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The impact of dietary fibre intake on the physiology and health of the stomach and upper gastrointestinal tract

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ABSTRACT

This review is the first in a series of three articles considering how different types of dietary fibre may affect how the gut functions and gut health. This first review will focus on the impact of dietary fibre intake on the upper gastrointestinal tract (i.e. the mouth, oesophagus and stomach). While a larger body of evidence links fibre intake to bowel health and disease, it is apparent that the presence of fibre, whether as an added ingredient in foods, or as an integral part of the structure of plant foods, also plays key roles on oral and gastric secretions and upper gut motility. These actions are possibly modulated through fibre's effects on the physicochemical properties of luminal contents in the gut.

The major physiological functions of the mouth, oesophagus and stomach are discussed and recent evidence relating dietary fibre intake to these actions is introduced. A summary of evidence linking habitual dietary fibre consumption to major mucosal diseases of the upper gastrointestinal tract is also provided.

Contents

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1. Introduction

An updated definition of dietary fibre was recently presented by Codex (Jones, 2014). This newer iteration has, within the long-standing definition of dietary fibre as indigestible carbohydrates of dietary origin, included resistant starches clearly within the definition while omitting lower chain-length saccharides (i.e. those between three and nine units long). Some countries still retain the shorter saccharide chains within their definition of dietary fibre (De Menezes, Giuntini, Dan, Sardá, & Lajolo, 2013). Regardless of these solidifications the consensus definition, it is important to note that the term dietary fibre represents a wide spectrum of different compounds, with divergent molecular structures and physicochemical properties. While dietary fibre intake is generally accepted as part of a positive dietary template with regards to improved health outcomes in many major, non-communicable diseases (European Heart Network, 2011; World Cancer Research Fund/American Institute for Cancer Research, 2007), the exact action through which fibre may have such effects is not well characterised. The association with higher fibre intake and improved health comes as a result of findings from large observational studies (Bingham et al., 2003; Howe et al., 1992; Hu et al., 2001; Rimm et al., 1996). Even with meticulous consideration of other confounding lifestyle factors (Kratz, Baars, & Guyenet, 2013), such evidence cannot separate the impact of dietary fibre intake from the intake of its major dietary sources (i.e. fruits, vegetables and cereal products) from other putatively beneficial components within these foods (Mellen et al., 2007), or the broader effect that inclusion of high amounts of these foods within the diet may have to displace other less optimal food choices (Bogart et al., 2014; Lazzeri et al., 2013).

Recent research on dietary fibre has tended to focus on how different types of fibre might interact with the large bowel microflora (e.g. Flint, 2012; Kaoutari, Armougom, Gordon, Raoult, & Henrissat, 2013; Kumar, Sinha, Makkar, de Boeck, & Becker, 2012; Shen, Zhao, & Tuohy, 2012). The mouth and stomach play crucial roles in mechanical, chemical and enzymatic digestion of food and are also thought to be key roles in appetite regulation and microbial defence (Jolliffe, 2009; van der Bilt, Engelen, Pereira, van der Glas, & Abbink, 2006). Aside from this, the sensing of texture and chemical composition of ingested foods results in neurohumoral signals being sent to other parts of the body, which can result in acute and long-term changes to whole body metabolism (Côté, Zadeh-Tahmasebi, Rasmussen, Duca, & Lam, 2014; Depoortere, 2014; Chen, 2009).

The current review is the first of a series of reviews within this journal that aim to update a previous, broader work considering the physiological roles of dietary fibres (Brownlee, 2011). Each review will focus on the actions of dietary fibre on a section of the gastrointestinal tract and critically consider the recent evidence in this field and highlight potential areas for future research. This review series will also highlight how inclusion of increasing amounts of fibre-rich food in the diet could relate to longer-term health consequences within the gut. As the first article in this series, it seems relevant to start with the mouth, oesophagus and stomach and work aborally in the future reviews (focused at the small intestine and large intestine).

2. Bolus production in the mouth

The mouth's major role in digestion is to grind food into more homogenous, softer entities (boluses) that can be swallowed and pass through the oesophagus to the stomach. Only minor digestion of macronutrients is believed to occur as a result of oral secretions (Pedersen, Bardow, Jensen, & Nauntofte, 2002). The main effectors of this homogenising process (known as mastication) are the teeth and a complex arrangement of the major facial muscle groups, namely the masseter, temporalis, lateral and medial pterygoid, digastric, milohyoid and geniohyoid muscles (Le Révérend, Edelson, & Loret, 2014). The action of mastication results in texture analysis of the ingested food in two ways. First, the amount of force that the muscles of mastication produce appears to provide signals (possibly generated in the muscle spindle) back to the medial division of the central nucleus of the amygdala, a structure well-linked to the development of conditioned responses (Lund & Kolta, 2006; Van Daele, Fazan, Agassandian, & Cassell, 2011). Second, the periodontal ligament that attaches teeth to the surrounding bone tissue is momentarily deformed by the deflection of the inset tooth as a result of chewing. The deformation leads to signal production from mechanoreceptors within the periodontal ligament. This signal is conveyed to the trigeminal nucleus area that occurs across the entire brainstem (Yamaguchi, Nakajima, & Kasai, 2012). It could be hypothesised that the hardwiring of these receptors to the brain allows development of conditioned food choice based on previous experience of texture analysis of foods. In other words, our previous feeling of pleasure or enjoyment associated with prior eating experiences could become linked to specific textures. Subsequent eating experiences that match that specific texture may therefore also be seen as positive, whereas subsequent eating experiences that do not match previous texture expectations may be viewed negatively. It must be noted that this would be extremely difficult to evidence experimentally.

Dietary fibre plays a key role in the texture of both plant-based foods and foods with added dietary fibre. In fruits and vegetables, the process of ripening is particularly important in the oral sensation of food. This process is perhaps primarily governed by the rate at which pectin (a highly branched polysaccharide mainly made up of uronic acid monomers) is degraded (Champa, Gill, Mahajan, & Arora, 2014; Guzmán, Sánchez, Salas, Del Moral, & Valenzuela, 2012). Pectin binds to water in the cell wall structure of plants, thereby exerting hydrostatic pressure onto the cellulose and hemicellulose lattice surrounding it (Jarvis, 2011). This increases the turgidity of plant tissues and thereby is a major factor in the perceived firmness, crunchiness and other organoleptic properties of plant foods, particularly those frequently consumed uncooked or with minimal processing (e.g. Billy et al., 2008; Makkumrai et al., 2014). Similarly, loss of the cellulose/hemicellulose meshwork around the pectin matrix is also likely to lead to changes in organoleptic