FIBER. PEELING BACK LAYERS OF COMPLEXITY TO IMPROVE ANIMAL HEALTH

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Abstract
Compared with other food constituents, fiber influences among the most diverse physiological functions, yet represents the most challenging to describe and quantify (Fahey, 2017). Fiber has been defined as a biological unit in relation to its role in plants. Fiber has been characterized analytically based on chemically recovered fractions. More recently, definitions related to fiber's physiological role in some animal species have been proposed. In fact, fiber for human diets was not formally defined until 27 May 2016 (FDA, 2016).

Fiber is not necessarily a single carbohydrate entity but can be a heterogenous mixture varying in quantity, characteristics and function. Plant cell walls are composed of insoluble lignin, cellulose, hemicellulose, pectin, gums, beta-glucans. Plant cell contents may include fructan polysaccharides. All these compounds are considered "fiber," the organic portion of feed resistant to endogenous vertebrate enzymes but may be considerably digested by gastrointestinal microorganisms (Van Soest, 1982). Fiber is not restricted to plants. Chitin, a structural carbohydrate found in cell walls of bacteria and fungi, and exoskeleton of insects and many marine invertebrates, may have a similar role as plant fiber in animal diets (Stevens & Hume, 1995).

Developed in the 1860's as part of the Proximate analysis system, fiber is characterized as crude fiber, an inconsistent and imprecise chemical procedure that persists today due in part to its regulatory required inclusion on animal feed labels. Beginning as early as 1889, the inadequacies of this method to characterize the fiber fraction of foods were presented. There is scientific community support to abandon this crude fiber for an appropriate replacement (Fahey, 2017).

Detergent fiber analysis, intended as a replacement for the crude fiber system, is a rapid method of dividing the dry matter into cell contents and cell wall constituents. Cell wall constituents insoluble in neutral detergent (e.g., cellulose, hemicellulose, fiber bound protein, lignin, and lignified nitrogen) are collectively measured as neutral detergent fiber (NDF). Soluble fiber (e.g., pectins, gums, beta-glucans) is not measured as part of the method. The insoluble NDF can be further characterized as acid detergent fiber (ADF; cellulose, lignin) and lignin (ADL). This system has been heavily used in agriculture since the late 1970's. Since that time, modifications of the procedure (i.e., sequential vs. nonsequential analysis; refluxing vs. automation) to improve its application to all feeds in individual laboratories resulted in variation among laboratories measuring "standard" samples. A standardized amylase-treated NDF method was developed and adopted by the AOAC (Mertens, 2002).

The total dietary fiber (TDF) method (AOAC 2009.001) divides non-starch polysaccharides into insoluble, slowly fermentable carbohydrates (e.g., cellulose, hemicellulose) and soluble, readily fermentable carbohydrates (e.g., pectins, beta-glucans, fructan polysaccharides). This analytical

method is used widely in human nutrition. TDF is gaining use in animal nutrition, particularly in the companion animal sector, with increasing evidence of the prebiotic benefits of dietary fiber.

Despite the widely accepted health benefits of both soluble and insoluble fibers, the perceived anti-nutritional factors of fiber described in the historic literature persist, with one undergraduate animal nutrition textbook describing the "feeding value [of an ingredient] as generally negatively related to fiber content" (Pond *et al*., 2005).

Empirical methods alone are inadequate to describe the nutritional concept of fiber. Fiber imparts physical properties and can lower caloric density of food. These physical properties may promote satiety, influence digesta passage and retention, alter digestibility, or influence fecal consistency in species (Edwards & Ullrey, 1999a, 1999b; Lickel, 2010; Edwards & Gordon, 2013; Modica, 2016).

Physically effective fiber (peNDF) is the physical characteristics of fiber (primarily particle size) that influence chewing and the biphasic nature of ruminal contents (the floating mat of large particles on a pool of small particles and liquid; Mertens, 1997). Effectiveness is an endpoint (Beauchemin, 2017). When the desired outcome is achieved, the fiber is considered effective.

In dairy cattle, effective fiber maintains chewing activity, ruminal pH, and milk fat percentages (Hall, 2017). Effective fiber (eNDF) is related to the sum ability of a feed to replace forage or roughage in a ration so that the percentage of fat in milk produced by dairy cattle consuming the ration is effectively maintained (Mertens, 1997).

Fiber effectiveness in other species has yet to be defined. Mean fecal particle size is proposed as an objective measure to evaluate fiber effectiveness, although the extent of mechanical particle size reduction that occurs in the oral cavity presents challenges for intraspecific comparisons (Fritz *et al*., 2010; Modica, 2016).

Fiber is perhaps the most important for the microbiome (Fahey, 2017). Commercial laboratories offered procedures to quantify (ruminant) in vitro fermentation of samples at fixed time points. Populations of microbiota are responsive to both soluble and insoluble fibers that escape digestion by the host and are delivered to the hindgut microbial ecosystem (Modica, 2016). Gut hypertrophy, sodium absorption, and protective mucin production are among many functions modulated via fiber by the microbiome (Fahey, 2017).

Although fiber consumption has been most closely associated with ruminant herbivores, the consumption of and beneficial role of fiber in nonruminant herbivores, fruigivores, and animalivores is widely recognized. Most analyses and response criteria used to characterize fiber in animal nutrition are derived from empirical research with dairy cattle. These measures focus primarily on insoluble fiber, which is appropriate for ruminants and the ingredients used to feed them in production environments. When formulating diets for animal species with food ingredients outside of this narrow range, the application of total dietary fiber, which characterizes both insoluble and soluble fiber, is more compelling.

Applying conventions accepted with other essential nutrients, it is reasonable to conclude animal species have a dietary fiber requirement. Furthermore, recommendations, deficiency, maximum tolerable, and toxicity fiber thresholds could be defined. Resolution of the complexities of quantifying both chemical and physical properties of fiber in feed ingredients, entangled with the challenge of measuring a “dose response” by the animal and/or microbiome, will allow experimental definition.

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