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Effect of diet composition and incubation time on feed indigestible neutral detergent fiber concentration in dairy cows

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ABSTRACT

Indigestible neutral detergent fiber (NDF) predicts forage digestibility accurately and precisely when determined by a 288-h ruminal in situ incubation, and it is an important parameter in mechanistic rumen models. The long incubation time required is a disadvantage. Further, intrinsic cell wall characteristics of feeds should be determined under ideal conditions for fiber digestion. The objective of this study was to determine the effects of diet composition and rumen incubation time on the concentrations of indigestible NDF (iNDF) for a wide range of feeds in dairy cows. Additionally, predicted concentrations of unavailable NDF generated using the National Research Council (NRC) model and the Cornell Net Carbohydrate and Protein System (CNCPS) were evaluated. Indigestible NDF was evaluated in 18 feeds using 4 cows in a split-split plot design. Treatments were in a 3 × 3 factorial arrangement, consisting of different diets and incubation times. Diet composition was primarily varied by changing the level of concentrate supplementation between 190 (low), 421 (medium), and 625 (high) g/kg of diet dry matter (DM). Grass silage was used as the basal forage for all cows. The feeds were incubated for 144, 216, and 288 h. Indigestible NDF was determined from 2-g samples weighed into polyester bags with a pore size of 12 μm and a pore area equal to 6% of the total surface area, giving a sample size to surface ratio of 10 mg/cm^2. Across all feeds, the measured iNDF concentrations ranged from 6 to 516 g/kg of DM. The feed iNDF concentration was not affected by the cow used, but diet composition had a significant effect. The mean measured iNDF concentrations for cows consuming low-, medium-, and high-concentrate diets were 178, 186, and 197 g/kg of DM, respectively. The incubation time also affected the feed iNDF concentrations, which averaged 199, 185, and 177 g/kg of DM for 144-, 216-, and 288-h incubations, respectively. We also observed significant interactions between incubation time and feed, and between diet composition and feed, with fiber-rich feeds being most sensitive to these factors. The evaluation of model predictions of unavailable NDF indicated poor precision with prediction errors of 56 (NRC) and 84 (CNCPS) g/kg of DM. Indigestible NDF should be determined based on 288-h ruminal in situ incubations in cows consuming diets with a low proportion of concentrate to represent the feed fraction that is unavailable to the animal.
Key words: concentrate level, dairy cow, in situ, indigestible neutral detergent fiber

INTRODUCTION

Ruminant animals can utilize fibrous plant material efficiently because their digestive system is based on microbial degradation in the forestomachs and the mechanism of selective retention of feed particles in the rumen. The potential of ruminants to digest the cell walls of plant material has been defined from the fraction of NDF that is not digested by the anaerobic rumen microbes given indefinite rumen residence; that is, the material that cannot be broken down by the ruminal microbiota even after an infinite period. The determination of the indigestible cell wall fraction is critical when describing digestion kinetics. This fraction is called indigestible NDF (**iNDF**) and describes the intrinsic properties of a plant's cell walls (Mertens, 1993). However, it is not known whether extrinsic factors such as the diet composition of the animal will influence iNDF concentration.

Concentration of iNDF accurately and precisely predicted forage OM digestibility when determined from a 288-h ruminal in situ incubation (Nousiainen et al., 2003). Moreover, the relationship between iNDF and forage OM digestibility was more consistent than those for other in vitro methods in predictions of OM digestibility (Huhtanen et al., 2006; Krizsan et al., 2012b). A rapid and cost-effective method for iNDF analysis by commercial laboratories has been developed from calibration of near infrared reflectance spectroscopy (**NIRS**; Nousiainen et al., 2004); NIRS is now routinely applied in iNDF analyses of farm samples in all Nordic countries. Indigestible NDF is, by definition, an

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ideal nutritional entity (Van Soest, 1994) because its digestibility is zero across a wide range of feedstuffs. Therefore, it has been used as an internal marker when measuring total-tract digestibility (Huhtanen et al., 1994), in estimates of rumen outflow (Ahvenjärvi et al., 2000), and as a marker for evaluating the rate of passage in rumen evacuation studies (Krizsan et al., 2010). Indigestible NDF is also an important parameter in dynamic rumen models (Danfær et al., 2006).

Despite the wide application of iNDF, few documented recommendations of the method exist. In situ and in vitro laboratory methods should ideally be calibrated against in vivo digestibility data. The long incubation time in situ required in the determination of iNDF is a disadvantage. Moreover, the intrinsic cell wall properties of feeds should be determined under ideal conditions for fiber digestion. The objective of this study was to determine the effects of diet composition and rumen incubation time on the concentrations of iNDF for a wide range of feeds in dairy cows. Additionally, predicted concentrations of unavailable NDF generated using the National Research Council model (NRC, 2001) and the Cornell Net Carbohydrate and Protein System (**CNCPS**; Fox et al., 2004) were evaluated.

MATERIALS AND METHODS

Experimental Design, Cows, and Diets

The animals used in this experiment were registered and cared for according to guidelines approved by the University Animal Care and Use Committee, and the experiment was carried out in accordance with the laws and regulations controlling experiments performed with live animals in Sweden. The effects of the proportion of concentrate in the diet (low, medium, and high) and incubation time (144, 216, and 288 h) on the concentrations of iNDF were evaluated for 18 feeds (10 classified as concentrate ingredients and 8 as forages) using 4 ruminally cannulated cows in a split-split plot design. Cow within period was the main plot observation, incubation time within cow and period was the sub plot, and feed within time, cow, and period was the sub-sub plot. Two cows were used on each occasion, over a total of 6 ruminal in situ incubations. Four in situ incubations were conducted with lactating cows averaging (SD) 92 (22.5) DIM at the start of the incubations, and 2 incubations were conducted with dry cows. Average BW (SD) for all cows, and milk production (SD) for the lactating cows at the start of the incubations were 585 (70) kg, and 31 (6.5) kg of milk, respectively. The diets and incubation times were organized in a 3 × 3 factorial arrangement.

Diet composition was primarily varied by changing the concentrate proportion, aiming at low, medium, and high inclusions of 200, 400, and 600 g/kg of diet DM. Grass silage was used as the basal forage for all cows during the incubations. The lactating cows were kept in a loose house system and offered TMR ad libitum in Roughage Intake Control feeders (Insentec B.V., Marknesse, the Netherlands), and their intake was recorded individually at each visit. The lactating cows were provided feed on 6 occasions daily as follows: 0400, 0700, 1000, 1300, 1600, and 1900 h. The TMR consisted of grass silage, crimped barley, and canola meal (ExPro, Lantmännen Lantbruk AB, Stockholm, Sweden) and were supplemented with a commercial concentrate (Solid 220; Lantmännen Lantbruk AB) provided in separate concentrate feeders (Cablevey Feeding Systems, Intraco Inc., Oskaloosa, IA). Crimped barley was ensiled using propionic acid (Perstorp AB, Perstorp, Sweden) applied at a rate of approximately 4 L/t, holding an average DM of 72%. The dry cows were kept in a pen that housed 11 cows in total and were group-fed to provide 5 to 6 kg of grass silage DM per animal and day. Additionally, the dry cows were fed 1 kg of the same commercial concentrate as the lactating cows on an air-dry basis in separate concentrate feeders. The restricted feeding of silage of the dry cows resulted in the lowest level of concentrate supplementation. Assuming an average value of 5.5 kg/d in silage DMI, the maximum proportion of concentrate would be 190 g/kg with a CV of 15% and 2 standard deviation units range in silage DMI. Composite samples of each dietary ingredient were made from 3 samplings during each of the 6 incubations. Feed samples were dried at 60°C for 48 h and ground through a 1.0-mm screen before chemical analysis. The proportion of dietary DM from each ingredient was calculated from the average DM determined for the 3 weekly samplings of feed samples after drying at 60°C for 48 h, and from observed or estimated total feed intake. The composition of each diet was calculated from the chemical composition of the dietary ingredients and the proportion of dietary DM contributed by each ingredient.

In Situ Incubations and Rumen Fluid Sampling

The iNDF concentration of each feed sample was determined following in situ incubations of 144, 216, and 288 h in the rumen using 2 cows at each occasion. Samples of 2 g were weighed into polyester bags with a pore size of 12 μm and a pore area equal to 6% of the total surface area (Saatifil PES 12/6, Saatitech S.p.A., Veniano, Italy). The internal dimensions of the nylon bags and the sample size were adjusted to give a