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Whole grain intake: The Baltimore Longitudinal Study of Aging

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Abstract

Our objective was to identify major dietary sources of whole grains and to describe the construction of a database of whole grain content of foods. Dietary information was collected with 7-d food records from men and women in the Baltimore Longitudinal Study of Aging, mean age 62.1 ± 16.0 years, who participated in the dietary assessment portion of the study ($n = 1516$), and estimates of whole grain intake were obtained from a newly developed database. The Pyramid Servings database and 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII) recipe ingredients database were then used to calculate both servings and gram weights of whole grain intakes. Mean intakes of whole grains, refined grains, and total grains, as well as frequency of intake for major whole grain food groups and whole grain content for each group, were calculated. Top contributors of whole grains were ready-to-eat breakfast cereals (made with whole grain as well as bran), hot breakfast cereals (made with whole grain), multi-grain bread, and whole wheat bread. While more research is needed to better understand the benefits of whole grains, the development of research tools, including databases to accurately assess whole grain intake, is a critical step in completing such research.

Keywords

Whole grains; Wheat; Bran; Germ; Fiber; Database; Food composition

1. Introduction

Recent research has shown that a diet rich in whole grains may reduce the risk of certain diseases such as cardiovascular disease (Hu, 2003; Jacobs and Gallaher, 2004), obesity (Koh-Banerjee and Rimm, 2003), cancer (Kasum et al., 2001; Larsson et al., 2005), and diabetes (Health News, 2005; McKeown, 2004; Slavin, 2004). In 2005, the U.S. Departments of Agriculture and Health and Human Services released the sixth edition of the Dietary Guidelines for Americans, which set evidence-based recommendations for the public to help prevent disease (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005). The guidelines emphasize consumption of whole grain foods, recommending three or more ounce-equivalents of whole grain products per day to reduce the risk of several chronic diseases and help with weight maintenance. One ounce is the equivalent of 1 slice of bread,

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1/2 cup of breakfast cereal, or 1/2 cup of cooked rice or pasta. Of note, although they are called ounce-equivalents, actual serving sizes vary by food: 1 slice of whole grain bread includes 16 g of grain, 1/2 cup of cold cereal includes 28 g of grain, and 1/2 cup of cooked whole grain pasta or brown rice includes 28 g of grain.

Despite a growing awareness of the benefits of whole grains, consumption remains inadequate: data from the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII) (U.S. Department of Agriculture, Agricultural Research Service, 2000), indicated that the mean daily intake of foods containing whole grains was just one serving per day (Cleveland et al., 2000; U.S. Department of Agriculture, Agricultural Research Service, 2000). In addition, these CSFII dietary data showed that only 7% of Americans ate the recommended three or more servings of whole grain foods per day (Kantor et al., 2002). A more recent report, the National Health and Nutrition Examination Survey (NHANES) 1999–2002, indicated that only 4% of individuals aged 12 years and older met the whole grain recommendation (Carlson et al., 2005). Children, for example, consumed 0.8–1.1 mean servings of whole grains per day (U.S. Department of Agriculture, Agricultural Research Service, 1999).

It is important to examine the effect of whole grain consumption on risk of chronic disease. However, the whole grain content of foods is not currently available in most nutrient databases, particularly for mixed dishes. Thus, quantities of whole grain in the diet are difficult to estimate accurately, and this compromises the ability to measure associations with disease risk. Our objective was, therefore, to identify major dietary sources of grains in an older adult population, including whole grains and refined grains, and to describe how we constructed a database of whole grain foods based on 7-d food records obtained from participants.

2. Methods

The Baltimore Longitudinal Study of Aging (BLSA), which began in 1958, is designed to look at the normal functions of the body and cognitive aspects of aging and disease (Shock et al., 1984). The current study includes all individuals who have participated in the dietary assessment portion of the study since its onset ($n = 1516$). Dietary data were collected with 7-d food records. Earlier reports of dietary intake in the BLSA population and a full description of the dietary data collection methods are published elsewhere (Hallfrisch et al., 1990; McGandy et al., 1966). In brief, BLSA participants were trained to record their food intake by dietitians during their examination visit and ambiguous or incomplete records were clarified by telephone interview.

Throughout the study, dietary data were coded and analyzed for nutrient content at different locations. Dietary data collected from 1961 to 1965 were sent to the Heart Disease Control Branch of the NIH for nutrient analysis; from 1968 to 1975, to Washington University; and from 1984 to 1991 they were coded into a nutrient database maintained by the BLSA. Since 1993, dietary data have been entered into the Minnesota Nutrient Data System (NDS) (Program 2.9, Food Database version 11A, Nutrient Database version 26, University of Minnesota Nutrition Coordinating Center) at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University. Dietary data from previous years were recoded into NDS, and nutrient intakes from earlier years were back-adjusted to correct for changes in the food supply using previous USDA food composition tables (U.S. Department of Agriculture, Agricultural Research Service, 2007), specifically changes in the composition of pork, beef, breakfast cereals, and other fortified foods using data from the USDA for appropriate time intervals (Watt and Merrill, 1963; U.S. Department of Agriculture, Agricultural Research Service, 1999).

For this study, all foods containing grains and mixed dishes with grains, either whole or refined, were identified (Appendix A). Each of these foods was then assigned the best-matched pyramid code from the Pyramid Servings Database (U.S. Department of Agriculture, Agricultural Research Service, 1997), a reference database of servings for 30 food groups, including three grain groups (total grain, whole grain, and non-whole grain).

In most cases, an exact match for the foods consumed by the study participants was available in the Pyramid Servings Database. However, there were some instances where foods seldom consumed by participants were not found in the Pyramid Servings Database (e.g., rice flour, rye flour, potato flour, quinoa, and triticale). In these cases, we matched foods to the best possible match in the Pyramid Servings Database on the basis of whole grain content. For example, rye flour was matched to the Pyramid Servings Database food code for whole-wheat flour. When questions remained about whether a product was made with whole or refined grains (such as the whole grain content of corn-based salty snacks, for example), food manufacturers were contacted to obtain information about ingredients and whole grain content.

An important goal of building the whole grains database was to use the dietary data from the 7-d dietary records to estimate grain intakes in gram weights per day rather than servings per day. This process involved several steps because of changes in the nutrient database over time (e.g., categorizing foods vs. ingredients) and challenges in quantifying how many grams of whole grains are contained in a given serving of grain food.

Many of the foods in the whole grains database are recipes or mixed dishes, which are composed of more than one ingredient such as sandwiches, soups, and casseroles. To quantify the whole grain content and the percent contribution of grains (whole grain and non-whole grain) from these mixed dishes and recipes, we merged the whole grains database with the CSFII 1994–96 recipe database to disaggregate whole foods into ingredients and to obtain gram weights of individual ingredients. The grain components of the ingredients were first calculated on the basis of 100 g of the total recipe and then remerged with the Pyramid Servings Database to obtain grain servings. For example, in a cookie with 11 ingredients and 10 g of white flour per 100 g of the total cookie, the flour gram weight was merged to the Pyramid Servings Database to obtain 0.63 servings of a non-whole grain (i.e., refined grain).

In the whole grains database, some foods cannot be disaggregated to the ingredient level. In these cases, the reference gram amount of grains was determined by multiplying by the number representing the pyramid serving. Specifically, a grain serving of 1 slice of bread contains 16 g of grain, while a grain serving of 1/2 cup of cereal contains 28 g of grain. Once the whole grains database was completed, we calculated the absolute amount of grain consumed by each individual by multiplying the gram amount eaten by the reference values/100 for both servings and grams.

Using these methods, we were able to estimate precise quantities of grains at both the ingredient and food levels. Some unexpected foods were identified as containing grain. This is mostly because many foods contain ingredients such as corn starch or other stabilizers and fillers, which are made from grains. For example, imitation mayonnaise contributes a very small amount of non-whole grain due to corn starch. Because the dietary data are obtained from food records, we were able to count these foods as contributing to grain consumption despite their limited contribution, thus improving the accuracy of our estimates.

3. Database challenges

One particular challenge in quantifying whole grain content using dietary records was estimating the whole grain content of savory snack foods. Most of the recipes derived from the Pyramid Servings Database represent the average range of products rather than a specific

product from one manufacturer, as it is not feasible to compile a comprehensive list of every specific branded product for every food code. For example, baked tortillas can be made with refined corn meal (non-whole grain) or whole corn meal (whole grain), depending on the manufacturer's recipe. Therefore, it is necessary to check the ingredients on the nutrition label for an individual food product and/or contact the food manufacturer to determine the precise composition of each unique food associated with a given food code. Furthermore, the Pyramid Database does not distinguish between corn meal, which is often refined, and whole grain corn in some of their recipes. Thus, it is challenging to decide which of these products contain whole grain and which do not. For corn flour or corn meal to be considered a whole grain, it must contain the pericarp (part of the bran). In the US, most corn meal or masa flour is not a whole grain, as the germ and (usually) some of the bran is generally removed by the liming process. For example, the USDA recipe for "salty snacks, corn or corn meal base, tortilla chips, low-fat, baked without fat" contains the ingredient "corn flour, masa, enriched." As this food specifies "masa," this item is considered a non-whole grain, and all of the grain servings are placed in the non-whole grain group. Conversely, the recipe "salty snacks, corn or corn meal base, tortilla chips, low-fat, baked without fat, unsalted" contains the ingredient "corn meal, whole grain, yellow," which is categorized as whole grain. Therefore, all of the grain servings for this food are placed in the whole grain group. Based on these definitions and communications with colleagues at both the USDA and in the food industry, we categorized certain brands of corn chips as 100% whole grain, as they are made with whole corn, while others, including taco chips, were categorized as multi-grain chips, which are not 100% whole grain. Although it is likely that this technique has some measurement error, the method improves estimation of the whole grain contributions from the various brands of savory snack foods. This is important, as the amount of whole grain intakes from snack foods has increased over time.

An additional challenge in creating the whole grains database was how to estimate grain content of foods with added bran or germ. In the USDA Pyramid Servings Database, added bran and germ are counted toward servings of whole grains. However, the FDA has recently ruled that such foods do not count towards whole grain consumption as they do not, by definition, include all portions of the grain, that is, the bran, germ and endosperm (Food and Drug Administration, 2006). Following the USDA definition, we elected to count the contributions from added bran and germ toward whole grain consumption. Thus, the values for whole grain intakes may be somewhat inflated according to the recent definition of the FDA. There are several reasons we decided to retain the added bran and germ to count towards whole grain intake. First, the USDA Pyramid Servings Database is commonly used to count whole grain servings, so we wanted our database to be consistent. Second, the values for gram weights were estimated using the CSFII ingredients database, and the investigation of the database suggested it would be difficult to subtract the added bran and germ content from many of the foods accurately, which would add error. For example, there are many foods with added bran or germ that also contain whole wheat. It is possible that whole grain databases may change in the future, as greater clarity is gained on what foods should and should not count towards whole grain consumption.

4. Statistical analyses

The frequency of intake for major whole grain food groups was calculated using data from all available dietary records. Food contributors were ranked based on percent contribution to total whole grain intake. All analyses were performed using the Statistical Analysis System (SAS) for Windows, Version 9.1 (SAS Institute, Cary, NC).

5. Results

On average, women consumed more whole grains per day than men (25.1 ± 25.0 g/d vs 19.9 ± 23.0 g/d, respectively), while men consumed more refined grains per day than women (80.6 ± 31.7 g/d vs 65.4 ± 31.7 g/d, respectively) (Table 1). Men had a mean BMI of 25.3 kg/m^2 and women had a mean BMI of 24.6 kg/m^2 . Twenty-three percent of men and 37% of women were vitamin-supplement users. Seventeen percent of men and 10% women were smokers.

Foods with high whole grain content include high fiber hot cereal, corn chips made with whole grain corn, high fiber cold breakfast cereal, whole wheat bread and popcorn (Table 2). Women consumed more whole wheat bread than men while men consumed more rye bread (Table 3). Women consumed more high fiber hot cereal, corn chips, popcorn and brown rice than men, while men consumed more high fiber cold breakfast cereal. Although multi-grain bread has less than half the whole grain of whole wheat bread, it was consumed nearly 8 times more frequently. As a percentage of total intake, cold cereals were the major sources of whole grain. Several foods with appreciable amounts of whole grain per serving, such as brown rice and whole wheat bread, contributed relatively little to daily whole grain intake due to low frequency of consumption. Some corn chips can have a good amount of whole grain, although, as previously noted, not all corn chips are made with whole grain corn. Many brands of corn chips are made with refined cornmeal, which is not a good source of whole grain.

Grain foods differ in nutrient content, as shown in Table 4. In general, whole grain varieties of foods are higher in magnesium, potassium and selenium, as well as fiber. Both whole wheat flour, made from hard red winter wheat, and white whole wheat flour, made from hard white winter wheat, have higher fiber, protein, magnesium, vitamin B6 and vitamin K than enriched white flour. Enriched white flour is higher in folate due to regulations concerning folate fortification. The calcium content of whole wheat flour is also higher than in white flour, although similar in the refined and whole varieties for cornmeal, rice and barley.

6. Discussion

The dietary guidelines advise consumers to consume three or more ounce-equivalents of whole grains each day, with the rest of the recommended grains coming from enriched or whole grain foods. This analysis shows that the major source of whole grain in this population of older US adults was breakfast cereals, with whole wheat bread and brown rice consumed less frequently.

The creation of a whole grains database such as this one will increase the ability to precisely measure whole grain intakes and quantify risk of disease in a research setting. In a recent study, we used this database to show that individuals in the highest quintile of whole grain intake had lower BMI and weight, smaller waist circumference, lower total and LDL cholesterol, and lower 2-h glucose (Newby et al., 2007).

Beyond research considerations, however, it is important to encourage individuals to consume whole grains in their daily diet, and to consider whether and how the whole grain message is being communicated to consumers. Although consumers likely understand that whole grains are more nutritious than refined grains, education alone does not lead to behavior change. Indeed, increasing whole grain consumption presents a number of challenges. The first challenge concerns confusion about which foods contain whole grains. Many consumers assume that whole grains are darker in color than refined grains. However, whole grains cannot easily be identified based on color alone, as color additives are often used to change the color of the food. It is therefore important that consumers are educated to understand which ingredients on the nutrition fact panel can be used to identify whole grain foods. Most 100% whole grain breads will list “whole” or “whole grain” in the ingredients and increasingly manufacturers are listing 100% “whole grain” directly on the food package. Commonly used

terms that identify refined grain foods are bleached flour, unbleached flour, wheat flour, enriched flour, semolina, 100% pure durum semolina, organic unbleached flour, multi-grain (depending on the ingredients), pearled barley and degermed corn meal. Unfortunately, the use of these terms can be confusing to consumers.

To help consumers easily identify whole grain products, the Whole Grains Council issued a whole grain stamp in 2005, which now appears directly on food packages (Oldways Preservation Trust and The Whole Grains Council, 2006). The original whole grain stamps noted products as either a “Good Source” (8–15 g of whole grain per serving) or an “Excellent Source” (at least 16 g of whole grain per serving). The stamps were recently revised to specifically state either “Whole grain: 8 g or more per serving” (providing at least 1/2 serving or more of whole grain) or “100% whole grain: 16 g or more per serving” (providing a full serving, with all of the contents as whole grain). The stamps use serving size information from the pyramid servings database and are in accordance with the whole grain recommendations in the 2005 Dietary Guidelines for Americans (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005).

In 2005, an industry petition to the FDA to adopt the use of the whole grain labels on products was denied (Pape, 2004). The FDA responded that the whole grain labels were associated with the fiber health claims rather than the whole grains themselves, and that there is currently no RDA or DRI for whole grains. However, the FDA did acknowledge the need for further education to help consumers identify whole grain products. The FDA has since drafted guidelines for what the agency considers to be whole grains, that is, “cereal grains that consist of the intact, ground, cracked or flaked fruit of the grains whose starchy endosperm, germ and bran are in the same proportions as the intact grain” (Food and Drug Administration, 2006).

An additional challenge of increasing whole grain consumption is consumer perceptions of the taste and texture of whole grain foods. Many consumers associate whole grains with the coarse textures and flavors found in oat bran, wheat germ and whole grain flours. Recent advances in food technology and innovations by the food industry have attempted to break down some of these barriers to consumption. For example, white whole wheat flour that is closer in flavor, texture and nutrients to white flour was recently introduced to the market. As this product is closer to the preferred taste and texture of white flour along with the nutritional benefits of whole wheat flour, products made with this type of flour may help consumers increase their consumption of whole grains.

Fiber has also been found to be protective against cardiovascular disease and the dietary guidelines recommend increasing fiber intakes (Lairon et al., 2005). Further, the American Dietetic Association (ADA) advises adults that “the public should consume adequate amounts of dietary fiber from a variety of plant foods” (Marlett et al., 2002). The ADA also recommends that children aged 2–18 years gradually increase fiber in their diet, including easily digested cereals for younger children. However, there are health benefits beyond the fiber content of whole grain.

Whole grains are rich in many important nutrients, including B vitamins, folate, antioxidants, minerals, lignans, and phenolic compounds, which have been associated with reduced risk of cancer, obesity, diabetes and heart disease (Health News, 2005; Hu, 2003; Jacobs and Gallaher, 2004; Kasum et al., 2001; Koh-Banerjee and Rimm, 2003; Larsson et al., 2005; McKeown, 2004; Slavin, 2004). While more research is clearly needed to better understand the benefits of whole grains in promoting health and preventing disease and to better understand the biological mechanisms involved, the development of research tools including databases to accurately assess whole grain intake are critical steps in completing such research. We found that there are many complexities that require careful attention to separate the whole grain and

non-whole grain components in foods; hence the quantification of whole grain intakes remains challenging. Further steps are also needed to develop whole grain guidelines, to establish FDA labeling laws to regulate food companies that produce whole grain products, and to increase consumer education to promote the consumption of whole grains.

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Table 1

Sample characteristics of 1516 men and women participating in the Baltimore Longitudinal Study on Aging at time of first visit.

Sample characteristics ^a	Women (n = 517)	Men (n = 999)
Whole grain (g/d)	25.1 ± 25.0	19.9 ± 23.0
Refined grain (g/d)	65.4 ± 31.7	80.6 ± 31.7
Age (year)	57.6 ± 16.9	57.4 ± 17.0
BMI (kg/m ²)	24.6 ± 4.2	25.3 ± 2.9
Waist circumference (cm)	78.0 ± 10.7	90.3 ± 9.54
Systolic blood pressure (mmHg)	125 ± 21	131 ± 21
Diastolic blood pressure (mmHg)	76.4 ± 10.7	81.3 ± 11.4
Fasting glucose (mg/dl)	93.8 ± 10.4	99.5 ± 11.3
Average total energy (kcal)	1751 ± 425	2225 ± 539
Physical activity (kcal/kg)	15.2 ± 5.1	13.8 ± 3.9
Vitamin users (%)	37	23
Current smokers (%)	10	17

^aMean ± S.D. unless otherwise indicated.

Table 2

Whole grain per serving, mean serving size, and frequency of consumption for major food groups contributing to whole grain intake among Baltimore Longitudinal Study on Aging participants.

Food group	USDA serving size^a	Weight (g)	Reported serving size (g) (mean $\pm$ S.D.)	Whole grain per serving from this food (g) (mean $\pm$ S.D.)	BLSA frequency of reported use^b
High fiber hot breakfast cereal ^c	1 cup	234	180 $\pm$ 102	41 $\pm$ 25	2118
Brown rice	1/2 cup	98	131 $\pm$ 92	22 $\pm$ 15	207
Corn chips, snack type	1 oz	28	41 $\pm$ 56	29 $\pm$ 39	632
Popcorn	3 cups	24	32 $\pm$ 33	26 $\pm$ 30	540
High fiber cold breakfast cereal ^d	1/2 cup	15	35 $\pm$ 26	25.6 $\pm$ 22	6726
Whole wheat bread, 100%	1 slice	28	48 $\pm$ 21	26 $\pm$ 11	572
Multi-grain bread ^e	1 slice	26	46 $\pm$ 24	10 $\pm$ 6	3,936
Rye bread	1 slice	32	47 $\pm$ 25	11 $\pm$ 6	1733

^aBased on 1 ounce equivalent of grains.

^bIn 16,245 sample size.

^cIncludes oatmeal and other high fiber hot cereals.

^dIncludes all cold breakfast cereals made with whole grains, as well as added bran.

^eIncludes mixed grain breads made with whole grains (other than 100% whole wheat).

Table 3

Major food group contributors to whole grain intakes and percent contribution to intakes of adults in the Baltimore Longitudinal Study of Aging among women and men.

Food group	Total (%)	Male (%)	Female (%)
High fiber cold breakfast cereal ^a	42.5	45.6	37.7
High fiber hot breakfast cereal ^b	15	14.4	15.9
Multi-grain bread ^c	10.4	10	11.2
Whole wheat bread, 100%	6.1	5.7	6.8
Corn chips, snack type	4.2	3.5	5.2
Popcorn	3.8	3.4	4.5
Rye bread	3.6	4	3
Wheat Crackers	2.9	2.6	3.2
High fiber cereal grains	1.7	1.4	2.3
Brown rice	1.6	1.4	2
Total whole grain intake (g) (mean $\pm$ S.D.)	23.7 $\pm$ 23.6	22.7 $\pm$ 23.9	26.4 $\pm$ 22.7

^a Includes all cold breakfast cereals made with whole grains, as well as added bran.

^b Includes oatmeal and other high fiber hot cereals.

^c Includes mixed grain breads made with whole grains (not 100% whole wheat).

Table 4

Nutrient composition of selected whole and refined grains per 100 g.

	Wheat flour ^a		Cornmeal ^b		Rice, cooked ^c		Barley, raw ^d		
	White, enriched	Whole wheat	White-Wheat	Refined	Whole	White, long-grain, enriched	Brown, long-grain	Pearled	Hulled
Energy (kcal)	364	339	339	366	362	130	111	352	354
Carbohydrate (g)	76	73	73	77	77	28	23	78	74
Fiber (g)	3	12	12	4	7	<1	2	16	17
Protein (g)	10	14	14	9	8	3	3	10	13
Niacin (mg)	6	6	6	5	4	1	2	5	5
Folate (µg)	183	44	44	233	25	58	4	23	19
Magnesium (mg)	22	138	138	40	127	12	43	79	133
Potassium (mg)	107	405	405	162	287	35	43	280	452
Selenium (µg)	34	71	71	8	16	8	10	38	38
Calcium (mg)	15	34	34	5	6	10	10	29	33
Iron (mg)	5	4	4	4	3	1	<1	3	4

Source: U.S. Department of Agriculture, Agricultural Research Service, 1997.

^aWhite flour is refined and enriched; whole wheat flour retains the bran and germ from hard red winter wheat; white-wheat flour uses the whole kernel of hard white winter wheat to obtain the texture of white flour and the nutrient composition of whole wheat flour.

^bRefined cornmeal is "degermed"; whole cornmeal retains all parts of the grain.

^cThe bran and germ have been removed from white rice, while brown rice retains these.

^dThe bran has been removed from pearled barley, while the hulled barley retains all parts of the grain.

Appendix A

Food groups used for analysis

Food group	Food items
Whole grains	Amaranth, barley (pearled or flour), buckwheat (whole, groats, or flour), quinoa, bulgur, corn flour or corn meal (whole grain), kasha, wheat germ, processed bran (corn, oat, or wheat), phyllium seed, oats/oatbran, brown rice, wild rice, rice flour, rye and rye flour, triticale flour (whole grain), wheat (all hard/soft, spring/winter), whole wheat, popcorn, corn chips or corn tortillas (made with whole corn), oatmeal (instant or prepared), granola, oatmeal cookies, oatmeal bread, whole wheat pastas, whole grain breads (whole wheat, rye bread, other multi-grain and whole grain breads (including light), whole wheat cracker, whole whet panckes, waffles, or bagels, mixed dishes made with whole grains, all cold breakfast cereals (fortified and non-fortified), made with whole grains, as well as bran ($\geq 25\%$ by weight).
Refined grains	White bread (including light), roll, stuffing, cracker, biscuit, bagel, pancake, waffle, white flour, corn meal (refined), corn bread (made with refined), hush puppies, grits, corn chips, tortillas (made with white or refined corn flour), salty snacks, couscous, cracked wheat bread, croutons, cream of wheat or rice, couscous, all sweet baked goods (made with white flour), white rice, steamed or fried, mixed dishes with white rice, rice and beans, pasta with vegetables, macaroni and cheese, mixed pasta dishes made with refined grains, refined grain cereals ($< 25\%$ by weight).