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Effects of growth stage and growing degree day accumulations on triticale forages: 2. In vitro disappearance of neutral detergent fiber

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ABSTRACT

The use of winter triticale (X *Triticosecale* Wittmack) in dairy-cropping systems has expanded greatly in recent years, partly because of its value as a forage crop but also to improve land stewardship by providing winter ground cover. Our objectives were to use 2-pool and 3-pool nonlinear models to characterize in vitro disappearance of neutral detergent fiber (NDF) and then describe the relationship between estimated parameters from those models with plant growth stage or growing degree days (GDD) >5°C for winter triticale forages harvested during 2016 and 2017 in Marshfield, Wisconsin. Forages were harvested from replicated field plots each year at growth stages ranging from stem elongation to soft dough. All NDF analyses included use of sodium sulfite and heat-stable α-amylase with residual fiber corrected for contaminant ash (asNDFom). Nonlinear 3-pool models for in vitro disappearance of asNDFom that included fast (Bfast) and slow (Bslow) disappearance pools as well as an associated disappearance rate for each ($K_d$fast and $K_d$slow, respectively) were easily fitted provided that a single discrete lag time was applied to both Bfast and Bslow pools to reduce the number of parameters to be estimated. An unresolved issue related to fitting 3-pool decay models was the incomplete recovery of asNDFom from immature triticale forages at 0 h, which was partially resolved with 2 approaches that produced similar estimates of $K_d$fast and $K_d$slow. Most parameters obtained from 2- and 3-pool decay models for asNDFom could be related to growth stage or GDD using polynomial regression techniques, often with high coefficients of determination (R^2). For 3-pool models of asNDFom disappearance, Bslow increased with plant maturity, but the associated $K_d$slow ranged narrowly from 0.011 to 0.015/h and could not be related to growth stage or GDD by quartic, cubic, quadratic, or linear regression models. Despite different cultivars coupled with substantial differences in precipitation across years, single endpoint estimates of in vitro disappearance of asNDFom after 24, 30, or 48 h of incubation were closely related ($R^2 \geq 0.906$) to growth stage and GDD by linear or quadratic regression models that were generally similar across production years. Typical recommendations for harvesting triticale at boot stage to facilitate the planting of a double crop are strongly supported by the extensive 30-h in vitro disappearance of asNDFom at that growth stage, which was 63.1 and 64.8% of asNDFom during 2016 and 2017, respectively.
Key words: double cropping, harvest timing, in vitro fiber disappearance, triticale

INTRODUCTION

The use of triticale (X *Triticosecale* Wittmack) in dairy-cropping systems has expanded greatly in recent years, partly as a management tool to capture N from land-applied manure but also to improve stewardship of the land by providing winter ground cover. However, triticale also is recognized as a valuable forage crop (Maloney et al., 1999; McCormick et al., 2006; Baron et al., 2012) with potential for use across a range of livestock classes. Most production scenarios in the north-central United States target fall establishment after removal of corn for silage or soybeans (Schwarte et al., 2005; Gibson et al., 2007), followed by harvest as silage the following spring or early summer. Generally, a high-energy forage suitable for lactating dairy cows is obtained by harvesting when the flag leaf is fully emerged but no seed heads are visible (Kilcer et al., 2010). Using this management approach, triticale silage has been successfully substituted for corn silage in diets of lactating cows at a rate of 10% of dietary DM (Harper et al., 2017). However, harvests at the late milk to early dough stages of growth also have occurred

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commonly for cereal grain forages (McDonald et al., 1991; McCartney and Vaage, 1994; Kennelly and Weinberg, 2003), and this delayed harvest approach provides a considerable yield advantage (>300%) over harvest at the boot stage of growth for triticale (Coblentz et al. 2018). Substantial yield differentials between harvests at the boot and soft dough stages of growth also have been reported for other cereal grain forages (Acosta et al., 1991; Edmisten et al., 1998). In one study where triticale silage was harvested at the soft dough stage of growth, it was observed to be less acceptable than barley or oat silage for beef heifers and sheep, based primarily on poorer palatability and reduced DMI (McCartney and Vaage, 1994). Therefore, there is a need for both conceptual and empirical information providing guidance to producers on how to best manage and use triticale forages. An important component within this effort is an in-depth characterization of in vitro NDF disappearance kinetics for these forages.

It has long been understood that forage fiber is not homogeneous, and it is incompletely digested by ruminants, which can be illustrated clearly by application of a Lucas test (Van Soest, 1982). Within the Lucas concept, an ideal feed fraction is a feed component for which a regression of the amount digested is directly proportional to the amount of that feedstuff component consumed, thereby yielding a slope of approximately 1. Some components, such as ADL, may exhibit no digestion regardless of intake (slope = 0) and are also considered ideal. However, most fiber components, such as NDF, ADF, hemicellulose, and cellulose, are incompletely digested and are considered nonideal, resulting in a slope <1 but >0. The heterogeneous nature of forage fiber has long complicated nutritional models for dairy cattle as well as associated analysis techniques. In recent years, refinements in measuring in vitro NDF digestion to support existing nutritional models have emphasized (1) use of NDF measured with heat-stable α-amylase and sodium sulfite and corrected for residual ash (**asNDFom**), (2) determinations of indigestible NDF following a 240-h in vitro or in situ digestion (**U**), and (3) increased recognition that fiber digestion may be better characterized by more complex models that include rapidly and slowly degrading fiber pools (Raffrenato and Van Amburgh, 2010; Grant, 2015). In particular, these efforts have focused special attention on direct quantification of U rather than relying on the calculated estimate U = (2.4 × ADL)/NDF × 100% proposed by Chandler et al. (1980). Historically, kinetics of NDF degradation have been fitted to first-order 2-pool (**2P**) decay models comprising U and a potentially degradable NDF pool (**B**) using natural log (ln)-transformation or nonlinear regression techniques (Mertens and Loften, 1980; Nocek and English, 1986). Recently, this analytical paradigm has been challenged by the concept that forage fiber is not homogeneous and that NDF degradation kinetics characterized by fast (**Bfast**), slow (**Bslow**), and U pools (3 pools; **3P**) might better explain ruminal fermentation of NDF (Raffrenato and Van Amburgh, 2010; Grant, 2015; Mertens, 2016). This concept has been developed in conjunction with efforts to better estimate U at extended incubation times (~240 h), where plots of the natural logarithm of potentially digestible NDF remaining versus incubation time are curvilinear, suggesting that potentially digestible NDF may comprise fast- and slow-digested pools, each with a different digestion rate (Mertens, 2016). Initially, these concepts focused some attention on differences between forage types (Raffrenato and Van Amburgh, 2010); however, within-species effects of accumulated growing degree days (**GDD**) >5°C or plant growth stage at harvest have not been investigated. In a companion report, we described the effects of growth stage or GDD on various indices of nutritive value (Coblentz et al., 2018). Based on the increased use of triticale forages in the north-central United States, our objectives were to use 2P and 3P nonlinear models to characterize in vitro disappearance of asNDFom (**NDFD**) and then describe the relationship between estimated parameters from those models with plant growth stage or GDD for triticale forages harvested during 2016 and 2017 in Marshfield, Wisconsin.

MATERIALS AND METHODS

Forages

2016 Harvest. All specifics regarding establishment of triticale, soil fertility, fertilization, weather, and sampling procedures are described in detail in a companion report (Coblentz et al., 2018), and only a brief summary of salient points relevant to the experimental design is repeated here. Twenty-five 3.7-m × 9.1-m plots were established in 5 field blocks (5 plots/block) on September 30, 2015. Plots were no-till seeded into corn silage stubble with 'Forerunner' triticale (Legacy Seeds, Scandinavia, WI). Within each field block, the 5 plots were assigned randomly to 1 of 5 harvest dates based on a normal progression of advancing growth stages. During the spring and early summer of 2016, these growth stages and harvest dates were (1) stem elongation (May 19), (2) boot (May 25), (3) heading (May 31), (4) anthesis (June 9), and (5) soft dough (July 1). On each harvest date, 3 plants/plot were assessed for growth stage using the linear model suitable for serving as an independent variable for regression procedures (Stauss, 1994), where tillering = 20 to 29,