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Evaluating the Economics of Gluten-Free Households

Keia Mornys Alicia Jones
University of Arkansas, Fayetteville

Evaluating the Economics of Gluten-Free Households

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Keia Mornys Alicia Jones
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Michael R. Thomsen, Ph.D.
Thesis Director

Di Fang, Ph.D.
Committee Member

Christine Yung Hung Ph.D.
Committee Member

Abstract

Over the past two decades, the diagnoses of gluten allergies and celiac disease has increased significantly. Although there has been no development of a cure for either ailment, these conditions can be managed by the elimination of glutenous foods from a person's diet. In previous studies, the financial cost of replacing or excluding glutenous foods was higher than the financial cost of diets that do not exclude gluten. The objective of this study is to examine the differences in the economic feasibility of a conventional diet in comparison to a gluten-free diet. Using a sample of foods and prices from the *Food and Nutrient Database for Dietary Studies* (FNDDS), the differences in price were examined. This study builds on the methodology used for the United States Department of Agriculture (USDA) Supplemental Nutrition Assistance Program (SNAP) Thrifty Food Plan (TFP). Of all food plans, the Thrifty Food Plan represents the lowest-cost way to meet minimum nutritional recommendations for vitamins and nutrients. The models require that the nutritional recommendations from the Thrifty Food Plan and Dietary Guidelines for Americans have been satisfied.

Keywords: Centers for Disease Control and Prevention, CDC, National Health and Nutrition Examination Survey, NHANES, Supplemental Nutrition Assistance Program, SNAP, United States Department of Agriculture, USDA, Gluten-Free, Food Security.

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Table of Abbreviations

ARS	Agricultural Research Service
BLS	Bureau of Labor Statistics
CDC	Centers for Disease Control
CNPP	Center for Nutrition Policy and Promotion
CPI	Consumer Price Index
DGA	Dietary Guidelines for Americans
FALCPA	Food Allergen Labeling and Consumer Protection Act
FDA	Food and Drug Administration
FNS	Food and Nutrition Service
FPED	Food Patterns Equivalents Database
GDP	Gross Domestic Product
GF	Gluten-Free
ERS	Econimic Research Service
NHANES	National Health and Nutrition Examination Survey
OAS	Oral Allergy Syndrome
SSI	Supplemental Security Income
TFP	Thrifty Food Plan
USDA	United States Department of Agriculture
WWEIA	What We Eat In America

Chapter 1: Introduction

According to the Centers for Disease Control (CDC), one in ten adults over the age of eighteen have a food allergy, and one in thirteen children under the age of eighteen copes with a food allergy (Gupta et al., 2018). In the U.S., eight allergens are considered significant. These major food allergens include milk, eggs, peanuts, tree nuts, wheat, soy, fish, and shellfish (Gupta et al., 2018). Due to the extensive set of symptoms that result from allergies, it is challenging to pinpoint allergies as the source of discomfort (Singh & Whelan, 2011). Therefore, the allergic population may be larger than previously measured by a confirmation of diagnosis. Because avoidance of gluten-free products is the only treatment for gluten sensitivity, allergies, and Celiac disease, it is vital that GF consumers can afford foods that are a dietary necessity.

This study focuses on the cost differences between conventional diets and gluten-free diets in the United States of America. There is a particular interest in the affordability of gluten-free items for people on the Supplemental Nutrition Assistance Program in the United States. Cost differences in gluten-free products impact SNAP participants whether they choose the diet voluntarily or have a medical need to adhere to a gluten-free diet.

Allergies are most consistent with immune overreactions to proteins in foods and environmental factors (AAAAI, 2020). Symptom severity can range from mild to acute. Allergies resulting from food ingestion can be identified as Oral Allergy Syndrome (OAS). OAS is indicative of an oral allergy and symptoms of discomfort within the oral region. A physician's conclusion of an allergy is often defended by additional symptoms or reaction histories and accompanied by biological testing.

Of these significant allergens, the diet change resulting from a wheat allergy is most widely known as a “gluten-free diet.” Gluten is identified as one of the proteins in wheat that cause a wheat allergy. The other possibilities can be albumin, globulin, and gliadin (FDA, 2018). Because gluten is the most commonly identified factor related to allergic reactions to wheat, doctors recommend that patients adopt a gluten-free diet to avoid discomfort.

Another condition limiting the consumption of wheat and gluten-based products is Celiac Disease, which affects over 1% of the U.S. population, about three million people (University of Chicago Medicine 2005). Celiac disease is another immune disorder that causes sensitivity to the gluten protein. The ingestion of gluten causes damage to the small intestine (NIH, 2020). Symptoms vary and can be consistent with abdominal pain, slowed growth in teenagers, and mood disorders, mainly in adults (AAFP, 2019). Celiac disease is treated by permanently avoiding glutenous foods (Gorgitano & Sodano, 2019).

The allergies, sensitivities, and celiac conditions hinder general life practices and may even become debilitating over time. In the United States, an estimated 1% of people have celiac disease, and an estimated 1% have a wheat allergy (Mahadov & Green, 2011). An estimated 6% of the U.S. population also has gluten sensitivity. For these individuals, avoidance of wheat and gluten is currently the most beneficial treatment. These immune disorders combined may potentially be affecting up to 8% of the U.S. population (Igbinedion et al., 2017).

As the diagnoses of these disorders climb, there is an increasing need to accommodate the changing lifestyles. Regulation is also needed to make sure ingredient labeling is correct, and that foods are affordable. The United States government has attempted to make the identification of allergens simpler. In 2004 the Food and Drug Administration (FDA) passed the *Food Allergen Labeling and Consumer Protection Act* (FALCPA). The Act applies to labeling packaged foods containing any of the eight major allergens stated beforehand, including gluten, which is the allergen of focus in this paper. The Act also includes imported goods, providing extra protection to American consumers. The eight major allergens account for over 90% of documented food allergens, so this step is necessary for consumers to make informed decisions (FDA, 2018). To ensure adherence to the 2004 regulations, the FDA inspects several foods to ensure labeling is correct.

Gluten-free foods are made without the gluten protein, often found in ingredients like wheat and rye. These replacement foods often imitate or replace their conventional counterparts. Some examples may be gluten-free macaroni and cheese, cookies, or bread. Prior studies measure the price difference of these replacement foods to be between 130% to 500% of the price of their conventional counterparts (Singh & Whelan, 2011; Stevens & Rashid, 2008).

The cost burden of these foods is increasing for gluten-sensitive people. The labeling requirement has made it easier to identify allergens. However, the growing niche market for gluten-free products has driven up the price of those packaged goods.

My project aims to provide insight into the cost burden of gluten-free foods on American households by measuring the cost of gluten-free food substitutes a SNAP participant could purchase with the current Thrifty Food Plan benefit level. The increased cost is most burdensome on people who qualify as low-income or on welfare assistance programs. In 2018, 38.1 million people lived below the poverty line. The United States Department of Agriculture (USDA) Economic Research Service (USDA-ERS) recognized the 40.3 million people used SNAP assistance that same year. SNAP is the most extensive social welfare program in the United States. The heavily funded program can be more efficient by personalizing need-based aid

(Poverty USA, 2020; USDA-ERS, 2019). Evaluating the increased cost of a medically necessary diet is essential for maintaining effective welfare programs.

The Supplemental Nutrition Assistance Program (SNAP) is the most wide-ranging food assistance program in the United States. Over forty million people in the United States used SNAP at some point during the year 2018 (U.S. Bureau of Economic Analysis, 2021). The program's impacts are significant, but literature shows more effective welfare programs tailor to people's needs (Kenworthy, 1999; Gorgitano & Sodano, 2019). The current SNAP food plans attempt to provide examples of costs under different budget levels. The policies consist of a Thrifty Food Plan; the lowest and most basic budget; the Low-Cost, Moderate-Cost, and Liberal food plans. Each version is meant to represent a nutritious diet and variant costs.

The MyPyramid guidelines are federal guidelines based on the information published in the Dietary Guidelines for Americans (USDA & HHS, 2020). The guidelines are adjusted approximately every five years and were modified before the 2006 Thrifty Food Plan (Carlson et al., 2007) and before this project. MyPyramid guidelines reflect the 2005 dietary guidelines, and this project uses the updated 2020-2025 dietary guidelines and MyPlate guidelines (USDA & HHS, 2020). MyPyramid guidelines describe the number of servings in each food group that should be consumed in a day. The Pyramid consists of grains and carbohydrates, vegetables, fruits, dairy, meats, and fats (Carlson, Lino, & Fungwe, 2007). The 2005 guidelines show that grains and carbohydrates should be consumed the most of all other dietary components, which can be a more significant burden on those who cannot consume conventional grains due to a gluten-free diet (AAAAI, 2020). In 2011 MyPyramid recommendations were updated to the MyPlate visual interpretation of the Dietary Guidelines for Americans (DGA) (DeNoon, 2011; USDA & HHS, 2020).

Objectives and Hypotheses

This study aims to assess the differences in prices of gluten-free and conventional foods for consumers. Using NHANES survey data to distinguish foods that constitute a gluten-free diet from those that comprise a traditional diet, the analysis will use three NHANES datasets as a representative sample of gluten-free consumers. Data from the DGA is also used to fulfill the baseline dietary recommendations of the SNAP Thrifty Food Plan. The culmination of data sources and hypothetical implementation into the Thrifty Food Plan model will allow us to view the potential impact of additional benefits to those consumers who need to purchase gluten-free items.

We hypothesize that the cost of the gluten-free diet to consumers will be higher than that of conventional consumers.

Chapter 2: Social and Dietary Factors of a Gluten-Free Diet

The following studies reviewed provide comprehensive analyses of gluten-free price differences. A few pinpoint gaps in research that fall within the United States. Of the studies, few recommend social welfare changes. Food security issues in the U.S. may resemble other countries' programs that tailor to individuals. Three significant components need to be considered. Welfare policy and the benefits to society improve when more unique and tailored welfare measures are considered (Kenworthy, 1999; Singh & Whelan, 2011). Next, established gluten-free cost comparisons can create a baseline for price differences between conventional and gluten-free foods. Finally, we can evaluate the nutrition standards set within the USDA SNAP Thrifty Food Plan, assess the program's adherence level, and what obstacles are faced in pursuit of nutritional guidelines.

Food-Based Welfare

Through the years, various impacts of social welfare have been evaluated. In recent years, reducing poverty has been constricted, and welfare policies have been under the highest scrutiny. The current structure of the government of the United States is very similar to other western countries. However, political theater is increasing within the lawmaking branch and can prevent meaningful policy from being quickly passed and enacted. Contrarily, increasing efficiency in welfare policy research and proposals can be attributed to growth in data availability, updates in technology, and adequate research on poverty reduction strategies. One result of a report depicted a decrease of 0.75% on the poverty rate, with a 1% increase in government welfare transfers (Kenworthy, 1999). Evidence has not yet been found that the SNAP program has the same effect. However, the government welfare transfer was the most similar concept to this current experiment. Welfare programming in western countries is evaluated in this section, and the strategies can easily be compared to strategies in the United States.

Welfare policies demand heavy monetary resources. Between 1960-91, the estimated contribution of a country's Gross Domestic Product (GDP) was between 10% and 30% attributed to social welfare programming (Kenworthy, 1999). The expected number of impoverished people was set to diminish over the years before considering the COVID-19 pandemic, and welfare programs were set to become more cost-effective, which the pandemic may also alter in untold ways. However, there is evidence that slight changes in wealth distribution and policy changes make an enormous difference in the poverty rate over several years. Kenworthy (1999) assessed this assertion using a cross-national approach in fifteen countries. The research evaluated poverty rates and reduction over a thirty-year period and used regression analysis to measure poverty rates post-tax and post-government transfer. Considering social welfare programs, policy extensiveness, and national wealth, the study found that social welfare policies do help reduce poverty rates in the 15 countries studied over ~30 years (Kenworthy, 1999).

In this case, it is crucial to investigate what made practices more efficient than the last. They found that, on average, for the fifteen nations studied, poverty rates reduced by 0.75%, with every 1% of GDP spent on cash transfers (Kenworthy, 1999). Each country was then omitted in the regression to account for outliers. The results were still consistently positive and significant at a $p=0.1$ level. Social welfare policies seem to have helped reduce both absolute and relative poverty in the wealthiest industrialized countries over the past several decades. A diminishing marginal return was also felt with more aggressive government transfer measures. It seems that more extensive actions would not necessarily cause a further decrease in poverty levels to the same degree. Additional transfers were also not seen as directly beneficial to decreasing poverty rates in those added situations. Instead, peripheral variables explain more of the decrease than the transfers do.

The United States was included as one of the affluent countries in this investigation but was an outlier based on the number of resources, they put into welfare projects. The input was considerably lower than that of other sample countries (Kenworthy, 1999). The pre-transfer and post-transfer poverty rates were more than double the highest of any other countries studied. A few reasons for the increased poverty rate may be that American social welfare programs are less effective than those in the other fourteen countries in this study. The United States may be socially more cautious of adopting welfare programs as policy and more careful about this money transfer method. The article asserts that their plans were not as effective because of the U.S.'s stingy view on welfare. Even so, compared to countries with similar social welfare expenditures, the U.S. still falls behind. Kenworthy (1999) states that this is due to tailoring social welfare programs to people's needs. The "coverall" strategy is another underlying reason why foreign countries overtake the U.S. in successful welfare programming.

Canada provided a guaranteed income to elderly occupants of the country. The income ranged between 55-60% of the country's median income, and food stamps further supplement at 35-40% of the nation's median income (Kenworthy, 1999). This example shows a strategy for targeting welfare towards at-risk groups and considering some issues that arise with poverty in the country.

The Canadian v. U.S. example may suggest that increased social welfare policy effectiveness may be possible without a substantial rise in expenditures. Relatively small increases in welfare benefit levels for programs that assist nonworking and low-income workers might bring the U.S. poverty rates down to rival other prosperous nations (USDA-ERS, 2019).

The USDA published the 2018 Household Food Security Report, which solidifies the inconsistent nature of social welfare in the United States, especially when it comes to food assistance. The report shows that low-income households on SNAP may show a false sense of security. In other words, food-insecure homes may only become secure because of their assistance usage (USDA-ERS, 2019).

Medical Necessity of a Gluten-Free Diet

Diagnoses of allergies, Celiac disease, and allergen sensitivity are reasons for a higher level of observance of gluten-free dietary practices. As allergies rise in the United States, so does the importance of correct diagnosis and treatments. An allergic reaction is an immune response to an allergen. In most cases, a skin test can confirm an allergy (Hadley, 2006). If not, other methods can be used, including blood tests and hair tests, to name a few. Diagnoses of Celiac disease may take a similar route, but the diagnosis is often prolonged. “Continued exposure (to gluten) declines the intestine’s ability to absorb nutrients, including iron, calcium, vitamin D, and folic acid” (Richardson, 2018, p.13). If Celiac disease goes untreated, it may cause other autoimmune conditions, including but not limited to Type one diabetes and thyroid problems (Richardson, 2018)

If a doctor cannot adequately diagnose Celiac disease or an allergy, they may report the patient as gluten sensitive. Gluten sensitivity is also used as an intermediate diagnosis term. Additional tests can be run to see whether the patient reacts to another component in the food. Parent-reported allergies also play a vital role because many children show symptoms. Since gluten is in many foods, avoidance is difficult because some grains are carriers but do not contain the glutenous component. Oats are an example of a grain grown without gluten but may be a gluten carrier if a gluten-containing crop is grown nearby (Richardson, 2018).

Treatment for several food allergies includes total avoidance of any products containing the allergen. Proper food labeling is a helpful instrument to aid people in their treatment. Substitute foods often label as "gluten-free" or "allergen-free" on the front of the package. A study has not yet been performed to evaluate how much time is saved by labeling products as "gluten-free" on the front of packages rather than searching for the disclaimer on the ingredient label. The FALCPA requires food manufacturers to label food products that contain an ingredient that is or contains protein from a major food allergen in one of two ways, by listing the allergen directly after the ingredient, or at the bottom of the ingredient list (FDA, 2018). Labeling requirements make it easier for those diagnosed with sensitivities to avoid the food that causes them discomfort. Advocating for labeling was one of the initiatives that helped shoppers make the right consumption choice. It also takes the blame away from the consumer for being misinformed.

Gluten-Free Cost Comparisons

The cost of a gluten-free diet has steadily increased over conventional products (Lee et al., 2007). Extensive research has been completed analyzing price diversity in Canada and several in Europe. The research on allergies and allergens is more advanced in Western cultured regions than in other areas. The comprehensive set of studies compiles various sample sizes and types that vary from market baskets, inclusivity of brand names, and grocery store samples (Stevens & Rashid, 2008). The foods included represent Western diets, including common foods listed like bread, pasta, and cereals. All studies in this section involve celiac disease as a common source of each study's relevancy.

The American experiment by Lee (2007) used a market basket comparable to the United States consumption patterns reported by the USDA Economic Research Service (Lee et al., 2007). The market basket included portions for a wide variety of foods used. “The study “market basket” focused on the foods that would necessitate a gluten-free substitute, such as pasta, bread, crackers, cereal, waffles, cookies, pretzels, pizza, macaroni and cheese, and cake” (Lee et al. 2007, p.424). When considering the availability in United States regions, the accessibility of products varied considerably, although the overall price difference between gluten-free and conventional foods was similar.

Stevens’ (2008) investigation focused on fifty-six individual food comparisons. The list of items is split into nine larger categories that usually include glutenous foods. The researchers managed to find a one-to-one match to compare each product. The lowest price product was used for both the conventional and gluten-free categories. The unit cost of each item was valued at the given price per one-hundred grams of the product—the stable valuation limits inconsistency in weight and price of products (Stevens & Rashid, 2008).

Cost Burden

The reviewed titles emphasize the burden of adherence to a gluten-free diet. In many cases, the qualifications for the test sample included labeling the product as “gluten-free.” It was seen as a basic qualification for inclusion in the model. Those gluten-free tagged items are then compared against conventionally labeled items. The conclusion found that gluten-free labeled foods were, on average, 242% more expensive than their conventional counterparts (Stevens & Rashid, 2008).

The Stevens (2008) research shows that there are varying cost differences based on the product type. Items that naturally do not contain gluten seem to receive a higher cost once they are labeled gluten-free. Compared to conventional goods in this study, there was a 32% price increase in gluten-free labeled meat products and an increase in the cost of soups and sauces by 455% on average if they contained the gluten-free label (Stevens & Rashid, 2008). This increase indicates that labeling can contribute to the characterization of items as specialty goods.

<u>Availability of Product</u>

Because gluten-free item products' availability is inconsistent, patients find it challenging to locate their desired goods. The availability is most likely found in specialty stores and online. Online retailers usually have a continuous supply and report a 100% availability of all products requested by the researchers. Between the United Kingdom and the United States, "markets in the U.K. tend to offer a wider range of gluten-free products" (Lee et al., 2007, p.247). Gorgitano (2019) attempted to gather adequate samples from each market type by requiring product pricing from each of the three store types for each product tested. The Hedonic Price Model (H.P.M.) identifies the "premium price associated with different attributes of individual selling units" (Gorgitano & Sodano, 2019, p.3). The model integrates two-hundred and sixty-two items and is unique because it includes the product's implicit value to their consumers more than the other studies do. Some of the products that had implicit value showed in customer's utility from purchasing special foods. The final HPM integrates various attributes (pack size, brands, G.F. certification, product features, and ingredients) into a single regression model. These values provide a feeling of security and quality to Italians and value for the cost. The report also focused on the geographic availability of the product and the ingredients in the substitute product. In this case, 44.3% of stores had gluten-free pasta available. The price is also consistent with other studies in the European region "The average cost for G.F. pasta is €5.08 per kg, much higher than the average price of conventional pasta, which is €2.02 for stores offering G.F. pasta and €1.66 for the remaining stores" (Gorgitano & Sodano, 2019, p.8).

Summary of Cost Comparison Evidence

Although gluten-free items' availability is higher in specialty stores and online than in grocery stores, results show that these items' cost is always greater than conventional diets (Lee et al., 2007). The article found that the most extensive price statistical range was found in crackers, pretzels, pizza, and cake (Lee et al., 2007). Stevens, 2008 concluded that the average cost difference was 242% more expensive for customers to order gluten-free products (Stevens & Rashid, 2008). "Generally, the gluten-free products were more costly by 240%" of the conventional counterparts' cost (Lee et al., 2007, p.426).

Gorgitano (2019) notes that the high price is especially burdensome for less affluent people. They re-affirm the direct connection to people affected by celiac disease. For the people in Italy, the accessibility of gluten-free pasta was inadequate, and most retailers did not offer the option. High prices in the region reinforced inaccessibility (Gorgitano & Sodano, 2019). The products online and in-store were certified by food safety organizations, ensuring they would be generally reliable and accepted as safe by people in Italy. The paper suggests that the high quality of G.F. items may trigger price increases in the future, and more people without dietary restrictions will be drawn to them. The price rise will be even more burdensome on individuals in poverty who have dietary restrictions, and may lead to a lack of adherence to the G.F. diet (Gorgitano & Sodano, 2019).

SNAP Participation and Nutrition Goals

The Supplemental Nutrition Assistance Program is used as a poverty relieving mechanism. Food insecurity may have many stemming factors, and those categorized as food insecure may not always be eligible for SNAP benefits. We find that food-insecure individuals are more likely to be obese, and the level of food insecurity positively correlates with increased weight generally (Coffino, 2018). The Thrifty Food Plan is a market basket of foods that will satisfy nutritional recommendations at similar volumes to what Americans currently eat on average. Each basket has recommendations based on the amount of benefit a family may receive. Since the program aims to reduce food insecurity, families can only purchase ingredients to cook at home. Unfortunately, people are restricted from using the benefits on toiletries, some condiments, and readymade foods. The reality of people's choices is exposed when many people still end up food insecure with the maximum benefit allowed (USDA-ERS, 2019).

Persistent food insecurity can be illustrated further by a study that uses a sample of three tested and given incentives to choose nutritious items with the given budget of the maximum SNAP benefit. The randomized control trial split the groups into one that would receive a $10 incentive for choosing nutritious foods. One educated the participants about choosing healthy items, and one was given a default market basket that they could decide to change. When they received a default basket and were allowed to change items as they see fit, all participants changed foods in the default basket, and about 40% changed the quantities of the foods received. Of that 40%, about 32% of participants changed of their default basket (Coffino, 2018).

After food selection, researchers took note of the nutrients in the selected baskets. The default basket was shown to be generally more nutritious than the altered versions. The group was given the default market basket and allowed to change selected items with fewer calories, saturated fats, sodium, and cholesterol. They also bought more fruits and vegetables. The number of servings was even smaller for that group, indicating that SNAP funds of this amount are not sufficient for a healthy diet. The outcome showed that people are not willing to use the SNAP recommended market baskets as written. When participants are given incentives to choose nutritious items, they may still opt for the more affordable or familiar option.

Additionally, the group given education was the second most effective in purchasing healthy options, and it still was not as beneficial as the default basket. Although SNAP encourages education about food choices and gives various examples of market baskets, people will still receive fewer servings of food with the current maximum benefit. Applied to SNAP participants who currently adhere to a gluten-free diet, the number of food servings may be even more limited. There is still varying evidence on the nutritional quality of a gluten-free diet because a person may make it more affordable by leaving out gluten-free grains and supplement with other food groups. Leaving out the grain category of a diet is not advisable by the 2005 USDA MyPyramid, which recommends nine servings of whole grains per day (USDA-ERS, 2019).

SNAP Adherence

The Supplemental Nutrition Assistance Program uses government funds for citizen food purchases. Although the goal is to alleviate hunger and nutritional deficiencies, the monetary benefit does not always supply enough food or nutrients to their participants. One study found that although their sample used less money than the lowest benefit SNAP plan at 79% of the SNAP household grocery expenditure, the time that factors into cooking meals from scratch is not always available for low-income households and they may end up additionally purchasing food outside of an at home setting (Sanjeevi et al., 2019). Households did not meet SNAP purchase recommendation amounts of fruits, low-fat dairy, seafood, nuts, and all vegetables except "other." The buying choices were also skewed towards buying processed grains and sweetened snacks (Sanjeevi et al., 2019). Observance of SNAP recommendations is moderate and needs to be observed in gluten-free dieters. There may be a similar rate of adherence if funding is not increased at the federal level.

Chapter 3: Methodology

Considerations for Data Collection

The data collection was primarily based on the SNAP Thrifty Food Plan data and the needs of their objective function and constraints. The Center for Nutrition Policy and Promotion (CNPP) made one revision to the 1999 Thrifty Food Plan. The CNPP consideration being, the incorporation of current dietary guidance and consumption (Carlson et al., 2007). Additionally, the basket items in the previous Thrifty Food Plan were adjusted for inflation.

The Food Data Central data, What We Eat In America (WWEIA) data, and Food Patterns Equivalents data were derived from the Agricultural Research Service (ARS) (USDA-ARS. The Food and Nutrition Service (FNS) carried the price data from the Food Prices Database (USDA-FNS, 2009). The National Health and Nutrition Examination Survey (NHANES), conducted by the CDC, contributed data about current consumption patterns for Americans and was the source of G.F. consumers' eating patterns. Dietary Guidelines for Americans (DGA) issued from the USDA Food and Nutrition Service. Consumer Price Indices (CPI) were procured from the Bureau of Labor Statistics (BLS) under the U.S. Department of Labor.

Data Valuation and Usage

NHANES

The National Health and Nutrition Examination Survey provided survey material from participants in the United States and examined their food intake habits. The goal of the NHANES is to produce national estimates representative of the total noninstitutionalized civilian U.S. population" (Carlson et al., 2007). The NHANES material used consisted of demographics data, survey data of daily food intake, and nutrition information, including dietary preferences. In the

United States, an estimated 1% of people have celiac disease, and an estimated 1% have a wheat allergy (Mahadov & Green, 2011). An estimated 6% of the U.S. population also has gluten sensitivity. This combination of disorders in the United States makes up about 8% of the total population. Contrarily, the number of people in the NHANES survey who indicated a gluten-free diet is .1% which is considerably less of the survey sample than the population reporting to have a case of either celiac disease or gluten allergies.

Respondents answered questions over a two-day period about their dietary habits. These datasets are composed of survey data of an interview portion called "What We Eat In America." The survey compiles results into a database accounting for data documentation, codebooks, and response frequencies for each day the respondents choose to report their dietary practices. The survey is conducted every other year in the United States, and datasets are available through the CDC, dating back to the year 1999. This project uses datasets between the years 2013 and 2018.

The demographic data and documentation are helpful in this project, supplying respondents' age, gender, race, and dietary preferences. The segment also enumerates the number of respondents, education level, and annual household income. Each respondent was assigned a number, tying the data to other datasets in the survey year.

Three sections from the dietary data section of the survey were used. Two were datasets for each day the survey required individual responses and documentation. The answers separated into day one and day two were connected again to each respondent's sequence number. This portion took note of respondents' intake patterns and nutrients ingested. Total nutrient intake was also listed in detail. Both sections indicate if each respondent preferred a gluten-free diet. The third section is a segment that encompasses the total nutrients consumed for each respondent.

The third section is also where special diets are listed, including the diet of interest, the gluten-free diet.

My study used three NHANES releases, including bi-yearly issues from 2013-2014, 2015-2016, and 2017-2018. Each NHANES release is released approximately once every two years. A total of 28,061 respondents' data was used for this project. Only 61 of the respondents self-identified as adhering to a gluten-free diet. Those who identified as a gluten-free consumer account for 0.22% of the total respondents in our datasets. Of the 8,704 respondents in 2017-2018, 16 self-identified as adhering to a gluten-free diet. In the datasets from 2015-2016 and 2013-2014, respectively, there were 14 and 31 respondents per survey cycle.

FoodData Central

The USDA Agricultural Research Service (USDA-ARS, 2020) releases data on foods sold in the U.S. FoodData Central contains data on each food type. A unique identifier, known as "fdc-id" in FoodData Central datasets, creates a path to merge data into one dataset where we combined all attributes we thought necessary to competing the project. The fdc-id is a six-digit code that identifies an individual food item in the dataset (USDA-ARS, 2020). Inclusion of these datasets was important for obtaining a wide range of individual products and their nutritional values.

Food Pricing

The price values crucial to determining the price difference between conventional and gluten-free diets are obtained from the USDA Food and Nutrition *Service Food Plans: Cost of Food* monthly reports (CNPP, 2004). We had the goal of using the most recent pricing data that is consistent with the TFP. The TFP used 2001-2002 released CNPP pricing data

(Carlson, Lino, & Fungwe, 2007). The most recent CNPP pricing data was the subsequent release from 2003-2004 (CNPP, 2004). The results from this project are listed in 2004 prices. The CNPP pricing is consistent with the NHANES foods listed and uses average consumer reported prices from Nielsen data. The Nielsen company surveys over 16,000 people who reside throughout the United States. The combined use of these resources offered through the USDA created a unique profile for this project's relevant data.

The increase in gluten-free consumption may cause an increase in the price of the specialized product. Gorgitano (2019) warns against trivializing the damage caused by consumers with celiac disease. The excessive consumption by non-medically necessary consumers may lead to less strict regulation for gluten contamination and subsequently become a more dangerous environment for Celiac and allergic dieters (Gorgitano & Sodano, 2019). Contrarily, the noticeable uptick in gluten-intolerant consumers and voluntary gluten-free consumers may create an increase in supply and lower the average price of such products over time.

Figure 1 shows the average cost of conventionally consumed items and the cost of items said to be consumed by GF respondents per 100g of each product. The blue bars represent conventional items, and the orange represents GF items. The higher categories represent the consolidated WWEIA codes by the food categories shown in MyPlate with the addition of condiments, baby foods, sugar, beverages, and other foods. Figure 1 shows the continuous availability of prices in all the consolidated categories. Within the more significant categories, sub-categories show an inconsistent availability of prices for all WWEIA coded sub-categories. In the NHANES data, the cost of conventional items was more than that of GF items per the respondents' reports. There was a similar distribution in the cost of each item category throughout each of the diet types. The exception is the baby foods and juices category, which shows consumption by the conventional consumers but not the GF consumers. Without implementing the model, there is an assumption that the model will offer a less costly solution for the GF diet group in comparison to the conventional diet group because the GF average cost is less than that of the traditional group.

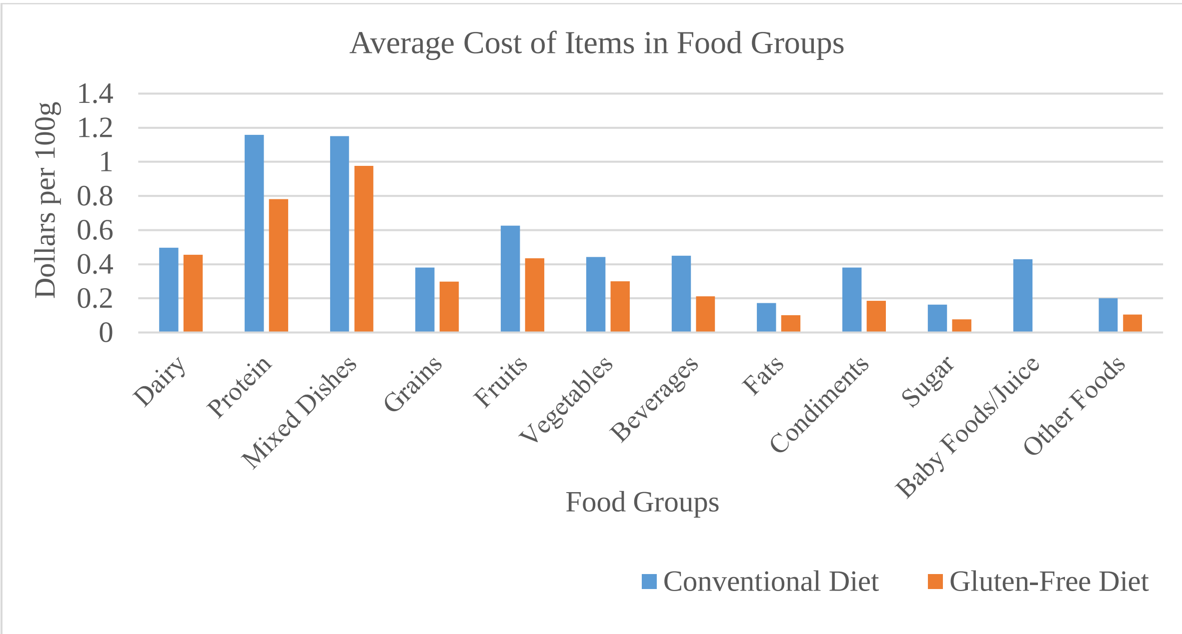

Figure 1:Average Cost of Items in Conventional and G.F. Diets Separated By Food Groups

<u>Food Category Creation</u>

The What We Eat in America Food Categories help separate foods into 167 four-digit sub-categories. All sub-categories fit within the Thrifty Food Plan and MyPlate categories. This project used the four-digit food codes to create consolidated codes using the first three digits from the WWEIA codes. Those three-digit codes make up our 55 food codes that correspond with the 58 TFP food codes. This project used all food codes from the TFP, excluding human milk, plain water, and alcoholic beverages from the TFP categories. The remaining categories remained intact. The food codes were further consolidated into MyPlate adjacent food classes. The large classes cover grains, fruits, vegetables, milk products, meat, and beans, and "other foods," which include prepackaged foods, frozen meals, sauces, and soups. This project used all three coding structures to create categories that are representative of all dietary guideline formats. The current consumption patterns of American consumers shown in Appendix A, and the purchasing limits of the TFP were considered when creating our food categories.

Exclusion of Data

Samples for fish and shellfish were only collected for ages one and older based on the frequency of consumption. This study includes eating patterns for ages one and above as well. Alcoholic beverages were removed from the data because SNAP does not allow for the purchase of alcohol, nor does the DGA recommend alcoholic beverages for consumption (Carlson et al., 2007; USDA & HHS, 2020). Some items were removed due to missing cost data. These codes include 540-snack and meal bars, 648-veggies on a sandwich, 750- alcoholic beverages, 770-plain, tap, or bottled water, and 980- protein & nutritional powders. Individual food codes with an outlier price were also removed, including whey powder and liquid-filled wax candy.

Methodology of Model

Dietary Standards

The recommendations for dietary standards were derived from the *Dietary Guidelines for Americans* (DGA) *2020-2025* (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). The 2006 Thrifty Food Plan report was based on dietary recommendations from MyPyramid. In 2011, the USDA developed a new plan for dietary recommendations called "MyPlate" (DeNoon, 2011). Both MyPyramid and MyPlate plans were based on the Dietary Guidelines for Americans. This project used the most recent data available for this constraint, so the MyPlate plan modeled after the 2020-2025 DGA report was used.

Model Optimization

The objective function that was considered the current consumption of food in each food group and the pricing for each item. The function is then constrained by nutrient intake guidelines for vitamin and mineral content and constrained for the government's intended price contribution to each SNAP participant. The price ceiling is set by the cost level of the plan, the "Thrifty Food Plan" being the lowest cost (USDA-CNPP, 2004). The USDA Thrifty Food Plan measured weekly consumption of food. Table 8 shows the weekly cost limit for the TFP which was divided by seven to reflect the daily cost of all meals on the plan.

Objective Function

The objective functions to minimize the cost of a balanced diet. Prices used in the objective function represent weighted averages for each food category. Weights are determined by grams consumed across NHANES.

Constraints

The objective function is subject to nutrient constraints, MyPlate constraints, and cost constraints. The model function was modeled after the TFP function as closely as possible. The objective was set to minimize the cost of all foods in the market basket given the constraint of the daily TFP cost limit, the recommendations for food servings, and nutrient intakes. The cost constraint was not binding for this project, so it was taken as a secondary constraint. All five constraints were binding in the TFP model. Table 1 shows the data considerations taken to satisfy nutrient constraints similar to TFP nutrient constraints.

Table 1: Datasets and Factors Considered for Nutrient Constraints

Factors Considered for Nutrient Constraints					
Nutrient	NHANES Code	Dietary Guidelines of America Code	Dietary Guidelines Measurements	Constraint Limits	Demographic Specific Guideline

Nutrient Constraints

Of the several constraints, nutrients guidelines were observed for eleven age groups. Each nutrient was considered from the specifications within the DGA recommendations and the SNAP Thrifty Food Plan (Carlson et al., 2007; USDA & HHS, 2020).

Nutrients for all vitamins, minerals, and macronutrients were considered for each food choice and food group. The "total" nutrient content in any food was considered. Any nutrients described as "added" were not individually considered.

Nutrient constraints consist of vitamins A, C, E, B6, B12, thiamin, riboflavin, niacin, riboflavin, calcium, phosphorus, magnesium, iron, folate, and zinc. Copper and potassium are also included in nutrient constraints and fiber content in foods, linoleic (18:2) and alpha-linoleic (18:3) acids, protein content, carbohydrate content, and total fat content. Table 2, Table 3, and Table 4 show the nutrient recommendations for our target age ranges.

Table 2: Nutrient Constraint Ranges for Children Ages 1 to 18

Nutrient	Child 1 year	Child 2 to 3 years	Child 4 to 8 years	Child 9 to 13 years	Child 14 to 18 years
Vitamin A (mcg)	≥300	≥300	≥400	≥600	≥700
Vitamin C (mg)	≥15	≥15	≥25	≥45	≥65
Vitamin E (mg)	≥6	≥6	≥7	≥11	≥15
Vitamin B6 (mg)	≥0.5	≥0.5	≥0.6	≥1	≥1.2
Vitamin B12 (mcg)	≥0.9	≥0.9	≥1.2	≥1.8	≥2.4
Thiamin (mg)	≥0.5	≥0.5	≥0.6	≥0.9	≥1
Riboflavin (mg)	≥0.5	≥0.5	≥0.6	≥0.9	≥1
Niacin (mg)	≥6	≥6	≥8	≥12	≥14
Calcium (mg)	≥700	≥700	≥1000	≥1300	≥1300
Phosphorus (mg)	≥460	≥460	≥500	≥1250	≥1250
Magnesium (mg)	≥80	≥80	≥130	≥240	≥360
Iron (mg)	≥7	≥7	≥10	≥8	≥15
Folate (mcg)	≥150	≥150	≥200	≥300	≥400
Zinc (mg)	≥3	≥3	≥5	≥8	≥9
Copper (mcg)	≥340	≥340	≥440	≥700	≥890
Potassium (mg)	≥2000	≥2000	≥2300	≥2300	≥2300
Fiber (g)	≥19	≥14	≥17	≥22	≥25
Linoleic Acid (g)	≥7	≥7	≥10	≥10	≥11
Alpha-linoleic Acid (g)	≥0.7	≥0.7	≥0.9	≥1	≥1.1
Protein (g)	≥13	≥13	≥19	≥34	≥46
Carbohydrate (g)	≥130	≥130	≥130	≥130	≥130
Total Fat (g)	≥39	≥39	≥39	≥52	≥58
Total Fat (g)	≤52	≤52	≤54	≤73	≤82
Saturated Fat (g)	≤13	≤13	≤16	≤21	≤23
Sodium (mg)	≤1200	≤1200	≤1500	≤1800	≤2300
Cholesterol (mg)	≤300	≤300	≤300	≤300	≤300
Calories (KCAL)	≥1000	≥1000	≥1200	≥1600	≥1800
Calories (KCAL)	≤1050	≤1050	≤1260	≤1680	≤1890

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

In this study, children were combined into demographic groups based on age and recommended caloric intake. Children account for 44% of all SNAP consumers (USDA-FNS, 2020). Recommended caloric intake for children was then used to determine what level of nutrients the age group should digest. In the TFP, children are separated into groups by age but are not split into genders. NHANES does separate children by age and gender, so age groups needed to be constructed manually.

Table 3: Nutrient Constraint Ranges for Women Above Age 18

Nutrient	Woman 19 to 30 years	Woman 31 to 50 years	Woman 51+ years
Vitamin A (mcg)	≥700	≥700	≥700
Vitamin C (mg)	≥75	≥75	≥75
Vitamin E (mg)	≥15	≥15	≥15
Vitamin B6 (mg)	≥1.3	≥1.3	≥1.5
Vitamin B12 (mcg)	≥2.4	≥2.4	≥2.4
Thiamin (mg)	≥1.1	≥1.1	≥1.1
Riboflavin (mg)	≥1.1	≥1.1	≥1.1
Niacin (mg)	≥14	≥14	≥14
Calcium (mg)	≥1000	≥1000	≥1200
Phosphorus (mg)	≥700	≥700	≥700
Magnesium (mg)	≥310	≥320	≥320
Iron (mg)	≥18	≥18	≥8
Folate (mcg)	≥400	≥400	≥400
Zinc (mg)	≥8	≥8	≥8
Copper (mcg)	≥900	≥900	≥900
Potassium (mg)	≥2600	≥2600	≥2600
Fiber (g)	≥28	≥25	≥22
Linoleic Acid (g)	≥12	≥12	≥11
Alpha-linoleic Acid (g)	≥1.1	≥1.1	≥1.1
Protein (g)	≥46	≥46	≥46
Carbohydrate (g)	≥130	≥130	≥130
Total Fat (g)	≥52	≥47	≥41
Total Fat (g)	≤91	≤82	≤73
Saturated Fat (g)	≤26	≤23.5	≤20.5
Sodium (mg)	≤2300	≤2300	≤2300
Cholesterol (mg)	≤300	≤300	≤300
Calories (KCAL)	≥2000	≥1800	≥1600
Calories (KCAL)	≤2100	≤1890	≤1680

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

Table 4: Nutrient Constraint Ranges for Men Above Age 18

Nutrient	Man 19 to 30 years	Man 31 to 50 years	Man 51+ years
Vitamin A (mcg)	≥900	≥900	≥900
Vitamin C (mg)	≥90	≥90	≥90
Vitamin E (mg)	≥15	≥15	≥15
Vitamin B6 (mg)	≥1.3	≥1.3	≥1.7
Vitamin B12 (mcg)	≥2.4	≥2.4	≥2.4
Thiamin (mg)	≥1.2	≥1.2	≥1.2
Riboflavin (mg)	≥1.3	≥1.3	≥1.3
Niacin (mg)	≥16	≥16	≥16
Calcium (mg)	≥1000	≥1000	≥1000
Phosphorus (mg)	≥700	≥700	≥700
Magnesium (mg)	≥400	≥420	≥420
Iron (mg)	≥8	≥8	≥8
Folate (mcg)	≥400	≥400	≥400
Zinc (mg)	≥11	≥11	≥11
Copper (mcg)	≥900	≥900	≥900
Potassium (mg)	≥3400	≥3400	≥3400
Fiber (g)	≥34	≥31	≥28
Linoleic Acid (g)	≥17	≥17	≥14
Alpha-linoleic Acid (g)	≥1.6	≥1.6	≥1.6
Protein (g)	≥56	≥56	≥56
Carbohydrate (g)	≥130	≥130	≥130
Total Fat (g)	≥62	≥57	≥52
Total Fat (g)	≤109	≤100	≤91
Saturated Fat (g)	≤31	≤28.5	≤26
Sodium (mg)	≤2300	≤2300	≤2300
Cholesterol (mg)	≤300	≤300	≤300
Calories (KCAL)	≥2400	≥2200	≥2000
Calories (KCAL)	≤2520	≤2310	≤2100

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

MyPlate Constraints

MyPlate constraints are composed of larger food groups. These food groups are grains, dairy, fruits, vegetables, and proteins. “Other foods” are also considered and can be composed of foods that may be available for consumption but do not fit in any of the main categories and may not necessarily be recommended by DGA. Table 5, Table 6, and Table 7 present 2020-2025 DGA recommendations, serving as our MyPlate constraints for our target age ranges (USDA & HHS, 2020)

Table 5 shows how children were combined into demographic groups based on age and recommended caloric intake. In the DGA, all age groups had a recommended range of food groups for dietary intake. Each MyPlate food group was based on DGA recommendations.

Table 5: MyPlate Constraint Ranges for Children Ages 1 to 18 years

MyPlate Daily Recommendations	Child 1 year	Child 2 to 3 years	Child 4 to 8 years	Child 9 to 13 years	Child 14 to 18 years
Total Fruit (cup/day)	≥0.5	≥1	≥1	≥1.5	≥1.5
Total Fruit (cup/day)	≤1	≤1.5	≤2	≤2	≤2
Fruit Juice (cup/day)	-	-	-	-	-
Fruit Juice (cup/day)	-	-	-	-	-
Total Vegetables (cup/day)	≥0.6	≥1	≥1.5	≥1.5	≥1.5
Total Vegetables (cup/day)	≤1	≤2	≤2.5	≤3.5	≤4
Dark Green Vegetables (cup/day)	≥0.04	≥0.07	≥0.14	≥0.21	≥0.21
Dark Green Vegetables (cup/day)	≤0.14	≤0.21	≤0.21	≤0.36	≤0.36
Total Red and Orange Vegetables (cup/day)	≥0.14	≥0.36	≥0.43	≥0.43	≥0.79
Total Red and Orange Vegetables (cup/day)	≤0.36	≤0.57	≤0.93	≤1	≤1.07
Total Starchy Vegetables (cup/day)	≥0.14	≥0.29	≥0.5	≥0.5	≥0.71
Total Starchy Vegetables (cup/day)	≤0.29	≤0.57	≤0.71	≤1	≤1.14
Other Vegetables (cup/day)	≥0.1	≥0.21	≥0.36	≥0.36	≥0.57
Other Vegetables (cup/day)	≤0.21	≤0.57	≤0.57	≤0.79	≤1
Beans, Peas, and Lentils (cup/day)	≥0.04	≥0.07	≥0.07	≥0.07	≥0.21
Beans, Peas, and Lentils (cup/day)	≤0.7	≤1	≤1.5	≤2.5	≤3
Total Grains (oz/day)	≥1.7	≥3	≥4	≥5	≥6
Total Grains (oz/day)	≤3	≤5	≤6	≤9	≤10
Whole Grains (oz/day)	≥1.5	≥1.5	≥2	≥2.5	≥3
Whole Grains (oz/day)	≤2	≤3	≤3	≤4.5	≤5
Refined Grains (oz/day)	≥0.2	≥1.5	≥2	≥2	≥3
Refined Grains (oz/day)	≤1	≤2.5	≤3	≤4.5	≤5
Total Protein Foods (oz/day)	≥2	≥2	≥3	≥4	≥5
Total Protein Foods (oz/day)	≤2.1	≤4.5	≤5.5	≤6.5	≤7
Total Dairy (oz/day)	≥1.7	≥2	≥2.5	≥3	≥3
Total Dairy (oz/day)	≤2	≤2.5	≤2.5	≤3	≤3
Oils (g/day)	≤13	≤15	≤17	≤22	≤24
Solid Fats (g/day)	≤13	≤13	≤16	≤21	≤23
Added Sugars (g/day)	≤13	≤13	≤16	≤21	≤23

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

The DGA guidelines gave recommendations for all of the groups used in this project. The age group distribution followed DGA guidelines which consolidated child demographics more than the TFP. The TFP included five categories for children, aged 1 year, 2 to 3 years, 4 to 5 years, 6 to 8 years, and 9 to 11 years. The 2020-2025 DGA considers child categories to be people under age 18, and consolidates categories into the same structure used in this project.

Table 6 and Table 7 show our nutrient constraint and MyPlate constraint ranges for the adult demographics. Table 6 includes women demographics with age ranges 19 to 30, 31 to 50, and 51 years and above. Table 7 shows the same age ranges for male demographics.

Table 6: MyPlate Constraint Ranges for Women Above Age 18

MyPlate Daily Recommendations	Woman 19 to 30 years	Woman 31 to 50 years	Woman 51+ years
Total Fruit (cup/day)	≥1.5	≥1.5	≥1.5
Total Fruit (cup/day)	≤2	≤2	≤2
Fruit Juice (cup/day)	-	-	-
Fruit Juice (cup/day)	-	-	-
Total Vegetables (cup/day)	≥2.5	≥2	≥2
Total Vegetables (cup/day)	≤4	≤3	≤3
Dark Green Vegetables (cup/day)	≥0.21	≥0.21	≥0.21
Dark Green Vegetables (cup/day)	≤0.29	≤0.29	≤0.29
Total Red and Orange Vegetables (cup/day)	≥0.79	≥0.57	≥0.57
Total Red and Orange Vegetables (cup/day)	≤0.86	≤0.86	≤0.86
Total Starchy Vegetables (cup/day)	≥0.71	≥0.57	≥0.57
Total Starchy Vegetables (cup/day)	≤0.86	≤0.86	≤0.86
Other Vegetables (cup/day)	≥0.57	≥0.5	≥0.5
Other Vegetables (cup/day)	≤0.71	≤0.71	≤0.71
Beans, Peas, and Lentils (cup/day)	≥0.21	≥0.14	≥0.14
Beans, Peas, and Lentils (cup/day)	≤2	≤2	≤2
Total Grains (oz/day)	≥6	≥5	≥5
Total Grains (oz/day)	≤8	≤7	≤7
Whole Grains (oz/day)	≥3	≥3	≥3
Whole Grains (oz/day)	≤4	≤3.5	≤3.5
Refined Grains (oz/day)	≥3	≥2	≥2
Refined Grains (oz/day)	≤4	≤3.5	≤3.5
Total Protein Foods (oz/day)	≥5	≥5	≥5
Total Protein Foods (oz/day)	≤6.5	≤6	≤6
Total Dairy (oz/day)	≥3	≥3	≥3
Total Dairy (oz/day)	≤3	≤3	≤3
Oils (g/day)	≤27	≤24	≤22
Solid Fats (g/day)	≤26	≤23.5	≤20.5
Added Sugars (g/day)	≤26	≤23.5	≤20.6

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

Table 7: MyPlate Constraint Ranges for Men Above Age 18

MyPlate Daily Recommendations	Man 19 to 30 years	Man 31 to 50 years	Man 51+ years
Total Fruit (cup/day)	≥2	≥2	≥2
Total Fruit (cup/day)	≤2.5	≤2.5	≤2
Fruit Juice (cup/day)	-	-	-
Fruit Juice (cup/day)	-	-	-
Total Vegetables (cup/day)	≥3	≥3	≥2.5
Total Vegetables (cup/day)	≤4	≤4	≤3.5
Dark Green Vegetables (cup/day)	≥0.29	≥0.29	≥0.21
Dark Green Vegetables (cup/day)	≤0.36	≤0.36	≤0.36
Total Red and Orange Vegetables (cup/day)	≥0.86	≥0.86	≥0.79
Total Red and Orange Vegetables (cup/day)	≤1.07	≤1.07	≤1
Total Starchy Vegetables (cup/day)	≥0.86	≥0.86	≥0.71
Total Starchy Vegetables (cup/day)	≤1.14	≤1.14	≤1
Other Vegetables (cup/day)	≥0.71	≥0.71	≥0.57
Other Vegetables (cup/day)	≤1	≤1	≤0.79
Beans, Peas, and Lentils (cup/day)	≥0.29	≥0.29	≥0.21
Beans, Peas, and Lentils (cup/day)	≤3	≤3	≤2.5
Total Grains (oz/day)	≥8	≥7	≥6
Total Grains (oz/day)	≤10	≤10	≤9
Whole Grains (oz/day)	≥4	≥3.5	≥3
Whole Grains (oz/day)	≤5	≤5	≤4.5
Refined Grains (oz/day)	≥4	≥3.5	≥3
Refined Grains (oz/day)	≤5	≤5	≤4.5
Total Protein Foods (oz/day)	≥6.5	≥6	≥5.5
Total Protein Foods (oz/day)	≤7	≤7	≤6.5
Total Dairy (oz/day)	≥3	≥3	≥3
Total Dairy (oz/day)	≤3	≤3	≤3
Oils (g/day)	≤31	≤29	≤27
Solid Fats (g/day)	≤31	≤28.5	≤26
Added Sugars (g/day)	≤31	≤28.5	≤26

Note: Shaded cells indicate lesser than or equal to/ upper bound constraints

Cost Constraint

Table 8 shows that the cost constraints were binding in the TFP model. Our project retrieved weekly costs for each age group represented in the TFP (USDA-CNPP, 2004). The cost constraint was divided into the daily cost of the TFP plan before integrating into the objective function.

Table 8: Thrifty Food Plan Weekly Cost for Respective Demographic Groups

Demographic Group	TFP Weekly Cost
Child 1 year	$17.8
Child 2 to 3 years	$17.7
Child 4 to 8 years	$19.6
Child 9 to 13 years	$28.7
Child 14 to 18 years	$29.9
Woman 19 to 30 years	$29.9
Man 19 to 30 years	$33
Woman 31 to 50 years	$29.9
Man 31 to 50 years	$33
Woman 51+ years	$29.6
Man 51+ years	$30.3

Figure 2 represents the food budget share of our food categories. The food budget share is the percentage of the TFP budget that is spent on a certain food group. The food budget share is the basis for weighting a food category over another. The food budget share is equal to the current price of one food group divided by the sum of the current price of all food groups in the model.

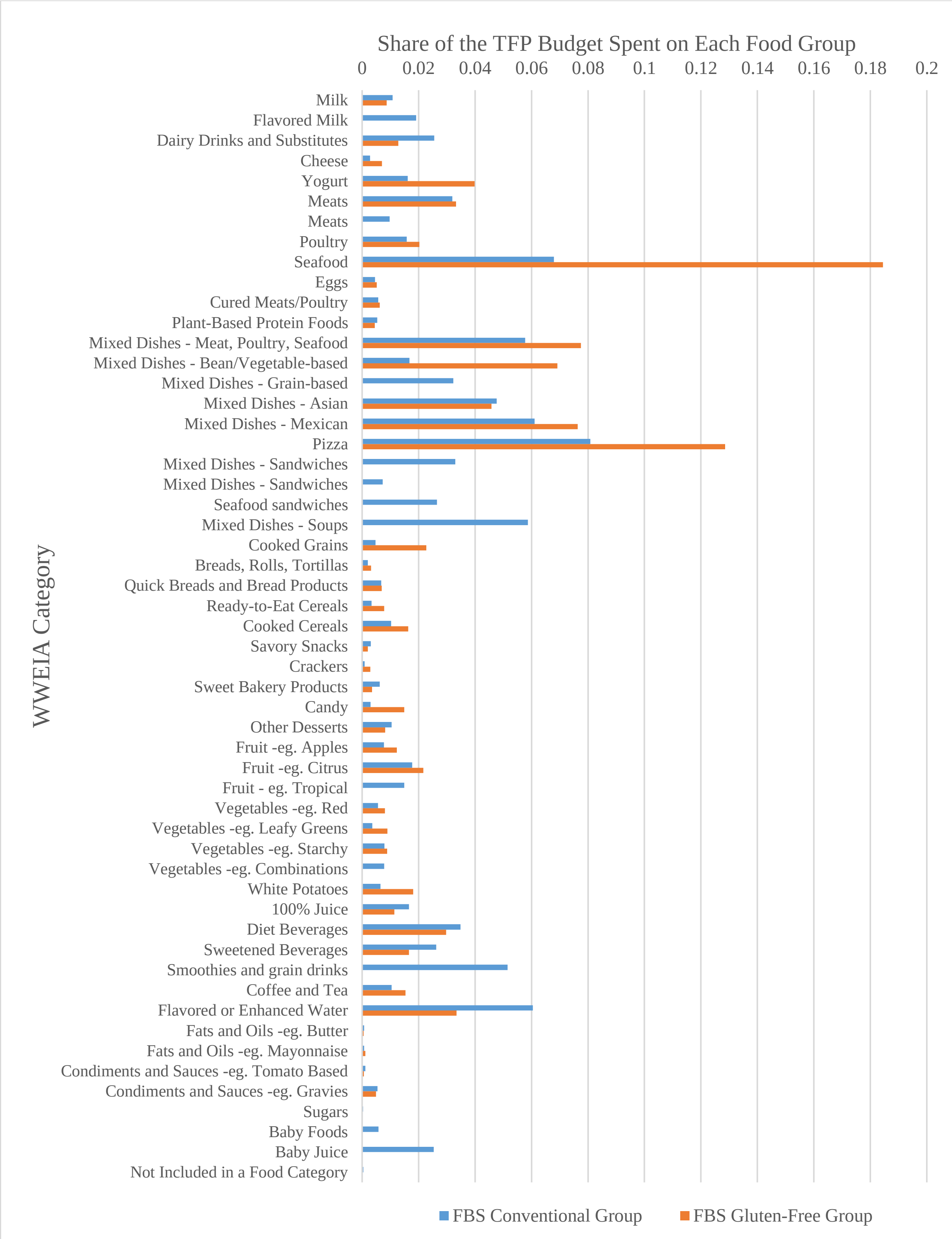

Figure 2: Food Budget Shares for Conventional and Gluten-Free Consumer Groups

Chapter 4: Results and Discussion

The feasibility of the conventional model, shown in Table 9 indicates feasibility in most of the demographic age groups studied. NHANES separated all survey responses by gender, while the TFP did not separate children by gender. Our models were presented using the NHANES format in order to give a more detailed arrangement of the solutions.

Table 9: Feasibility of Conventional Model for Each Age Group and Objective Value

Conventional (Non- Restricted) Food Consumers					
Demographic Group	Age (years)	Initial Model Feasible	Bound Model Feasible	Upper Bound	Objective Value (dollars per day)
Female Child	1	Yes	Yes	1.7	$4.81
Male Child	1	Yes	Yes	1.9	$4.93
Female Child	2-3	Yes	Yes	1.6	$3.51
Male Child	2-3	Yes	Yes	1.6	$3.48
Female Child	4-8	Yes	Yes	5	$4.89
Male Child	4-8	Yes	Yes	3	$4.89
Female Child	9-13	No	No	-	-
Male Child	9-13	Yes	Yes	8	$6.08
Female Child	14-18	Yes	Yes	3	$6.40
Male Child	14-18	No	No	-	-
Woman	19-30	No	No	-	-
Man	19-30	Yes	Yes	8	$9.57
Woman	31-50	Yes	Yes	1.6	$8.22
Man	31-50	No	No	-	-
Woman	51+	Yes	Yes	3	$6.88
Man	51+	Yes	Yes	23	$7.72

Because the models for children are separated by age, we can also analyze the difference in consumption patterns for each gender and can speculate how combining the genders into one demographic group may have changed the solution based on the consumption patterns of children of certain age groups in general. In comparison, the Thrifty Food Plan does not separate their cost solutions by gender for children under the age of 18 years. The TFP uses actual consumption of food groups and attempts to adhere the model to actual consumption as closely as possible. The actual consumption of food groups between opposite gendered children may have allowed the TFP some operating room for finding a solution for children. The initial model did not bind the consumption of any food group in the model. The bound model shows the lowest point of consumption the model would allow for a food group to keep the model feasible. Table 9 and Table 10 show the successful and unsuccessful attempts of the function in solving for each diet and demographic group. In Table 9 and Table 10, we also include children including and above the age of 1 year. The DGA includes recommendations for this age group, and the 2006 TFP does include results for the age group.

Table 10: Feasibility of Gluten-Free Model for Each Age Group and Objective Value

Gluten-Free Food Consumers					
Demographic Group	Age (years)	Initial Model Feasible	Bound Model Feasible	Upper Bound	Objective Value (dollars per day)
Female Child	1	No*	No	-	-
Male Child	1	No	No	-	-
Female Child	2-3	No	No	-	-
Male Child	2-3	No	No	-	-
Female Child	4-8	No	No	-	-
Male Child	4-8	No	No	-	-
Female Child	9-13	No	No	-	-
Male Child	9-13	Yes	Yes	3	$4.90
Female Child	14-18	No	No	-	-
Male Child	14-18	No*	No	-	-
Woman	19-30	No	No	-	-
Man	19-30	No	No	-	-
Woman	31-50	Yes	Yes	1.6	$7.39
Man	31-50	No	No	-	-
Woman	51+	Yes	Yes	2	$6.24
Man	51+	No	No	-	-

*Indicates no respondents in that age group

Table 11 shows that the gluten-free objective model found solutions for three of the eleven demographic groups studied. Solutions were found for male children ages 9 to 13, women, ages 31 to 50 and women including and above the age of 51 years. There were 61 NHANES respondents for this diet type, so the range of food consumption for each group was limited and may have made it harder for the model to find a solution with such limited options.

Table 11: Weekly Cost Comparison for TFP, Objective Conventional Diet and Objective GF Diet

Group	Age (years)	TFP Weekly Cost	Objective Conventional Weekly Cost	Objective GF Weekly Cost
Female Child	1	$17.80	$33.67	-
Male Child	1	$17.80	$34.51	-
Female Child	2-3	$17.70	$24.57	-
Male Child	2-3	$17.70	$24.36	-
Female Child	4-8	$19.60	$34.23	-
Male Child	4-8	$19.60	$34.23	-
Female Child	9-13	$28.70	-	-
Male Child	9-13	$28.70	$42.56	$34.30
Female Child	14-18	$29.90	$44.80	-
Male Child	14-18	$29.90	-	-
Woman	19-30	$29.90	-	-
Man	19-30	$33	$66.99	-
Woman	31-50	$29.90	$57.54	$51.73
Man	31-50	$33	-	-
Woman	51+	$29.60	$48.16	$43.68
Man	51+	$30.30	$54.04	-

The objective function produced similarities between the conventional and GF diet solutions. Both diets are missing solutions for four demographic groups, 9 to13 year old female children, 14 to 18 year-old male children, 19 to 30 year-old women, and 31 to 50 year-old men. The weekly costs of all diet solutions are higher than the TFP. The conventional diet solution is on average a 71% higher cost than the TFP. The GF diet solution is on average 47% higher than the costs for the TFP. The conventional diet was on average 14% more costly than the GF diets, rejecting the hypothesis. That cost difference was about $6.18 on average. The cost differences were analyzed using only the demographics that produced solutions for both the conventional and GF groups.

The cost differences in the solutions for each demographic group are based on the cost of the items in each category at a 2004 price level. We acknowledge that price distribution in food categories may have shifted in the time period between 2004 to 2021. The result is adequate because the 2004 market basket prices were constrained by the TFP cost from December 2004.

Figure 3, Figure 4, and Figure 5 show the market basket distribution for our food categories. They compare the consumption patterns reported to NHANES compared to the consumption of each food category recommended by the model. Cool colors show the conventional diet analytics, warm colors show consumption for the GF diet and the model solution. The blue bars show that in all cases there is higher consumption in most of the food categories. Milk was the category consistently the category that bound the solution for most demographic groups.

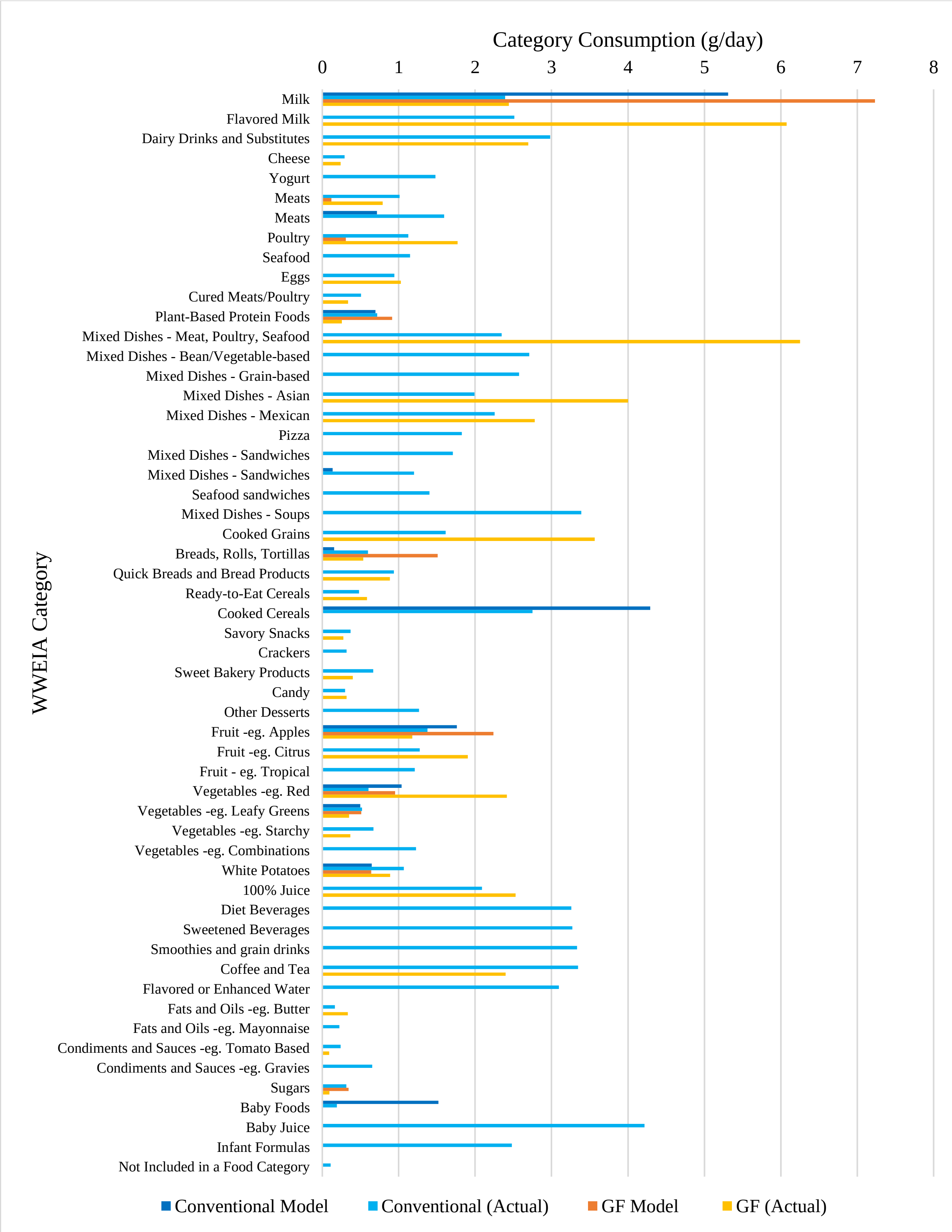

Figure 3: Model v. Actual Consumption for Male Children Aged 9 to 13 years in Both Diet Types

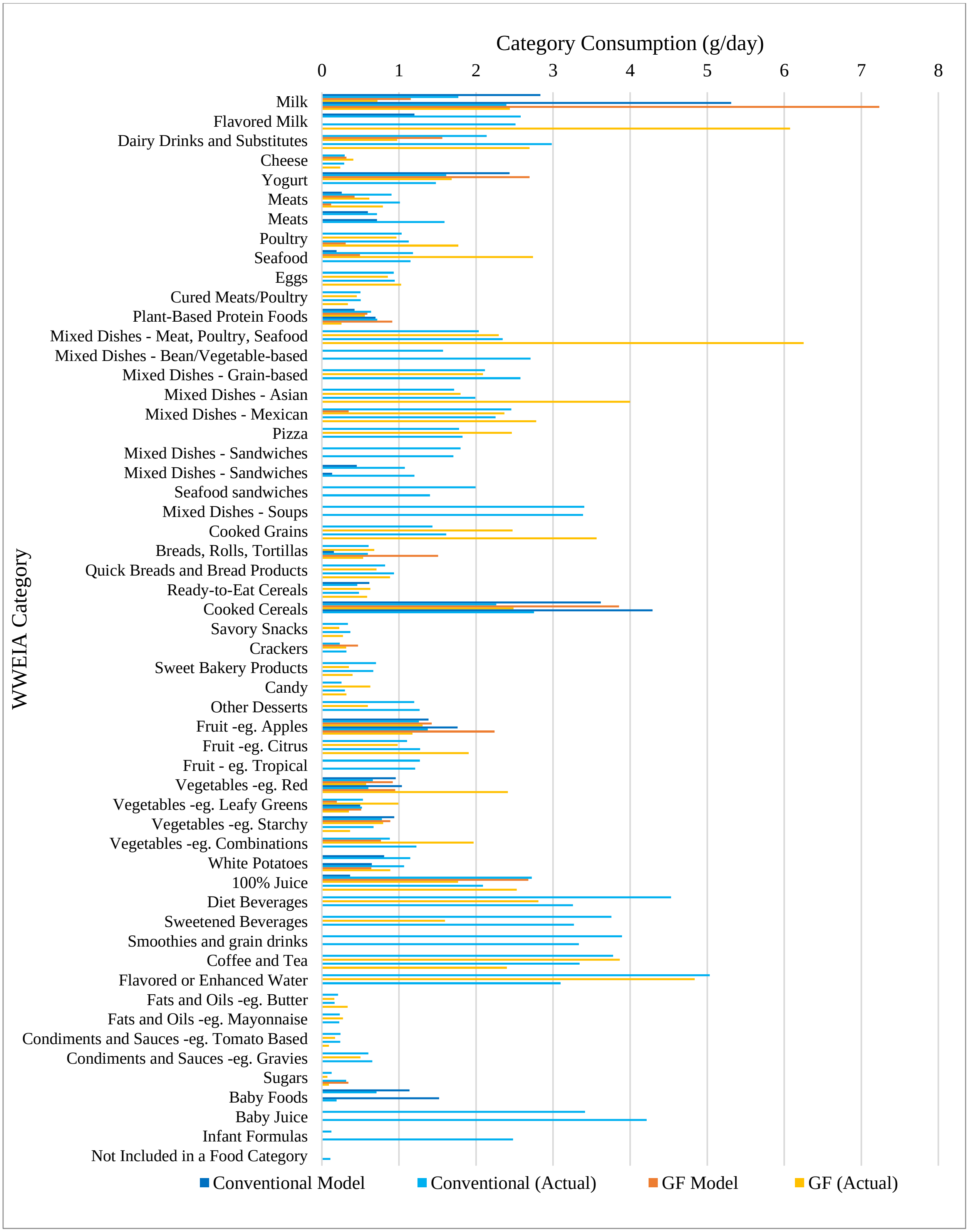

Figure 4: Model v. Actual Consumption for Women Aged 31 to 50 years in Both Diet Types

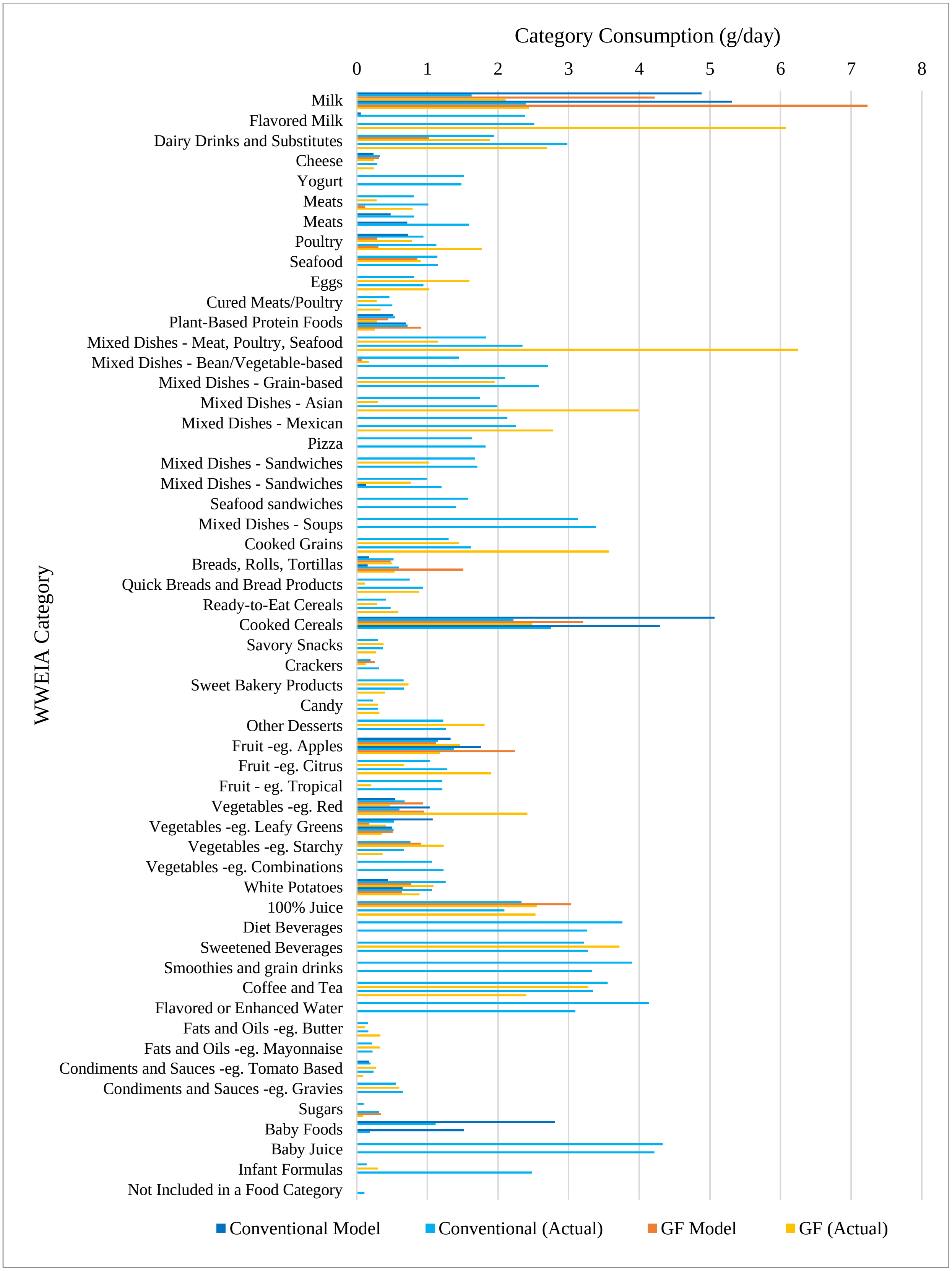

Figure 5: Model v. Actual Consumption for Women Aged 51 years and Above in Both Diet Types

Discussion

Advantages

The National Health and Nutrition Examination Survey provided an adequate sample for the actual consumption patterns for the conventional group of Americans.

Limitations

The study by Lee (2007) considered the availability of products. Availability of a wider variety of products was concentrated around Northern coastal regions, while less availability was seen in the Midwest and Southern regions. This study does not consider the availability or accessibility of gluten-free products, which was shown by Lee (2007) to be variable throughout regions. Accessibility issues may make the overall cost of a gluten-free diet higher.

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) creates a program targeting pregnant women and children under five years. Considering the impacts of WIC involvement would be beneficial for future studies.

Gluten-free consumers accounted for 0.22% of our total number of NHANES survey respondents. If there were price data for all foods in the 2009-2010 and 2011-2012 survey releases, there would have been 85 total gluten-free consumers and 47,652 conventional consumers. A more representative sample of GF consumers would have increased the traditional consumer data by almost double. Contrarily, the 85 gluten-free consumers would have accounted for 0.18% of the total consumer base.

Because there were very few respondents in NHANES that reported following a gluten-free dietary pattern. The unexpected finding on cost differences should be investigated further with additional data on consumers requiring specific diets. There was also an issue in the data where an unexpected dietary pattern was present. One was shown in the male child age 9 to 13 year demographic. That demographic showed intake of baby food, baby juice, infant formula, and coffee and tea. These categories are not recommended for a child of that age, so there may or may not be a discrepancy in actual consumption v. reported consumption.

Chapter 5: Conclusions

Finding affordable dietary options for all nutritional concerns and for all budgets is an important task. This project wished to fill a gap in research on the availability and affordability of gluten-free products in the United States of America. The introduction of this issue to the literature and the American policy structure may have untold benefits toward the welfare situation in the U.S.

The results fail to support the hypothesis. The results show that with the respondents that declare a gluten-free diet, it is possible for them to have a less costly dietary option than the conventional consumer group. Each group represented in this project covers a comprehensive range of nutritional constraints in the representative ages and genders. The NHANES survey gave a representative sample for actual consumption patterns for consumers in America. The NHANES survey did not represent the percentage of people in the U.S. that identify as a gluten-free consumer. However, it should be noted that there were very few respondents in NHANES that reported following a gluten-free dietary pattern relative to all consumers in NHANES. Thus, this unexpected finding should be investigated further with additional data on consumers requiring specific diets.

This project also aimed to prompt the distribution of food group consumption to be as close as possible to the actual consumption distribution. The aim was achieved by limiting the upper bound for the percentage a food group could go over 100% of current consumption. For example, if a food group's actual NHANES reported consumption was 150g of that food group per day, the model would solve at the point closest to 100% of that food group without going under 100% of that food group.

There were challenges in optimization for all of the TFP goals in this project. The challenges were overcome by the meticulous collection of nutrient and Myplate constraints. Future studies will have the challenge of collecting data specific to gluten-free consumers, including products labeled gluten-free, verification of ingredients in products consumed by gluten-free consumers, and accurate pricing for a broader range of products.

In future studies I would recommend matching non-gluten-free respondents based on other similar restrictive dietary patterns. This would facilitate better comparisons between gluten free diets and non-gluten-free diets.

References

American Academy of Allergy Asthma and Immunology (AAAAI), (2020). Food Allergy.https://www.aaaai.org/conditions-and-treatments/allergies/food-allergies

American Academy of Family Physicians (AAFP). (2019). Celiac Disease https://familydoctor.org/condition/celiac-disease/?adfree=true

American College of Allergy Asthma and Immunology (ACAAI), (2014). Wheat Allergy. https://acaai.org/allergies/types/food-allergies/types-food-allergy/wheat-gluten-allergy

Babb, A. M., Wasserman, J. K., Knudsen, D. C., & Lalevich, S. T. (2019). An Examination of Medically Necessary Diets within the Framework of the Thrifty Food Plan. *Ecology of food and nutrition*, *58*(3), 236–246. https://doi.org/10.1080/03670244.2019.1598978

Beyond Celiac, (2020). Non-Celiac Gluten Sensitivity. https://www.beyondceliac.org/wp-content/uploads/2020/08/Non-Celiac-Gluten-Sensitivity-Guide-from-Beyond-Celiac.pdf

Carlson, A., Lino, M., Juan, W-Y., Hanson, K., & Basiotis, P.P. (2007). Thrifty Food Plan, 2006. (CNPP-19). U.S. Department of Agriculture, Center for Nutrition Policy and Promotion.

Carlson, A., Lino, M., & Fungwe, T. (2007). The Low-Cost, Moderate-Cost, and Liberal Food Plans, 2007 (CNPP-20). U.S. Department of Agriculture, Center for Nutrition Policy and Promotion.

CDC, (2020). Food Allergies. https://www.cdc.gov/healthyschools/foodallergies/index.htm#:~:text=Food%20allergies%20are%20a%20growing,children%20in%20the%20United%20States.&text=That's%201%20in%2013%20children,immune%20response%20to%20certain%20foods.

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, (2020). https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx

Chen T.C., Clark J., Riddles M.K., Mohadjer L.K., Fakhouri THI.. National Health and Nutrition Examination Survey, 2015−2018: Sample design and estimation procedures. *National Center for Health Statistics. Vital Health Stat* 2 (184). 2020.

Coffino J.A. (2018). A Default Option to Enhance Nutrition Within Financial Constraints: A Randomized, Controlled Proof-of-Principle Trial. *Obesity: Clinical Trials and Investigations*, 26(6), 961-967.

DeNoon, D. (2011). USDA Ditches Food Pyramid for a Healthy Plate: Fruits and Veggies Make Up Half of Plate, With Side of Dairy. WebMD.

https://www.webmd.com/diet/news/20110602/plate-replaces-pyramid-as-diet-guideline-icon#1

Food and Drug Administration (FDA), (2018). Food Allergen Labeling And Consumer Protection Act of 2004 Questions and Answers. https://www.fda.gov/food/food-allergensgluten-free-guidance-documents-regulatory-information/food-allergen-labeling-and-consumer-protection-act-2004-questions-and-answers

Gorgitano M.T. & Sodano V. (2019). Gluten-Free Products: From Dietary Necessity to Premium Price Extraction Tool. *Nutrients*, 11, 1-12.

Grummon, A. H., & Taillie, L. S. (2018). Supplemental Nutrition Assistance Program participation and racial/ethnic disparities in food and beverage purchases. *Public health nutrition*, *21*(18), 3377–3385. https://doi.org/10.1017/S1368980018002598

Gupta, R. S., Warren, C. M., Smith, B. M., Blumenstock, J. A., Jiang, J., Davis, M. M., & Nadeau, K. C. (2018). The Public Health Impact of Parent-Reported Childhood Food Allergies in the United States. Pediatrics, 142(6), e20181235. https://doi.org/10.1542/peds.2018-1235

Hadley C. (2006). Food allergies on the rise?. *EMBO reports*, 7(11), 1080-1083.

Igbinedion, S. O., Ansari, J., Vasikaran, A., Gavins, F. N., Jordan, P., Boktor, M., & Alexander, J. S. (2017). Non-celiac gluten sensitivity: All wheat attack is not Celiac. *World journal of gastroenterology*, *23*(40), 7201–7210. https://doi.org/10.3748/wjg.v23.i40.7201

Kenworthy L. (1999). Do Social Welfare Policies Reduce Poverty?. *Social Forces*, 77(3):1119-39.

Lee A.R, Ng D.L., Zivin J., & Green HR (2007). Economic burden of a gluten-free diet. *Hum Nutr Diet*, 20, 423–430.

Mahadov, S., & Green, P. H. (2011). Celiac disease: a challenge for all physicians. *Gastroenterology & hepatology*, *7*(8), 554–556.

Mayo Foundation for Medical Education and Research (MFMER), (2020). Wheat Allergy. https://www.mayoclinic.org/diseases-conditions/wheat-allergy/symptoms-causes/syc-20378897#:~:text=If%20you%20have%20wheat%20allergy,%2C%20globulin%2C%20gliadin%20and%20gluten

National Institute of Health (NIH): United States National Library of Medicine, Medline Plus, (2020). Celiac Disease. https://medlineplus.gov/celiacdisease.html

Poverty USA, (2020). The Population of Poverty USA www.povertyusa.org/facts

Richardson B. (2018). Food Trends and Gluten. *Nutrition & Food Service Edge*. 12-16

Sanjeevi N., Freeland-Graves J. H., Sachdev P.K., & Sands J. (2019). Do food expenditure patterns of supplemental nutrition assistance program households meet thrifty food plan recommendations?. *Journal of Hunger & Environmental Nutrition*,14(3), 352-364.

Singh J. & Whelan K. (2011). Limited availability and higher cost of gluten-free foods. *Journal of Human Nutrition and Dietetics*, 24, 479-486.

Stevens L. & Rashid M. (2008). Gluten-Free and Regular Foods: A Cost Comparison. *Canadian Journal of Dietetic Practice and Research*, 69(3), 147-150.

The University of Chicago Medicine: Celiac Disease Center, (2005). Celiac Disease Facts and Figures. https://www.cureceliacdisease.org/wp content/uploads/341_CDCFactSheets8 _Facts Figures .pdf

U.S. Bureau of Economic Analysis, Government social benefits: to persons: Federal: Supplemental Nutrition Assistance Program (SNAP) [TRP6001A027NBEA] (2021), retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/TRP6001A027NBEA,

United States Department of Agriculture Agricultural Research Service (USDA-ARS), (2020). FoodData Central, April 2020. https://fdc.nal.usda.gov/download-datasets.html

United States Department of Agriculture Center for Nutrition Policy and Promotion (USDA-CNPP), (2004). Official USDA Food Plans: Cost of Food at Home at Four Levels, U.S. Average, November 2004. Issued December 2004. https://fns-prod.azureedge.net/sites/default/files/CostofFoodNov04.pdf

United States Department of Agriculture Economic Research Service (USDA-ERS), (2019). Percent of residents participating in SNAP decreased in 46 States from 2013 to 2018 https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=93509

United States Department of Agriculture Food and Nutrition Service (USDA-FNS), (2009). Food Prices Database, 2003-04. https://www.fns.usda.gov/food-prices-database-2003-04

United States Department of Agriculture Food and Nutrition Service (USDA-FNS), (2020). Characteristics of SNAP Households: FY2018. https://www.fns.usda.gov/snap/characteristics-households-fy-2018

U.S. Department of Agriculture and U.S. Department of Health and Human Services (USDA & HHS). Dietary Guidelines for Americans, 2020-2025. 9th Edition. December 2020. Available at DietaryGuidelines.gov.

Appendix

Appendix A: Table of 58 Food Categories

WWEIA Consolidated Code	Food Category Name
f100	Milk
f120	Flavored Milk
f140	Dairy Drinks and Substitutes
f160	Cheese
f182	Yogurt
f200	Meats
f201	Meats
f220	Poultry
f240	Seafood
f250	Eggs
f260	Cured Meats/Poultry
f280	Plant-Based Protein Foods
f300	Mixed Dishes - Meat, Poultry, Seafood
f310	Mixed Dishes - Bean/Vegetable-based
f320	Mixed Dishes - Grain-based
f340	Mixed Dishes - Asian
f350	Mixed Dishes - Mexican
f360	Pizza
f370	Mixed Dishes - Sandwiches
f372	Mixed Dishes - Sandwiches
f373	Seafood sandwiches
f380	Mixed Dishes - Soups
f400	Cooked Grains
f420	Breads, Rolls, Tortillas
f440	Quick Breads and Bread Products
f460	Ready-to-Eat Cereals
f480	Cooked Cereals
f500	Savory Snacks
f520	Crackers
f550	Sweet Bakery Products
f570	Candy
f580	Other Desserts
f600	Fruit
f601	Fruit
f602	Fruit
f640	Vegetables
f641	Vegetables

Appendix A: Continued

f642	Vegetables
f643	Vegetables
f680	White Potatoes
f700	100% Juice
f710	Diet Beverages
f720	Sweetened Beverages
f722	Smoothies and grain drinks
f730	Coffee and Tea
f780	Flavored or Enhanced Water
f800	Fats and Oils
f801	Fats and Oils
f840	Condiments and Sauces
f841	Condiments and Sauces
f880	Sugars
f900	Baby Foods
f920	Baby Juice
f999	Not Included in a Food Category

Appendix B: WWIEA Codes Within Our Three Digit Codes

Three Digit Codes	Four Digit WWEIA Codes	Category
100 Milk		
	1002	Milk, whole
	1004	Milk, reduced fat
	1006	Milk, lowfat
	1008	Milk, nonfat
120 Flavored Milk		
	1202	Flavored milk, whole
	1204	Flavored milk, reduced fat
	1206	Flavored milk, lowfat
	1208	Flavored milk, nonfat
140 Dairy Drinks and Substitutes		
	1402	Milk shakes and other dairy drinks
	1404	Milk substitutes
160 Cheese		
	1602	Cheese
	1604	Cottage/ricotta cheese
180/182 Yogurt		
	1820	Yogurt, regular
	1822	Yogurt, Greek
200/201 Meats		
	2002	Beef, excludes ground
	2004	Ground beef
	2006	Pork
	2008	Lamb, goat, game
	2010	Liver and organ meats
220 Poultry		
	2202	Chicken, whole pieces
	2204	Chicken patties, nuggets, and tenders
	2206	Turkey, duck, other poultry
240 Seafood		
	2402	Fish
	2404	Shellfish
250 Eggs		
	2502	Eggs and omelets
260 Cured Meats/Poultry		
	2602	Cold cuts and cured meats
	2604	Bacon
	2606	Frankfurters
	2608	Sausages

Appendix B: Continued

280 Plant-Based Protein Foods		
	2802	Beans, peas, legumes
	2804	Nuts and seeds
	2806	Processed soy products
300 Mixed Dishes - Meat, Poultry, Seafood		
	3002	Meat mixed dishes
	3004	Poultry mixed dishes
	3006	Seafood mixed dishes
310 Mixed Dishes - Bean/Vegetable-based		
320 Mixed Dishes - Grain-based		
	3202	Rice mixed dishes
	3204	Pasta mixed dishes, excludes macaroni and cheese
	3206	Macaroni and cheese
	3208	Turnovers and other grain-based items
340 Mixed Dishes - Asian		
	3402	Fried rice and lo/chow mein
	3404	Stir-fry and soy-based sauce mixtures
	3406	Egg rolls, dumplings, sushi
350 Mixed Dishes - Mexican		
	3502	Burritos and tacos
	3504	Nachos
	3506	Other Mexican mixed dishes
360 Pizza		
	3602	Pizza
370/372 Mixed Dishes - Sandwiches		
	3702	Burgers (single code)
	3703	Frankfurter sandwiches (single code)
	3704	Chicken/turkey sandwiches (single code)
	3706	Egg/breakfast sandwiches (single code)
	3708	Other sandwiches (single code)
	3720	Cheese sandwiches (single code)
	3722	Peanut butter and jelly sandwiches (single code)
380 Mixed Dishes - Soups		
	3802	Soups
400 Cooked Grains		
	4002	Rice
	4004	Pasta, noodles, cooked grains

Appendix B: Continued

420 Breads, Rolls, Tortillas		
	4202	Yeast breads
	4204	Rolls and buns
	4206	Bagels and English muffins
	4208	Tortillas
440 Quick Breads and Bread Products		
	4402	Biscuits, muffins, quick breads
	4404	Pancakes, waffles, French toast
460 Ready-to-Eat Cereals		
	4602	Ready-to-eat cereal, higher sugar (>21.2g/100g)
	4604	Ready-to-eat cereal, lower sugar (=<21.2g/100g)
480 Cooked Cereals		
	4802	Oatmeal
	4804	Grits and other cooked cereals
500 Savory Snacks		
	5002	Potato chips
	5004	Tortilla, corn, other chips
	5006	Popcorn
	5008	Pretzels/snack mix
520 Crackers		
	5202	Crackers, excludes saltines
	5204	Saltine crackers
540 Snack/Meal Bars		
	5402	Cereal bars
	5404	Nutrition bars
550 Sweet Bakery Products		
	5502	Cakes and pies
	5504	Cookies and brownies
	5506	Doughnuts, sweet rolls, pastries
570 Candy		
	5702	Candy containing chocolate
	5704	Candy not containing chocolate
580 Other Desserts		
	5802	Ice cream and frozen dairy desserts
	5804	Pudding
	5806	Gelatins, ices, sorbets
600/601/602 Fruit		
	6002	Apples
	6004	Bananas
	6006	Grapes

Appendix B: Continued

	6008	Peaches and nectarines
	6010	Berries
	6012	Citrus fruits
	6014	Melons
	6016	Dried fruits
	6018	Other fruits and fruit salads
640/641/642/643 Vegetables		
	6402	Tomatoes
	6404	Carrots
	6406	Other red and orange vegetables
	6408	Dark green vegetables, excludes lettuce
	6410	Lettuce and lettuce salads
	6412	String beans
	6414	Onions
	6416	Corn
	6418	Other starchy vegetables
	6420	Other vegetables and combinations
	6422	Vegetable mixed dishes
680 White Potatoes		
	6802	White potatoes, baked or boiled
	6804	French fries and other fried white potatoes
	6806	Mashed potatoes and white potato mixtures
700 100% Juice		
	7002	Citrus juice
	7004	Apple juice
	7006	Other fruit juice
	7008	Vegetable juice
710 Diet Beverages		
	7102	Diet soft drinks
	7104	Diet sport and energy drinks
	7106	Other diet drinks
720 Sweetened Beverages		
	7202	Soft drinks
	7204	Fruit drinks
	7206	Sport and energy drinks
	7208	Nutritional beverages
	7220	Smoothies and grain drinks
730 Coffee and Tea		
	7302	Coffee
	7304	Tea

Appendix B: Continued

780 Flavored of Enhanced Water		
	7802	Flavored or carbonated water
	7804	Enhanced or fortified water
800/801 Fats and Oils		
	8002	Butter and animal fats
	8004	Margarine
	8006	Cream cheese, sour cream, whipped cream
	8008	Cream and cream substitutes
	8010	Mayonnaise
	8012	Salad dressings and vegetable oils
840/841 Condiments and Sauces		
	8402	Tomato-based condiments
	8404	Soy-based condiments
	8406	Mustard and other condiments
	8408	Olives, pickles, pickled vegetables
	8410	Pasta sauces, tomato-based
	8412	Dips, gravies, other sauces
880 Sugars		
	8802	Sugars and honey
	8804	Sugar substitutes
	8806	Jams, syrups, toppings
900/901 Baby Foods		
	9002	Baby food: cereals
	9004	Baby food: fruit
	9006	Baby food: vegetable
	9008	Baby food: meat and dinners
	9010	Baby food: yogurt
	9012	Baby food: snacks and sweets
920 Baby Juice		
	9202	Baby juice
	9204	Baby water
999 Not Included in a Food Category		
	9802	Protein and nutritional powders
	9999	Not included in a food category

Appendix C: Further Breakdown of Category Ingredients

MyPyramid Food Group	FPED Components
Fruits	
	Total intact or cut fruits and fruit juices
	Intact fruits (whole or cut) of citrus, melons, and berries
	Intact fruits (whole or cut); excluding citrus, melons, and berries
	Fruit juices, citrus and non citrus
Vegetables	
	Total dark green, red, and orange, starchy, and other vegetables; excludes legumes
	Dark green vegetables
	Total red and orange vegetables (tomatoes + other red and orange)
	Tomatoes and tomato products
	Other red and orange vegetables, excluding tomatoes and tomato products
	Total starchy vegetables (white potatoes + other starchy)
	White potatoes
	Other starchy vegetables, excluding white potatoes
	Other vegetables not in the vegetable components listed above
	Legumes computed as vegetables
Grains	
	Total whole and refined grains
	Whole grains
	Refined or non-whole grains
Proteins	
	Total meat, poultry, seafood, organ meats, cured meat, eggs, soy, and nuts and seeds; excludes legumes
	Total meat, poultry, seafood, organ meats, and cured meat
	Beef, veal, pork, lamb, game meat; excludes organ meats and cured meat
	Cured/luncheon meat made from beef, pork, or poultry
	Organ meat from beef, veal, pork, lamb, game, and poultry
	Chicken, turkey, Cornish hens, and game birds; excludes organ meats and cured meat
	Seafood (finfish, shellfish, and other seafood) high in n-3 fatty acids
	Seafood (finfish, shellfish, and other seafood) low in n-3 fatty acids
	Eggs (chicken, duck, goose, quail) and egg substitutes
	Soy products, excluding calcium fortified soy milk and immature soybeans
	Peanuts, tree nuts, and seeds, excludes coconut
	Legumes computed as protein foods
Dairy	
	Total milk, yogurt, cheese, and whey
	Fluid milk and calcium fortified soy milk
	Yogurt

Appendix C: Continued

Cheese

Oils

Oils

Solid Fats

Solid fats

Added Sugars

Foods defined as added sugars