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In vitro digestion and fermentation methods, including gas production techniques, as applied to nutritive evaluation of foods in the hindgut of humans and other simple-stomached animals

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Abstract

For the purposes of food evaluation, in vitro digestion/fermentation methods are ethically superior, faster and less expensive than in vivo techniques, whilst still offering a degree of animal–food interaction that pure chemical analysis lacks. One such in vitro fermentation method is the in vitro gas production technique, which utilises the relationship between degradation and fermentative gas production to evaluate the nutritional parameters of foodstuffs. Several different methodologies have been proposed for the gas production technique, each varying in its complexity, shortcomings and benefits. Although the gas production technique has been used almost exclusively with ruminants, it may also be of value for nutritive evaluation of foods for man and other monogastric animals. The benefits of the technique include being able to run large batches simultaneously at low cost, the ability to measure fermentation kinetics of soluble as well as insoluble fractions of food, and the ability to easily make relative comparisons among different foodstuffs. This contribution reviews the in vitro gas production technique, and in vitro hindgut digestion assays generally, for their application in predicting in vitro hindgut digestion and fermentation in humans and monogastric farm animals. It is concluded that currently available in vitro digestion methods of relevance to human food evaluation

Abbreviations: DF, dietary fibre; DM, dry matter; GI, gastrointestinal; NSP, non-starch polysaccharides; OM, organic matter; RS, resistant starch; SCFA, short chain fatty acids; VFA, volatile fatty acids

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lack standardisation, in vivo validation and justification to support their specific methodology, and have not been tested with a wide range of fermentative substrates.

Keywords: Gas production; Fermentation; Digestibility; Monogastric; Hindgut

1. Introduction

Historically, and with regard to evaluating digestibility and availability of dietary energy in humans, in vitro digestion methods have focused primarily on upper tract digestion, the hindgut being considered of little nutritional significance (Dobbins and Binder, 1981; Cummings, 1983; Ramakrishna et al., 1990). However, the need for accurate in vitro methods to study digestion and fermentation in the hindgut of humans has become increasingly apparent given the recently recognised role of the hindgut in nutrition and gut health (Cummings, 1996; Williams et al., 2001a).

This review addresses in vitro methods, including the in vitro gas production technique, for the study of hindgut digestion and fermentation in humans and, where appropriate, as a means of comparison, in monogastric farm animals. The need for and purpose represented by in vitro digestion methods is discussed. The design features of batch in vitro fermentation methods are outlined along with a discussion of the criteria that a sound method should fulfill, and critical assessment of current in vitro hindgut digestion/fermentation methods.

2. The need for in vitro hindgut digestion/fermentation methods

In vitro hindgut digestion/fermentation methods for humans have been developed predominantly for pathophysiological studies, and specifically as a tool for greater understanding of colon cancer, its dietary causes, and possible prevention. The role of dietary fibre (DF) and its fermentation has been of considerable interest.

In addition to its physiological roles in maintenance of health and gut function, the dietary fibre component of food has a nutritional role. For humans on a typical Western diet low in dietary fibre, hindgut fermentation contributes around 3–11% of maintenance energy needs (Cummings, 1983; McNeil, 1984; McBurney et al., 1987; McBurney and Thompson, 1989; Cummings and Macfarlane, 1991), while for pigs, the value is more significant and may range from 7 to 40% (Yen et al., 1991; Breves et al., 1993; Freeman et al., 1993).

As diets rich in dietary fibre become more commonplace, a suitable means of studying and describing their fate in the digestive system is necessary. It is difficult and expensive to study nutrient digestion and fermentation in the human hindgut directly and there are important differences in hindgut function among different species of simple-stomached animals making the choice of an in vivo model difficult. Thus, there is an important potential role for in vitro techniques.