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Is Whole Cereal Grain a Functional Food? What is the Functional Food Concept Trying to Accomplish?

David R. Jacobs, Jr.

Division of Epidemiology, School of Public Health, University of Minnesota, Minneapolis, MN 55454, USA. E-mail: jacobs@epi.umn.edu

ABSTRACT

The relatively new concept of functional foods is supportive of sales of food products that deliver isolated 'nutrient' or 'food compound' substances, much as is done by dietary supplements. Whether such isolated substances have benefit must be investigated in each instance; such investigations can be complex. At the same time, simply prepared natural plant foods contain a myriad of substances that, in accord with the concept of food synergy, are beneficial for health. Whole grain foods are an example of such healthy fare, based on strong epidemiologic and experimental evidence. If the concept of functional foods is to be of use for the public health, it should support the consumption of healthy traditional foods as well as promoting "novel" foods; in this sense, whole grain foods, which have great functionality, should be regarded as functional foods.

INTRODUCTION

There has been much discussion of functional foods in recent years. In parallel, epidemiologic and experimental work points to a health benefit of whole grain consumption. This article reviews the concept of functional foods, the evidence for a health benefit of whole grain foods, and the role of functional foods and whole grain foods in the health of the public and of the economy.

Definition of Functional Foods

Various authors have defined functional food. Roberfroid and Slavin say it is "a food ingredient which affects physiological function(s) of the body in a targeted way so as to have positive effect(s) which may, in due course, justify health claims" (1). The General Accounting Office of the US Government has described a functional food as one with a "claim to have health benefits beyond basic nutrition" and stated that the boundary between functional foods and dietary supplements is blurred (2). Palou, Pico, and Bonet (3) say, "Functional foods have at least one component, whether it be a nutrient or not, that affects the target functions of the organism in a specific, positive way and produces a physiologic effect beyond its traditional nutritional value". Palou et al. (3) virtually equate functional foods with "novel foods", citing European legislation (4) that includes "transgenic foods; foods and ingredients that have a new molecular structure; those derived from microorganisms, fungi and algae; those from animals and plants that are reproduced from nontraditional methods; and those obtained with new production processes involving significant changes in the composition or structure of the foods or ingredients that affect their nutritional value, metabolism or levels of non-desirable substances."

These three definitions are approximately summarized in Table 1. They have much in common, with focus on targeting a particular condition, emanating from a single novel change in the food, and going beyond a baseline

Table 1. Correspondence of whole grain foods with functional foods definition

Functional foods criterion	Do whole grain foods satisfy criterion?
Food with active component	Yes - probably many such, in common with many other natural foods
Targeted beneficial physiologic effect	Yes, both cardiovascular diseases and diabetes
Beyond basic nutrition	No
Novel	No

of "basic nutrition". Interestingly, though, none of these authors define "basic nutrition". Palou et al. (3) come close when they refer to an "adequate diet" as one that provides enough nutrients to ensure survival, satisfy metabolic needs, and pleasantly gratify the sensation of hunger; this as opposed to an "optimum diet", that is one that benefits health.

The words "adequate diet" do not ring true. How can a diet that does not maintain health be called adequate? Is a proatherosclerotic diet adequate? There is a logical inconsistency here, well illustrated by the case of whole grain foods. Whole grain foods have the functionality of reducing heart disease, stroke, and diabetes risk (5). A bread made from whole grain certainly satisfies the intent of beneficially targeting a certain illness and of doing so in a way that is novel compared to current dietary habits in most Western cultures, wherein most grain is consumed in a suboptimal, refined form. Yet, it seems that whole grain foods do not meet the above definitions of functional food (Table 1). The grains of cereal grasses have been eaten traditionally at least since the advent of agriculture 10,000 years ago; wild grass seeds were probably gathered and eaten long before that. Furthermore, it seems that the health benefit of whole grain foods depends not on a single ingredient, but on synergy of the constituents of the bran, germ, and endosperm (6). They are not "novel" in the sense that their development was not recent. Bread made from whole wheat is therefore probably not a functional food. On the other hand, ironically, a bread might qualify as a functional food if it were made from a genetically-engineered species of wheat that has a white-colored outer covering (bran and germ), so that the whole wheat bread looks like refined white bread. Whether such genetically engineered change would have any unanticipated adverse consequence would require investigation.

Evidence that Whole Grain Reduces Risk of Diabetes and Heart Disease

As we have previously noted (5), refined grain is formed during conventional cereal grain milling by removing the bran and germ. In the process almost all biologically important molecules except starch are lost. Whole grain food, on the other hand, contains bran, germ, and endosperm in their natural proportions, approximately 13% bran, 2% germ, and 85% endosperm, depending on the grain. All the parts of the grain are present in whole grain foods, but the kernel may be crushed. Crushing and pulverizing to a fine flour is not likely to cause much damage to the many phytochemicals contained in the whole grain, given the microscopic size of cells. In fact, some disruption of the cells may actually increase digestibility. However, the larger particle size of intact or sliced grains does improve the glycemic index (lower glucose response after eating). Among the compounds contained in the bran are most of the fiber, many B-vitamins, minerals, and major groups of antioxidants including several cinnamic acids, flavonoids, and tocopherols, as well as unidentified compounds. The germ is rich in fatty acids and antioxidant compounds. The bran and germ perform many functions on behalf of the plant, including signaling activation of biologic processes, preventing adverse oxidation, and defense of the seedling

against microorganisms. The endosperm contains mostly starch and serves as the food source for the new plant before it takes root.

Our recent review (5) found 13 observational cohort studies (Table 2) of whole grain food intake and cardiovascular diseases, mostly in people who were middle-aged at year 0 (one study was restricted to age >65). Most were conducted in the United States, one study was in Norway, 2 in Finland, and 1 in England. They included 481,134 men and women with followup of 6 to 19 years. There were over 8700 heart attacks, strokes, or other cardiovascular disease, either fatal or nonfatal. The relative risk for high vs. low whole grain intake, usually assessed in the highest vs. lowest quintile of intake, ranged from 0.56～0.86. Another 4 studies had incident diabetes as the endpoint, all in people who were middle-aged at year 0. Three were in the United States and 1 was in Finland. They included 158,723 men and women with 4373 cases of incident type 2 diabetes during 6 to 12 years of followup. The relative risk for high vs. low whole grain intake ranged from 0.62～0.79. There was also a long history of assertions that whole grain foods are healthful, often in the form of statements that a high fiber diet should be eaten. Seven studies reduced cardiovascular disease risk with more cereal fiber. In 2004, a pooled analysis of raw data from 11 studies found the same reduced risk. Three additional articles found reduced type 2 diabetes risk for higher cereal fiber intake. These observational studies were complemented with randomized or otherwise experimentally designed feeding and supplementary food studies of weeks-long duration that showed beneficial changes in factors related to cardiovascular disease and diabetes with whole grain feeding. These factors include body weight, blood lipids, blood pressure, insulin sensitivity, glucose, and lipid peroxidation.

Data about whole grain foods from epidemiologic studies refers largely to commercially available whole grain foods, which contain mostly finely crushed whole grains. Whether use of intact or sliced grains would yield additional benefit is not known. In any case, it is clear that whole grain is used in traditional foods and its consumption has great functionality in the sense of the definition of functional foods: it targets a particular set of diseases.

Synergy vs. Reductionism

The definition of functional foods relies heavily on novelty and single important components. This is a reductionist view (7), that there are simple pathways that link food intake to health and pathology. How well does this reductionist view work? For deficiency diseases, such as scurvy or beri-beri, restoration of a single nutrient can restore health. There are cases in which an isolated constituent does have the same effect as does the constituent in food. Most notable is the protective association of folate with neural tube defects (8). In another example, supplemental magnesium intake has been shown experimentally to improve insulin sensitivity in Type 2 diabetics

Table 2. Summary of prospective cohort studies of whole grain food consumption and incident cardiovascular disease or diabetes

Predictor	Outcome	Number of studies	Relative risk
Whole grain food	Cardiovascular disease	13	0.56～0.86
Whole grain food	Diabetes	4	0.62～0.79
Cereal fiber	Cardiovascular disease	7	All<1
Cereal fiber	Diabetes	3	All<1
Meta-analysis of raw data from 11 studies			0.90 for total CHD events and 0.75 for CHD death per 10 g
Cereal fiber		11	cereal fiber/day

Detailed citations are given in reference 5.

who have low serum magnesium (9).

Nevertheless this is not always the case. In a non-deficiency state, consumption of isolated nutrients does not fare so well. The most striking example is that of supplementary beta-carotene, which has been administered in several large, long term clinical trials, with the effect of increasing disease (10). Higher antioxidant nutrient intake was associated with more diabetic retinopathy in one study (11). Other provocative examples from the author's observational work include that supplemental vitamin C in diabetics was associated with increased coronary heart disease (12); and that supplemental iron in association with breakfast cereal intake (which is often fortified with supplemental iron) was associated with an increased rate of distal colon cancer (13).

An improvement in health is generally seen for these same nutrients consumed in a natural food matrix. Thus as noted above, whole grain breakfast cereals (5,14,15) are associated with reduced chronic disease risk, as are fruits and vegetables (10,16), which are high in beta-carotene and vitamin C, among a wide variety of other phytochemicals. The food synergy idea (7) rests on the concept that all biochemicals can have good or adverse metabolic effects; in order for an organism to live, it must contain substances that balance each other in a way that is good for the organism and that is beneficial for the consuming organism. In a very simple example, vitamin E functions as an antioxidant by accepting electrons, after which it exists in an oxidized state, that is, as a pro-oxidant. To reduce the risk that it will cause damage, it must be reduced, which is done by vitamin C. One important in vitro study illustrated this point by showing that cell proliferation in a cancer cell line was much lower when incubated with apple or apple skin than it was when incubated with an amount of isolated vitamin C that had an equivalent total antioxidant capacity (17). It is thought that this balance, as well as consumption of multiple constituents, each with important functionality, is important in nutrition. These ideas are in conflict with the idea that added isolated ingredients always make a better product. Added substances must always be tested for safety and efficacy (3), and such investigations are not always simple or easy to interpret. Long term adverse consequences of consumption of isolated substances are very difficult to rule out; investigators were clearly surprised by the adverse findings for beta-carotene supplementation (10). Food, especially those items that deliver a wide variety of nutrients, is itself the better product. In these senses, the functional foods concept should help to promote consumption of healthy foods, whether traditional or not, and whole grain foods should qualify as functional.

Can We Have a Healthy Population and a Healthy Economy?

The food industry supplies almost all food eaten in our modern societies. Therefore the economic health of the food industry is of great importance to the population, which must eat. When industry serves food that is suboptimal, populations suffer; for example, when refined grain foods are heavily promoted at the expense of whole grain foods. On the other hand, the food industry works in a for-profit economy, and any advantage that an individual company can get in the marketplace improves its profitability. Therefore simple answers, simple formulations and simple messages to the public are attractive to industry. Given the public interest in health and nutrition, a health claim on a food package can garner some market share. Functional foods are attractive in marketing because of their presumed health benefit, their easy identification with health, and the fact that they can often be patented and become uniquely available from a single company. However, the healthy push that might give to the economy does not necessarily translate into the physical health benefit that can be derived from simply prepared traditional foods selected for their delivery of nutrients. There is a perception that a company has to work harder to profit from selling such traditional foods. In this sense, the functional foods concept may

lead more to a healthy economy than to a healthy population.

However, the concept underlying functional foods relates to that of providing the consumer with point of purchase nutrition education. Such nutrition education is much needed and is facilitated by legitimate health claims on food packaging. If the functional foods concept could work for the public health in this way, it might be helpful; if it relates only to the economic health of companies, it should be rethought.

Judging whether health claims and functional foods work one way or the other is complex. This author consulted with General Mills, Inc. intermittently between 1994 and 1999, in a sort of uneasy science/profit alliance. Initial work concerning health effects of whole grain (14,17,18) was encouraged by General Mills. The author worked with General Mills to obtain a health claim concerning whole grain (19). In the next period, however, General Mills acquired another food company and seemed to this author to lose focus on whole grain. All along, the financial advantage of whole grain to General Mills was not clear, given that it had many refined grain products that might be displaced if it encouraged whole grain consumption. Nevertheless, the idea of the value of positioning General Mills' products on a whole grain platform was apparently percolating. Several years after the close working relationship between the author and General Mills ended, the company on September 30, 2004 announced its intention to change its entire breakfast cereal line to include only whole grains. It remains to be seen what effect this move has on sales. It would not be surprising if this move by one of the top two breakfast cereal producers in the US was financially successful and did cause other manufacturers to follow suit. The evidence suggests that the result would be an improvement in the health both of the economy and the population.

If the functional food idea is to be of use to the public health, food formulations that increase palatability, convenience, and general appeal of whole grain foods ought to be called functional. One example is novel whole grain breakfast cereals that also deliver nuts and dried fruit and that have potential by their appeal to increase whole grain consumption. Another example is typified by novel blends of whole grains that can be cooked and eaten in a manner similar to rice.

CONCLUSION

Whole grain foods, like many other simply prepared natural plant foods, have great functionality but may not qualify as functional foods. If the concept of functional foods is to be useful to the public health as well as in the growth of profits, it must be carefully tailored to support the consumption of healthy foods, whether traditional or novel, based on the concept of food synergy.

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