

Appendix D

Determination Of Energy Values For Fibers

A side issue related to how dietary fiber is defined is how its contribution to food energy is determined. Exact values for digestible, metabolizable, and net energy of fibers are difficult to determine. Differences in food composition, patterns of food consumption, the administered dose of fiber, the metabolic status of the individual (i.e., obese, lean, malnourished, etc.), and digestive capabilities of individuals influence the digestible energy consumed and the metabolizable energy available from various dietary fibers. Similarly, individual variation in physical and metabolic activities affects net energy. In addition, interspecies differences from basic research studies, the variety of analytical methods used, the numerous experimental variables tested, and the variation in standard operating procedures used by investigators make data interpretation difficult and hamper the determination of exact values for metabolizable energy and net energy from dietary fiber. Finally, the amount of carbon from dietary fiber that ends up as microbial matter and the nutrient trapping effect (i.e., more protein and fat are excreted in feces as a result of dietary fiber ingestion) affect the results obtained.

Despite these complexities, approximate values or ranges of values sufficiently accurate for regulatory purposes have been derived from available data. These values should be viewed with caution because many experimental animal studies and human clinical trials from which energy values are taken have differences in protocol design and conduct that make statistical analysis and comparisons difficult.

Several methods exist to determine the energy concentration of dietary fibers. These were reviewed by Fahey and Grieshop (2000) and include gross energy determination, energy balance method, factorial calculation of the metabolizable energy value, calculation of the net energy of maintenance, indirect calorimetry, breath hydrogen determination, and radiolabel technique.

Because the process of fermentation is anaerobic, less energy is recovered from dietary fiber than the 4 kcal/g obtained from aerobic glycolysis. Fermentation balance equations and molar ratios of short chain fatty acids in human stool can be used to estimate that anaerobic metabolism yields 2 to 3 kcal/g of hexose fermented (Hungate, 1966; Miller and Wolin, 1979), a calculation that assumed that short chain fatty acids were actively absorbed from the large intestine and that those generated by one strain of bacteria were not utilized by another microbial species.

Available data suggest that neither of these assumptions apply. It appears that the short-chain fatty acid, propionate, is utilized by some bacteria and is, therefore, unavailable for absorption. Also, data suggest that in monogastric species, short-chain fatty acids are passively absorbed from the large intestine, meaning that only when the concentration is greater in the colonic lumen than in the adjacent tissue does absorption occur (Fleming and Yeo, 1990).

Absorption of short-chain fatty acids is closely linked to the movement of water and electrolytes from the lumen, and participation in the normal secretory and absorption activities in the colon is one of the important physiological functions of short-chain fatty acids (Argenzio et al., 1975). Short-chain fatty acids are the main anions in human feces (Høverstad et al., 1984). Although this has not been well documented, humans, in contrast to most animals that consume highly defined diets, consume excess electrolytes and protein, the latter requiring ample buffering capacity. The role of short-chain fatty acids in electrolyte and acid-base balance undoubtedly dominates over their absorption and subsequent use as an energy source. Therefore, it is not possible for anaerobic fermentation to generate 4 kcal/g, and it is unlikely that the theoretical yield of 3 kcal/g is absorbed from the large intestine. Indeed, data indicate that the average energy yield from dietary fiber fermentation in monogastric species is in the range of 1.5 to 2.5 kcal/g (Livesey, 1990; Smith et al., 1998).