MODELING THE CONTRIBUTION OF ENRICHMENT AND FORTIFICATION TO B VITAMIN AND IRON INTAKE IN THE US POPULATION



GRAIN FOODS RESEARCH INSTITUTE

EXECUTIVE SUMMARY

Dietary intake data show persistent micronutrient shortfalls across the U.S. population, while the broader communications environment exposes Americans to increasing nutrition misinformation. The most recent authoritative review of nutrition science and determination of recommended dietary patterns – completed by the 2025 Dietary Guidelines Advisory Committee (DGAC) – showed foods in the Grains group to be significant contributors of all macronutrients and many vitamins and minerals, including some that are underconsumed in vulnerable populations (e.g., iron, folate).[1] The DGAC also found that reducing carbohydrate-containing foods can worsen nutrient inadequacy.[2]

Despite these findings, policy and public discourse continue to emphasize anti-carbohydrate and anti-refined grain messaging. At the same time, growing focus on "ultraprocessed" foods has the potential to pressure manufacturers to reformulate products to achieve "clean" labels, including reducing or eliminating enriched and/or fortified ingredients.



Given this landscape, the Grain Foods Research Institute (GFRI) sought to understand the impact on nutrient adequacy if enriched flour was replaced with unenriched flour in bread aisle products (i.e., bagels/English muffins, flatbread/pita, wheat flour tortillas, white rolls, and white bread). For grain foods, the term "enrichment" traditionally refers to the addition of niacin, riboflavin, thiamin, and iron, whereas "fortification" refers specifically to the addition of folic acid. For the purposes of this modeling analysis, we use "enrichment" as an umbrella term to describe the addition of all five micronutrients (i.e., niacin, riboflavin, thiamin, iron, and folic acid). Although intake of refined enriched grain foods currently exceeds recommended levels, these products play a critical public health role by helping the population meet needs for thiamin, riboflavin, niacin, folate, and iron. Reformulating to unenriched flour would substantially reduce intake of these nutrients and widen existing gaps – particularly among adolescents and women of childbearing age.

The following are key findings related to the contribution of enriched bread aisle products to current nutrient intakes and needs:

- Enriched grain foods in the bread aisle currently provide meaningful amounts of B vitamins and iron, accounting for approximately one-fifth of daily folate and thiamin intake, along with notable shares of riboflavin, niacin, and iron (9-15%). If these foods were reformulated with unenriched flour, the contribution of all B vitamins and iron would fall to only 1–7% of daily intake.
- These enriched grain foods help Americans meet 20–30% of recommended intakes for key nutrients, including 24–30% of thiamin and folate needs and 12–27% of iron needs, with contributions varying by sex. Without enrichment, contributions toward recommended intakes would decline to only 2–9%.

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BACKGROUND AND RATIONALE

Historical Deficiencies

In the early 1900s, prevalence of B vitamin deficiency diseases such as pellagra (niacin deficiency), beriberi (thiamin deficiency), and riboflavin deficiency disease was high. Enrichment of refined flour was voluntarily undertaken by bakers in the 1930s to help address these diseases.[3] Refined flour was an ideal vehicle for enrichment and fortification due to its widespread consumption throughout the year by a large proportion of the at-risk population.[4] Enrichment with B vitamins and iron also did not change the sensory properties of the flour and was embraced by the baking industry for a cost they could bear without passing along higher prices to consumers. The U.S. Enrichment Act of 1942 mandated adding B vitamins and iron to enriched grain products and, in 1996, the FDA modified the standard of identity to also include folic acid.

Before the enrichment of refined grain foods, deficiency diseases such as pellagra caused tens of thousands of U.S. deaths annually and widespread hospitalization, with roughly 250,000 pellagra cases and 7,000 deaths each year in the early 20th century.[5] Mortality data suggest pellagra was potentially the most severe nutrient deficiency disease in U.S. history.[6] Additionally, pellagra often presented with severe neuropsychiatric symptoms and historical reviews estimate that up to 40% of patients experienced confusion, hallucinations, or psychosis, leading to frequent institutionalization in state mental hospitals.[7]



Enrichment and fortification of refined flour have played a significant role in virtually eliminating once-common deficiency diseases – including pellagra (niacin), beriberi (thiamin), and riboflavin deficiency – in the U.S. population.[8] Folate/folic acid inadequacy is a leading and preventable cause of neural tube defects (NTD) in U.S. babies. Mandatory folic acid fortification since 1998 has prevented approximately 1,300 neural tube defect–affected births in the U.S. each year, generating lifetime direct medical cost savings exceeding $500 million annually.[9] However, even with folic acid added to the food supply, one-third of teen girls and one-quarter of women of child-bearing age still consume too little folate/folic acid, keeping NTD risk elevated.[1]

Nutrient Intake in the U.S.

Longstanding dietary guidance has recommended that half of consumer intake of grain foods be whole grain with the other half as refined enriched grain foods. Americans typically consume more than recommended amounts of refined grain foods and underconsume whole grain foods. Despite enrichment, and current intake of refined grain foods, many Americans still fall short of recommended intakes of thiamin, folate, and iron although, at the population level, the extent of these deficiencies do not rise to the level of being classified as nutrients of public health concern.[1]

Iron and folic acid are a notable concern for some populations – particularly those of childbearing age. For instance, at least one in five females ages 14–50 consume too little iron, putting them at increased risk of deficiency.[1] Starting at age 14 through 71+, females exhibit a high prevalence of folate inadequacy with 24-34% with usual folate intakes below the Estimated Average Requirement (EAR).[1] This is especially concerning as it affects women of childbearing age – with approximately one-third of adolescent girls ages 14-18 years, and one-quarter of women ages 18-50 years, having usual folate intakes below the EAR.[1] Ensuring sufficient folate status prior to pregnancy and during the first trimester is critical for proper neural tube formation and early fetal growth.

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Sources of Underconsumed Nutrients

Grain foods overall – assuming half are whole and half are refined – provide more than 15% of all macronutrients (carbohydrate – including dietary fiber, protein, and dietary fats), as well as vitamins (folate, thiamin, niacin, riboflavin, vitamin B6) and minerals (iron, magnesium, zinc, copper, phosphorous, calcium).[1] Further, analysis by the 2025 DGAC demonstrated that inadequate intake of nutrient-dense carbohydrate-containing foods leads to nutrient deficiencies, including vitamin A, thiamin, riboflavin, niacin, folate, calcium, copper, iron, magnesium, phosphorous, zinc, choline, potassium, and fiber. Additional nutrients fall below recommendations for pregnancy and lactation, including vitamin C, vitamin B6, and vitamin B12.[2]

Refined grain products eaten today are almost exclusively made from enriched flour. Whole grain foods are not subject to enrichment or fortification. Because enrichment and fortification are intended to replace nutrients lost during milling, FDA standards of identity apply only to refined grain products from which the bran and germ have been removed. Analyses of dietary intake from the National Health and Nutrition Examination Survey (NHANES) have shown that enriched and fortified grain products play an essential role in helping both adults[10] and children/adolescents[11] meet requirements for thiamin, riboflavin, niacin, iron, and folate. According to the 2025 DGAC, leading sources of folate for Americans two years and older include burgers and sandwiches (including tacos and burritos); breakfast cereals and bars; and rice, pasta, and other grain-based mixed dishes.[1]

Further, Drewnowski et al. analyzed and identified healthy grain foods using two different scoring schematics – the Carbohydrate Food Quality Score (which allocates points based on fiber, whole grain, and added sugars content) and the Nutrient Rich Foods Index (which scores foods based on nutrients to encourage and those to limit). This paper showed that consumers of healthy grain foods – based on each scoring system – had higher HEI scores and consumed more fruit.[12]

Grain foods overall – assuming half are whole and half are refined – provide more than 15% of all macronutrients, as well as vitamins and minerals.

Dietary Patterns and Chronic Disease

Enriching wheat flour with B vitamins (thiamin, riboflavin, niacin, folic acid) and iron was strategic – to combat widespread nutrient-deficiency diseases. However, current public health dogma villainizes refined grains, including staple grain foods (e.g., breads, pasta, rice, tortillas). This is in part because many epidemiological studies introduce a bias against refined grain foods by grouping them with foods that are associated with unhealthy dietary patterns (e.g., sugar-sweetened beverages, fried foods, etc.). A review of 11 meta-analyses of 24 cohort studies isolating refined grain foods showed no significant association between their intake and risk of all-cause mortality, cardiovascular disease, type 2 diabetes, coronary heart disease, stroke, hypertension, or cancer.[13] Additionally, the study by Drewnowski et al. showed that consumers who eat healthy grains were less likely to live with obesity and had significantly lower fasting plasma insulin levels.[12]



Current Messaging Environment

Authoritative bodies, respected academic institutions, and public health groups warn against consuming refined grains without distinguishing between those that are staple foods and those that are indulgent. Similarly, refined grain foods are often used as a poster child for ultraprocessed foods to limit. For example, the Make America Healthy Again (MAHA) assessment warns against consuming "ultraprocessed grains," defined in the report as including dietary staples, such as refined enriched grain breads.

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These non-science-based messages are breaking through to the consumer. According to the International Food Information Council, approximately eight in 10 consumers say they consider whether a food product is processed when making a purchase decision, and close to two-thirds say they avoid processed foods at least sometimes.[14] Further, about two-thirds of consumers identified white bread as a processed food – more than other carbohydrate-containing foods considered and higher than both energy bars and granola bars.[15]

Applying the term "ultraprocessed" to staple refined grain foods without nuance is problematic. The term is inconsistently defined in research, poorly understood by consumers, and does not reliably indicate nutritional quality or public health contribution. Broad use of the label on staple grain foods that are enriched may lead to unintended consequences, including reduced intake of nutrients provided through enrichment and wider nutrient gaps among groups already at higher risk of deficiency.

Finally, the 2025-2030 Dietary Guidelines for Americans (DGA) released in January 2026 promote foods high in saturated fat and warn against refined grain food consumption. These recommendations are in direct conflict with the scientific review of the 2025 DGAC and are likely to further exacerbate consumer confusion.

Modeling Objectives

Given that staple grain foods located in the bread aisle (i.e., bagels/English muffins, flatbread, pita, flour tortillas, rolls, and bread) account for nearly 40% of refined grain food consumption in the U.S., GFRI set out to evaluate the impact of removing enrichment and fortification from these products on current nutrient intake, as well as nutrient adequacy.

Because whole grains are not part of enrichment policy, they were not included in this modeling exercise. The analysis is specific to staple refined grain foods that are required to meet FDA enrichment standards.



METHODS & MODELING APPROACH

The mean daily intake of the Refined Grains subgroup by Americans ages one and older was obtained from the 2025 DGAC Scientific Report. The daily intake of bread aisle refined grain foods (i.e., bagels/English muffins, flatbread/pita, wheat flour tortillas, white rolls, and white bread) was then calculated using the Basis Nutrient Profiles Analysis Food Pattern Modeling (FPM) Report, which provides the percent contribution of all foods consumed in each food group and subgroup using NHANES 2017-2018 data. USDA's FoodData Central was used as the source of nutrient values for each of the representative foods listed in the FPM report for the specified bread aisle foods. The Food Pattern Equivalents Database[16] and USDA Food Buying Guide for Child Nutrition Programs[17] were utilized to convert gram values to ounce-equivalents (oz-equivalents). The daily intake of each B vitamin and iron from these bread aisle foods was then calculated.

Using the FDA standard of identity for enriched refined flour[18] and the standard amount of flour in an oz-equivalent of grain products provided in the Food Pattern Equivalents Database, the amounts of niacin, riboflavin, thiamin, iron and folic acid provided by an oz-equivalent of flour were calculated. These were then subtracted from the nutrient profile of an oz-equivalent of the enriched product to create a hypothetical unenriched version of each of the bread aisle foods.

What We Eat in America, NHANES 2017-2018 was used for the mean intake of each B vitamin and iron by Americans ages two and older as this is the data source used by the 2025 DGAC for their FPM.[19] The percentage of mean daily consumption of each B vitamin and iron from NHANES and the percentage of the Recommended Dietary Allowance (RDA)/Adequate Intake (AI) for each nutrient was then calculated for both the enriched and unenriched versions of bread aisle products.



RESULTS

The mean intake of refined grains by Americans ages one and older is 5.7 oz/d. White rolls comprise the largest percentage of Refined Grain subgroup intake at just under 12%, followed by white bread (11%), wheat flour tortilla (11%), bagels and English muffins (4%), and flatbread/pita (1%). This translates to less than one oz-equivalent consumed per day of each type of bread aisle food (Table 1). In total, Americans ages one and older consume 2.21 oz-equivalents per day of these refined bread aisle foods.[20]

Table 1. Daily Consumption of Refined Bread Aisle Foods

Food	Amount Consumed (oz-equivalents per day)
Bagel/English Muffin	0.22
Flatbread/Pita	0.06
Wheat Flour Tortilla	0.62
White Bread	0.64
White Roll	0.67
Total	**2.21**

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Refined, enriched bread aisle foods contribute meaningful amounts of essential nutrients to the daily diet at current intake levels and help Americans close gaps between consumption and recommendations.

Impact on Current Nutrient Intake

Enriched bread aisle foods provide a substantial share of key nutrient intakes: nearly one-fifth of daily folate (19%) and approximately 10-20% of other B vitamins (21% of thiamin, 15% of iron, 11% of niacin, and 9% of riboflavin) and iron. Without enrichment, the contribution of these bread aisle foods would plummet to only 1 – 7% (7% of thiamin, 4% of iron, 4% of niacin, 2% of riboflavin, and 1% of folate), leaving a significant gap in the American diet (Table 2).

Table 2. Current Intake of B Vitamins and Iron and the Percentage Provided by Enriched and Unenriched Bread Aisle Foods*

Nutrient	Current Mean Intake†	Percent Provided by Enriched Bread Aisle Foods*	Percent Provided by Unenriched Bread Aisle Foods*
Thiamin (mg)	1.58	21%	7%
Folate (DFE)	499	19%	1%
Iron (mg)	14	15%	4%
Niacin (mg)	25.1	11%	4%
Riboflavin (mg)	2.04	9%	2%

*The percentage of B vitamins and iron provided by enriched and unenriched bread aisle foods was calculated based on modeling analyses.
†Current mean intake among Americans ages 2 and older (NHANES 2017-2018).

Enriched bread aisle foods provide nearly one-fifth of daily folate and approximately 10-20% of other B vitamins (21% of thiamin, 19% folate, 11% of niacin, and 9% of riboflavin) and iron (15%).

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Impact on Recommended Intake

Enriched bread aisle foods deliver roughly one-fifth to one-quarter – or more – of daily needs for key B vitamins and iron, with percentages varying by sex. In men, these enriched grain foods account for 14% of riboflavin, 17% of niacin, 24% of folate, 27% of thiamin, and 27% of iron recommendations. In women, these enriched grain foods contribute 12% of iron, 16% of riboflavin, 20% of niacin, 24% of folate, and 30% of thiamin recommendations. If these foods were made with 100% unenriched flour, the percent contribution to recommendations would be substantially lower – only 2% of folate for men and women, 3% of riboflavin intake for men and women, 3% of iron for women and 8% of iron for men, 6% of niacin for men and 7% of niacin for women, and 9% of thiamin for men and women (Table 3).

If bread aisle foods were made with 100% unenriched flour, the percent contribution to recommendations would be substantially lower – only 2% of folate, 3% of riboflavin, and 9% of thiamin for men and women.

Population Subgroups

In their final report, the 2025 DGAC recommended that messaging regarding Whole and Refined Grains be slightly modified to reflect that at least half of grain foods consumed should be whole. However, as demonstrated in Table 4, in certain populations, consuming refined grain foods at levels less than half of total Grains could result in iron inadequacy.

Table 3. Nutrient Contribution of Enrichment in Bread Aisle Products Compared to Recommendations in Adult Men and Women

	With Enrichment % RDA / AI		Without Enrichment % RDA / AI	
Nutrient	**Males**	**Females**	**Males**	**Females**
Niacin (mg)	17%	20%	6%	7%
Riboflavin (mg)	14%	16%	3%	3%
Thiamin (mg)	27%	30%	9%	9%
Iron (mg)	27%	12%	8%	3%
Folate (DFE)	24%	24%	2%	2%

Table 4. Iron Adequacy Risk at DGAC Refined Grain Intake Levels

Age/Life Stage	Energy Level in Pattern	Refined Grain Recommendation	Risk per DGAC Analysis
Children 4-8 yrs	1200	< 2	Iron falls below goal (84% of RDA) at the 2 oz-equivalent recommendation and worsens with any refined grain reduction
Females 14-18 yrs	2000	< 3	Iron falls below goal (88% of RDA) at 2.5 oz-equivalent and worsens with further reduction
Females 19-30 yrs	2000	< 3	Iron falls below goal (76% of RDA) at the 3 oz-equivalent recommendation and worsens with any refined grain reduction

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DISCUSSION

The findings from this analysis demonstrate that enrichment of grain foods meaningfully contributes to population-level nutrient adequacy of B vitamins and iron. These nutrients are essential for red blood cell formation, cognitive development, and metabolic function – yet many remain underconsumed in the general population, particularly at key life stages. The contribution of enriched refined grain foods to nutrient adequacy is not incidental; it reflects decades of public health policy intended to prevent neural tube defects and B vitamin deficiency diseases.

Although the 2025 DGAC encouraged future *Dietary Guidelines for Americans* to advise individuals to mostly consume their grain foods through whole grain options, food pattern modeling showed potential unintended consequences of lowering enriched refined grain food intake. For instance, in several age and life-stage groups, reducing Refined Grain intake below approximately half of total Grain recommendations results in iron inadequacy. Additionally, given the importance of adequate folate intake in the first trimester of pregnancy, it is concerning that Americans would consume 93% less folic acid/folate if the vitamin were not added to enriched bread aisle foods. Further, these foods provide close to one-quarter of folate needs in female adults. Without the folate provided by enrichment of bread aisle foods, female adults would be meeting 22% less of their needs.

Additionally, public health guidance should clearly distinguish between staple and indulgent grain foods. Staple refined grain foods, like bread products, are most often consumed as part of balanced meals and contribute essential nutrients, including those provided by enrichment. They also serve as familiar, affordable carriers for vegetables, beans, dairy, fruit, and lean protein. In contrast, indulgent grain foods (e.g., desserts, pastries) are typically higher in added sugars or saturated fats and play a different dietary role. Although Americans exceed recommended limits for added sugars, indulgent grain foods account for less than one-quarter of total refined grain intake. Treating all refined grain foods as nutritionally equivalent obscures important differences in nutrient contribution and health impact.

Further, staple refined grain foods also hold significant cultural and heritage value. For instance, flour tortillas, pasta/noodles, pita bread, and white rice are foundational to identity, family food traditions, and everyday eating patterns across many communities. Guidance that discourages or stigmatizes these foods risks undermining cultural relevance, dietary satisfaction, and healthy habit formation, and may reduce the practicality and acceptance of recommended eating patterns.

Taken together, these findings indicate that enriched refined grain foods play a central role in supporting nutrient adequacy and culturally resonant eating patterns. Future dietary guidance and food system discussions should continue to promote dividing Grain intake equally between whole grain and refined grain foods, while also acknowledging the public health importance of clearly differentiating the unique roles of staple and indulgent refined grain products.

Reducing or eliminating enrichment and fortification of refined staple grain foods could have dire short- and long-term public health implications.



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Public Health Implications

- **Risk of re-emerging deficiencies:** Enrichment has been a proven, cost-effective public health strategy for nearly a century. Removing it would risk rolling back the gains made in eliminating beriberi, pellagra, and riboflavin deficiency disease.
- **Worsening deficiencies:** Removing enrichment may expose the population to meaningful increases in the prevalence of iron and folate inadequacy, particularly among adolescent girls and women of childbearing age, heightening risk for iron deficiency anemia and neural tube defects.
- **Widened inequities:** Populations with lower access to diverse diets and those relying on affordable staple foods would be disproportionately affected, potentially exacerbating nutrition security and health disparities.
- **Reduced practicality of dietary guidance:** Without enriched staple grain food options, meeting micronutrient needs through food alone would require more expensive, less familiar, and less accessible food substitutions, reducing feasibility. Dietary guidance has long recommended that nutrient intake come from the diet and not dietary supplements.

Research and Communication Opportunities

Opportunities exist to understand the role of staple refined grain foods in healthy dietary patterns and help consumers build healthier eating habits with familiar and preferred foods.

Research

- **Need for more nuanced grain categorization in research:** Studies should separate staple refined grain foods from indulgent options to avoid confounding and inaccurate health risk associations.
- **Modeling of substitution effects:** Research must evaluate realistic food substitutions – in the context of overall dietary patterns – and effects on nutrient adequacy if enrichment were removed.
- **Monitoring nutrient status over time:** Because of the likely effect of consumption of unenriched flour on micronutrient status, it will be critical to maintain robust national data (e.g., NHANES) on dietary intake and biomarker status, particularly among high-risk populations.
- **Better translation and messaging research:** Additional work is needed to understand how consumers interpret terms such as “refined,” “enriched,” and “ultraprocessed foods” and how these terms influence purchasing and eating patterns.

Communication

- **Need for clear differentiation of staple vs. indulgent grain foods:** Public health messaging must distinguish more often consumed and nutrient-dense staple grain foods (e.g., pasta, sandwich breads, tortillas, rice) from less frequently consumed and energy-dense indulgent grain foods (e.g., pastries, desserts).
- **Avoiding stigma and confusion:** Over-simplified messages to “avoid refined grains” or “avoid ultra-processed foods” risk directly undermining foods that not only deliver essential nutrients and underconsumed food groups but are core to cultural identity.
- **Improving education among health professionals:** Better understanding by health professionals and other message multipliers about grain foods nutrition science is critical to supporting consumers in building healthy long-term dietary habits.
- **Rebuilding consumer trust:** Communicators should emphasize that nutritional value depends on the food’s role and formulation, not processing level alone.

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CONCLUSION

Discouraging and/or removing enrichment and fortification from staple refined grain foods would:

- Increase nutrient inadequacy at the population level
- Disproportionately harm vulnerable groups
- Undermine culturally relevant and affordable dietary options
- Contradict the foundation that informed U.S. micronutrient fortification policy and its long-term success

Therefore, enrichment and fortification remain critical public health interventions. Not only should enrichment and fortification be supported in policy, but refined staple grain foods should be clearly differentiated from indulgent grain foods in science, policy, and consumer communications.



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About the Grain Foods Research Institute

The Grain Foods Research Institute (GFRI) is a nonprofit organization committed to supporting research to better understand the nutritional role of grain foods in healthy lifestyles.

GFRI champions evidence-based research that explores the importance of grain foods in a balanced diet. By partnering with its sister organization, the Grain Foods Foundation (GFF), GFRI aims to amplify the understanding of how grain-based foods contribute to overall health and wellness to consumers, health professionals, policymakers and industry stakeholders.

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