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Whole-Grain and Refined Wheat Flours Show Distinct Metabolic Profiles in Rats as Assessed by a ^{1}H NMR-Based Metabonomic Approach[1]

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Abstract

The protection against diabetes and cardiovascular disease provided by whole-grain cereal consumption has been attributed to the fiber and micronutrients present in the bran. But exactly how this occurs remains unclear due to both diversity of bran constituents and the complexity of the metabolic responses to each of these constituents. We investigated the metabolic responses of 2 groups of rats ($n = 10$/group) fed 2 diets, for 2 wk each, in a crossover design. One diet contained 60 g/100 g whole-grain wheat flour (WGF) and the other contained 60 g/100 g refined wheat flour (RF). Markers of oxidative stress [urinary isoprostanes and malondialdehydes (MDA), plasma ferric-reducing ability of plasma, MDA, and vitamins E and C] and lipid status (liver and plasma triglycerides and cholesterol) were measured. Urine samples collected during the feeding periods and plasma and liver samples collected at the end of experiment were analyzed by ^{1}H NMR spectroscopy. Metabonomic analyses showed that each group reached a new metabolic balance within 48 h of changing the diet. Urinary excretion of some tricarboxylic acid cycle intermediates, aromatic amino acids, and hippurate was significantly greater in rats fed the WGF diet. Although the diets did not affect conventional lipid and oxidative stress markers, there were decreases in some liver lipids and increases in liver reduced glutathione and betaine as shown by metabonomic analyses. These suggest that the WGF diet improved the redox and lipid status. J. Nutr. 137: 923–929, 2007.

Introduction

Epidemiological studies suggest that whole-grain cereal consumption protects against metabolic diseases such as atherosclerosis, diabetes, and cancer (1). Whole-grain products differ from refined products by their bran content, which is rich in fiber, micronutrients, and other phytochemicals. These compounds are thought to improve bowel physiology and lipid and antioxidant status, and help suppress tumor growth (2,3). The hypocholesterolemic effects of some cereal products are attributed to fiber, particularly soluble fiber (4). Some authors have also suggested that certain antioxidants in whole-grain cereals improve redox status and decrease the risk of associated disorders (2,5,6). However, apart from some studies on colored rice varieties that are particularly rich in antioxidants (7), these effects have not been established in in vivo studies.

Exactly how whole-grain cereals protect against metabolic diseases remains largely unknown, partly because of the diversity of the active constituents in whole-grain products and partly because of the complexity of the metabolic responses to each of them.

^{1}H NMR spectroscopy or MS can be used in a metabonomic study to analyze simultaneously several hundreds or thousands of metabolites in biological fluids such as urine, plasma, or tissues (8). Multivariate statistical analysis is then used to identify markers influenced by an intervention (9). This approach is capable of describing the effects of diet on metabolism, because it can assay many metabolites in a single sample; traditional approaches focused on specific biomarkers often fail to detect metabolic changes. Metabonomic studies on the influence of complex foods or diets on metabolic profiles have been used only rarely to date. The regular consumption of chamomile tea was shown to influence urinary metabolic profiles in humans (10). These effects were persistent and still observed 14 d after ending chamomile consumption, possibly because of some modifications of the gut microbiota. Ingesting soy isoflavone affects human endogenous metabolism, including osmolyte fluctuation and energy metabolism (11). A metabolomic study also revealed some effects of epicatechin consumption on the endogenous metabolism of rats (12).

We have postulated that there are detectable, unequivocal differences in the metabolism of animals consuming whole-grain

[1] Supplemental Figures 1 and 2 are available with the online posting of this paper at jn.nutrition.org.

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