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Pectin is not pectin: A randomized trial on the effect of different physicochemical properties of dietary fiber on appetite and energy intake

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HIGHLIGHTS

- Physicochemical properties may differ within a defined class of fiber.
- Dietary fibers with different physicochemical properties differently affect appetite.
- The method of dietary fiber supplementation affects appetite.
- A reduction in appetite is likely mediated by preload physical properties.

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ABSTRACT

An increased intake of dietary fiber has been associated with reduced appetite and reduced energy intake. Research on the effects of seemingly identical classes of dietary fiber on appetite has, however, resulted in conflicting findings. The present study investigated the effects of different fiber properties, including methods of supplementation, on appetite and energy intake. This was a randomized crossover study with 29 subjects (21 ± 2 y, BMI: 21.9 ± 1.8 kg/m^2) consuming dairy based liquid test products (1.5 MJ, 435 g) containing either: no pectin, bulking pectin (10 g), viscous pectin (10 g), or gelled pectin (10 g). The gelled pectin was also supplemented as capsules (10 g), and as liquid (10 g). Physicochemical properties of the test products were assessed. Appetite, glucose, insulin and gastric emptying were measured before ingestion and after fixed time intervals. Energy intake was measured after 3 h. Preload viscosity was larger for gelled > viscous > bulking > no pectin, and was larger for gelled > liquid > capsules. Appetite was reduced after ingestion of gelled pectin compared to bulking ($p < 0.0001$), viscous ($p = 0.005$) and no pectin ($p < 0.0001$), without differences in subsequent energy intake ($p = 0.32$). Gastric emptying rate was delayed after gelled pectin (82 ± 18 min) compared to no pectin (70 ± 19 min, $p = 0.015$). Furthermore, gelled ($p = 0.002$) and viscous ($p < 0.0001$) pectin lowered insulin responses compared to no pectin, with minor reductions in glucose response. Regarding methods of supplementation, appetite was reduced after ingestion of the gelled test product compared to after capsules ($p < 0.0001$) and liquid ($p < 0.0001$). Energy intake was lower after ingestion of capsules compared to liquid (−12.4%, $p = 0.03$). Different methods of supplementation resulted in distinct metabolic parameters. Results suggest that different physicochemical properties of pectin, including methods of supplementation, impact appetite and energy intake differently. Reduced appetite was probably mediated by preload physical properties, whereas inconsistent associations with metabolic parameters were found.

1. Introduction

An increased intake of dietary fiber has been associated with increased satiety and reduced energy intake [1–3]. Dietary fibers may affect satiety via diverse mechanisms. These include: lowering the energy density of a food; increasing sensory exposure time to a food in the oral cavity; slowing down gastric emptying; modifying the postprandial glucose response; and changing neural and humoral signals in the gut [1–3].

Dietary fiber is a term that reflects a heterogeneous group of compounds which differ in their chemical structure and physicochemical properties [4]. In a systematic review we observed that effects of dietary fiber on satiety can differ due to different fiber properties, but effects can also differ due to the interaction of fiber with the food matrix [5]. At present, most intervention studies on the satiating effects of dietary

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fiber comprise effect studies of one specific fiber or fiber mixture. Moreover, many studies do not describe the physicochemical properties of the fibers [6,7], even though earlier research has highlighted the importance of fiber characterization (e.g. [8–10]). Hence, the present study aims to systematically explore the effects of different fiber properties and different supplementation methods on appetite and subsequent energy intake.

Variations in effects between seemingly identical classes of fibers may be explained by differences in molecular structure. A good example of a fiber that is naturally present in many different molecular structures is pectin. Pectin as present in fruit and vegetables is one of the major plant cell wall components, and depending on its molecular weight and degree of esterification, pectin can vary in its viscosity and gelling ability [11]. The viscosity of a liquid refers to the resistance to flow, informally described as "thickness", whereas gelation is the cross-linking and formation of three-dimensional networks of molecules that can entrap the liquid and behave like solids, which is commonly called "gel".

Apart from the molecular structure of the fiber, also the interaction of the fiber with foods or food components, processing procedure during food preparation, as well as its interaction with gastrointestinal content may differentially affect satiety [12,13]. When mixed with liquids, soluble fibers are expected to hydrate. When hydrated, viscous fibers may induce thickening and gel forming fibers may start forming a gel, if the required conditions are fulfilled (e.g. presence of Ca^{2+} or H^{+}, temperature, etc.) [14,15]. The thickening or gelling of a fiber depends therefore not only on factors such as the molecular weight and degree of esterification, but also on the rate of hydration and the gastrointestinal environment.

The present study aimed to investigate whether different physicochemical properties of one specific dietary fiber class affect appetite sensations and subsequent energy intake differently. The secondary aim was to explore the underlying mechanisms for potential differences. To accomplish this, pectins with different physicochemical properties were added to a dairy based liquid food matrix. The different treatments selected were: 1) no pectin (control), 2) non-viscous, non-gel forming pectin (hereafter referred to as bulking), 3) viscous pectin and 4) gel-forming pectin (gelled), which were all provided hydrated in the food matrix. Furthermore, the gel forming pectin was provided in two more supplementation methods: 5) not hydrated, as capsules, and 6) hydrated-but not yet gelled, as two separate liquids (hereafter referred to as liquid). Together these six treatments test the effects of (a) the fiber bulking, viscosity and gelling properties on appetite sensations and energy intake, and (b) the effects of supplementation methods that affect hydration and gel formation on appetite sensations and energy intake.

2. Subjects and methods

2.1. Subjects

Thirty healthy young men (aged 18 to 30 y), with a normal BMI (18.5–25.0 kg/m^2) were recruited from Wageningen, The Netherlands, and surroundings. Exclusion criteria were as follows: scoring high on restrained eating (Dutch Eating Behavior Questionnaire (DEBQ), score > 2.89) [16], lack of appetite, an energy restricted diet during the past two months, body weight change > 5 kg during the past two months, stomach or bowel diseases, hypersensitivity for the ingredients of foods under study, diabetes, thyroid disease or any other endocrine disorder, fasting glucose > 5.8 mmol/L, anemia (Hb < 8.0 mmol/L), smokers and heavy alcohol users (>5 drinks a day). We also excluded subjects donating blood six weeks before or during the study. In total, 29 men with a mean age (±SD) of 21 ± 2 y, a BMI of 21.9 ± 2.8 kg/m^2 and a DEBQ score of 1.8 ± 0.5 completed the study. One subject dropped out after 3 test days due to intestinal problems. The subjects were unaware of the exact aim of the study and were informed that we were interested in the effect of dietary fiber on metabolic parameters. They were informed about the other outcome measures after the study. To detect a difference in energy intake of 10% between pairs [17,18], which has been considered to be a biologically meaningful effect size [19] (CV = 13% [20], $\alpha = 0.05$, $1 - \beta = 0.8$), a sample size of 30 subjects was calculated, given an anticipated dropout rate of 10%.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Medical Ethics Committee of Wageningen University (registration number NL 33684.081.10). Written informed consent was obtained from all subjects. The study was registered in the NIH clinical trial database (ClinicalTrials.gov number NCT01257295).

2.2. Test products

In Table 1 the ingredients and specifications of the test products are given. The basic recipe of the six test products consisted of a mixture of soft cheese (quark), milk, apple juice and strawberry syrup. The test products were served with water. To each test product, 10 g of pectin was added, but the type of pectin and the method of supplementation differed. The six test products contained: 1) no fiber (control); 2) non-viscous, non-gel forming pectin (hereafter referred to as bulking); 3) viscous pectin; 4, 5 and 6) gel forming pectin (gelled). To hydrate the pectins, the apple juice and syrup were heated to 80 °C before the pectin was added and dissolved. After cooling down, the soft cheese and milk were added. Product 6 was composed slightly different and consisted of two liquid drinks (hereafter referred to as liquid), served with 200 g apple juice. The two liquids were consumed in a fixed order, first the pectin liquid, then the dairy liquid. For gastric emptying measurements, 100 mg of $1-^{13}$C-sodiumacetate was added to all the test products. The test products were prepared twice per week and stored for a maximum of two days at 7 °C. The energy content of each test product corresponded to an estimated 13% of the daily energy requirements in young male adults [21], which was 1544 kJ (366 kcal), excluding the available energy from fiber. Other macronutrients were 12 g of protein (13% of energy (en%), 49 g (54en%) of carbohydrates and 14 g (34en%) of fat.

Preload viscosity of the test products as consumed was measured at 20 °C using a rheometer (MCR 300, Anton Paar, Graz, Austria). A shear sweep was performed at 0.1–1000/s in logarithmic scale. Data obtained at a shear rate of 90/s were used to compare between the samples. Viscosity and water holding capacity of the test products were also measured under simulated 'oral' and 'gastric' conditions according to methods described earlier [22], with adaptations for the high water content of the products, and adjustments for simulating the different methods of supplementation. In short, after simulation of 'oral' and 'gastric' conditions with enzymes and reagents, the samples were centrifuged. Viscosity was measured in the supernatant at 37 °C and data obtained at a shear rate of 100/s were reported. Water holding capacity was measured from the pellet containing the insoluble material. The water holding capacity was expressed as the amount of water held by the insoluble material from 100 g of the test product.

2.3. Study design

The study was a randomized cross-over experiment, blinded for subjects, with six test sessions of approximately 4 h. The study ran from January to June 2011. The six test products were randomized according to a Williams Latin Square. Thirty unique orders were produced by computer generated numbers and allocated by the date upon entering the study. The washout period between test sessions was at least 12 days.