Appendix E-3.7
Replacing all Non-Whole Grains with Whole Grains: Food Pattern Modeling Analysis

RESEARCH QUESTION

What is the impact on intake of folate and other nutrients if all recommended grain intake amounts are selected as whole grains rather than half whole and half non-whole grains?

BACKGROUND

Recommended daily intake of all grains used in calculating the USDA food pattern at the 2000 calorie level is 6 ounce-equivalents, with 3 ounce-equivalents of whole grains and 3 of non-whole grains. For total grain intake, the patterns range from 3 ounce-equivalents in the 1000 kcal pattern to 10 ounce-equivalents in the 3200 kcal pattern, with half of each amount as whole grains. As of 2001 to 2004, usual intake of all grains for individuals 1 year or older was about 6.9 ounce-equivalents per day, with only about 0.6 ounce-equivalents from whole grains.

The most commonly consumed non-whole grains are enriched with folate, iron, and other B vitamins. Since these nutrients are important for nutrient adequacy, dietary guidance encourages that any non-whole grains consumed be enriched. Whole grain foods are usually not enriched, since enrichment nutrients are naturally present in the whole grain. However, whole grain ready-to-eat (RTE) breakfast cereals are typically fortified with a range of nutrients, including enrichment nutrients.

The 2005 DGAC requested a food pattern modeling analysis to determine if nutrient adequacy would be maintained if enriched non-whole grains were not consumed. The major findings from the 2005 analysis were:

- Non-whole grain products contributed important amounts of certain nutrients to the 2005 USDA food patterns, for example, 25% of folate, 24% of iron, 9% of calcium, 10% of dietary fiber, 27% of thiamin, 16% of riboflavin, and 20% of niacin in the 1800 calorie pattern.
- If non-whole grains were omitted from the food patterns and not otherwise replaced, shortfalls of folate, calcium, magnesium, iron, and fiber would result. In other words, inclusion of only 3 ounce-equivalents of whole grains (at the 2000 calorie level) and no non-whole grains did not result in nutrient adequacy.
- Increasing the amount of whole grains to replace the omitted non-whole grains totally replaced the shortfall nutrients and resulted in nutrient adequacy (but note caveat on p. 2).

The 2005 Dietary Guidelines recommended: "Consume 3 or more ounce-equivalents of whole grain products per day, with the rest of the recommended grains coming from enriched or whole grain products. In general, at least half of the grains should come from whole grains." Based in part on the modeling analysis, the Guidelines included the statement that "at least half" be whole grains, with the implication that consuming more than half and up to all grains as whole grains was acceptable.

The whole grain nutrient profile that was used in the 2005 modeling analysis contained fortified RTE breakfast cereals. RTE whole grain cereals were about 26% of the whole grain consumption, and so the nutrient profile for whole grains reflected a large component of these fortified cereals. Realistically, if a person were to substitute whole grains for all the non-whole grains they currently eat, RTE cereal would make up a much smaller percentage of their total consumption. It is likely that they would consume grain products similar to the non-whole grain products they now consume. For example, for white bread they would likely substitute whole wheat bread rather than a whole grain RTE cereal. Only a small percent of the substituted whole grain products would be fortified. RTE cereals make up only about 3% of total non-whole grains consumption, while breads and baked items made from white flour make up about 72% of non-whole grains consumption. Table A1 lists the percent of total grain consumption for all whole grain and non-whole grain item clusters.

The rationale for the current modeling analysis was to identify the impact on nutrient adequacy, especially for folate, of consuming all grains as whole grains. The present analysis updates and expands on the 2005 analysis. A key assumption for the current analysis is that proportions of non-whole grain foods are maintained but replaced with whole grain versions, such as replacing white bread with whole wheat bread, and pasta with whole grain pasta. Fortified whole grain RTE cereals are included at the levels currently consumed (1.3% of total grain intake), and non-whole grain RTE cereals (2.6% of total grain intake) are replaced with (1) non-fortified whole grain cereals or (2) fortified whole grain cereals..

METHODS

- Used existing whole and non-whole grain item clusters, as listed in Table A1, as the basis for analysis. (For more information on item clusters, please see Appendix E-3.1 *Adequacy of USDA Food Patterns*.)
- For each non-whole grain item cluster, identified replacement whole grain foods from the Food and Nutrient Database for Dietary Studies (FNDDS) and the USDA National Nutrient Database for Standard Reference—Release 22 (SR22) to represent the cluster. Except for RTE cereals, replacement representative foods were specifically selected from non-fortified whole grain products.
    - Used SR22 data to identify nutrient content of each cluster per 100 grams, based on the nutrients in the replacement representative food.
    - Used the MyPyramid Equivalents Database for the FNDDS representative food to identify the number of grain ounce equivalents per 100 grams of the food item.

- For the item cluster of non-whole grain RTE cereals, identified two replacement foods: a non-fortified RTE whole grain cereal, and a fortified whole grain RTE cereal.
- Calculated the nutrient content per ounce equivalent using MPED and SR22 data. (Nutrient content per ounce equivalent = nutrient per 100 grams / ounce equivalents per 100 grams).
- Constructed two "replacement-whole grain" nutrient profiles (for scenario 1 and scenario 2) by weighting each item cluster's nutrient content by that cluster's percent of non-whole grain consumption (Table A1) and summing all of the weighted values.
- Applied the replacement-whole grain nutrient profiles and whole grain nutrient profiles in the food patterns, using intakes that represent proportionate consumption between the subgroups of 9.2% whole grains and 90.8% non-whole grains (Table A1). Current whole grain intake was represented by the existing whole grain nutrient profile. The remaining amounts of recommended grain intake were included using either the scenario 1 or scenario 2 replacement-whole grain profiles (Table 1). For example, in the 2000 calorie food pattern, 0.55 ounce equivalents of the existing whole grain profile and 5.45 ounce-equivalents of the replacement-whole grain profile were included.

Table 1. Amounts in ounce equivalents of whole and replacement-whole grains applied to the food pattern at each calorie level

Food Pattern	Total grain intake recommendation	Whole Grains	Replacement-Whole grains
1000	3	0.28	2.72
1200	4	0.37	3.63
1400	5	0.46	4.54
1600	5	0.46	4.54
1800	6	0.55	5.45
2000	6	0.55	5.45
2200	7	0.64	6.36
2400	8	0.74	7.26
2600	9	0.83	8.17
2800	10	0.92	9.08
3000	10	0.92	9.08
3200	10	0.92	9.08

RESULTS

Foods in the replacement-whole grain nutrient profile

For most of the non-whole grain item clusters, a non-fortified whole grain replacement food could be identified. In some cases there was not an appropriate food choice. For example, the SR22 database does not include a 100% whole wheat tortilla, or an appropriate whole wheat flour-based dessert item. In these cases, the flour in the product was represented by an equivalent amount of whole wheat flour.

For the RTE cereal cluster, 2 scenarios were modeled: a non-fortified whole grain RTE cereal and (2) a fortified whole grain RTE cereal. See Table 2 for all replacement representative foods.

Table 2. Representative foods selected for each item cluster for the replacement-whole grain nutrient profile calculations

Non-Whole Grain Item Clusters	Replacement-Whole Grain Representative Foods
White bread	Bread, whole wheat, commercially prepared
White rolls	Rolls, dinner, whole wheat
Pizza crust	Bread, pita, whole wheat[a]
White flour-based desserts	Flour, whole wheat[b]
Pasta and noodles	Spaghetti, whole wheat, cooked
Corn tortillas & cornmeal-based foods	Tortilla, corn[c]
White rice	Brown rice, long grain, cooked
Wheat flour tortillas—refined grain	Flour, whole wheat[b]
Crackers	Crackers, whole wheat
Breadings and stuffings	Bread, whole wheat, commercially prepared
Bagels and English muffins	English muffin, whole wheat
Refined grain RTE cereals	(1) Shredded Wheat cereal, plain (2) Wheat Chex cereal
Quick breads (incl. pancakes, waffles)	Pancakes, whole-wheat, dry mix, prepared
Pie crusts	Flour, whole wheat[b]
French breads	Bread, whole wheat, commercially prepared
Biscuits	Flour, whole wheat[b]
Cornstarch as a thickener or filler	Flour, whole wheat[b]
Flour as a thickener	Flour, whole wheat[b]
Cooked refined grain cereals	Cereals, Wheatena, cooked with water

[a] Substituted for pizza crust; do not have nutrient data for pizza crust without toppings.

[b] Substituted whole wheat flour for flour-based baked products if a whole grain version was not available in the databases. Amounts are calculated to represent the amount of flour in the final baked product.

[c] Used the same corn tortilla product as in original data. Corn tortillas do not have a suitable whole grain substitute in the databases.

Comparison of Grain Nutrient Profiles

The two replacement-whole grain nutrient profiles differ from both the non-whole grain profile and the whole grain profile in a number of nutrients, as would be expected (see Table 3). In comparison to non-whole grains, the profiles are higher in fiber, magnesium, zinc, copper, and potassium. Most notably, the replacement-whole grain foods in scenario 1 contained 80% less folate (10 mcg DFE versus 50 mcg DFE) than the non-whole grain foods they replaced. The scenario 2 profile, with the addition of a fortified whole grain RTE cereal, contained more than double the folate (22 mcg) of the scenario 1 profile, but still 56% less than the non-whole grain profile. The scenario 1 profile is also lower in vitamin A and iron than scenario 2. Both replacement-whole grain nutrient profiles are also

substantially lower in thiamin, riboflavin, and sodium and somewhat lower in calories, carbohydrates, and niacin than the non-whole grain profile.

In comparison to the whole grain nutrient profile, which includes a greater percentage of fortified RTE cereals, the replacement-whole grain profiles are lower in all nutrients. In particular, the whole grain profile is substantially higher in folate, iron, calcium, and vitamin A than the replacement profiles because of the higher proportion of fortified whole grain RTE cereals included.

Table 3. Comparison of selected nutrients in one ounce-equivalent of the non-whole grains, whole grains, and replacement-whole grains nutrient profiles.

Nutrient values presented are for 1 ounce-equivalent of grain product.

Nutrients (units)	Non-Whole Grains[1]	Whole Grains[1]	Replacement-Whole Grains (1)[2]	Replacement-Whole Grains (2)[2]
Energy (kcal)	81	89	79.00	79.00
Protein (g)	2.21	3.23	3.05	3.05
Total fat (g)	1.2	1.4	1.2	1.2
Carbohydrate (g)	15.2	17.0	14.6	14.7
Dietary fiber (g)	0.71	2.52	2.06	2.06
Calcium (mg)	21	37	33	35
Iron (mg)	1.04	2.07	0.78	1.02
Magnesium (mg)	7	31	25	25
Potassium (mg)	29	97	74	74
Sodium (mg)	110	82	91	99
Zinc (mg)	0.22	1.32	0.53	0.58
Copper (μg)	0.05	0.09	0.08	0.08
Vitamin A (μg RAE)	5	38	5	7
Thiamin (mg)	0.13	0.15	0.08	0.09
Riboflavin (mg)	0.10	0.11	0.07	0.08
Niacin (mg)	1.18	1.58	1.09	1.14
Folate (μg DFE)	50	78	10	22

[1] The non-whole grains nutrient profile includes about 3% fortified RTE cereals, while the whole grains nutrient profile includes about 28% fortified RTE cereals.
[2] (1) with no fortified whole grains included; (2) with a fortified RTE whole grain cereal included.

Nutrient Adequacy of Food Patterns with All Whole Grains

The food patterns with the replacement-whole grain profiles substituted for non-whole grains provide adequate amounts of most nutrients. However, there are shortfalls of folate, iron, and vitamin A for some age/gender groups (see Table 4).

The modified patterns without any fortified replacement whole grains do not provide sufficient folate for girls 14-18 and women of all ages in the 1600, 1800, and 2000 calorie patterns. The total folate in these patterns is from 70% to 85% of applicable RDAs. In addition, the patterns are low in iron for children ages 2 to 8, teen girls 14 to 18, and women 19 to 50. Iron ranges from 71% to 93% of the RDA. Vitamin A levels in the patterns for sedentary men over 30 and for teen boys had been marginally adequate in the original patterns but decreased by 10% in the replacement-whole grain patterns. Amounts of thiamin, riboflavin, and niacin—the other mandatory enrichment nutrients—were well above the RDAs in the original pattern and remain at adequate levels in all of the food patterns. (See Table A2 for results for all nutrients.)

The modified patterns with fortified RTE cereals substituted for nonwhole grain RTE cereals are somewhat improved, especially in folate. They provide sufficient folate in the 1800 and 2000 calorie patterns, but are still low (84% of RDA) in the 1600 calorie pattern for women over 50. In addition, the patterns remain low in iron for some children ages 2 to 8 and women 19 to 50. Vitamin A levels in the patterns for sedentary men over 30 and for teen boys remain below the RDA. (See Table A3 for results for all nutrients.)

Table 4. Nutrient shortfalls if non-whole grains are replaced with replacement-whole grains--(1)non-fortified and (2) fortified RTE cereals only--in food intake patterns

Nutrient	Food Pattern	Sex-Age Group	Existing Patterns Amount	Existing Patterns % of goal	Replacement-Whole Grains (1)* Amount	Replacement-Whole Grains (1)* % of goal	Replacement-Whole Grains (2)* Amount	Replacement-Whole Grains (2)* % of goal
Folate (µg DFE)	1600	M/F 9-13	534 µg	178%	281 µg	94%	335 µg	112%
	1600	F 51-70	534 µg	134%	281 µg	70%	335 µg	84%
	1800	F 14-18	614 µg	154%	337 µg	84%	402 µg	101%
	1800	F 31-50	614 µg	154%	337 µg	84%	402 µg	101%
	2000	M 51-70	628 µg	157%	340 µg	85%	405 µg	101%
	2000	F 19-30	628 µg	157%	340 µg	85%	405 µg	101%
Iron (mg)	1000	M/F 1-3	8 mg	110%	6 mg	82%	6 mg	92%
	1200	M/F 4-8	10 mg	104%	8 mg	77%	9 mg	86%
	1400	M/F 4-8	13 mg	126%	9 mg	93%	10 mg	104%
	1800	F 14-18	16 mg	110%	13 mg	85%	14 mg	93%
	1800	F 31-50	16 mg	91%	13 mg	71%	14 mg	78%
	2000	F 19-30	17 mg	94%	13 mg	72%	14 mg	79%
Vitamin A	2000	M 51-70	851 µg	95%	769 µg	85%	783 µg	87%
	2200	M 14-18	930 µg	103%	834 µg	93%	851 µg	95%
	2200	M 31-50	930 µg	103%	834 µg	93%	851 µg	95%

*(1) with no fortified whole grains included; (2) with a fortified RTE whole grain cereal included.

For some nutrients, the replacement of non-whole grains with non-fortified whole grains slightly improved the nutrient levels in the patterns. Patterns in both scenarios with replacement-whole grains were higher in fiber and vitamin E than the original patterns. For example, in the 2000 calorie pattern dietary fiber increased from 30 to 33 grams, vitamin E increased slightly from 8.3 to 8.6 (scenario 1) or 8.7 mg (scenario 2). Calories were slightly lower, with a decrease of 29 or 26 calories from the base pattern at the 2000 calorie level. The decrease seen in calories can at least be partially explained by the need to substitute whole wheat flour for baked non-whole grain items that did not have a comparable whole grain substitute. For example, the flour tortilla with 94 calories per ounce equivalent and the low-fat biscuit with 63 calories per ounce equivalent were both replaced with whole wheat flour with 54 calories per ounce equivalent.

SUMMARY

This analysis examined the impact on nutrient adequacy if consumers were to consume all of their recommended amounts of grains as whole grains, under two scenarios. In scenario 1, amounts of fortified whole grains, in particular, fortified whole grain RTE cereals, were not increased above current consumption levels. Fortified non-whole grain RTE cereals were replaced with a non-fortified whole grain RTE cereal. In scenario 2, fortified non-whole grain RTE cereals currently consumed were replaced with a fortified whole grain RTE cereal. All other replacement whole grains were not fortified. For some age/gender groups, adequate intakes of folate, iron, and vitamin A could be compromised, especially under scenario 1 and for those who are sedentary and, therefore, have a lower calorie intake recommendation. These shortfalls would be mitigated or eliminated if additional fortified whole grain products were consumed above the amounts now eaten, such as by replacing fortified non-whole grain RTE cereals with fortified whole grain RTE cereals. The shortfalls could also be mitigated or eliminated if some enriched non-whole grains were consumed. Consumption of all grains as whole grains, without any additional amount consumed as a fortified grain product, would lower folate and iron intake levels to less than adequate amounts for individuals in population groups that may have a high risk for inadequate intakes of these nutrients.

Appendices

Appendix A

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Table A1. Percent of total grain consumption for non-whole and whole grain item clusters

Item Cluster Name	Percent of Consumption[a] by Item Cluster % Total Grains	Percent of Consumption[a] by Item Cluster % of Non-Whole or Whole Grain Subgroup
NON-WHOLE GRAINS		
White bread	13.2%	14.5%
White rolls	10.1%	11.1%
Pizza crust	9.9%	10.8%
White flour-based desserts	8.3%	9.1%
Pasta and noodles	8.9%	9.8%
Corn tortillas & cornmeal-based foods	7.9%	8.7%
White rice	4.5%	4.9%
Wheat flour tortillas—refined grain	4.1%	4.5%
Crackers	4.1%	4.5%
Breadings and stuffings	4.0%	4.4%
Bagels and English muffins	3.3%	3.6%
Refined grain RTE cereals	2.6%	2.8%
Quick breads (incl. pancakes, waffles)	2.1%	2.3%
Pie crusts	1.9%	2.1%
French breads	2.0%	2.2%
Biscuits	1.8%	2.0%
Cornstarch as a thickener or filler	1.6%	1.6%
Flour as a thickener	0.6%	0.6%
Cooked refined grain cereals	0.5%	0.5%
Subgroup Total	**90.8%**	**100.0%**
WHOLE GRAINS		
Whole wheat bread	1.6%	17.8%
Oatmeal (cooked whole grain cereals)	1.6%	17.4%
Whole oat RTE cereals	1.3%	14.0%
Popcorn	1.2%	12.6%
Whole wheat RTE cereals	1.3%	13.8%
Whole wheat crackers	0.5%	5.6%
Whole grain-based snacks and desserts	0.5%	5.0%
Whole wheat quick breads	0.4%	3.9%
Whole grain bagels & Eng. muffins	0.3%	2.8%
Brown rice	0.2%	2.6%
Rye bread	0.2%	2.2%
Whole grain rolls (not sweet)	0.1%	1.1%
Whole grain pasta	0.1%	1.1%
Subgroup Total	**9.2%**	**100.0%**
Overall Total	**100.0%**	

[a]Consumption data from NHANES 2003-04.

Table A2. Nutrient adequacy of food patterns with non-fortified whole grains (scenario 1) replacing non-whole grains. Amount in pattern as a percent of the nutrient goal for that pattern. Nutrient amounts that were adequate or marginally adequate in original patterns but below 90% of RDA in the substituted patterns are highlighted yellow and underlined.

Pattern calorie level[a]		1000	1200	1400	1600	1600	1800	1800	1800	2000	2000	2200	2200	2400
Sex-Age group		M/F 1-3	M/F 4-8	M/F 4-8	M/F 9-13	F 51-70	M/F 9-13	F 14-18	F 31-50	M 51-70	F 19-30	M 14-18	M 31-50	M 19-30
Nutrient	**Goal**													
Energy		98%	98%	97%	98%	98%	101%	101%	101%	98%	98%	98%	98%	98%
Protein	RDA	342%	234%	349%	246%	182%	263%	195%	195%	166%	202%	196%	182%	193%
Total fat	25-35% kcal	34%	33%	31%	31%	31%	30%	30%	30%	33%	33%	32%	32%	33%
Carbohydrate	RDA	96%	116%	137%	151%	151%	184%	184%	184%	194%	194%	214%	214%	232%
Dietary Fiber	14g/1000kcal	108%	116%	118%	117%	117%	128%	128%	128%	117%	117%	123%	123%	120%
Calcium	AI	153%	103%	109%	92%	100%	97%	97%	126%	105%	126%	102%	132%	136%
Iron	RDA	82%	77%	93%	135%	135%	159%	85%	71%	162%	72%	136%	187%	201%
Magnesium	RDA	235%	183%	218%	138%	103%	160%	107%	120%	93%	126%	107%	105%	117%
Potassium	AI	57%	56%	64%	67%	64%	78%	75%	75%	76%	76%	83%	83%	86%
Sodium	UL	58%	56%	65%	69%	66%	74%	71%	71%	73%	73%	80%	80%	86%
Zinc	RDA	215%	163%	194%	150%	150%	162%	144%	162%	122%	167%	134%	134%	144%
Copper	RDA	205%	207%	248%	182%	141%	216%	170%	168%	171%	171%	196%	194%	206%
Vitamin A	RDA	135%	118%	125%	112%	96%	124%	107%	107%	85%	110%	93%	93%	95%
Vitamin E	RDA	70%	73%	80%	63%	47%	73%	54%	54%	58%	58%	64%	64%	67%
Thiamin	RDA	141%	152%	181%	141%	116%	163%	147%	133%	125%	136%	141%	141%	150%
Riboflavin	RDA	221%	215%	244%	209%	171%	225%	203%	184%	159%	187%	170%	170%	179%
Niacin	RDA	153%	160%	199%	153%	131%	171%	147%	147%	134%	153%	151%	151%	163%
Folate	RDA	101%	97%	114%	94%	70%	112%	84%	84%	85%	85%	100%	100%	105%

[a]Only patterns with 2400 calories or less are shown. Patterns with 2600 to 3200 calories did not have any shortfalls due to the substitution of replacement-whole grains for non-whole grains.

Table A3. Nutrient adequacy of food patterns with non-fortified whole grains and fortified whole grain RTE cereals (scenario 2) replacing non-whole grains. Amount in pattern as a percent of the nutrient goal for that pattern. Nutrient amounts that were adequate or marginally adequate in original patterns but were below 90% of RDA in the scenario 1 patterns are highlighted yellow and underlined.

Pattern calorie level[a]		1000	1200	1400	1600	1600	1800	1800	1800	2000	2000	2200	2200	2400
Sex-Age group		M/F 1-3	M/F 4-8	M/F 4-8	M/F 9-13	F 51-70	M/F 9-13	F 14-18	F 31-50	M 51-70	F 19-30	M 14-18	M 31-50	M 19-30
Nutrient	**Goal**													
Energy		98%	99%	98%	99%	99%	101%	101%	101%	99%	99%	98%	98%	98%
Protein	RDA	342%	234%	349%	246%	182%	263%	195%	195%	166%	202%	196%	182%	193%
Total fat	25-35% kcal	33%	33%	31%	31%	31%	30%	30%	30%	33%	33%	32%	32%	33%
Carbohydrate	RDA	96%	116%	137%	151%	151%	184%	184%	184%	194%	194%	214%	214%	233%
Dietary Fiber	14g/1000kcal	108%	116%	118%	117%	117%	128%	128%	128%	117%	117%	123%	123%	120%
Calcium	AI	154%	103%	110%	93%	100%	97%	97%	127%	106%	127%	102%	133%	137%
Iron	RDA	92%	86%	104%	148%	148%	175%	93%	78%	178%	79%	150%	206%	223%
Magnesium	RDA	234%	182%	216%	137%	103%	160%	106%	120%	92%	125%	107%	104%	117%
Potassium	AI	57%	56%	64%	67%	64%	78%	75%	75%	76%	76%	84%	84%	86%
Sodium	UL	59%	57%	67%	70%	67%	76%	73%	73%	75%	75%	82%	82%	89%
Zinc	RDA	219%	166%	198%	152%	152%	165%	147%	165%	124%	170%	137%	137%	146%
Copper	RDA	205%	207%	248%	182%	141%	216%	170%	168%	171%	171%	196%	194%	206%
Vitamin A	RDA	138%	120%	128%	114%	98%	127%	109%	109%	87%	112%	95%	95%	98%
Vitamin E	RDA	70%	73%	81%	64%	47%	74%	54%	54%	58%	58%	64%	64%	68%
Thiamin	RDA	143%	155%	185%	144%	118%	166%	149%	136%	127%	138%	143%	143%	153%
Riboflavin	RDA	225%	219%	249%	212%	174%	229%	206%	188%	161%	191%	174%	174%	183%
Niacin	RDA	155%	163%	202%	155%	133%	174%	149%	149%	135%	155%	152%	152%	165%
Folate	RDA	122%	119%	141%	112%	84%	134%	101%	101%	101%	101%	119%	119%	126%

[a]Only patterns with 2400 calories or less are shown. Patterns with 2600 to 3200 calories did not have any shortfalls due to the substitution of replacement-whole grains for non-whole grains.