Cow's milk is an important source of iodine for prenatal health and switching to plant-based milk can lead to iodine insufficiencies

and

Bridging the dietary fiber gap in children: Need for improved methods to measure dietary fiber exposure and health outcomes in epidemiological studies

A PLAN B RESEARCH PROJECT
SUBMITTED TO THE FACULTY OF THE UNIVERSITY OF MINNESOTA
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Dr. Renee Korczak, PhD, RDN, CSSD, LD, Committee Member
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Chapter 1: Cow's milk is an important source of iodine for prenatal health and switching to plant-based milk can lead to iodine insufficiencies

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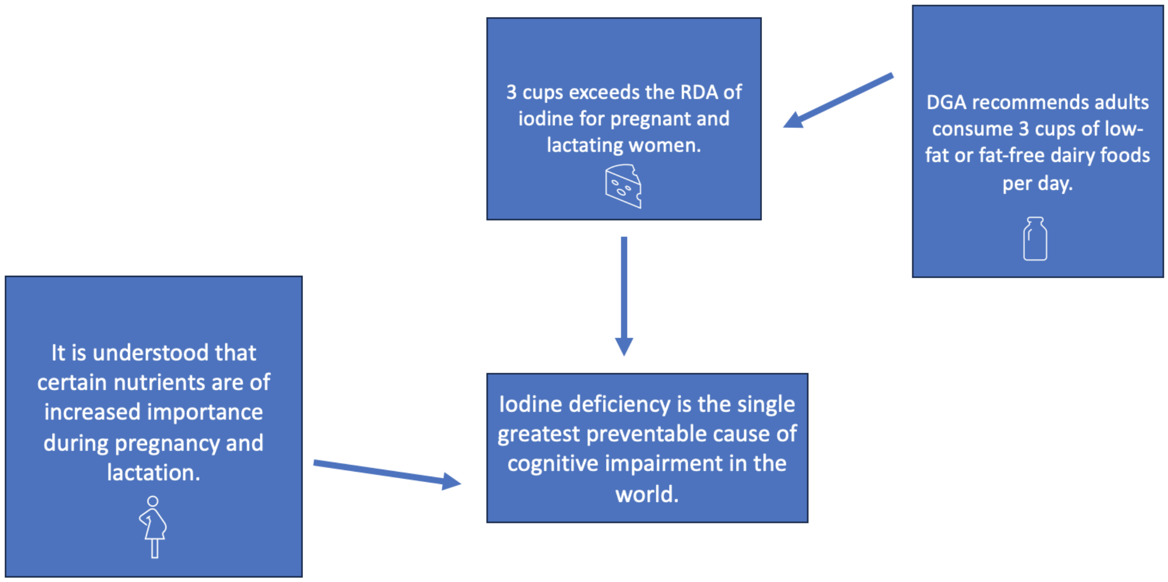
Graphical Abstract



Summary

Iodine is an essential nutrient that is particularly important during pregnancy, lactation, and infancy. Iodine is found naturally in seafood, but an important source is iodized salt which has decreased in the food supply with limits on sodium intake. Dairy products are important sources of iodine with one cup of milk providing 39% of a women's need. Unfortunately, as consumers replace dairy products with plant-based alternatives, they are decreasing their iodine intake as plant-based milk alternatives are not fortified with iodine.

Highlights

- Dairy products are an important source of iodine.
- Iodine intakes support brain, bone, and organ development and are particularly important during growth and development stages.
- Although dairy products are essential for intakes of Vitamin D, Calcium, and high-quality protein, most consumers do not know that consuming the recommended amounts of dairy products also ensures adequate intake of iodine.

Abstract

Iodine insufficiencies are common among many populations, particularly pregnant women. One of the main functions of iodine is making thyroid hormone. The two main hormones that iodine influences are triiodothyronine (T3) and thyroxine (T4). Thyroid hormone impacts the metabolism of most tissues. For the average adult, the Recommended Dietary Allowance, RDA, for iodine is 150 mcg. During certain stages of life, such as pregnancy, lactation, and infancy, the importance of iodine is even greater as it supports brain, bone, and organ development. The RDA for iodine during pregnancy is 220 mcg and, while breastfeeding, the RDA is 290 mcg. Consuming enough iodine in the diet during pregnancy helps support fetal neurodevelopment. Iodine is found in several food sources such as seafood and iodized salt, however, dairy products are one of the major sources of iodine in American diets. It is important to note that only bovine milk products are rich in this mineral. One cup of milk provides 39% and 57% of the daily iodine needs for average adult woman and pregnant woman, respectively. As the Dietary Guidelines for Americans (DGA) recommends limiting sodium intake, which includes iodized salt, dairy may be an especially important source of iodine. However, according to the United States Department of Agriculture, about 90% of the U.S. population does not meet the dairy recommendations presented in the DGA. In recent years, plant-based diets have received a lot of attention. A market for plant-based milk alternatives has grown and includes a variety of options such as almond, soy, and oat milk. Plant-based milks do not naturally contain iodine and are typically not fortified with iodine. Women of childbearing age who drink plant-based milks instead of cow's milk have lower urinary iodine concentrations than women who consume cow's milk. This review will focus on the importance of iodine in the diet to support prenatal health, lactation, and infant health.

Review

Iodine is an important trace mineral necessary during all stages of life. It cannot be synthesized in the body, so iodine must be consumed in the diet. Iodine is important for development and growth and aids in the body's ability to utilize nutrients. Iodine acts as a cofactor for thyroid hormones T3 and T4 (Lee et al., 2016). T3 and T4 work together to aid in metabolism and growth for the body's cells. Thyroid-stimulating hormone, TSH, is responsible for much of the thyroid function as it allows for the intake of iodine by the thyroid gland (Shahid et al., 2022). As part of the endocrine system, the hypothalamus secretes thyrotropin-releasing hormone (TRH), which then signals the pituitary gland to secrete TSH (*How Does the Thyroid Gland Work? - InformedHealth.Org - NCBI Bookshelf*, n.d.). TSH will then signal the thyroid hormone (TH) to secrete T3 and T4 hormones into the bloodstream (*How Does the Thyroid Gland Work? - InformedHealth.Org - NCBI Bookshelf*, n.d.). The pituitary gland is responsible for determining how much T3 and T4 is secreted based on physiological needs (*How Does the Thyroid Gland Work? - InformedHealth.Org - NCBI Bookshelf*, n.d.). T3 and T4 concentrations are regulated via a negative feedback loop. When levels of T3 and T4 decrease below normal levels, the pituitary gland is stimulated to produce TSH. Once the thyroid then increases blood concentrations levels of T3 and T4 back to their normal levels, the secretion of TRH by the hypothalamus and, in turn, the secretion of TSH by the pituitary gland, are inhibited.

The main functions of TH are to regulate metabolism and support growth and development. The secretion of TH is necessary from fetal development through adolescence to support myelination of the nervous system and cognitive development. TH continues to be important during adulthood to support healthy reproductive outcomes. TH is also important when the heart is beating faster and when body temperature is elevated (*How Does the Thyroid Gland Work? - InformedHealth.Org - NCBI Bookshelf*, n.d.). When there is insufficient iodine in the body, TSH concentrations remain high, and the size of the thyroid gland increases with the decrease in thyroid hormone production. This growth of the thyroid gland is given the clinical name of goiter. In cases where the thyroid cannot produce enough hormones for an extended period of time due to severe iodine deficiency, hypothyroidism can occur (Kapil, 2007). This condition prevents the body from proper metabolism, regulation of body temperature, and heart rate (Kapil, 2007). In severe cases of iodine deficiency during pregnancy, stillbirth and developmental issues can occur (Lee et al., 2016). In the maternal diet, iodine deficiency is the single greatest preventable cause of brain development issues in the world (de Benoist et al., 2008).

Severe iodine deficiency, which can lead to goiter formation, has been reported in the literature as occurring as far back as 2700 BC (Niazi et al., 2011). Much of what we know about goiter and the importance of iodine intake originates from research dating back to the 19th and 20th centuries (Niazi et al., 2011). In the 19th century, scientist Eugen Baumann studied the thyroid gland of sheep and found a significant amount of iodine (Niazi et al., 2011). Later, Adolphe Chatin, a French chemist, proved that iodine derived from freshwater plants, such as seaweed and phytoplankton, could prevent goiter (Niazi et al., 2011).

Iodine is naturally present in the Earth's soil (Zimmermann, 2011). However, certain areas of the world that have experienced flooding, erosion, and other disruptions to the soil have less iodine in the soil, and therefore, less iodine in the foods grown in that soil. Historically, regions with high prevalence of goiter were sent salt from regions with no goiter prevalence. This exchange reduced the incidence of goiter. Although this proved the relationship between iodine and goiter, it took many years for commercially iodized salt to become readily available (Niazi et al., 2011). In the 20th century, David Marine proved the essentiality iodine for thyroid function (Niazi et al., 2011). In the 1920s, the Great Lakes, Northwest, and Appalachian regions were areas of the highest incidence of goiter and were coined the "goiter belt" (Leung et al., 2012). These regions lacked iodine-rich soil, therefore food sources that grew in the soils had low iodine content (Leung et al., 2012). In 1922, at the Michigan State Medical Society thyroid symposium, David Cowie, the chairman of Pediatrics at the University of Michigan proposed the addition of iodine in table salt as it is a cheap, accessible product used by everyone (Markel, 1987). Prior to the implementation of iodized salt, many places in the U.S. suffered from iodine deficiency (*Iodine Deficiency | American Thyroid Association*, n.d.). Now, the incidence of goiter is limited in the U.S., however, there are still many places around the world that still have high rates of iodine deficiency and goiter.

Iodine recommendations in the U.S. vary by age and life stage. As iodine supports brain development, infants require greater amounts of iodine than older children. From early childhood through adulthood, iodine requirements increase. The life stages with the greatest iodine requirements are pregnancy and lactation. Due to iodine's critical role in thyroid function, sufficient iodine intake is crucial during pregnancy and lactation.

Table 1: Recommended Dietary Allowances for Iodine (*Iodine - Health Professional Fact Sheet*, n.d.)

Age	Male/Female	Pregnancy	Lactation
Birth to 6 months	110 mcg	-	-
7-12 months	130 mcg	-	-
1-8 years	90 mcg	-	-
9-13 years	120 mcg	-	-
14+ years	150 mcg	220 mcg	290 mcg

Throughout pregnancy, thyroid function is especially crucial. The iodine supply in the body must increase accordingly. Pregnancy is a notable time for not only the developing fetus, but also for maternal physiologic changes associated with gestation. These changes include increased thyroid hormone (TH) production, increased renal iodine excretion, and physiologic accommodation for fetal iodine requirements (Alexander et al., 2017; *Iodine - Health Professional Fact Sheet*, n.d.). These processes each require adequate maternal iodine status, and without adequate amounts, "the most damaging effect of iodine deficiency is on the developing brain" (*Iodine - Health Professional Fact Sheet*, n.d.; Micronutrients, 2001). To accommodate for these demands of pregnancy and the developing fetus, the Recommended Dietary Allowances (RDA) increases from 150 mcg/day for non-pregnant adults to 220 mcg/day (*Iodine - Health Professional Fact Sheet*, n.d.; Micronutrients, 2001). The National Institutes of Health Office of Dietary Supplements lists pregnant individuals as a group at risk of iodine inadequacy due to increased needs (*Iodine - Health Professional Fact Sheet*, n.d.; Micronutrients, 2001). National Health and Nutrition Examination Survey (NHANES) data from 2003-2014 indicate that a large portion of pregnant individuals in the U.S. population did not fall into sufficient iodine ranges based upon spot urinary concentrations below the minimum adequacy threshold of 150 mcg/L (*Iodine - Health Professional Fact Sheet*, n.d.).

Some of the best natural sources of iodine are seafood products such as cod, seaweed, and oysters (*Iodine - Health Professional Fact Sheet*, n.d.). However, for the general population, taste, and cultural preference impact how much seafood is consumed. Iodized salt is also an important source of iodine for Americans (*Sodium Reduction | FDA*, n.d.). One gram of iodized salt contains 45 mcg of iodine/gram of salt, so about 3 quarters of a teaspoon (1,725 mg sodium) fulfills iodine requirements for the average adult. Actions to combat deficits associated with iodine deficiency include the World Health Organization (WHO)'s Universal Salt Iodization Recommendation. The WHO recommends using salt as a vehicle for iodine due to worldwide usage of salt in food (*Universal Salt Iodization and Sodium Intake Reduction: Compatible, Cost-Effective Strategies of Great Public Health Benefit*, n.d.). Organizations, such as the American College of Obstetricians and Gynecologists, that provide health and/or dietary guidance for those who are pregnant recommend that women consume between 220 and 250 mcg of dietary iodine per day, during pregnancy. Some of these organizations additionally recommend supplementation of at least 150 mcg/day during pregnancy to ensure adequate intake (Alexander et al., 2017),(*Universal Salt Iodization and Sodium Intake Reduction: Compatible, Cost-Effective Strategies of Great Public Health Benefit*, n.d.),(*Nutrition During Pregnancy | ACOG*, n.d.),(*Iodine - Health Professional Fact Sheet*, n.d.),(Paulson et al., 2014).

Another important source of iodine for Americans is dairy products. Milk, yogurt, and cheese are all good sources of iodine. For consumers who may have a lactose allergy, lactose-free milks also contain iodine. The season in which the milk is produced, pasteurization, farming practicing (organic and non-organic), and fat content can all contribute to differing concentrations of iodine in milk (O'Kane et al., 2018; Stevenson et al., 2018). In a study from the United Kingdom, researchers assessed the iodine content of organic milk and Ultra High Temperature (UHT) processed milk during different seasons. Organic milk produced in the winter had 44% lower iodine concentrations than conventional milk (Stevenson et al., 2018). UHT milk also had 27% less iodine than conventionally pasteurized milk. Understanding why there are differences in iodine concentration in cow's milk is complex. Factors such as housing (i.e., year-round housing, summer-housing, winter-housing) as well as geographical location can affect iodine concentrations since iodine is atmospherically transferred into the soil and into the diet of cows through grazing (McKernan et al., 2020). Further research is necessary to determine how to keep iodine concentrations more consistent across these parameters.

However, the amount of iodine in cattle feed is the main contributor to the amount of iodine in milk (O'Kane et al., 2018). Iodine is incorporated in the diets of cattle as they also require iodine for thyroid gland functions (Schöne et al., 2017). Iodine requirements for dairy cattle are 0.5 - 1.5 mg kg^{-1} dry matter (Schöne et al., 2009). There is a direct linear relationship between iodine in cattle feed and milk iodine (Niero et al., 2023). Common feed types for farms are dependent on cattle breed as well as dairy farm practices. Iodine content in feed can vary (i.e. corn, grass, hay, *Ascophyllum nodosum* meal) (Niero et al., 2023). The naturally occurring iodine in feed depends on the amount of iodine that is taken up from the soil by the plants (Niero et al., 2023).

Table 2: Iodine Content of Dairy Products and Percent Daily Value (Dellavalle & Barbano, 1984; *Iodine - Health Professional Fact Sheet*, n.d.)

Dairy Product	Serving Size	Micrograms (mcg) per Serving	Percent Daily Value (%DV)
Non-fat Milk	1 cup or 8 oz	85	57
Non-fat Greek Yogurt	3/4 cup	87	58
Chocolate Ice Cream	2/3 cup	28	19
Cheddar Cheese	1 ounce	15	19
Whey Protein Powder	25 grams	118	79

In addition to iodine from the cow's diet, iodine can also enter milk products through use of iodized sanitizers in the milking process (Flachowsky et al., 2013). Some of the iodine from iodophor-based sanitizers used during the milking processes is transferred into the milk. The amount of iodine in milk that comes from sanitation practices may be negligible (Conrad & Hemken, n.d.). One study compared iodine content in milk from cows treated with iodophor-based teat dips to milk from cows on which a tincture of iodine was sprayed on the skin between the vulva and udder (Conrad & Hemken, n.d.). Iodine concentration was higher in the cows treated with iodine spray than from the cows treated with teat dips, indicating that iodine is absorbed into the skin of the cow and secreted into the milk (Conrad & Hemken, n.d.). On average, one cup of nonfat milk contains 85 mcg of iodine (Table 2) (Ershow et al., 2022; Micronutrients, 2001),(Roseland et al., 2020).

Bovine dairy products are good sources of iodine (*Iodine | The Nutrition Source | Harvard T.H. Chan School of Public Health*, n.d.). The Dietary Guidelines for Americans (DGA), recommends that adults consume three cups of fat-free or low-fat dairy foods per day in the Healthy U.S.-Style and Healthy Vegetarian Dietary Patterns (*Home | Dietary Guidelines for Americans*, n.d.),(*USDA ERS - Fluid Milk Consumption Continues Downward Trend, Proving Difficult to Reverse*, n.d.). This recommendation provides amounts of iodine that exceed the RDA for average adults and meets the requirements for pregnant and lactating women. Dairy foods can be an important source of iodine during pregnancy (Whitbread et al., 2021). NHANES data from 2001-2006 showed that pregnant females who consumed dairy products had higher urinary iodine concentrations than those who did not report to have consumed dairy within the past 24 hours (*Iodine - Health Professional Fact Sheet*, n.d.).

Plant-based milk alternatives cannot meet iodine needs in the same way, as these products are not significant sources of iodine. One study compared at the iodine content of 30 different milk alternatives found that, on average, these products contained 3.1 ± 2.5 mcg/250mL of iodine (Ma et al., 2016). This is lower than the iodine content of cow's milk. Of course, there are plant-based milk alternatives available on the market that are fortified with certain nutrients to match the nutrient profile of cow's milk. However, even these fortified milk alternatives are typically not fortified with iodine as it can alter the flavor profile of the product (*Iodine And Potassium Iodide (Strong Iodine) (Oral Route) Side Effects - Mayo Clinic*, n.d.). Iodine can have a metallic after-taste, so many milk-alternative companies do not want to change the flavor of their product to match the iodine content of cow's milk.

Dietary guidance on intake of iodine-rich foods in conjunction with the iodization of salt can help to combat low dietary iodine intake, both in pregnancy and the general population. Dairy foods including milk can help pregnant individuals achieve the recommended iodine intake of 220-250 mcg/day (Alexander et al., 2017),(*Universal Salt Iodization and Sodium Intake*

Reduction: Compatible, Cost-Effective Strategies of Great Public Health Benefit, n.d.),(*Nutrition During Pregnancy | ACOG*, n.d.),(*Iodine - Health Professional Fact Sheet*, n.d.),(Paulson et al., 2014). For individuals who follow specific dietary patterns (such as various vegetarian dietary patterns) and may not consume dairy foods or seafood rich in iodine, special care should be taken by the pregnant individual's healthcare provider to discuss alternate dietary sources and/or iodine supplementation to ensure adequate iodine status is achieved. Lactose-free milk and other dairy foods may be an important source of iodine for people with lactose intolerance.

Iodine is an important trace mineral due to its role in supporting metabolism, growth, and brain development (Glinoer, 2004). Iodine is particularly important during pregnancy to support thyroid hormone production of both mother and baby. Dairy products, including milk, yogurt, and cheese, are good sources of iodine and will provide adequate amounts of this nutrient when consumed in accordance with DGA recommendations. Other than fortified soy products, plant-based milk alternatives are not recommended as dairy food servings by the DGA. Possible ways of consuming more dairy milk throughout the day include making oatmeal using milk, adding milk to smoothies or cereal, or, of course, drinking a glass of milk with meals.

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Chapter 2: Bridging the dietary fiber gap in children: Need for improved methods to measure dietary fiber exposure and health outcomes in epidemiological studies

Abstract

Dietary fiber recommendations in the United States are based on the relationship between dietary fiber intake in prospective cohort studies and risk of developing cardiovascular disease. These modeling studies support that 14 grams of dietary fiber per 1000 kcalorie intake are protective against cardiovascular diseases so dietary recommendations for fiber are then determined by multiplying the calorie intake of a population group by 14 grams per 1000 kcalories. Using this model for children creates problems as the recommended intakes of dietary fiber are based on calorie recommendations, not physiological measures. Thus, the recommended fiber intakes for children are 19 grams per day which far exceeds the clinical recommendation for dietary fiber for children as the "age plus 5 grams of fiber" rule. Dietary fiber intake in children and adolescent populations is concerningly low, with most estimates suggesting that intake of dietary fiber should be doubled in children's diets. We review the current intake of dietary fiber for children and describe what food sources are currently the most important contributors to dietary fiber intake. We examine new strategies to increase dietary fiber intake, including snack foods and substitution of flour high in resistant starch to add to breads and bakery goods, as well as whole grain products that are acceptable to children. Additionally, we review information on fruit and vegetable products that are acceptable to children and can enhance the intake of dietary fiber. Our work also finds that foods popular with children, for example pasta, actually have more dietary fiber than the amounts listed in nutrient databases. To address the dietary fiber gap in children we must appreciate the current dietary fiber sources that children accept and introduce new methods to increase dietary fiber intake in children. Development of improved methods to estimate dietary fiber exposure and accepted physiological endpoints to include in population based studies in children is urgently needed.

Introduction

Dietary fiber is described by the Institute of Medicine, Food and Nutrition Board as "nondigestible carbohydrates and lignin that are intrinsic and intact in plants (1). Added fibers of functional fibers are synthetic carbohydrate polymers that have been shown to have a physiological benefit on health (2). The health effects of dietary fiber are broad including effects on bowel function, lipid lowering, glucose control, energy metabolism, blood pressure, and mineral absorption. Fibers that change the gut microbiota are described as prebiotic fibers (3).

In the US, dietary fiber recommendations are based on lowered risk of cardiovascular disease in large prospective, cohort trials. The Dietary Reference Intakes (DRIs) for dietary fiber are based on a model that 14 grams dietary fiber per 1000 kcalories is protective against cardiovascular disease. Thus, for the standard 2000 kcalorie diet, an Adequate Intake (AI) for dietary fiber is 28 g/day. The Nutrition Facts label in the US uses 28 grams per day as the accepted daily intake (DV) for dietary fiber.

Using this model for recommendations for children creates problems as the recommended intakes of dietary fiber are based on calories, not a physiological measure. Thus, recommended intakes of dietary fiber for children are 19 grams/day, which is not a reasonable amount for a small child. More practical recommendations have been suggested, a daily intake of fiber for children equivalent to age plus 5 g/day for those over 2 years (4). Usual intakes of dietary fiber in the US are only 17 g/day for all consumers and children's intakes are also less than recommended amounts.

There are no recommendations for different types of fiber, insoluble vs. soluble, for instance. Food groups are recommended, including whole grains, legumes, nuts and seeds, and fruits and vegetables as sources of dietary fiber. Added fibers can also be considered, although especially for small children it is best to include foods with dietary fiber in the diet rather than relying on fiber supplements.

Most of the fiber research in children is observational, documenting intake levels and associations with the prevalence of common childhood conditions such as constipation (2). Performing fiber interventions in young populations is difficult due to the legal and ethical concerns of doing research on healthy children. Holscher et al (5) reviewed the challenges of assessing tolerance to nondigestible carbohydrates consumption. Special issues related to studies in children were discussed. Our laboratory conducted a study of oatmeal consumption in children assessing markers of bowel function (6). No statistical differences were seen in stool frequency or consistency between the low fiber diet and the oatmeal intervention. The addition of oatmeal to children's diets is an effective way to increase fiber consumption and may reduce some GI symptoms such as gas, straining, and feeling of incomplete evacuation. An earlier review found limited data that dietary fiber intake in children's diets is linked to constipation, obesity, or diabetes (7).

Not all effects of fiber consumption on children are positive. High intakes of dietary fiber in small children may be associated with reduced growth and iron deficiency (8). In this review, the authors identified 5,644 studies and 5 articles that met their inclusion criteria. No association was found between dietary fiber intake and growth. No study was found that examined fiber intake and iron status. They conclude that supplementation of dietary fiber led to higher stool frequency and softer stools in small children, but that the association of high fiber intake in young children with growth remains unclear.

Dietary fiber has long been considered a nutrient of concern in the adult population and is currently a topic of great significance in research due to the impact low fiber intake may have on the human gut microbiome and on general wellbeing (9). The trend of inadequate fiber consumption has proven to extend to children and adolescents as well, with reported intakes reflecting just over half the recommended daily amount for both male and female children ages 1-18 (10). Low fiber consumption in children is a subject of particular concern because it can be linked to multiple conditions that are increasing in prevalence, such as constipation, obesity, and type 2 diabetes mellitus (DM) (7). Constipation is a condition characterized by infrequent bowel movements and painful or difficult-to-pass stools, and it affects up to 10% of US children (7). Dietary changes, including increased fiber intake, are among the first line of treatment for constipation (11). While constipation may be either acute or chronic, obesity and type 2 DM are chronic conditions that appear to have a pathophysiology that may be at least partially linked to long-term low fiber intake (12). All of these conditions have an impact not only on physical and mental health, but also on overall quality of life.

Determining dietary fiber recommendations for children can be challenging. Not only do fiber intake recommendations differ between age groups, but gender also plays a contributing factor for creating dietary reference intakes (DRIs). The current DRI for dietary fiber is based only on data for adults, and the recommendations for children are pulled from these numbers (2). Adequate intake (AI) for fiber has been set at 14 g/1000 kcal, suggesting kids ages 1-3 should consume approximately 19 g/d, kids ages 4-8 should aim for about 25 g/d, and so on. Other possible recommendations are set forth by the American Academy of Pediatrics (AAP), including an intake of the child's age (years) plus 5 g of fiber, or a fiber intake of 0.5 g/kg of body weight, not exceeding 35 g/d, for children over 2 years of age. Yet, regardless of which recommendation is used for comparison, average intakes for US children are suboptimal (2).

Recent years have been marked by a gaining popularity in FAD diets, such as gluten-free diets, grain-free diets, and the ketogenic diet. All of these diets include a push away from grains, both refined and whole, and therefore eliminating a major source of dietary fiber. While it is typically adults who follow such diets, children often suffer the consequences. Parents practicing FAD diets may result in less available grain sources in the household or family meals that adhere to the restrictions of these diets, which means children end up consuming less grains. This could also lead to children developing a negative relationship to grain products in general, so when they are able to make their own food choices later in life, they are more likely to avoid these foods (13).

While FAD diets introduce the idea of little to no grain products at all, health and nutrition professionals emphasize the consumption of whole grains over refined grains. The current USDA Dietary Guidelines for Americans indicate that half of all grains consumed should be whole grains (14). Whole grains are beneficial for many reasons, and most have a higher fiber content than refined grains. However, evidence shows that kids tend to prefer refined grain products more than whole grains (15). Although refined grain products are not especially high in fiber, children consume these foods in such great quantities that they provide one of the major sources of fiber in a child's diet (16). In a 2017 study analyzing dietary data from 34,391

Americans ages 2-85 years, it was found that approximately 72% of an individual's daily fiber from grain-based foods came from non-whole grain sources, and these results did not differ between age groups (17). While it may be ideal for children to consume at least half of their grains as whole grains, the reality is that they do not. Because refined grains are a significant component of the diets of many US children, it is important to obtain an accurate picture of what these refined grain products can provide in terms of fiber contribution to the diet.

Although the Food and Drug Administration (FDA) states that the newest methods of testing fiber in foods are most in line with their definition of dietary fiber (18), it does not explicitly require manufacturers to retest fiber content of foods using these methods. Additionally, the FDA does not identify acceptable sources for accessing dietary fiber values in foods to put on labels (19). Food manufacturers are personally responsible for the information included on their nutrition facts labels (20). This means that even when new nutrition labels are printed for food products, the value of dietary fiber for that product may be pulled from a database that lists fiber quantity based on outdated methods. This further brings to light the question of whether or not manufacturers are fully aware of the accuracy of databases being utilized. Even though differences might be small between new and outdated methods, it emphasizes the need to ensure all nutrition databases are updated to reflect the most recent advancements in dietary fiber testing technology.

Because the effects of low fiber intake in children might not be outwardly observed and do not always result in physical manifestations from the start, it is something that is easily overlooked. Still, encouraging adequate consumption is crucial to a child's overall health. The purpose of this research project was to measure the dietary fiber content of generic enriched white spaghetti pasta, a refined grain product commonly consumed by children in the US, using the most current and accurate validated methods in order to gain a better picture of the amount of fiber refined grain products can provide for children.

Methods

Generic enriched white spaghetti pasta was the sample selected for testing. This type of pasta was selected due to the fact that the nutrient content of generic pasta is relatively consistent when compared between different retailers, and it is widely consumed among the general public. Samples of the same pasta were tested by CODEX Definition method at two different labs to validate results. Three reputable labs in the Minneapolis-St. Paul metropolitan area were selected and further narrowed down to two based on pricing. Medallion Labs and Merieux NutriSciences, Silliker, Inc. were able to perform these tests for our pasta sample. A number of different fiber tests were offered by each company. The generic testing option, AOAC 991.43, allowed for testing of either soluble or insoluble fiber individually or a total dietary fiber for the sample. Another test, AOAC 2009.01, is considered a CODEX definition test, which is the "gold standard" in testing. The AOAC 2009.01 provides only total dietary fiber. However, we chose to use another CODEX definition test, AOAC 2011.25, which quantifies both soluble and insoluble fiber individually, as well as Total Dietary Fiber (TDF) through an enzymatic-gravimetric method and liquid chromatography (21). According to Medallion Labs, the AOAC 2011.25 CODEX definition test most closely resembles the human digestive system, and it is the most current validated method for determining dietary fiber in foods and food ingredients (21). It is recommended to use a CODEX definition test when the results are intended for nutrition facts labeling purposes.

For testing, each company received one box, 454 g, of generic brand dry, enriched, white spaghetti pasta. Samples of 100 g from these boxes were taken for CODEX Definition method testing. As mentioned, the goal of the AOAC 2011.25 test is to simulate the human digestive system for the most accurate results. Following standard procedure for this method, the enzymes alpha amylase and amyloglucosidase were used to originally digest the product at 37 degrees C. Enzymes and proteins in the sample were then denatured using a heat of 95 degrees C, and proteases subsequently digested the product further. Insoluble dietary fiber (IDF) was measured first by filtering any particles that were resistant to digestion. Another step of filtration was completed to determine the amount of gravimetric soluble dietary fiber (G-SDF). High performance liquid chromatography (HPLC) was carried out to measure HPLC-SDF, and total soluble dietary fiber (SDF) was calculated by adding the G-SDF to HPLC-SDF. Finally, the sum of IDF and SDF was calculated to determine total dietary fiber (TDF) (22).

Results

The following table exhibits results for insoluble dietary fiber (IDF), soluble dietary fiber (SDF), and total dietary fiber (TDF) from both labs.

Table 1. IDF, SDF, and TDF quantities in generic dry enriched white spaghetti pasta, as measured by the CODEX Definition AOAC 2011.25 test at two different labs.

	Medallion Labs	**Merieux NutriSciences, Silliker, Inc.**
Insoluble Dietary Fiber (IDF) (per 100g)	1.9 g	1.9 g
Soluble Dietary Fiber (SDF) (per 100g)	3.7 g	3.5 g
Total Dietary Fiber (TDF) (per 100g)	5.6 g	5.4 g

Values for each of these results are based on 100 g samples of the dry pasta. The quantity of IDF was equal for both labs, and the values for SDF and TDF each differed by only 0.2 g.

Discussion

According to the nutrition facts label for the pasta used as our sample, a 56 g serving of the product contains 2 g of fiber. Based on the total fiber content from Medallion Labs, a 56 g sample of this same product would contain 3.1 g of fiber. Results from Silliker Labs reflect that a 56 g sample of the product would contain 3.0 g of fiber. Both of these results suggest that the fiber content included on nutrition facts labels for generic enriched white spaghetti pasta stems from outdated testing methods and may need to be updated.

Table 2. TDF reported in USDA SR Legacy Foods Nutrient Database (23) compared to values found in this study.

	Total Dietary Fiber (TDF)	
	Per 100 g	**Per serving (56 g)**
USDA Nutrient Database	3.6 g	2.0 g
Merieux NutriSciences, Silliker, Inc.	5.4 g	3.0 g
Medallion	5.6 g	3.1 g

The USDA Nutrient Database is commonly used for determining the nutrient content of foods. This database lists the value of dietary fiber for the exact brand and type of pasta used in this study as approximately 2 g per serving (Table 2) (23), which aligns with what is printed on the nutrition facts label for this product. The FDA allows a "good source" claim for any food item that contains 10-19% of the daily value for fiber in one serving, which is equivalent to 2.8-5.4 g (20). Current fiber values on nutrition labels for generic white spaghetti pasta are not recognized by the FDA as a "good source" of fiber. However, according to the results of this research, updating nutrient databases and nutrition facts labels on these products would allow for a "good source" claim to be made.

Although a difference of just over 1 g of fiber may seem insignificant, this amount can add up to make an impact, especially considering how low the current fiber intake is for most US children. As mentioned previously, children often consume refined grain products in large quantities (16). Therefore, a child may consume two servings of generic enriched white spaghetti pasta rather than just one. According to the results from both labs, two servings of this pasta would provide over 6 g of dietary fiber- almost a third or more of a child's daily fiber recommendations, depending on their age and sex (7). Although there is still a push for children to consume more fruits and vegetables that are high in fiber, this research indicates that even refined grains can play an important role in children's diets to increase fiber intake.

It should be noted that, while this research indicates that the fiber content of white enriched pasta is slightly higher than what is stated on the label, whole grain pasta is still likely a better source of fiber. The current nutrition facts label for whole wheat spaghetti pasta of the same generic brand used in this study reflects that there are 5 g of fiber per serving versus only 2 g of fiber per serving of white spaghetti pasta (23,24). Results of this study demonstrate a discrepancy between nutrition labeling and the true value of fiber in pasta, suggesting that the amount of fiber in whole grain spaghetti may actually be higher than 5 g per serving. Despite the fact that refined grains remain a secondary solution in terms of trying to increase fiber consumption in children, it is important to support a greater awareness among consumers, such as parents, that refined grains still provide a source of dietary fiber. Updating nutrition labels to exhibit the correct fiber values has the potential to shed a more positive light on pasta in general and, thus, push back against an increasing popularity of grain-free diets. At the very least, it would provide a better understanding of the true fiber content in a food that is commonly consumed by children in order to make the best recommendations for kids and find effective ways to educate parents on increasing the fiber content of their child's diet.

Salvatore S et al (25) reviewed dietary fiber in healthy children and in pediatric gastrointestinal disorders. They note that fibers naturally present in foods, fruits, vegetables, legumes, cereals or those used as supplements have different physical, chemical and functional profiles. They note the exact amount and characteristics of the fiber requirement in infants and children need to be further established. Intake of excessive fibers may cause flatulence and abdominal discomfort and is not recommended. There is some information that psyllium, an isolated fiber, may be effective in children with gastrointestinal disorders, but the limited and heterogenous data do not allow a specific recommendation.

Efforts to increase the fiber content of whole grains have also been used to increase fiber consumption in children. High amylose wheat flour, a source of resistant fiber, provides an opportunity to increase children's consumption of fiber by using a higher fiber flour that still has the properties of usual wheat flour (26). These efforts to increase fiber consumption with foods that children like are more likely to be successful then expecting a change in a family's food intake with busy schedules.

Using the age plus 5 fiber recommendation would support that a 3 year old consume 8 grams of fiber and a 12 year old consume 17 grams of fiber. As most foods contain 1 – 3 grams of dietary fiber, the recommendations on food groups should provide these levels of dietary fiber (9).

The US Nutrition facts label requires that manufacturers list total dietary fiber per serving. Information about soluble and insoluble are optional for food manufacturers. The FDA now requires that all added fibers show a beneficial physiological effect before they can be counted as dietary fiber on the label. A wide range of physiological benefits can support the beneficial physiological effect of a dietary fiber, including improved laxation, lowered blood lipids, better glucose control, and increased absorption of nutrients, including calcium as examples. Other label claims allowed are good and excellent source of dietary fiber.

Conclusion

Low fiber intake is a widespread problem among US children. Despite a constant push for increased whole grain consumption, kids continue to express a preference for refined grain products. Dietary fiber values listed on the nutrition facts labels and in nutrition databases for white enriched pasta may not be entirely accurate, and they indicate that the fiber content of these foods are, in fact, higher than what is represented. Updated methods for testing dietary fiber should be utilized to ensure correct labeling of these food products.

Promoting intakes of plant foods including grains, vegetables, fruits, and legumes are critical to enhance dietary fiber intakes in children. Expanding inclusion of natural fibers in the popular children's foods is another public health strategy to improve health outcomes and decrease disease risk in children. Convenient, low cost, higher fiber foods that are liked by children are also needed to ensure access to higher fiber diets to our most at risk populations.

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Chapter 3: Summary of Future Research

How to communicate the significance of iodine in the diet for prenatal health

It is clear from the large body of evidence that iodine is an important trace mineral in the diet for all life stages. Iodine is particularly important during pregnancy and lactation to support the growing fetus. In the maternal diet, iodine deficiency is the single greatest preventable cause of brain development issues in the world (de Benoist et al., 2008).

Some of the best sources of iodine include seafood products, iodized salt, and dairy. Most dairy products, including fluid milk, milk protein powders, and yogurt, contain significant amounts of iodine making it an accessible source of iodine in the diet. This also includes lactose-free dairy for those with an allergy. The Dietary Guidelines for Americans (DGA), dairy recommendations are in alignment with the Recommended Dietary Allowances (RDA) for iodine (*Home | Dietary Guidelines for Americans*, n.d.). However, it is important to understand that iodine content in plant-based products is not a significant source of iodine.

To ensure women of childbearing age are meeting the iodine requirements for a healthy pregnancy, perhaps implementation of new educational strategies should occur for women to feel confident during this stage. For one, clearer labeling on the packaging that highlights dairy products as good sources of iodine. Secondly, ensure that women receive optimal prenatal health education and the importance of certain nutrients for a healthy pregnancy.

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