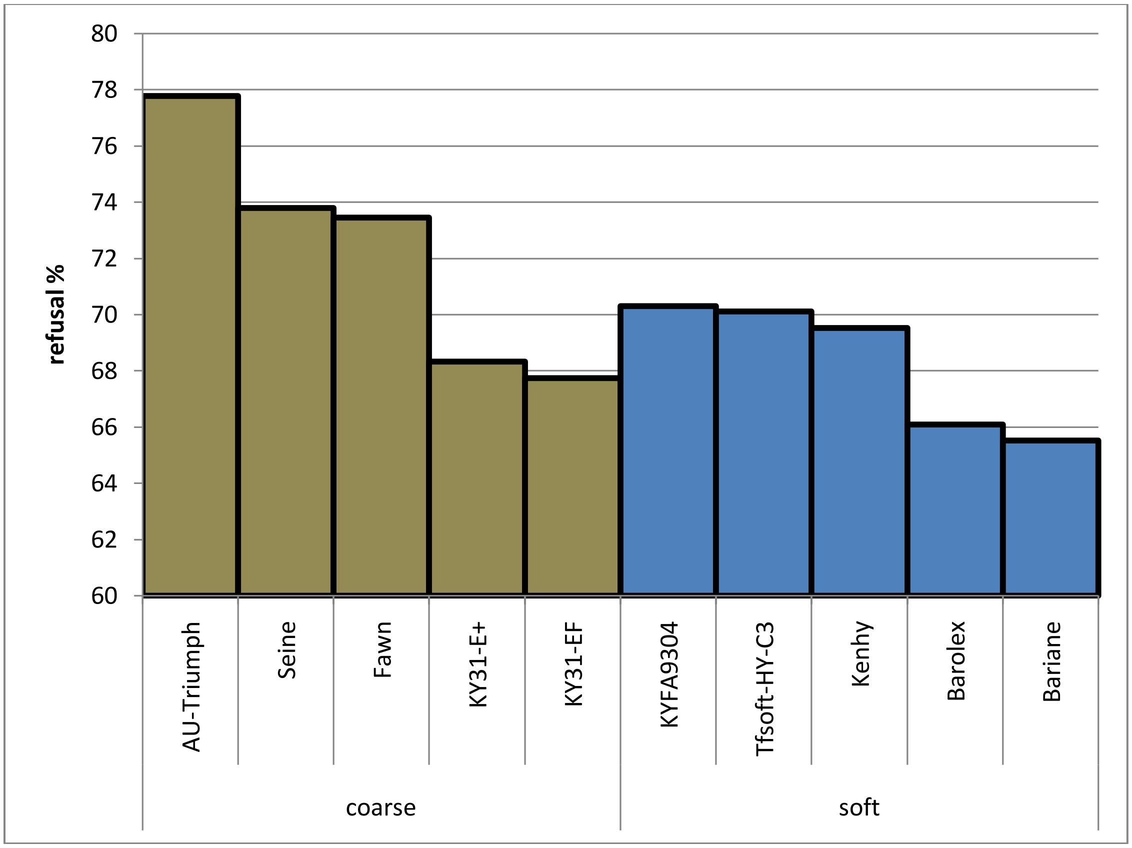

Figure 3.3. Refusal percentages for tall fescues sorted base on leaf softness. Those varieties in taupe are conventionally considered coarse; those in blue were breed to have soft leaves.

REFERENCES

Aderibigbe A.O., Church D.C., Frakes R.V., Petersen R.G. (1982) Factors Determining Palatability of Ryegrass to Cattle. Journal of Animal Science 54:164-172.

Albright J.L. (1993) Feeding-Behavior of Dairy-Cattle. Journal of Dairy Science 76:485-498.

Annicchiarico P., Romani M. (2005) Genetic variation, heritability and genetic correlations for forage quality and yield traits of Mediterranean tall fescue germplasm. Plant Breeding 124:99-101. DOI: 10.1111/j.1439-0523.2004.01024.x.

Arnold G.W. (1966) Special Senses in Grazing Animals .I. Sight and Dietary Habits in Sheep. Australian Journal of Agricultural Research 17:521-&.

Asay K.H., Buckner R.C., Frakes R.V. (1979) Breeding and Cultivars, in: R. C. Buckner and L. P. Bush (Eds.), Tall fescue, American Society of Agronomy, Madison. pp. 111-140.

Augner M., Bernays E.A. (1998) Plant defence signals and Batesian mimicry. Evolutionary Ecology 12:667-679.

Augner M., Provenza F.D., Villalba J.J. (1998) A rule of thumb in mammalian herbivores? Animal Behaviour 56:337-345.

Bailey D.W., Rittenhouse L.R., Hart R.H., Swift D.M., Richards R.W. (1989) Association of Relative Food Availabilities and Locations by Cattle. Journal of Range Management 42:480-482.

Baumont R. (1996) Palatability and feeding behaviour in ruminants. A review. Annales De Zootechnie 45:385-400.

Baumont R., Prache S., Meuret M., Morand-Fehr P. (2000) How forage characteristics influence behaviour and intake in small ruminants: a review. Livestock Production Science 64:15-28.

Beck P.A., Hutchison S., Stewart C.B., Shockey J.D., Gunter S.A. (2007) Effect of crabgrass (Digitaria ciliaris) hay harvest interval on forage quality and performance of growing calves fed mixed diets. J. Anim Sci. 85:527-535. DOI: 10.2527/jas.2006-358.

Begall S., Cerveny J., Neef J., Vojtech O., Burda H. (2008) Magnetic alignment in grazing and resting cattle and deer. Proceedings of the National Academy of Sciences of the United States of America 105:13451-13455. DOI: DOI 10.1073/pnas.0803650105.

Bertrand A., Tremblay G.F., Pelletier S., Castonguay Y., Bélanger G. (2008) Yield and nutritive value of timothy as affected by temperature, photoperiod and time of harvest. Grass and Forage Science 63:421-432. DOI: 10.1111/j.1365-2494.2008.00649.x.

Boissy A., Dumont B. (2002) Interactions between social and feeding motivations on the grazing behaviour of herbivores: sheep more easily split into subgroups with familiar peers. Applied Animal Behaviour Science 79:233-245. DOI: Pii S0168-1591(02)00152-1.

Boling J.A., Bush L.P., Buckner R.C., Pendlum L.C., Burrus P.B., Yates S.G., Rogovin S.P., Tookey H.L. (1975) Nutrient Digestibility and Metabolism in Lambs Fed Added Perloline. Journal of Animal Science 40:972-976.

Bosworth S.C., Hoveland C.S., Buchanan G.A. (1986) Forage Quality of Selected Cool-Season Weed Species. Weed Science 34:150-154.

Bouton J.H., Latch G.C.M., Hill N.S., Hoveland C.S., McCann M.A., Watson R.H., Parish J.A., Hawkins L.L., Thompson F.N. (2002) Reinfection of tall fescue cultivars with non-ergot alkaloid-producing endophytes. Agronomy Journal 94:567-574.

Browning R., LeiteBrowning M.L. (1997) Effect of ergotamine and ergonovine on thermal regulation and cardiovascular function in cattle. Journal of Animal Science 75:176-181.

Buckner R.C., Powell J.B., Frakes R.V. (1979) Historical Development, in: R. C. Buckner and L. P. Bush (Eds.), Tall fescue, American Society of Agronomy, Madison. pp. 1-8.

Burda H., Begall S., Cerveny J., Neef J., Nemec P. (2009) Extremely low-frequency electromagnetic fields disrupt magnetic alignment of ruminants. Proceedings of the National Academy of Sciences of the United States of America 106:5708-5713. DOI: DOI 10.1073/pnas.0811194106.

Burns J.C., Chamblee D.S. (1979) Adaptation, in: R. C. Buckner and L. P. Bush (Eds.), Tall fescue, American Society of Agronomy, Madison. pp. 9-30.

Burritt E.A., Provenza F.D. (1989) Food aversion learning: ability of lambs to distinguish safe from harmful foods. J Anim Sci 67:1732-9.

Buxton D.R., Redfearn D.D. (1997) Plant limitations to fiber digestion and utilization. Journal of Nutrition 127:S814-S818.

Casler M.D. (2001) Breeding forage crops for increased nutritional value, Advances in Agronomy, Academic Press. pp. 51-107.

Clark D.H., Mayland H.F., Lamb R.C. (1987) Mineral Analysis of Forages with near-Infrared Reflectance Spectroscopy. Agronomy Journal 79:485-490.

Clark D.H., Cary E.E., Mayland H.F. (1989) Analysis of Trace-Elements in Forages by near-Infrared Reflectance Spectroscopy. Agronomy Journal 81:91-95.

Clarke J.L., Welch D., Gordon I.J. (1995) The Influence of Vegetation Pattern on the Grazing of Heather Moorland by Red Deer and Sheep. II. The Impact on Heather. Journal of Applied Ecology 32:177-186.

Darwin C. (1909) The Origin of Species P.F. Collier & son.

Distel R.A., Laca E.A., Griggs T.C., Demment M.W. (1995) Patch Selection by Cattle - Maximization of Intake Rate in Horizontally Heterogeneous Pastures. Applied Animal Behaviour Science 45:11-21.

Dumont B., Petit M. (1998) Spatial memory of sheep at pasture. Applied Animal Behaviour Science 60:43-53.

Dumont B., Dutronc A., Petit M. (1998) How readily will sheep walk for a preferred forage? Journal of Animal Science 76:965-971.

Dumont B., Carrere P., D'Hour P. (2002) Foraging in patchy grasslands: diet selection by sheep and cattle is affected by the abundance and spatial distribution of preferred species. Animal Research 51:367-381. DOI: DOI 10.1051/animres:2002033.

Duncan A.J., Ginane C., Elston D.A., Kunaver A., Gordon I.J. (2006) How do herbivores trade-off the positive and negative consequences of diet selection decisions? Animal Behaviour 71:93-99. DOI: DOI 10.1016/j.anbehav.2005.03.035.

Dutoit J.T., Provenza F.D., Nastis A. (1991) Conditioned Taste-Aversions - How Sick Must a Ruminant Get before It Learns About Toxicity in Foods. Applied Animal Behaviour Science 30:35-46.

Early D.M., Provenza F.D. (1998) Food flavor and nutritional characteristics alter dynamics of food preference in lambs. J Anim Sci 76:728-34.

Edouard N., Fleurance G., Dumont B., Baumont R., Duncan P. (2009) Does sward height affect feeding patch choice and voluntary intake in horses? Applied Animal Behaviour Science 119:219-228. DOI: DOI 10.1016/j.applanim.2009.03.017.

Edwards G.R., Newman J.A., Parsons A.J., Krebs J.R. (1996) The use of spatial memory by grazing animals to locate food patches in spatially heterogeneous environments: An example with sheep. Applied Animal Behaviour Science 50:147-160.

Emlen J.M. (1966) Role of Time and Energy in Food Preference. American Naturalist 100:611-&.

Fahey Jr G.C., Berger L.L. (1988) Carbohydrate Nutrition of Ruminants, in: D. C. Church (Ed.), The Ruminant animal : digestive physiology and nutrition, Prentice-Hall, Englewood Cliffs. pp. 269-297.

Faverdin P. (1999) The effect of nutrients on feed intake in ruminants. Proceedings of the Nutrition Society 58:523-531.

Favreau A., Baumont R., Duncan A.J., Ginane C. (2010) Sheep use preingestive cues as indicators of postingestive consequences to improve food learning. J Anim Sci 88:1535-44. DOI: jas.2009-2455 [pii]

Fisher D.S., Mayland H.F., Burns J.C. (1999) Variation in ruminants' preference for tall fescue hays cut either at sundown or at sunup. Journal of Animal Science 77:762-768.

Ganskopp D., Myers B., Lambert S., Cruz R. (1997) Preferences and behavior of cattle grazing 8 varieties of grasses. Journal of Range Management 50:578-586.

Garcia J. (1989) Food for Tolman: Cognition and Cathexis in Concert, in: T. Archer and L.-G. Nilsson (Eds.), Aversion, avoidance, and anxiety: perspective on aversively motivated behavior, Lawrence Erlbaum Associates, Ann Arbor. pp. 45-89.

Gesshe R.H., Walton P.D. (1981) Grazing Animal Preferences for Cultivated Forages in Canada. Journal of Range Management 34:42-45.

Gilbertson D.M., Monroe W.T., Milliet J.R., Caprio J., Gilbertson T.A. (1997) Citrate ions enhance behavioral and cellular responses to taste stimuli. Physiol Behav 62:491-500. DOI: S0031-9384(97)00005-X [pii].

Ginane C., Petit M. (2005) Constraining the time available to graze reinforces heifers' preference for sward of high quality despite low availability. Applied Animal Behaviour Science 94:1-14. DOI: DOI 10.1016/j.applanim.2005.02.010.

Ginane C., Dumont B. (2006) Generalization of conditioned food aversions in grazing sheep and its implications for food categorization. Behavioural Processes 73:178-186. DOI: DOI 10.1016/j.beproc.2006.05.006.

Ginane C., Petit M., D'Hour P. (2003) How do grazing heifers choose between maturing reproductive and tall or short vegetative swards? Applied Animal Behaviour Science 83:15-27. DOI: Doi 10.1016/S0168-1591(03)00110-2.

Ginane C., Duncan A.J., Young S.A., Elston D.A., Gordon I.J. (2005) Herbivore diet selection in response to simulated variation in nutrient rewards and plant secondary compounds. Animal Behaviour 69:541-550. DOI: DOI 10.1016/j.anbehav.2004.06.008.

Goatcher W.D., Church D.C. (1970) Taste Responses in Ruminants .4. Reactions of Pygmy Goats, Normal Goats, Sheep and Cattle to Acetic Acid and Quinine Hydrochloride. Journal of Animal Science 31:373-&.

Grovum W.L. (1988) Appetite, Palatability and Control of Feed Intake, in: D. C. Church (Ed.), The Ruminant animal : digestive physiology and nutrition, Prentice-Hall, Englewood Cliffs. pp. 202-216.

Gunter S.A., Beck P.A. (2004) Novel endophyte-infected tall fescue for growing beef cattle. J Anim Sci 82 E-Suppl:E75-82. DOI: 82/13_suppl/E75 [pii].

Gwinn K.D., Collins-Shepard M.H., Reddick B.B. (1991) Tissue print-immunoblot, an accurate method for the detection of *Acremonium coenophialum* in tall fescue. Phytopathology. Vol. 81, no. 7, pp. 747-748.

Halgerson J.L., Sheaffer C.C., Martin N.P., Peterson P.R., Weston S.J. (2004) Near-infrared reflectance spectroscopy prediction of leaf and mineral concentrations in alfalfa. Agronomy Journal 96:344-351.

Hand M., Cogan N., Stewart A., Forster J. (2010) Evolutionary history of tall fescue morphotypes inferred from molecular phylogenetics of the Lolium-Festuca species complex. BMC Evolutionary Biology 10:303.

Hardison W.A., Reid J.T., Martin C.M., Woolfolk P.G. (1954) Degree of Herbage Selection by Grazing Cattle. Journal of Dairy Science 37:89-102.

Heady H.F. (1964) Palatability of Herbage and Animal Preference. Journal of Range Management 17:76-82.

Hemken R.W., Jackson J.A., Boling J.A. (1984) Toxic Factors in Tall Fescue. Journal of Animal Science 58:1011-1016.

Hill N.S., Bouton J.H., Thompson F.N., Hawkins L., Hoveland C.S., McCann M.A. (2002) Performance of tall fescue germplasms bred for high- and low-ergot alkaloids. Crop Science 42:518-523.

Hopkins A.A. (2005) Grazing tolerance of cool-season grasses planted as seeded sward plots and spaced plants. Crop Science 45:1559-1564. DOI: DOI 10.2135/cropsci2004.0353.

Horadagoda A., Fulkerson W.J., Nandra K.S., Barchia I.M. (2009) Grazing preferences by dairy cows for 14 forage species. Animal Production Science 49:586-594. DOI: Doi 10.1071/Ea08299.

Jones L.I. (1952) Measurements of Palatability, Proceedings of the 6th International Grassland Congress, Pennsylvania State College Press, State College. pp. 1348-1353.

Joost R.E. (1995) Acremonium in fescue and ryegrass: boon or bane? A review. J Anim Sci 73:881-8.

Jung H.G., Allen M.S. (1995) Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. J Anim Sci 73:2774-90.

Krueger W.C. (1972) Evaluating Animal Forage Preference. Journal of Range Management 25:471-&.

Krueger W.C., Laycock W.A., Price D.A. (1974) Relationships of Taste, Smell, Sight, and Touch to Forage Selection. Journal of Range Management 27:258-262.

Launchbaugh K.L., Provenza F.D. (1991) Learning and Memory in Grazing Livestock Application to Diet Selection. Rangelands 13:242-244.

LeDoux J.E. (1992) Brain mechanisms of emotion and emotional learning. Curr Opin Neurobiol 2:191-7. DOI: 0959-4388(92)90011-9 [pii].

Lundberg K.M., Hoffman P.C., Bauman L.M., Berzaghi P. (2004) Prediction of Forage Energy Content by Near Infrared Reflectance Spectroscopy and Summative Equations. The Professional Animal Scientist 20:262-269.

MacAdam J.W., Mayland H.F. (2003) The relationship of leaf strength to cattle preference in tall fescue cultivars. Agronomy Journal 95:414-419.

Malinowski D.P., Belesky D.P. (1999) Neotyphodium coenophialum-endophyte infection affects the ability of tall fescue to use sparingly available phosphorus. Journal of Plant Nutrition 22:835-853.

Mayland H.F., Cheeke P.R. (1995) Forage-induced Animal Disorders, in: R. F. Barnes, et al. (Eds.), Forages, Iowa State University Press, Ames. pp. 121-135.

Mayland H.F., Shewmaker G.E. (1999) Plants Attributes that Affect Livestock Selection and Intake, in: K. Launchbaugh, et al. (Eds.), Grazing behavior of livestock and wildlife: Pacific Northwest Range Short Course, University of Idaho, Rangeland Ecology and Management, Moscow. pp. 70-74.

Mayland H.F., Flath R.A., Shewmaker G.E. (1997) Volatiles from fresh and air-dried vegetative tissues of tall fescue (Festuca arundinacea Schreb): Relationship to cattle preference. Journal of Agricultural and Food Chemistry 45:2204-2210.

Mayland H.F., Martin S.A., Lee J., Shewmaker G.E. (2000) Malate, citrate, and amino acids in tall fescue cultivars: Relationship to animal preference. Agronomy Journal 92:206-210.

Mayland H.F., Shewmaker G.E., Harrison P.A., Chatterton N.J. (2000) Nonstructural carbohydrates in tall fescue cultivars: Relationship to animal preference. Agronomy Journal 92:1203-1206.

Milchunas D.G., Lauenroth W.K., Chapman P.L., Kazempour M.K. (1989) Effects of grazing, topography, and precipitation on the structure of a semiarid grassland. Plant Ecology 80:11-23. DOI: 10.1007/bf00049137.

Mirza S.N., Provenza F.D. (1994) Socially Induced Food Avoidance in Lambs - Direct or Indirect Maternal Influence. Journal of Animal Science 72:899-902.

Moisey D.M., Bork E.W., Willms W.D. (2005) Non-destructive assessment of cattle forage selection: A test of skim grazing in fescue grassland. Applied Animal Behaviour Science 94:205-222. DOI: DOI 10.1016/j.applanim.2005.02.017.

Moser L.E., Volenec J.J., Nelson C.J. (1982) Respiration, Carbohydrate Content, and Leaf Growth of Tall Fescue. Crop Science 22:781-786.

Narra S., Fermanian T.W., Swiader J.M. (2005) Analysis of Mono- and Polysaccharides in Creeping Bentgrass Turf Using Near Infrared Reflectance Spectroscopy. Crop Sci. 45:266-273. DOI: 10.2135/cropsci2005.0266.

Nie Z., Tremblay G.F., Belanger G., Berthiaume R., Castonguay Y., Bertrand A., Michaud R., Allard G., Han J. (2009) Near-infrared reflectance spectroscopy prediction of neutral detergent-soluble carbohydrates in timothy and alfalfa. Journal of Dairy Science 92:1702-1711. DOI: DOI 10.3168/jds.2008-1599.

NIRS Forage & Feed Testing Consortium I. (2011) NIRS Consortium Product Equation Package.

Nolte D.L., Provenza F.D. (1992) Food Preferences in Lambs after Exposure to Flavors in Milk. Applied Animal Behaviour Science 32:381-389.

Nombekela S.W., Murphy M.R., Gonyou H.W., Marden J.I. (1994) Dietary Preferences in Early Lactation Cows as Affected by Primary Tastes and Some Common Feed Flavors. Journal of Dairy Science 77:2393-2399.

Norris K.H., Barnes R.F., Moore J.E., Shenk J.S. (1976) Predicting Forage Quality by Infrared Reflectance Spectroscopy. Journal of Animal Science 43:889-897.

Nyquist W.E., Baker R.J. (1991) Estimation of heritability and prediction of selection response in plant populations. Critical Reviews in Plant Sciences 10:235 - 322.

Parish J.A., McCann M.A., Watson R.H., Paiva N.N., Hoveland C.S., Parks A.H., Upchurch B.L., Hill N.S., Bouton J.H. (2003) Use of nonergot alkaloid-producing endophytes for alleviating tall fescue toxicosis in stocker cattle. Journal of Animal Science 81:2856-2868.

Pedersen J.F., Sleper D.A. (1993) Genetic manipulation of tall fescue. Agriculture, Ecosystems & Environment 44:187-193.

Pendlum L.C., Boling J.A., Bush L.P., Buckner R.C. (1980) Digestibility and Metabolism of Kenhy Tall Fescue Harvested at Three Stages of Physiological Maturity. J. Anim Sci. 51:704-711.

Peters C.W., Grigsby K.N., Aldrich C.G., Paterson J.A., Lipsey R.J., Kerley M.S., Garner G.B. (1992) Performance, forage utilization, and ergovaline consumption by beef cows grazing endophyte fungus-infected tall fescue, endophyte fungus-free tall fescue, or orchardgrass pastures. J Anim Sci 70:1550-61.

Pfister J.A., Cheney C.D., Provenza F.D. (1992) Behavioral-Toxicology of Livestock Ingesting Plant Toxins. Journal of Range Management 45:30-36.

Phillips C. (2002) Cattle behaviour and welfare. 2nd ed. Blackwell Science, Oxford

Provenza F.D. (1995) Postingestive Feedback as an Elementary Determinant of Food Preference and Intake in Ruminants. Journal of Range Management 48:2-17.

Provenza F.D. (1996) Acquired aversions as the basis for varied diets of ruminants foraging on rangelands. J Anim Sci 74:2010-20.

Provenza F.D., Balph D.F. (1987) Diet Learning by Domestic Ruminants - Theory, Evidence and Practical Implications. Applied Animal Behaviour Science 18:211-232.

Provenza F.D., Balph D.F. (1990) Applicability of five diet-selection models to various foraging challenges ruminants encounters, in: R. N. Hughes (Ed.), Behavioural Mechanisms of Food Selection, Springer-Verlag, Berlin, Heildelberg. pp. 423-459.

Provenza F.D., Cincotta R.P. (1993) Foraging as a Self-Organizational Learning Process: Acceoting Adaptability at the Expense of Predictability, in: R. N. Hughes (Ed.), Diet selection : an interdisciplinary approach to foraging behaviour, Blackwell Scientific Publications, Oxford. pp. 78-101.

Provenza F.D., Pfister J.A., Cheney C.D. (1992) Mechanisms of Learning in Diet Selection with Reference to Phytotoxicosis in Herbivores. Journal of Range Management 45:36-45.

Provenza F.D., Lynch J.J., Nolan J.V. (1994) Food Aversion Conditioned in Anesthetized Sheep. Physiology & Behavior 55:429-432.

Provenza F.D., Kimball B.A., Villalba J.J. (2000) Roles of odor, taste, and toxicity in the food preferences of lambs: implications for mimicry in plants. Oikos 88:424-432.

Ralphs M.H., Provenza F.D. (1999) Conditioned food aversions: principles and practices, with special reference to social facilitation. Proc Nutr Soc 58:813-20. DOI: S002966519900110X [pii].

Reid R.L., Jung G.A., Murray S.J. (1966) Nitrogen Fertilization in Relation to Palatability and Nutritive Value of Orchardgrass. Journal of Animal Science 25:636-&.

Roguet C., Dumont B., Prache S. (1998) Selection and use of feeding sites and feeding stations by herbivores: A review. Annales De Zootechnie 47:225-244.

Rook A.J., Harvey A., Parsons A.J., Penning P.D., Orr R.J. (2002) Effect of long-term changes in relative resource availability on dietary preference of grazing sheep for perennial ryegrass and white clover. Grass and Forage Science 57:54-60.

Rumbaugh M.D., Mayland H.F., Pendery B.M., Shewmaker G.E. (1993) Utilization of Globemallow (Sphaeralcea) Taxa by Sheep. Journal of Range Management 46:103-109.

Saha M., Mian R., Zwonitzer J., Chekhovskiy K., Hopkins A. (2005) An SSR- and AFLP-based genetic linkage map of tall fescue (<i>Festuca arundinacea</i> Schreb.). TAG Theoretical and Applied Genetics 110:323-336. DOI: 10.1007/s00122-004-1843-1.

SAS Institute, Inc., 2008. Base SAS 9.2 Procedures Guide: Statistical Procedures. Cary, NC: SAS Institute, Inc.

Scehovic J., Poisson C., Gillet M. (1985) Palatability and Organoleptic Characteristics of Grasses .1. Comparison between Rye-Grass and Tall Fescue. Agronomie 5:347-354.

Schardl C.L., Grossman R.B., Nagabhyru P., Faulkner J.R., Mallik U.P. (2007) Loline alkaloids: Currencies of mutualism. Phytochemistry 68:980-996. DOI: DOI 10.1016/j.phytochem.2007.01.010.

Scott L.L., Provenza F.D. (1999) Variation in food selection among lambs: effects of basal diet and foods offered in a meal. J Anim Sci 77:2391-7.

Scott C.B., Provenza F.D., Banner R.E. (1995) Dietary Habits and Social Interactions Affect Choice of Feeding Location by Sheep. Applied Animal Behaviour Science 45:225-237.

Scott C.B., Banner R.E., Provenza F.D. (1996) Observations of sheep foraging in familiar and unfamiliar environments: familiarity with the environment influences diet selection. Applied Animal Behaviour Science 49:165-171.

Shenk J.S., Westerhaus M.O. (1991) Population Definition, Sample Selection, and Calibration Procedures for near-Infrared Reflectance Spectroscopy. Crop Science 31:469-474.

Shenk J.S., Westerhaus M.O. (1995) Forage Analysis by Near Infrared Spectroscopy, in: R. F. Barnes, et al. (Eds.), Forages, Iowa State University Press, Ames. pp. 111-120.

Shenk J.S., Landa I., Hoover M.R., Westerhaus M.O. (1981) Description and Evaluation of a near-Infrared Reflectance Spectro-Computer for Forage and Grain Analysis. Crop Science 21:355-358.

Shewmaker G.E., Mayland H.F., Hansen S.B. (1995) Determining Animal Preference for Grasses: Methods and Error Analysis, V International Rangeland Congress, Proceedings of the V International Rangeland Congress, Salt Lake City, Utah. pp. 508.

Shewmaker G.E., Mayland H.F., Hansen S.B. (1997) Cattle grazing preference among eight endophyte-free tall fescue cultivars. Agronomy Journal 89:695-701.

Shewmaker G.E., Mayland H.F., Hansen S.B. (1997) Border Effects on Cattle Grazing Preference, XVIII International Grassland Congress, Proceedings of the XVIII International Grassland Congress, Winnipeg, Manitoba and Saskatoon, Saskatchewan.

Sleper D.A., Buckner R.C. (1995) the Fescues, in: R. F. Barnes, et al. (Eds.), Forages, Iowa State University Press, Ames. pp. 345-356.

Smith D. (1973) The Nonstructural Carbohydrates, in: G. W. Butler and R. W. Bailey (Eds.), Chemistry and biochemistry of herbage, Academic Press, London. pp. 105-155.

Smith K.F., Reed K.F.M., Foot J.Z. (1997) An assessment of the relative importance of specific traits for the genetic improvement of nutritive value in dairy pasture. Grass and Forage Science 52:167-175. DOI: 10.1111/j.1365-2494.1997.tb02347.x.

Soder K.J., Rook A.J., Sanderson M.A., Goslee S.C. (2007) Interaction of plant species diversity on grazing behavior and performance of livestock grazing temperate region pastures. Crop Science 47:416-425. DOI: DOI 10.2135/cropsci2006.01.0061.

Soder K.J., Sanderson M.A., Gregorini P., Orr R.J., Rubano M.D., Rook A.J. (2009) Relationship of bite mass of cattle to sward structure of four temperate grasses in short-term grazing sessions. Grass and Forage Science 64:421-431. DOI: DOI 10.1111/j.1365-2494.2009.00710.x.

Steen W.W., Gay N., Boling J.A., Lacefield G., Bush L.P., Buckner R.C. (1979) Evaluation of Kentucky 31, G1-306, G1-306 and Kenhy Tall Fescue as Pasture for Yearling Steers I. Forage Composition. J. Anim Sci. 48:607-617.

Sullivan T.J., Rodstrom J., Vandop J., Librizzi J., Graham C., Schardl C.L., Bultman T.L. (2007) Symbiont-mediated changes in Lolium arundinaceum inducible defenses: evidence from changes in gene expression and leaf composition. New Phytologist 176:673-679. DOI: DOI 10.1111/j.1469-8137.2007.02201.x.

Tava A., Berardo N., Cunico C., Romani M., Odoardi M. (1995) Cultivar Differences and Seasonal-Changes of Primary Metabolites and Flavor Constituents in Tall Fescue in Relation to Palatability. Journal of Agricultural and Food Chemistry 43:98-101.

Terrell E.E. (1979) Taxonomy, Morphology, and Phylogeny, in: R. C. Buckner and L. P. Bush (Eds.), Tall fescue, American Society of Agronomy, Madison. pp. 31-40.

Thompson F.N., Stuedemann J.A. (1993) Pathophysiology of fescue toxicosis. Agriculture, Ecosystems & Environment 44:263-281.

Thorhallsdottir A.G., Provenza F.D., Balph D.F. (1987) Food Aversion Learning in Lambs with or without a Mother - Discrimination, Novelty and Persistence. Applied Animal Behaviour Science 18:327-340.

Van Soest P.J. (1994) Nutritional ecology of the ruminant. 2nd ed. Cornell University Press.

Vecellio L.C., Jung G.A., Harpster H.W., Shaffer J.A., Engle C.E., Everhart J.R. (1995) Endophyte-free tall fescue cultivars grazed by sheep: Forage quality and sward characteristics. Agronomy Journal 87:1169-1175.

Villalba J.J., Provenza F.D. (2000) Roles of flavor and reward intensities in acquisition and generalization of food preferences: Do strong plant signals always deter herbivory? Journal of Chemical Ecology 26:1911-1922.

Villalba J.J., Provenza F.D., Stott R. (2009) Rumen distension and contraction influence feed preference by sheep. Journal of Animal Science 87:340-350. DOI: DOI 10.2527/jas.2008-1109.

Waldron B.L., Davenport B.W., Malechek J.C., Jensen K.B. (2010) Relative Cattle Preference of 24 Forage Kochia () Entries and Its Relation to Forage Nutritive Value and Morphological Characteristics. Crop Sci. 50:2112-2123. DOI: 10.2135/cropsci2009.10.0610.

WallisDeVries M.F. (1996) Effects of resource distribution patterns on ungulate foraging behaviour: a modelling approach. Forest Ecology and Management 88:167-177.

Wang Z.Y., Spangenberg G. (2007) Tall Fescue, in: E.-C. Pua and M. R. Davey (Eds.), Transgenic Crops VI, Springer Berlin Heidelberg. pp. 357-372.

White J.F., Cole G.T. (1985) Endophyte-Host Associations in Forage Grasses .2. Taxonomic Observations on the Endophyte of Festuca-Arundinacea. Mycologia 77:483-486.

Yue Q., Miller C.J., White J.F., Jr., Richardson M.D. (2000) Isolation and characterization of fungal inhibitors from Epichloe festucae. J Agric Food Chem 48:4687-92. DOI: jf990685q [pii].

Zhao D., MacKown C.T., Starks P.J., Kindiger B.K. (2008) Interspecies Variation of Forage Nutritive Value and Nonstructural Carbohydrates in Perennial Cool-Season Grasses. Agron. J. 100:837-844. DOI: 10.2134/agronj2007.0178.

Zohary D. (2004) Unconscious selection and the evolution of domesticated Plants. Economic Botany 58:5-10. DOI: 10.1663/0013-0001(2004)058[0005:usateo]2.0.co;2.

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