Available online at www.sciencedirect.com

ScienceDirect

www.nrjournal.com

Original Research

Fiber content of diet affects exhaled breath volatiles in fasting and postprandial state in a pilot crossover study

*Kaisa J. Raninen, Jenni E. Lappi, Maria L. Mukkala, Tomi-Pekka Tuomainen, Hannu M. Mykkänen, Kaisa S. Poutanen, Olavi J. Raatikainen**

Institute of Public Health and Clinical Nutrition, University of Eastern Finland, PO Box 1627, 70211, Kuopio, Finland

ARTICLE INFO

Article history:
Received 30 November 2015
Revised 15 February 2016
Accepted 16 February 2016

Keywords:
Exhaled breath
Volatile organic compounds
Dietary fiber
Postprandial test
Randomized crossover trial

ABSTRACT

Our pilot study examined the potential of exhaled breath analysis in studying the metabolic effects of dietary fiber (DF). We hypothesized that a high-fiber diet (HFD) containing whole grain rye changes volatile organic compound (VOC) levels in exhaled breath and that consuming a single meal affects these levels. Seven healthy men followed a week-long low-fiber diet (17 g/d) and HFD (44 g/d) in a randomized crossover design. A test meal containing 50 g of the available carbohydrates from wheat bread was served as breakfast after each week. Alveolar exhaled breath samples were analyzed at fasting state and 30, 60, and 120 minutes after this meal parallel to plasma glucose, insulin, and serum lipids. We used solid-phase microextraction and gas chromatography–mass spectrometry for detecting changes in 15 VOCs. These VOCs were acetone, ethanol, 1-propanol, 2-propanol, 1-butanol, acetic acid, propionic acid, butyric acid, valeric acid, isovaleric acid, 2-methylbutyric acid, hexanoic acid, acetoin, diacetyl, and phenol. Exhaled breath 2-methylbutyric acid in the fasting state and 1-propanol at 120 minutes decreased (P = .091 for both) after an HFD. Ingestion of the test meal increased ethanol, 1-propanol, acetoin, propionic acid, and butyric acid levels while reducing acetone, 1-butanol, diacetyl, and phenol levels. Both DF diet content and having a single meal affected breathVOCs. Exploring exhaled breath further could help to develop tools for monitoring the metabolic effects of DF.

1. Introduction

Epidemiological studies demonstrate that intakes of dietary fiber (DF) and whole grain foods is inversely related to many chronic diseases including type 2 diabetes [1]. Rye bread, a major source of whole grain and DF in the Northern Europe, has beneficial effects on postprandial insulin responses [2,3] and glucose metabolism after prolonged use [4]. The

Abbreviations: BCFA, branched-chain fatty acid; DF, dietary fiber; GC-MS, gas chromatography–mass spectrometry; HFD, high-fiber diet; IS, internal standard; LFD, low-fiber diet; RT, retention time; SCFA, short-chain fatty acid; SPME, solid-phase microextraction; VOC, volatile organic compound.

* *Corresponding author at:* University of Eastern Finland Kuopio campus, Institute of Public Health and Clinical Nutrition, PO Box 1627, FI-70211, Kuopio, Finland. Tel.: +358 405505971 (GSM).

E-mail addresses: kaisa.raninen@uef.fi (K.J. Raninen), jenni.lappi@pakkasmarja.fi (J.E. Lappi), maria.mukkala@gmail.com (M.L. Mukkala), tomi-pekka.tuomainen@uef.fi (T.-P. Tuomainen), hannu.mykkanen@uef.fi (H.M. Mykkänen), kaisa.poutanen@vtt.fi (K.S. Poutanen), olavi.raatikainen@uef.fi (O.J. Raatikainen).

http://dx.doi.org/10.1016/j.nutres.2016.02.008
0271-5317/

mechanisms behind these associations are unclear but may involve gut-related events [5,6]. Production of short-chain fatty acids (SCFAs) and release of phenolic compounds by gut microbes are maybe involved in the improvement of glucose metabolism [7,8]. However, it is challenging to study these mechanisms because of the large variability in human gut microbiota and anaerobic conditions in the gut. New noninvasive tools are warrended to study the gut-related effects of DF.

Effects of nutrients are usually investigated using blood and urine analysis, but exhaled breath is also a potential matrix of increasing interest because of noninvasive sampling and instant responses. There are almost 900 volatile organic compounds (VOCs) in the exhaled breath of healthy humans [9]; thus, it is possible to find new biomarker compounds in exhaled breath relating to a specific metabolic event or quality of diet. Nevertheless, there are essentially only 2 types of breath tests used in the nutritional and gastroenterology studies: ^{13}C-isotope and hydrogen [10], although also methane [11,12] and some VOCs [13] have been considered essential in monitoring gastrointestinal disorders. Thus far, there have been only a few study monitoring the effects of diet on the composition of exhaled breath [14–18]. Many possibilities of measuring microbial VOCs exist for health applications [19,20], such as analyzing VOCs in fecal samples from gastrointestinal patients [21,22]. Exhaled breath could be used to study the gut-related metabolic effects of DF because the bacterial fermentation of DF produces numerous volatile metabolites [6].

Our aim was to examine the potential of exhaled breath analysis to study the metabolic effects of DF. We hypothesized that a diet high in DF containing whole grain rye increases microbial fermentation in the gut, which in turn increases the levels of these VOCs in the circulation and in exhaled breath. Furthermore, we postulated that consuming a single meal changes the levels of these compounds in exhaled breath postprandially by activating the digestion and absorption processes in the gut. To test these hypotheses, a pilot dietary intervention with crossover design with 2 diets different in DF content was conducted; postprandial tests in the end of the diet periods were carried out, and the levels of selected VOCs were monitored from exhaled breath.

2. Methods and materials

2.1. Protocol

A randomized crossover study with 2 different diets was performed. The test diets were a low-fiber diet (LFD) and a high-fiber diet (HFD) both lasting for a week. The subjects followed their habitual diet during a 2-week washout period between the diet periods. They were advised to maintain their body weight and lifestyle habits throughout the study. The compliance was monitored by weighing and using 4-day food records and activity computers (Polar Electro, Finland), which recorded physical activity during the diet periods. Blood and exhaled breath samples were taken in postprandial tests at the end of the diet periods. The study protocol was approved by the Research Ethics Committee, Hospital District of Northern Savo. Each individual provided a written informed consent before participation in the study.

2.2. Study participants

Seven men were recruited with campus advertising in the University of Eastern Finland. The subjects were healthy (no diagnosis of chronic diseases and no evidence of disturbed glucose metabolism), nonsmokers, and 25 to 46 years old (average age 32) and had an average body mass index 26.0 kg/m^2 (21.7-32.5 kg/m^2) and regular eating and exercise habits.

2.3. Diets

The recommended energy level for each subject was calculated using the formula of Mifflin-St Jeor [23], and the amount of DF was adjusted to 7.5 g/1000 kcal (4180 kJ) during the LFD and 15 g/1000 kcal (4180 kJ) during the HFD period. During the LFD, low-fiber cereal products such as white wheat bread, white rice, and pasta were recommended, and during the HFD, high-fiber cereal products such as wholegrain rye bread, wholegrain pasta, and muesli were recommended. The subjects were advised to limit their fruit and vegetable intake to 3-4 servings per day, depending on their estimated energy level, and the intake of berries to 1 dL/wk and to avoid oat and barley porridge, and oat pasta during the diet periods. In addition, they received instructions to avoid foods that affect bowel function, such as legumes, plums, dried fruits, seeds, brans, and licorice. Otherwise, the subjects were supposed to maintain their habitual diet. Compliance with the diets was monitored by 4-day food records maintained by the subjects during the diet periods. Diet32 software (Aivo Finland Oy, Turku, Finland) was used to calculate nutrient intake.

2.4. Postprandial test

Postprandial tests were performed at the end of the diet periods in the morning after an overnight fast of about 12 hours. The subjects were advised to avoid exhausting physical exercise, sauna bathing and heavy meals the previous 24 hours and to abstain from alcohol ingestion 48 hours before the tests. To standardize the bacterial fermentation in the mouth, the subjects were asked to brush their teeth with a toothpaste in the morning of the test day and again without a toothpaste before the first breath sample and after the test meal.

The subjects consumed a test meal containing 50 g of the available carbohydrates (106 g of sliced white wheat bread) and 3 dL energy-free juice (Funlight, Felix Abba Oy Ab, Turku, Finland). The bread was stored frozen and thawed at room temperature before the test. The subjects were advised to consume the test meal within 10 minutes and to use equal amount of time during both test meals.

Blood and breath samples were collected before the meal (fasting) and at 30, 60, and 120 minutes after starting the meal. Venous blood samples were analyzed in the Research Institute of Public Health (University of Eastern Finland, Kuopio, Finland) for glucose and insulin from plasma, and total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides from serum.