



Can Fast Food Eating Patterns Be Healthy? An Optimization-Based Analysis of Popular US Fast-Food Chains

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Received: 3 July 2022 / Accepted: 8 December 2022 / Published online: 8 March 2023
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Abstract

This paper applies linear programming modeling to determine whether USDA dietary guidelines can be satisfied by an optimal selection of items from the current menus of popular fast-food chains. More specifically, optimization models aiming to determine diets that minimize one of the three objectives (calories from sugars, calories from fat, or sodium consumption), while satisfying the key USDA dietary guidelines are proposed. The models are applied to the menu data of 44 popular fast food restaurants available via Fast Food Nutrition database. A detailed study is performed for 13 age-sex groups specified in USDA guidelines. It is found that only one of the 44 restaurants was found acceptable for each of the 13 age-sex groups, and 10 restaurants were found acceptable for at least one group. Moreover, removing only a small fraction of foods from the combined fast-food menu including all the items from the 44 restaurants eliminates the possibility of designing an acceptable diet based on the remaining menu items. Therefore, it is concluded that the available fast-food options provide very limited opportunities for supporting healthy eating patterns that would satisfy the USDA dietary guidelines. Optimization methods are not only useful for determining the acceptability of a menu with respect to given guidelines, but can also be utilized towards developing better dietary guidelines and healthier menus.

Keywords Linear programming · The diet model · Fast food · Dietary guidelines · Healthy diet · Nutrition informatics

1 Introduction

The increasing accessibility of nutrition data provides unprecedented opportunities for detailed quantitative analysis and comparison of various diets. The US Department of Agriculture (USDA) and the US Department of Health

and Human Services (HHS) maintain the *Dietary Guidelines for Americans* [1], updated every 5 years. This document provides guidelines and recommendations for healthy diets based on state-of-the-art research; see Fig. 1 for a brief summary. In particular, it is used as the basis for the Healthy Eating Index (HEI), a quantitative metric developed by Food and Nutrition Service of the US Department of Agriculture, which aims to measure diet quality with respect to the key recommendations of the Dietary Guidelines for Americans [2].

According to the US Census Bureau, estimated fast-food (limited service restaurants) sales in the USA increased from 87.26 billion dollars in 1992 to 392.44 billion dollars in 2021 [3]. During 2013–2016, 36.6% of adults consumed fast food on a given day, and the percentage of consumption of fast food by adults decreased with age and increased with increasing family income [4]. A similar study reported that 36.3% of children and adolescents consumed fast food on a given day [5].

The focus of this paper is on the quality of fast-food menus, a topic that has attracted considerable attention both in the media and in research literature. Unsurprisingly, the narrative focus has been on the adverse effects the fast-food nutrition has on the public health. More specifically, the published studies have connected fast foods with obesity and increased risk of diabetes [6–8]. While major fast-food restaurant chains responded to these widespread criticisms by introducing numerous healthier options to their menus, the improvements have arguably been insignificant [9], and concerns over the low quality of fast food have persisted. For example, Kirkpatrick et al. [10] evaluated the menus of five major fast-food chains (Burger King, McDonald's, Subway, Taco Bell, and Wendy's) by determining their Healthy Eating Index-2005 (HEI-2005) scores. They concluded that "fast-food menu offerings vary in dietary quality, but are consistently poor."

It should be noted, however, that the studies concerning the fast-food menus focused on their *overall* quality, measured across all the offerings. In particular, according to the authors of [10], "Each unique item was counted once to provide a sense of the overall quality of each chain's offerings." Notwithstanding the validity and merits of this approach for evaluating the general quality of a menu, it has obvious limitations. For example, it does not take into account the popularity of each menu item and provides no information on the level of customer demand for the newly introduced healthy options. Also, an arguably more important question is the following: Do fast-food restaurant menus provide options for forming eating patterns that satisfy the recommendations of the Dietary Guidelines for Americans? The objective of this work is to address this question, which naturally falls within the emerging discipline of *nutrition informatics*, defined as "the effective retrieval, organization, storage and optimum use of information, data and knowledge for food and nutrition related problem solving and decision-making" [11]. This nontrivial task will be approached by taking advantage of mathematical optimization tools.

Nutrition planning has a long and illustrious history in operations research and optimization modeling [12, 13]. In fact, the classic *diet problem* is universally used as a textbook example of linear optimization modeling. The first known instance of this problem was presented by Stigler in 1945 [14] and was stated as follows:

KEY GUIDELINES

1. Follow a healthy dietary pattern at every life stage.
2. Customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations.
3. Focus on meeting food group needs with nutrient-dense foods and beverages, and stay within calorie limit.
4. Limit foods and beverages higher in added sugars, saturated fat, and sodium, and limit alcoholic beverages.

KEY RECOMMENDATIONS

Consume a healthy eating pattern that accounts for all foods and beverages within an appropriate calorie level.

A healthy eating pattern includes:

- Vegetables of all types — dark green; red and orange; beans, peas, and lentils; starchy; and other vegetables
- Fruits, especially whole fruits
- Grains, at least half of which are whole grains
- Dairy, including fat-free or low-fat milk, yogurt, and cheese, and/or lactose-free versions and fortified soy beverages and yogurt as alternatives.
- Protein foods, including lean meats, poultry, and eggs; seafood; beans, peas, and lentils; and nuts, seeds, and soy products
- Oils, including vegetable oils and oils in food, such as seafood and nuts

A healthy eating pattern limits:

- Added sugars, saturated fat, sodium, and alcoholic beverages

Key quantitative recommendations for the components that are of particular public health concern in the United States:

- Consume less than 10 percent of calories per day from added sugars starting at age 2. Avoid foods and beverages with added sugars for those younger than age 2.
- Consume less than 10 percent of calories per day from saturated fats starting at age 2.
- Consume less than 2,300 milligrams (mg) per day of sodium — and even less for children younger than age 14.
- Adults of legal drinking age can choose not to drink, or to drink in moderation by limiting intake to 2 drinks or less in a day for men and 1 drink or less in a day for women, when alcohol is consumed. Drinking less is better for health than drinking more. There are some adults who should not drink alcohol, such as women who are pregnant.

Fig. 1 A brief summary of key guidelines and recommendations provided in [1]

For a moderately active man weighing 154 pounds, how much of each of 77 foods should be eaten on a daily basis so that the man's intake of nine nutrients will be at least equal to the recommended dietary allowances (RDAs) suggested by the National Research Council in 1943, with the cost of the diet being minimal?

In his original work, Stigler provided a heuristic solution with total cost of \$39.93 in 1939 US dollars. Several years later, the development of Dantzig's simplex algorithm allowed them to solve the problem to global optimally with the exact solution value of \$39.69. This was the first ever "large scale" example of a problem solved by the simplex method; a task that took 120 clerk-days (with nine clerks operating desk calculators) to complete in 1947 [12, 15]. Modern optimization solvers handle problems of this scale in a fraction of a second and routinely solve linear models with millions of variables and constraints.

While the objective of the classic diet problem was to minimize the cost of a diet satisfying the recommended dietary allowances, this study is not concerned with cost. Instead, the aim is to minimize the consumption of three entities specified in the key quantitative recommendations of Dietary Guidelines for Americans [1], as described in Fig. 1: (1) calories from sugars, (2) calories from fats, and (3) sodium. One of these three entities is used in the minimization objective, and the remaining two entities are incorporated in the constraints, along with the recommendations for other intakes, including carbohydrates, dietary fiber, protein, and calories. This approach allows us to not only assess the feasibility of healthy eating patterns based on a fast-food menu, but also provide a comparison and ranking of the menus of different fast-food restaurant chains based on the specific quantitative criteria.

The remainder of this article is organized as follows. Section 2 describes the proposed optimization models and describes the data used. Section 3 reports the results of empirical study based on the menu data of 44 fast-food restaurants, and Section 4 concludes the paper. Details of optimal solutions obtained for each restaurant and age-sex group are reported in [Appendix](#).

2 Methods

This section provides a detailed description of the proposed optimization models based on the recommendations in the 2020–2025 edition of Dietary Guidelines for Americans [1]. Specifically, the focus is on minimizing the consumption of nutrients specified in the key quantitative recommendations (that is, calories from sugars, calories from fats, and sodium), subject to the limits on the most common nutrients described in the daily nutritional goals in [1]. While the document provides intake recommendations for a number of macronutrients, minerals, and vitamins, only those of the entities that are reported in the Fast Food Nutrition website [16] are taken into account in the considered models. To the best of the authors' knowledge, this is the most comprehensive publicly available resource on fast-food nutrition facts; hence, it is utilized in this study. The website provides nutrition facts for over 40 popular fast-food restaurants operating in the

USA. More specifically, for each menu item represented in the online database, the serving size and the per-serving amount of the following nutrients are given:

- **Macronutrients:** carbohydrates, dietary fiber, protein, fat, cholesterol, and sugars;
- **Minerals:** calcium, iron, and sodium;
- **Vitamins:** vitamin A and vitamin C.

Figure 2 provides an illustration of the format of presentation of the nutrition facts on the website. As can be seen from the figure, the data for vitamins, calcium, and iron are listed in terms of percentage of the daily value, without any specific reference. Moreover, many of the items on the website contain no entries for vitamins. Hence, to ensure the consistency of analysis, the vitamin, calcium, and iron requirements will not be included in the proposed mathematical models. Table 1 displays the daily nutritional goals with respect to each of the nutrients included in the study at the specified calorie level for each age-sex group, ages 2 and older. (It should be noted that [1] also provides guidelines for infants, toddlers, pregnant women, and lactating women, as well as recommendations for calorie levels depending on a life style. While this study can be easily extended to the additional groups, it focuses on the groups included in the table.)

Next, the details of the mathematical models, stated for a given restaurant and age-sex group, are described.

Sets, indices, and parameters

Fig. 2 A screenshot of nutrition facts for McDonald’s Big Mac from Fast Food Nutrition website [16]

McDonald's Big Mac

Nutrition Facts

[Compare](#)

Serving Size	1 Burger	
Calories	540	
Calories From Fat	250	
	Amount Per Serving	% Daily Value*
Total Fat	28g	43%
Saturated Fat	10.0g	50%
Trans Fat	1.0g	
Cholesterol	80mg	27%
Sodium	950mg	40%
Total Carbohydrates	46g	15%
Dietary Fiber	3g	12%
Sugars	9g	
Protein	25g	50%
Vitamin A		10%
Vitamin C		2%
Calcium		15%
Iron		25%

*All percent daily value figures are based on a 2,000 calorie diet.

Nutritional information source: [McDonald's](#)

Table 1 Daily nutritional goals, ages 2 and older, according to Table A1-2 of [1]. The abbreviations in the “Source of goal” column stand for acceptable macronutrient distribution range (AMDR), recommended dietary allowance (RDA), Dietary Guidelines for Americans (DGA), and chronic disease risk reduction level (CDRR). RDAs for vitamin A are given as retinol activity equivalents (RAE)

Source of goal	Age-sex group												
	M/F	F	F	F	F	F	F	F	F	M	M	M	
Calorie level	1000	1200	1600	1800	1800	2000	1800	1600	1400	1800	2200	2400	2000
Nutrients													
Saturated fat (% kcal)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Added sugars (% kcal)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Sodium (mg)	1200	1500	1800	2300	2300	2300	2300	2300	1500	1800	2300	2300	2300
Carbohydrate (% kcal)	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65
Carbohydrate (g)	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130	≥ 130
Fiber	≥ 14	1000 kcal	≥ 17	≥ 22	≥ 25	≥ 28	≥ 25	≥ 22	≥ 20	≥ 25	≥ 31	≥ 34	≥ 28
Protein (% kcal)	5–20	10–30	10–30	10–30	10–35	10–35	10–35	10–35	10–30	10–30	10–30	10–35	10–35
Protein (g)	≥ 13	≥ 19	≥ 34	≥ 46	≥ 46	≥ 46	≥ 46	≥ 46	≥ 19	≥ 34	≥ 52	≥ 56	≥ 56

The following sets, indices, and parameters are employed in the proposed models to describe the nutrients, menu items, and nutritional characteristics and requirements for each meal.

- $i \in N$: the i -th element of the set of n considered nutrients $N = \{1, \dots, n\}$. The set of considered nutrients consists of the following elements: (1) fat, (2) sugar, (3) sodium, (4) carbohydrates, (5) dietary fiber, (6) protein, and (7) calories, so $n = 7$ in this study.
- $j \in M$: the j -th element of the set of m menu items $M = \{1, \dots, m\}$ of the considered restaurant. The set M and the number m of menu items depend on the specific restaurant.
- $k \in C$: the k -th element of the set of food categories $C = \{1, \dots, c\}$. The following categories were considered: (1) Appetizers, (2) Beverages, (3) Breakfast, (4) Condiments, (5) Desserts, (6) General, (7) Pizzas, (8) Salads, (9) Sandwiches, (10) Sides, (11) Soups, (12) Seafood, and (13) Tacos. That is, $c = 13$ in this study.
- $a_{ij}, i \in N, j \in M$: the amount of nutrient i contained in one serving of menu item j .
- $c_{jk}, j \in M, k \in C$: the amount a serving of menu item j contributes to food category k .
- $b_k, k \in C$: the upper bound on the amount of food from category k in a diet.
- $l_i, i \in N$: the lower bound on the daily consumption of nutrient i .
- $u_i, i \in N$: the upper bound on the daily consumption of nutrient i .
- $l_i^c, i \in N$: the lower bound on the daily consumption of calories yielded by nutrient i .
- $u_i^c, i \in N$: the upper bound on the daily consumption of calories yielded by nutrient i .

Decision variables

- $x_j \geq 0, j \in M$: a real variable representing the average number of servings of menu item $j \in M$ to be consumed (per day).

Objective function

In each proposed model, one of the three different objective functions will be minimized:

$$\text{minimize } z_p = \sum_{j \in M} a_{pj} x_j, \tag{1}$$

where $p \in \{1, 2, 3\} \subset N$ defines the nutrient addressed in the objective. Recall that the first three elements of N are (1) fat, (2) sugar, and (3) sodium, respectively; thus, z_p expresses the average daily consumption of the corresponding nutrient. In the proposed models, the consumption of the key nutrient $p \in \{1, 2, 3\}$ chosen in the objective will be minimized, while the consumption of the other two nutrients will be controlled by the constraints, as described next.

Constraints

The primary nutrient constraints are used to guarantee that the diet produced falls into the healthy-diet ranges as defined by Dietary Guidelines. Note that in Table 1 the requirements for sodium, carbohydrate, fiber, protein, and calories are specified in absolute figures (grams or milligrams), and the requirements for fat, added sugar, carbohydrate, and protein are given in terms of the percentage of consumed calories they are responsible for (% kcal). The first set of constraints addresses the requirements given in absolute terms:

$$l_i \leq \sum_{j \in M} a_{ij}x_j \leq u_i, \quad i \in N \setminus \{1, 2, p\}. \tag{2}$$

Nutrients 1 (fat) and 2 (sugar) are dropped from the set of nutrients providing a constraint of this type as the requirements for these nutrients are only given in percentage of calories in Table 1. Also, nutrient p is dropped since its quantity is minimized in the objective. We set $l_3 = 0$ and $u_4 = u_5 = u_6 = \infty$ since no corresponding lower or upper bound is given in Table 1.

The calorie requirements ($i = 7$) are included in constraints (2) by setting both the lower bound l_7 and the upper bound u_7 to the ‘‘Calorie Level’’ value from Table 1. For example, $l_7 = u_7 = 1000$ for the M/F 2–3 age-sex group. This will ensure that any feasible solution will provide a 1000-calorie diet plan based on the given restaurant’s menu.

The requirements given in terms of percentage of calories are converted into absolute figures by assuming 9 calories per gram of fat and 4 calories per gram of carbohydrate, sugar, or protein [17]. These values are multiplied by the amount a_{ij} of the respective nutrient i contained in the serving of a given menu item j in order to obtain the calorie yield nutrient i is responsible for in menu item j . In addition, the ranges for % kcal specified in Table 1 are divided by 100% and multiplied by the calorie level u_7 to obtain the appropriate bounds on the number of calories yielded by the respective nutrient. Hence, we have the following constraints:

$$\frac{u_7}{100} l_i^c \leq \sum_{j \in M} 9a_{ij}x_j \leq \frac{u_7}{100} u_i^c, \quad i \in \{1, 2\} \setminus \{p\}, \tag{3}$$

$$\frac{u_7}{100} l_i^c \leq \sum_{j \in M} 4a_{ij}x_j \leq \frac{u_7}{100} u_i^c, \quad i \in \{4, 6\}. \tag{4}$$

Note that no lower bounds are given for the % kcal from fat and sugars in Table 1; hence, $l_1^c = l_2^c = 0$. Observe that Table 1 contains requirements for percentage of calories from saturated fat and added sugar. However, the data set we use makes it difficult to differentiate between different types of fat and sugar. Hence, the constraints for these nutrients assume all the fat to be saturated fat and all the sugars to be added sugars. This makes the model somewhat more restrictive. However, we believe this assumption is reasonable in the context of fast foods.

Finally, category constraints can be imposed to ensure that the produced diet plans are balanced and do not include an excessive amount of food from the same category:

$$\sum_{j \in M} c_{jk} x_j \leq b_k, \quad k \in C. \quad (5)$$

Constraints (5) were added in response to impracticality of solutions obtained for models (1)–(4), as discussed in the next section.

3 Results and Discussion

Four sets of experiments with the proposed framework are conducted. In the first, constraints (5) (i.e., the category limits) are not considered, and the models (1)–(4) are solved for each individual restaurant. Such an experiment represents the least restricted scenario and can provide valuable insights with respect to the feasibility of each restaurant under the most favorable situation. In the second set of experiments, category limits are imposed in order to provide more reasonable diets. To address the practicality of obtained solutions for short-term diet planning, the third set of experiments imposes integrality constraints on the decision variables. Finally, the fourth set of experiments treats all the considered restaurants as one, with the menu combining all available items across all the restaurants. These experiments are discussed in detail in the following three subsections. All the data and codes used in this study are available online [18]. The models solved in this study contain between 11 and 576 variables and exactly 8 constraints. Each model solves in under one second using Gurobi when run in Windows 10 on an Intel core i5-3570k using 16GB of memory.

3.1 Results with No Category Limits

In our preliminary analysis, we consider solutions for the most relaxed situation, in which we do not impose any limits on the number of food items from a given category. This allows for an “optimistic” (and not necessarily realistic) evaluation of the potential feasibility of fast-food diets. To illustrate this point, we report the results of experiments for one of the age-sex groups, M 19–30. Table 2 summarizes the results and reports the optimal objective function value for each of the three objectives as well as the ranking of the restaurant according to each objective. More specifically, models (1)–(4) were solved for each $p \in \{1, 2, 3\}$ to obtain the optimal value for the corresponding objective. The results reveal several interesting observations. Notably, the optimal objective values are not always within daily nutritional goals. As an example, when minimizing sugars at Arby’s, the least possible sugar level in a menu satisfying other constraints is 361g, whereas the maximum value specified by the daily nutritional goals is 60g. Thus, we can conclude that even though sugar can be minimized at Arby’s while satisfying the other constraints, the objective cannot be under the maximum recommended value while satisfying the other constraints.

Table 2 Results for the models with no category constraints, M 19–30 age-sex group. Highlighted rows indicate the restaurants that were acceptable for the considered group. The infeasible cases are marked with a dash

Restaurant	Objective		
	Sugars (g)	Sodium (mg)	Calories From Fat
Sonic	0.00	0.00	0.00
Godfather's Pizza	0.00	56.00	0.00
Taco Bell	0.00	81.40	0.00
Popeyes	0.00	0.00	141.83
Blimpie	16.47	127.50	90.91
Wendy's	11.14	272.83	0.00
Bojangles	0.15	253.59	81.22
Panda Express	14.08	617.48	87.35
Dairy Queen	42.44	871.94	70.94
Culvers	18.92	1410.00	0.00
Dunkin Donuts	15.04	1703.02	70.67
Del Taco	1.47	1801.01	91.91
Domino's Pizza	43.36	1699.06	228.34
Long John Silver's	51.38	2110.09	155.98
Jack in the Box	53.63	2194.37	190.13
Chipotle	74.43	2734.52	296.93
Subway	144.84	3070.59	603.06
McDonald's	102.49	4212.00	410.71
Chick-fil-A	166.28	4329.58	678.75
KFC	64.72	7304.70	262.92
Whataburger	65.17	-	250.32
Burger King	213.13	-	430.41
Red Lobster	131.06	2699.29	-
Arby's	360.76	-	-
Boston Market	-	-	388.79
Zaxby's	427.81	-	-
Wingstop	-	-	852.59
Raising Cane's	-	-	912.40
Jersey Mike's	269.71	27,020.97	815.48
Taco John's	-	8761.95	-

All three models were infeasible for the following restaurants:
 Baskin-Robbins, Buffalo Wild Wings, Carl's Jr, Five Guys, Hardee's,
 In-N-Out Burger, Jimmy Johns, Little Caesars, Olive Garden,
 Papa John's, Pizza Hut, Quiznos, Shake Shack, Smashburger

However, we observe that any restaurant which has a feasible solution with objective within the allowable range for a given age-sex group (as described in Table 1) is guaranteed to have an optimal solution with the value within allowable range for each of the three objectives for the considered age-sex group. Thus, we can

refer to such a restaurant as *acceptable* for the considered age-sex group. Returning to our example using Arby's, the problem of optimizing for sugar with guidelines for men between 19 and 30 has a *feasible* solution, but because this value does not meet the dietary guidelines, Arby's is not an *acceptable* restaurant for this group. For example, out of the 44 restaurants, only 15 are acceptable for the M 19–30 group, even though 20 restaurants are feasible for each of the three models. This implies that these 15 restaurants are the healthiest choices amongst all of the restaurants (at least for the M 19–30 group). As such, it is not possible to satisfy the recommended levels of sodium as well as calories from sugar and fat simultaneously in 29 of the restaurants. Lastly, the results show that 14 restaurants (listed at the bottom of the table) are unable to meet the requirement of any of the objectives, implying that these choices are amongst the least healthy, even under the most optimistic outlook.

While this most relaxed model can provide useful observations and high-level insights, it is worth highlighting that it has some practical limitations. For instance, the capability of a human being to consume food is limited by factors such as stomach volume and chemical processes, neither of which are included in our data or addressed by our model. We observed such problematic solutions in the results. As an example, when minimizing sugar at Godfather's Pizza, the optimal meal consists of 34 servings of Salad Mix and 141.625 servings of Tomatoes (which is a half-cup serving of tomatoes from the salad bar). This solution is impractical from at least two standpoints. Clearly, most humans cannot eat 70 cups of tomatoes in a reasonable amount of time as the average human stomach has a capacity of ≤ 20 cups. In fact, such practical considerations are common and often limit the usability of the standard diet problem. In this paper, we attempt to overcome this drawback by imposing the category constraints (5). As we show next, these additional restrictions result in more reasonable diets and the analysis yields more practical insights and observations.

3.2 Results with the Category Limits

In this analysis, in an effort to provide more practical diets, we consider a restricted variation of the problem in which the number of servings of the food items belonging to the same category (see Section 2 for a list of categories) is limited to at most 3. This additional requirement is motivated by some of the impractical solutions obtained from the analysis in Section 3.1. We attempt to solve each of the three considered models, represented by the different objective functions, for each restaurant and every age-sex group.

Table 3 summarizes the optimal objective values for all the models that were found feasible. The restaurants that had no feasible model for any age-sex group are not listed in the table. For each included restaurant, the table lists as many rows as the largest number of models (out of three) that were feasible for an age-sex group. The cases that were infeasible for restaurants included in the table are marked with a dash in the corresponding cell. A feasible model is not necessarily acceptable, since the optimal objective value can exceed the allowable limit. Hence, the acceptable cases are shown in bold. Consider, for example, the first

Table 3 Optimal objective values for the models with the category limits. The objective values are expressed in grams. Values falling within the allowable ranges are shown in bold

Restaurant	Objective	Age-sex group																		
		M/F	F	F	F	F	F	F	F	F	F	F	F	F	F					
Arby's	Fat	317.2	385.1	-	636.9	-	636.9	524.7	-	-	-	-	-	-	-	-	-	-	-	-
	Sugar	148.5	181.2	-	-	-	-	-	213.8	-	-	-	-	-	-	-	-	-	-	-
	Fat	57.4	68.9	102.3	115.3	148.5	115.3	92.0	90.9	102.3	245.0	354.8	245.0	148.5	148.5	148.5	148.5	148.5	148.5	148.5
	Sugar	9.1	10.9	17.3	18.9	27.3	18.9	13.8	15.4	17.3	-	-	-	27.3	27.3	27.3	27.3	27.3	27.3	27.3
Bojangles	Sodium	371.8	653.7	1283.2	1630.3	2025.8	1630.3	1386.1	973.2	1283.2	2451.4	3082.5	2451.4	2027.2	2027.2	2027.2	2027.2	2027.2	2027.2	2027.2
	Fat	41.3	110.1	297.5	371.8	485.3	371.8	267.4	209.8	297.5	598.8	715.6	598.8	485.3	485.3	485.3	485.3	485.3	485.3	485.3
	Sugar	0.3	23.3	-	-	-	-	-	6448.6	-	-	-	-	-	-	-	-	-	-	-
	Sodium	229.2	1275.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boston Market	Fat	258.9	343.5	-	-	-	-	518.3	-	-	-	-	-	-	-	-	-	-	-	-
	Fat	257.4	332.9	495.4	576.6	-	576.6	486.1	428.7	495.4	-	-	-	-	-	-	-	-	-	-
	Sugar	99.4	134.6	209.7	251.2	292.6	251.2	209.8	174.7	209.7	-	-	-	-	-	-	-	-	-	-
	Fat	230.9	283.2	443.9	459.1	567.4	459.1	350.9	391.5	443.9	675.7	784.1	675.7	567.4	567.4	567.4	567.4	567.4	567.4	567.4
Chick-fil-A	Sugar	62.5	77.0	124.1	128.0	160.1	128.0	95.9	109.0	124.1	194.5	230.6	194.5	160.1	160.1	160.1	160.1	160.1	160.1	160.1
	Sodium	1964.7	2464.1	3485.3	4017.2	4549.1	4017.2	3485.3	2985.8	3485.3	5081.1	5613.0	5081.1	4549.1	4549.1	4549.1	4549.1	4549.1	4549.1	4549.1
	Fat	109.1	142.2	208.3	241.4	274.5	241.4	208.3	175.2	208.3	311.0	355.0	311.0	274.5	274.5	274.5	274.5	274.5	274.5	274.5
	Sugar	28.4	38.4	58.3	105.5	-	105.5	58.3	48.3	58.3	-	-	-	-	-	-	-	-	-	-
Culvers	Fat	10.3	47.9	160.3	213.1	293.6	213.1	142.1	113.1	160.3	435.1	652.9	435.1	310.3	310.3	310.3	310.3	310.3	310.3	310.3
	Sugar	9.9	18.0	40.1	54.7	128.7	54.7	35.3	29.1	40.1	274.5	-	280.0	128.7	128.7	128.7	128.7	128.7	128.7	128.7
	Sodium	747.2	954.3	1805.9	3146.9	4869.5	3146.9	1921.1	1268.0	1805.9	-	-	-	6663.7	6663.7	6663.7	6663.7	6663.7	6663.7	6663.7
	Fat	253.8	336.1	698.2	713.9	-	713.9	431.5	590.2	698.2	-	-	-	-	-	-	-	-	-	-
Dairy Queen	Sugar	63.7	85.4	135.4	161.93	185.8	161.9	139.8	109.7	135.4	239.2	289.3	239.2	206.2	206.2	206.2	206.2	206.2	206.2	206.2

Table 3 (continued)

Restaurant	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M
		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	
Del Taco	Fat	311.7	365.6	549.4	561.2	690.5	561.2	432.3	490.6	549.4	842.6	-	846.6	690.5	
	Sugar	96.4	-	182.2	185.3	231.5	185.3	139.0	161.9	182.2	277.8	-	277.8	231.5	
	Sodium	2229.0	115.7	-	-	-	-	-	-	-	-	-	-	-	
Dunkin Donuts	Fat	53.9	77.2	225.5	266.3	433.7	266.3	135.5	197.9	225.5	-	-	-	433.7	
	Sugar	5.3	20.2	59.0	69.4	106.2	69.4	32.7	50.3	59.0	146.6	187.3	146.6	106.2	
	Sodium	1041.8	1343.2	2160.6	2764.1	3444.3	2764.1	2160.6	1644.7	2160.6	4449.2	-	4449.2	3444.3	
Five Guys	Fat	364.5	437.0	629.6	-	-	-	-	525.6	629.6	-	-	-	-	
	Fat	100.5	178.4	334.9	431.0	520.6	431.0	363.1	253.4	334.9	621.7	746.3	627.7	532.4	
	Sugar	25.4	85.1	-	-	-	-	-	-	-	-	-	-	-	
Jersey Mike's	Fat	296.2	353.2	531.8	558.2	684.6	558.2	460.6	465.9	531.8	813.2	947.8	813.2	684.6	
	Sugar	106.9	126.9	182.8	192.1	232.1	192.1	162.4	161.1	182.8	272.2	315.1	272.2	232.1	
	Fat	111.7	145.9	307.6	365.2	501.0	365.2	239.2	224.2	307.6	641.2	819.1	641.2	501.0	
KFC	Sugar	28.2	43.5	76.4	90.5	-	90.5	72.9	61.0	76.4	-	-	-	-	
	Fat	12.4	94.8	319.2	369.7	-	369.7	227.0	226.2	319.2	-	-	-	-	
	Sugar	11.9	23.2	80.2	93.9	142.1	93.9	58.1	58.3	80.2	-	-	-	-	
Long John Silver's	Sodium	1017.4	1345.9	2710.1	-	-	-	2710.1	2028.0	2710.1	-	-	-	-	
	Fat	277.4	340.5	464.4	520.8	594.0	520.8	447.6	413.6	464.4	667.2	740.5	667.2	594.0	
	Sugar	84.2	104.9	152.7	180.8	208.8	180.8	152.7	130.4	152.7	237.5	275.6	237.5	208.8	
Olive Garden	Fat	-	-	-	-	-	-	469.1	-	-	-	-	-	-	
	Fat	45.0	85.9	164.5	223.8	281.7	223.8	172.1	126.9	164.5	365.4	-	365.4	286.7	
	Sugar	5.7	7.0	173.0	-	-	173.0	80.1	8.5	49.0	-	-	-	-	
Panda Express	Sodium	248.9	316.1	49.0	-	-	-	-	403.7	-	-	-	-	-	

Table 3 (continued)

Restaurant	Objective	Age-sex group																			
		M/F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M			
		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	
Popeyes	Fat	59.0	75.6	115.1	136.6	159.0	136.6	116.2	95.5	115.1	181.3	206.7	181.4	160.9							
	Sugar	0.1	0.4	0.9	1.2	1.5	1.2	0.9	0.7	0.9	1.8	5.3	1.8	1.5							
	Sodium	32.3	48.0	151.4	394.3	438.7	394.3	413.5	63.7	63.7	151.4	781.5	1102.5	825.4	607.9						
Raising Cane's	Fat	371.4	457.2	630.0	745.8	862.9	745.8	651.9	542.9	630.0	-	-	-	884.8							
	Sugar	61.0	80.1	145.1	166.7	214.6	166.7	122.2	121.9	145.1	280.7	-	287.9	226.5							
Red Lobster	Sodium	1973.9	2542.5	-	-	-	-	-	-	-	-	-	-	-							
	Fat	110.3	158.4	310.0	348.7	449.6	348.7	273.2	223.4	310.0	573.3	749.5	599.8	489.9							
Sonic	Sugar	31.9	52.9	106.2	147.1	158.8	147.1	139.5	73.8	106.2	191.9	231.7	198.0	186.0							
	Fat	130.2	132.9	286.4	196.3	346.3	196.3	127.0	280.4	286.4	520.6	756.3	520.6	346.3							
Subway	Sugar	32.7	33.8	73.1	49.3	89.4	49.3	32.2	72.7	73.1	136.6	186.3	136.6	89.4							
	Sodium	1286.1	1550.6	2079.6	2344.0	2608.5	2344.0	2079.6	1815.1	2079.6	2898.0	3197.1	2898.0	2608.5							
Taco Bell	Fat	73.8	110.3	317.0	371.1	478.3	371.1	273.8	208.0	317.0	626.1	771.1	652.5	556.8							
	Sugar	14.2	18.9	166.9	233.6	287.6	233.6	212.9	81.3	166.9	-	-	-	-							
Wendy's	Sodium	927.6	1373.6	-	-	-	-	-	2025.1	-	-	-	-	-							
	Fat	0.0	0.0	30.2	95.2	147.8	95.2	56.9	0.0	30.2	208.8	268.0	214.3	161.7							
Whataburger	Sugar	4.6	5.7	8.4	10.1	12.6	10.1	8.9	7.1	8.4	19.9	-	28.9	13.2							
	Sodium	73.3	93.3	299.3	668.2	847.2	668.2	521.1	113.3	299.3	1586.1	-	1746.3	1007.7							
Zaxby's	Fat	315.0	303.2	281.8	258.2	266.7	258.2	251.3	310.1	281.8	283.0	331.6	285.7	266.7							
	Fat	403.0	-	-	-	-	-	-	-	-	-	-	-	-							

Table 4 Feasibility statistics

	Age-sex group													
	M/F		F		F		F		F		F		F	
	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	
Acceptable restaurants	9	9	3	3	3	3	6	5	3	2	1	2	3	
No sugar limits	22	22	19	19	16	19	19	20	19	12	8	12	13	
No sodium limits	13	12	8	7	7	7	8	11	7	6	4	6	7	
No fat limits	26	25	23	23	19	23	25	23	19	17	15	17	19	
Three feasible models	12	11	8	7	7	7	8	10	6	4	3	4	7	
Two feasible models	9	10	10	11	5	11	10	8	7	7	3	7	4	
One feasible model	7	6	6	6	11	6	8	7	12	9	11	9	10	
No feasible model	16	17	20	20	21	20	18	19	19	24	27	24	23	

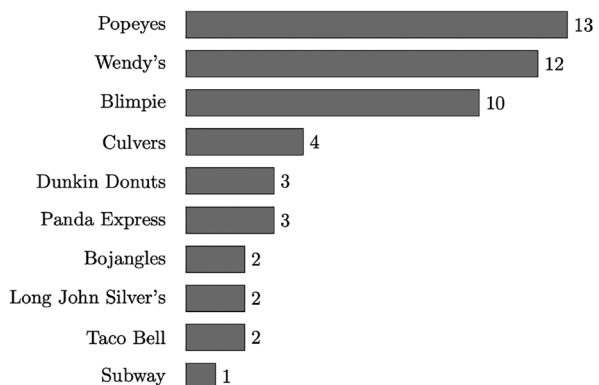
row, reporting the results for Arby's. There is only one row corresponding to Arby's (fat objective) since the models with the sugar and fat objectives were infeasible for all the age-sex groups. The fat-objective model was feasible for 5 out of 13 age-sex groups, and in each of these five cases the optimal objective value exceeds the allowable limit. In fact, having less than three rows dedicated to a particular restaurant indicates that there is no age-sex group for which that restaurant is acceptable. On the other hand, having at least one bold-faced entry for a given restaurant means that that restaurant is acceptable for at least one age-sex group, which ensures the presence of all three rows dedicated to that restaurant in the table.

Table 4 provides the model feasibility statistics for each age-sex group. The first row in this table specifies the number of acceptable restaurants for each group. The next three lines show the number of restaurants for which the model with the sugar, sodium, and fat objective, respectively, is feasible. (This is the same as saying that the model is feasible after dropping the sugar, sodium, and fat limits, respectively.) The last four lines in this table report the number of restaurants for which three, two, one, and no models were feasible, respectively. Note that restaurants for which all three models are feasible for a given group include the acceptable restaurants for that group.

Finally, Table 7 in the Appendix reports the details of optimal solutions (i.e., specific menu items and their quantities) found for each restaurant and every age-sex group.

The results reveal that the vast majority of restaurants cannot provide an acceptable diet for any age-sex group. In fact, out of the 44 restaurants only 10 can provide an acceptable diet satisfying all the considered intake requirements for at least one age-sex group. Figure 3 shows the number of groups for which each of these 10 restaurants is acceptable. Only three restaurants: Popeyes, Wendy's, and Blimpie, are acceptable for most age groups, while only one of these restaurants, Popeyes, offers a menu that is capable of satisfying all 3 objectives simultaneously for each of the 13 age-sex groups. In our view, this metric provides a clear and concise measure of the healthiness of restaurants' respective menus, and restaurants that cannot meet dietary recommendations are simply not ranked.

Fig. 3 The total number of age-sex groups for which a given restaurant is acceptable



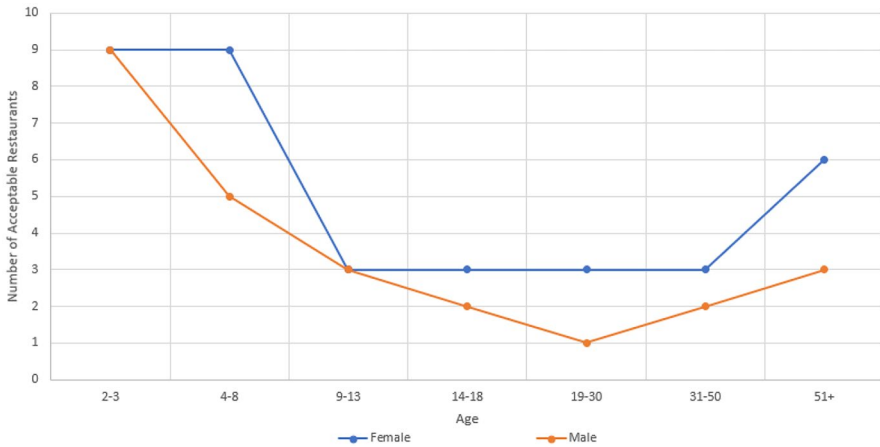


Fig. 4 The number of acceptable restaurants for each age-sex group

Beyond this ranking, we observed a number of interesting features of the solutions. Figure 4 shows the number of acceptable restaurants across age groups for each gender, and reveals two trends. (This figure is based on the data in the first row of Table 4.) Firstly, men had fewer acceptable restaurants compared to women, implying that it is more difficult for men to meet dietary recommendations at these restaurants than it is for women. Secondly, there is a clear dip in the number of acceptable restaurants around early adulthood and subsequent increase around middle age across both genders. We hypothesize that both of these trends are due to higher calorie recommendations forcing menus to reach category limits and consequently use less healthy foods.

Figure 5 illustrates the feasibility statistics for individual models, based on the data available in rows 2–4 of Table 4. We observe that across all age-sex groups there were significantly fewer restaurants feasible with respect to the sodium-objective model than the other two. This implies that meeting the recommendations for calories from fat and sugar simultaneously is more difficult than any other combination of the three key constraints.

Looking at the optimal menus qualitatively, we observed some interesting features. For instance, popular menu items (the items for which a restaurant is best known) were not selected at the majority of restaurants. This is not surprising, as popular menu items at fast-food restaurants are generally unhealthy (i.e., high in either sugar, sodium, or fat). However, at some restaurants, such as Burger King, Chipotle, and Red Lobster, the most well-known and popular menu items appeared in their optimal menus. This indicates that, at least for some restaurants, the optimal menu items are representative of an average order. In addition, our model did not account for alcoholic menu items, as these were not identified in our data set and can thus only be assumed by their name. As an example of a problematic menu that arose from this issue, the optimal menu at Red Lobster when minimizing sodium

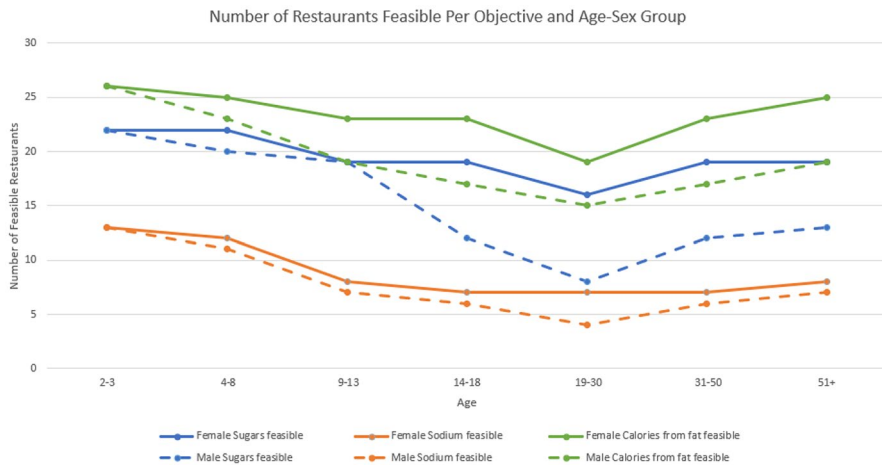


Fig. 5 The number of feasible restaurants for each age-sex group with respect to each of the three models

for the 2–3 age group includes 2.48 servings of raspberry Lobsterita (similar to a Margarita). This menu item would be both illegal and dangerous for a 2–3-year-old to consume. There were also two practical issues that we observed in the optimal menus. The first is that some optimal menus include very small portions of a meal. An example of this is the minimization of calories from fat at Blimpie for the female 9–13 group, where the optimal menu includes 0.02 servings of the Grande Chili with Bean and Beef menu item. While a customer could, in theory, eat exactly that portion of the menu item, it is practically difficult to eat a small percentage of a serving of food without measuring its weight. Additionally, many food items are not homogeneous mixtures, and thus extracting an exact percentage of a serving involves separating that percentage out from each part of the menu item. This issue could be addressed in a long-term planning, as one could consume, e.g., 2 servings of the Grande Chili with Bean and Beef during a 100-day period (recall that our decision variables represent the *average* number of servings per day, and the planning period may vary in duration). Nevertheless, in the next subsection, we experiment with a different way of addressing this problem, by imposing integrality restrictions on the decision variables. The other practical issue is cost. Some of the optimal menus are prohibitively expensive, especially given that some menu items can only be purchased as add-ons to others. This is difficult to measure quantitatively, as our data set does not include prices.

3.3 Results with Integer Restrictions

In order to eliminate fractional portions, we extend the model by restricting the decision variables to integers. The goal of this restriction is to create more practical

Table 5 Feasibility statistics for integer model

	Age-sex group																		
	M/F		F		F		F		F		F		F						
	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	
Acceptable restaurants	5	4	3	2	2	4	3	2	0	2	4	3	2	0	0	0	0	0	0
No sugar limits	19	18	17	15	15	17	27	14	10	15	17	27	14	8	6	8	8	8	8
No sodium limits	10	10	6	5	5	5	7	6	5	5	5	7	6	4	4	4	4	4	5
No fat limits	17	20	18	19	19	19	8	17	18	19	19	8	17	17	12	15	15	17	17
Three feasible models	8	9	6	5	5	5	7	4	4	5	5	7	4	3	2	3	3	3	3
Two feasible models	9	9	8	9	9	10	6	9	6	9	10	6	9	5	4	5	5	7	7
One feasible model	4	3	7	4	4	6	9	7	8	4	6	9	7	10	8	8	8	7	7
No feasible model	23	23	23	26	26	23	22	24	26	26	23	22	24	26	30	28	28	27	27

short-term solutions. This restriction was imposed on the model in addition to the category limits in order to generate the most practical possible solutions. The results of this analysis are presented in Table 5.

As expected, compared to the results without integrality restrictions (Table 4), the number of feasible restaurants decreases for most groups, and the number of acceptable restaurants also decreases for all groups. With integer constraints, 5 age-sex groups have no acceptable restaurants. However, whenever an integer model produces a solution, it is significantly more practical. As an example, we consider the solution obtained for Blimpie for the F 9–13 group, which included 0.02 servings of an item without integer constraints. The new optimal solution is composed of three plain Bluffins, three garden dressings, a classic-style thin pretzel, and two plain soft pretzels. This is significantly more practical from both cost and consumption standpoints and, furthermore, is an acceptable solution.

Although the solutions for this model are more practical, the low level of feasibility and acceptability limits their usefulness. We expect that with more accurate data integer models would be infeasible for most age-sex groups. Furthermore, the goal of this study is to assess the possibility of eating a healthy meal using fast-food restaurants, and studying the practicality of the solutions is of more value once more accurate data is available. The practicality considerations could be further addressed using goal programming methods [19, 20], which could be particularly suitable for creating personalized diets.

Fig. 6 Total number of times a menu item from each restaurant is used in the combined menu

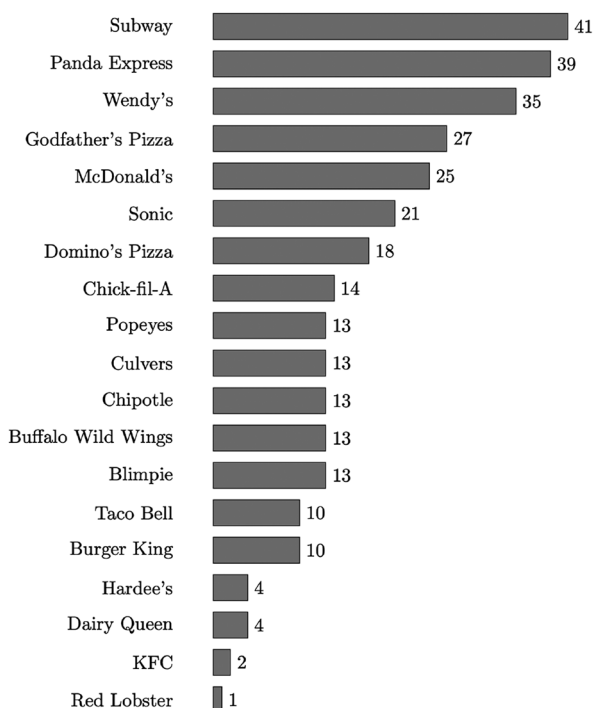


Table 6 Removing these 127 foods from 29 restaurants makes the combined fast-food menu infeasible for the M 19–30 age-sex group. The middle column (“#”) shows the number of items removed from the menu of the corresponding restaurant

Restaurant	#	Menu items
Arby's	1	Homestyle Fries
Baskin-Robbins	4	Cake Cone, Daiquiri Ice, Fat-Free Vanilla Frozen Yogurt, Mini Cone - Rainbow Sherbet
Blimpie	9	Bagel, Bluffin (Plain), Fritos, Popcorn, Pretzels Classic Thin Style, Red Wine Vinegar, Soft Pretzel (Cinnamon-Sugar), Soft Pretzel (Plain), Soft Pretzel (Salted)
Bojangles	1	Grits
Boston Market	1	Garlic Dill New Potatoes (Kid's Side)
Buffalo Wild Wings	1	Carrot Sticks
Burger King	3	Breakfast Syrup, Dried Fruit Topping Quaker Oatmeal (Original)
Chick-fl-A	4	4 Piece Grilled Chicken Nuggets, English Muffin, Kids Fruit Cup, Spicy Chicken Hash Brown Scramble Bowl
Chipotle	5	Black Beans, Lettuce, Pinto Beans, Steak Tacos w-soft-corn-tortilla, Supergreens
Culvers	6	Applesauce, Banana, Mashed Potatoes, Plain Cake Cone, Steamed Broccoli, Tropicana Pink Lemonade
Dairy Queen	3	Applesauce, Banana Slices, Side Salad
Del Taco	1	Del Combo Burrito (Turkey)
Domino's Pizza	3	Caesar Dressing, Extra Cheese, Ripe Olives
Dunkin Donuts	5	Cinnamon Raisin Bagel, English Muffin, Everything Bagel, French Roll, Plain Bagel
Godfather's Pizza	13	Broccoli, Cauliflower, Celery, Cucumber, Garbanzo/ Chick Peas Beans, Kidney Beans, Mushrooms, Onions, Pears, Radishes, Salad Mix, Tomatoes, Zucchini
Hardee's	2	Hand Breaded Chicken Tenders (5-piece), Natural-Cut French Fries
Jack in the Box	4	Grilled Onions, Log Cabin Syrup, Mustard, Side Salad
KFC	5	Corn on the Cob, Green Beans, Honey Sauce Packet, House Side Salad without Dressing, Sweet Kernel Corn
Long John Silver's	4	Baked Cod, Baked Potato, Baked Shrimp, Rice

Table 6 (continued)

Restaurant	#	Menu items
McDonald's	6	Basket of French Fries, Fat Free Chocolate Milk Jug, Peanuts for Sundaes, Regular Nonfat Latte, Side Salad, Sugar Free French Vanilla Nonfat Latte
Panda Express	5	Kids Brown Steamed Rice, Kids Mixed Veggies (Side), Kids White Steamed Rice, Steamed Brown Rice, Steamed White Rice
Papa John's	1	Apple Pie
Popeyes	4	Blackened Ranch, Chicken Blackened Tenders (3 Pes), Corn On The Cob, Grits
Red Lobster	6	Caesar Dressing, Cosmopolitan, Manhattan, Martini, Old Fashioned, Shrimp Cocktail
Sonic	9	Blackberry Syrup, Caramel Topping, Chocolate Fudge Topping, Diet Cherry Syrup, French Fries, Grape Slush, Mango Syrup, Nut Topping, Syrup
Subway	7	Black Bean Soup, Cucumbers, Fresh Fit Crispy Chicken Salad, Homestyle Crispy Chicken Salad, Onions, Spinach, Veggie Delite
Taco Bell	4	Black Beans & Rice, Coffee, Dragon Fruit Freeze (Regular), Iced Coffee
Wendy's	6	Barq's Root Beer, Cold Brew Iced Coffee, Lemonade, Orange Juice, Plain Baked Potato, Sour Cream & Chives Baked Potato
Whataburger	4	Fruit Chews, Garden Salad, Jalapeno & Cheese Whataburger, Sprite

3.4 Results for the Combined Menu

Having observed that the options offered by most individual restaurants are too limited for a healthy diet, in the last set of experiments, we combine the menu items of all restaurants into a single “fast food menu” and analyze it using our optimization models for each age-sex group. This experiment is of interest as from a practical standpoint it is possible to combine menu items from different restaurants with the goal of eating healthy.

The combined menu for the 44 considered restaurants contains the total of slightly over 6700 menu items. The detailed results are summarized in Table 8. We compute optimal solutions for each of the 3 objectives and every one of the 13 age-sex groups, yielding a total of 39 models to be solved for the combined menu. The detailed results are reported in Table 8 in the Appendix. Menu items from 19 different restaurants are represented in the solutions found for the 39 considered models. Figure 6 shows the total number of times a menu item from each of the 19 restaurants appeared in an optimal solution.

Given the large and diverse pool of items to choose from in the combined menu, one would expect to be able to produce a variety of fast-food nutrition plans satisfying the basic requirements reflected in the proposed optimization models. Our final set of experiments aims to find out if this is indeed the case as follows: We focus on the M 19–30 age-sex group, which we identified as the group with the requirements that are particularly difficult to fulfill using fast-food menus. We recursively repeat the following process, until the optimal objective value exceeds the allowable limit.

1. Find an optimal solution for each of the three models with different objectives;
2. Remove all items that appear in at least one optimal solution from the combined menu.

After performing 10 iterations of this process, we reduced the combined fast-food menu to the extent that no combination of the remaining items could produce an acceptable nutrition plan. Treating different-size portions of the same food as one, we find that removing just 127 foods from 29 restaurants makes the remaining combined fast-food menu unacceptable. This accounts for only 1.9% of the total available menu items, representing 65.9% of the considered restaurants. Table 6 provides the detailed list of the corresponding menu items. This finding further highlights the limitations of the options available for healthy nutrition in fast-food restaurants.

4 Conclusion

The results of this study raise several issues and can be useful for various stakeholders. While it had been long established that fast-food restaurants are not healthy in general, it is somewhat surprising to discover that the current menus of most restaurants do not provide options to satisfy even the most basic healthy diet

requirements. Incorporating additional criteria, such as the practical limitations discussed toward the end of Section 3.2, which were ignored in this study due to the lack of data, would only exacerbate this observation. The need for introducing more healthy options in fast-food restaurant menus is evident, and optimization methods could be used to help restaurants design such menu items in a cost-effective manner, while taking into account the customers' preferences. In addition, careful analysis of the differences in the results between the various age-sex categories could be helpful in developing improved dietary guidelines, which are regularly revised by experts. In particular, according to [1] "the U.S. and Canadian Dietary Reference Intake Steering Committees are currently developing plans to re-examine energy, protein, fat, and carbohydrate." Last but not least, we hope this study will inspire renewed interest in optimization problems related to nutrition in operations research community. The classical diet problem played a historically important role in the field of operations research, but was criticized as impractical due to early results, which had deficiencies similar to those observed in our first set of experiments. We demonstrate that simply adding the category constraints results in solutions that are practically reasonable. The superb performance of modern optimization solvers and constantly improving availability of data open up new opportunities for application of operations research tools in the emerging discipline of nutrition informatics.

Appendix. Detailed results

Table 7 Optimal solutions found for the models with category limits

Menu item	Objective	Age-sex group														
		M/F	F	F	F	F	F	F	F	F	F	F	M	M	M	M
Arby's		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+		
Chopped Side Salad	Fat				2.5		2.5									
Curly Fries, small	Fat	0.54	0.66		0.65		0.65	0.24								
French Toast Sticks	Fat	1.92	2.25	3	3	3	2.7									
Gold Peak Iced Tea	Fat	3	3	3	3	3	3									
Homestyle Fries, medium	Fat	0.19	0.23		0.43		0.43	0.62								
Marinara Sauce	Fat	0.03	0.35					0.7								
Potato Cakes, 3-piece	Fat				0.06		0.06									
Roast Chicken Salad	Fat				0.25		0.25	0.87								
Baskin-Robbins																
Cake Cone	Sugar	1.01	0.61						0.22							
Caramel Turtle Truffle Ice Cream, small-scoop	Sugar	1.59	1.89						2.2							
Key Lime Pie Ice Cream, large-scoop	Sugar									0.14						
Peanut Butter 'n Chocolate Milkshake, medium	Sugar									0.06						
Pineapple Coconut Ice Cream	Sugar	0.41	0.49					0.58	2.86							
Strawberry Banana Smoothie, medium	Sugar	1.43	1.75					2.06	0.73							
Tropical Banana Smoothie, medium	Sugar								1.9							
Blimpie																
Bagel	Fat	0.59	0.82		0.49		0.49	1.38						0.48		
	Sodium											0.12	1.34	0.12		
	Sugar				0.2											0.2

Table 7 (continued)

Menu item	Objective	Age-sex group																						
		M/F	F	F	9-13	14-18	19-30	F	F	31-50	F	M	4-8	M	9-13	M	14-18	M	19-30	M	31-50	M	51+	
Bluffin, Plain	Fat	0.07	3	2.51	3	2.51	3	2.51	3	2.51	3	2.51	3	2.51	3	2.52	3	2.52	3	2.52	3	2.52	3	3
	Sodium			1.37	2.74	3	2.74	3	2.74	3	2.74	3	2.74	3	2.74	2.88	1.66	2.88	3	2.88	3	2.88	3	3
Chicken Caesar Garden	Sugar			0.34	1.82	2.8	1.82	2.8	1.82	2.8	1.82	2.8	1.82	2.8	2.5									2.8
	Sodium																							0
Grande Chili with Bean & Beef	Fat	2.52	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sodium	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar			2.03	1.31	3	1.31	3	1.31	3	1.31	3	1.7	3										3
	Fat			0.02	0.13	0.21	0.13	0.21	0.13	0.21	0.13	0.21	0.13	0.21	0.13	0.05	0.16	0.06	0.16	0.06	0.16	0.21	0.21	0.1
Mustard, Yellow Deli Style Popcorn, large	Sodium	0.4	0.5	0.24	0.37	0.06	0.37	0.06	0.37	0.06	0.37	0.06	0.37	0.06	0.29									0.06
	Sugar																							0.33
Pretzels Classic Thin Style	Fat																							0.02
	Sodium	0.04	0.07	0.11	0.12	0.14	0.12	0.14	0.12	0.14	0.12	0.09	0.09	0.12	0.15	0.18	0.15	0.18	0.15	0.18	0.15	0.18	0.15	0.14
	Sugar	0.02	0.03	0.1	0.09	0.14	0.09	0.14	0.09	0.14	0.09	0.06	0.07	0.12										0.14
	Fat																							0.33
Red Wine Vinegar	Sodium	2.28	1.66	1	0.94	0.49	0.94	0.49	0.94	0.49	1.18	1.37	0.94											0.49
	Sugar	0.9	0.91																					0.59
Soft Pretzel, cinnamon-sugar	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sodium	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Sugar	Fat	0.63	0.62	2.03	1.89	2.65	1.89	2.65	1.89	2.65	1.89	0.62	1.67	2.02	2.78	2.58	2.78	2.58	2.78	2.58	2.78	2.58	2.78	2.65
	Sodium	0.68	1.27	1.89	1.93	2.38	1.93	2.38	1.93	2.38	1.93	1.73	1.54	1.93	2.85	2.34	2.85	2.34	2.85	2.34	2.85	2.34	2.85	2.38
	Sugar																							0.14

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
Soft Pretzel, plain	Fat	0.93	1.18	0.07	0.51	0.51	1.27	0.1						
	Sodium												0.49	
Bojangles	Sugar	1.46	1.84	2.9	2.91	2.72	2.91	2.94	2.34	1.77				2.72
BBQ Sauce	Fat	1.02	1.31	1.84	2.06	2.27	2.06	1.78	1.62	2.05	2.48	2.37	2.48	2.27
	Sodium	0.28	1.36					0.1						
Cajon Pinto Beans, picnic-size	Sugar		0.97											
	Fat	0.2												
Chicken Breast	Sodium								1.79					
	Fat			0.28	0.21	0.75	0.21		0.05	0.81	1.28	1.37	1.28	0.75
Chicken Rice Bowl	Fat	0.04	0.21					0.14						
	Sodium		0.09						0.38					
Chicken Thigh	Sugar		0.25											
	Fat	0.17	1.05	1.71	0.93	1.71	1.43	0.99	0.27	0.16			0.16	0.93
Cinnamon Twist	Sodium		0.41											
	Sugar	0.51	0.2											
Grits, picnic-size	Fat		0.07	0.46	0.6	0.8	0.6	0.34	0.36	0.66	1.01	1.19	1.01	0.8
	Sodium	0.1	0.14											
Cajon Pinto Beans, picnic-size	Sugar	0.1	0.06											
	Fat	2.8	3	3	3	3	3	3	3	3	3	3	3	3
Cajon Pinto Beans, picnic-size	Sodium	3	3					1.21						
	Sugar	3	3											

Table 7 (continued)

Menu item	Objective	Age-sex group																				
		M/F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M				
Sweet Potato Pie	Fat	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	0.37	
	Sodium		0.27																			
Boston Market																						
Chicken Noodle Soup	Fat						0.02															
Chocolate Brownie - Single	Fat						0.33															
Fresh Steamed Vegetables	Fat	1.11	2.3				0.98															
Garlic Dill New Potatoes	Fat	1.89	0.7																			
Garlic Dill New Potatoes, Kid's Side	Fat	1.55	0.93																			
Green Beans	Fat						2.02															
Rotisserie Chicken - Quarter White, No Skin	Fat						0.39															
Steamed Vegetables, Kid's Side	Fat						0.26															
Sweet Potato Casserole, Kid's Side	Fat	0.23	0.25																			
Veggie Bowl	Fat	1.22	1.82				2.36															
Zesty Barbecue (mild)	Fat	0.53	0.49																			
Burger King																						
Breakfast Syrup (1 oz)	Fat	0.84	0.5	0.37											0.22							
Chicken Garden Salad, w-grilled-chicken-no-dressing	Sugar	2.05	0.87	1.26	0.69	0.11	0.69	1.24	0.87	0.76												
	Fat			0.13	0.41		0.41	0.53														
	Sugar			0.18	0.33		0.18	0.04														
	Fat				0.14		0.14															
Crispy Taco	Fat		0.13	1.17	2.01		2.01	1.39	0.84													
Dried Fruit Topping	Sugar	0.95	2.13	1.74	2.31	2.89	2.31	1.76	2.13	2.24												
French Fries, medium	Fat	1.09	1.58	2.44	2.72		2.72	2.13	2.03													

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
Hand-Breaded Crispy Chicken Sandwich, original	Sugar	0.03	0.11	0.21	0.15	0.12	0.15	0.18	0.15	0.29				
	Fat			0.03										
Hand-Breaded Lettuce & Tomato Crispy Chicken Sandwich, original	Fat								0.05					
Hi-C Fruit Punch, large	Fat	2.31	2.55					3						
	Sugar	2.35												
Milk	Sugar	0.65	3	3	2.22	1.4	2.22	3	3	2.18				
Mott's Applesauce	Fat	0.62	1.42	0.56				0.65	0.97					
Quaker Oatmeal, maple-and-brown-sugar-flavor	Sugar	2.97	2.89	2.79	2.85	2.88	2.85	2.82	2.85	2.71				
Quaker Oatmeal, original	Sugar	0.2	2.94	3	3	3	3	2.93	1.65	3				
	Fat	3	3	3	3	3	3	3	3					
Strawberry Banana Smoothie	Sugar	3	2.8	0.06				0.07	1.35					
Chick-fil-A	Sugar				0.78	1.6	0.78			0.82				
Grilled Chicken Sandwich	Sodium			0.71	1.11	1.5	1.11	0.71	0.27	1.11	1.89	2.29	1.89	1.5
Kids Fruit Cup	Fat		0.18	0.38	0.98		0.98	1.1	0.06	0.38	2.02			
	Sodium	0.85	1.41	1.93				1.93	1.74		0.12	0.42	0.12	
	Sugar	3	3	3	3	3	3	3	3	3	3	3	3	3
Large Fruit Cup	Sugar					0.15					3	3	3	0.15
Medium Chicken Tortilla Soup	Sodium	0.14	0.2	0.28	0.36	0.44	0.36	0.28	0.28	0.36	0.52	0.6	0.52	0.44
Medium Waffle Fries	Fat	0.6			0.22		0.22		0.1	0.71	1.2	0.71	1.2	0.22
Simply Orange Juice	Sugar		0.12	1.65	1.78	2.79	1.78	0.75	1.15	2.68	3	3	3	2.79
Small Frosted Coffee	Sugar										0.63	2.03	0.63	
Small Fruit	Fat	0.56				1.12				1.57	1.57	1.57	1.57	1.12

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M
Cup	Sodium	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	2.38
	Sugar	1.83	3	3	3	2.85	3	3	3	3	2.15	2.48	2.4	2.48	2.38
Spicy Chicken Hash Brown Scramble Bowl	Fat		0.18	0.26	0.71	0.58	0.71	0.85	0.04	0.12	0.47	0.36	0.47	0.58	2.85
	Sodium	0.74	1.14	1.59	1.77	1.95	1.77	1.59	1.39	1.77	2.14	2.32	2.14	1.95	0.58
	Sugar	0.14	0.4	0.61	1.06	1.02	1.06	1.1	0.36	0.58	0.95	0.82	0.95	1.02	1.95
Spicy Southwest Salad without meat	Fat	0.17	1.39	2.45	2.63	3	2.63	1.94	2.08	3	3	3	3	3	1.02
	Sodium	0.23	0.41	0.47	0.46	0.45	0.46	0.47	0.46	0.46	0.45	0.44	0.45	0.45	3
	Sugar	0.19	0.36	0.66	0.86	0.98	0.86	0.73	0.48	0.78	0.92	0.61	0.92	0.98	0.45
Sunflower Multigrain Bagel without Cream Cheese	Fat	3	2.82	2.74	2.29	2.42	2.29	2.15	2.96	2.88	2.53	2.64	2.53	2.42	0.45
	Sodium	2.26	1.86	1.41	1.23	1.05	1.23	1.41	1.61	1.23	0.86	0.68	0.86	1.05	0.98
	Sugar	2.86	2.6	2.39	1.94	1.98	1.94	1.9	2.64	2.42	2.05	2.18	2.05	1.98	2.42
Chipotle	Fat	3	3	3											
Black Beans	Sugar	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Chicken Burrito	Fat										0.1				0.1
Chicken Tacos, w-soft-com-tortilla	Fat	0.91	1.28	2.01	2.38	2.75	2.38	2.01	2.38	2.01	2.38	2.01	2.38	2.01	2.38
	Sugar	0.81		1.48	1.7	1.7	1.7	1.48			1.7	1.48			1.7
Patron Margarita	Fat	1.15	1.37	1.81	2.03	2.25	2.03	1.81	1.59	2.03	2.47	2.7	2.47	2.25	2.25
	Sugar	1.31	1.78	2.7	2.2	2.2	2.2	2.7	2.24	2.2	2.2	2.2	2.2	2.2	2.2
Pinto Beans	Fat			3	3	3	3	3	3	3	3	3	3	3	3
	Sugar								3						3
Steak Burrito	Fat														0.4
Steak Tacos, w-soft-com-tortilla	Fat								1.65	2.38	3	3	3	3	2.75

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
Tractor Berry Agua Fresca, large	Sugar	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
	Sugar	1.03		0.8		0.8			1.26	1.7				
Culvers	Fat													
		Sodium	1.11	1.29					0.66		0.35	0.4	2.1	0.4
Almond	Sugar													
		Sodium							0.15					
Applesauce	Fat													
		Sodium	0.44	0.41	1.02	1.17	1.02	1.02	0.77	1.03	0.1	1.96	3	1.96
Banana	Sugar													
		Sodium	0.04	0.42	2	2.17	2	1.85	0.74	2				
Banana	Sugar													
		Sodium	0.71	0.42	1.97	2.85	1.97	1.2	2.13	2.34	3	3	3	2.85
Banana	Fat													
		Sodium	1.43	1.26	2.57	2.3	3	2.3	1.6	1.58	2.65	2.6	0.9	2.6
Banana	Sugar													
		Sodium	1.22	1.71	2.56	0.45	0.45	1.28	1.94	0.45				
Banana Split, 2-scoop	Sugar													
		Sodium												
Chicken Noodle Soup	Fat													
		Sodium	0.49	2.4	3	3	3	3	3	3	3	3	3	3
Crinkle Cut Fries, large	Sugar													
		Sodium	1.35	3	3	3	3	3	3	3	3	3	2.67	2.57
Crinkle Cut Fries, large	Fat													
		Sodium	2.18	3	3	3	3	3	3	3	3	2.67	2.57	3
Crinkle Cut Fries, small	Sugar													
		Sodium												
Garden Fresco Salad with Grilled Chicken	Fat													
		Sodium												
George's Chili	Sugar													
		Sodium	0.71	0.75	1.17	1.03	1.03	1	0.87	1	0.87	1	0.87	1
George's Chili	Fat													
		Sodium												
George's Chili	Sugar													
		Sodium												

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	M	M	M	M	M	M
Grilled Chicken Sandwich	Sugar	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	0.43
	Fat		0.04	0.27	0.21	0.27	0.32				0.33				0.18
Mashed Potatoes	Sodium			0.04	0.55	0.01	0.55	0.36			0.55				0.28
	Sugar			0.05	0.51	0.82	0.51	0.3			0.09	0.28			0.39
	Fat	0.06		0.39	0.3	0.3	0.12								0.82
	Sodium			0.4	0.55	0.08	0.55				0.55				
Mashed Potatoes & Gravy, large	Sugar			0.4	0.54	0.54					1.07				
	Fat				0.04	0.04									1.42
Northwoods Walleye Sandwich	Sodium					1.73					0.15				
	Sugar											0.01			
	Fat												0.13		
	Sugar											0.09			
Plain Cake Cone	Fat	3	2.56	1.42	0.32	0.32	1.48	1.3							
	Sodium	2.67	2.39	1.41	0.65	1.82									1.91
	Sugar	2.29	1.54	1.41		0.79									
Plain Waffle Cone	Fat														1.19
	Sodium	0.33	0.56												
Shrimp Cocktail Sauce	Fat	0.85	1.11	0.43	0.7	0.7	1.4	0.39							
	Sodium			0.44	2.55	3	2.55	0.25			2.55				3
	Sugar	0.35	0.66	0.43	0.52	0.52	1.3	0.23							
Side Salad	Fat					0.18									0.68
	Sugar					2.73									0.87
Sprinkles, Blue and White	Sodium	0.34													2.26
															2.73

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
Steamed Broccoli	Fat	2.94	3	2.61	2.7	2.96	2.7	2.88	3	3	3	3	3	3
	Sodium	3	3	2.6	2.45	1.19	2.45	3	3	2.45				1.58
	Sugar	3	3	2.6	2.46	3	2.46	3	3	1.93	2.85	3	3	3
Tomato Florentine Soup	Sodium					0.49				0.19	1.66	1.69	0.49	1.31
Tropicana Fruit Punch [®] , large	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3
Tropicana Pink Lemonade, small	Sodium	2.74	3	3	3	3	3	3	3	3	3	3	3	3
Wisconsin Swiss Melt, single	Sugar	1.99	2.35	3	3	2.51	3	3	3	2.81	1.34	1.31	2.51	0.22
	Fat									0.75	1.59	0.75	0.22	
Dairy Queen	Fat	0.09	0.19	0.41	0.41		0.41	0.17	0.37					
1/2 lb. GrillBurger with Cheese	Fat	3	3	3	3	3	3	3	3					
Antioxidant Boost	Sugar	2.64	2.39	1.79	1.44	1.27	1.44	1.7	2.49	2.1	0.53	0.45	0.94	1.02
Applesauce	Sugar										0.69	1.33	1.16	
Banana Slices	Fat	2.14	1.7					0.81						
Caramel Topping	Sugar	3	3	3	3	3	3	3	2.64	2.8	3	3	3	3
	Sugar								0.36	0.2				
Chicken Bacon Ranch Sandwich	Fat	0.57	0.54					0.4						
Chocolate Cone, medium	Sugar					0.01				0.25				
Deluxe Cheeseburger	Fat			0.56	0.6		0.6	0.43						
Ham	Sugar									0.25	0.48	0.26	0.04	
	Sugar							0.08						
Hash Browns	Fat			0.69	1.31		1.31	0.4						

Table 7 (continued)

Menu item	Objective	Age-sex group																
		M/F	F	F	F	F	F	F	F	M	M	M	M					
Oven Baked Lay's Potato Crisps	Fat	3	3	2.44	2.4	2.4	2.4	2.4	2.4	3	3	2.57						
	Sugar	3	3	2.85	2.87	2.72	2.87	2.87	2.87	3	3	2.94	1.78	0.98	1.17	1.33		
Pancake Platter, ham	Sugar				0.46		0.46		0.46	0.87								
	Fat		0.36	0.12	0.59		0.59		0.59	2.09								
Pancake Platter, regular	Sugar	0.89	1.33	2.02	1.68	2.69	1.68	0.65	1.64	1.93	2.39	2.16	2.37	2.59				
	Fat	0.86	1.3	0.16	2.82		2.82	2.19	1.09									
Peanuts	Fat			2.84	0.18		0.18		1.91									
	Sugar			0.15	0.13	0.28	0.13		0.06	0.28	0.21	0.41	0.62					
Rotisserie Style Chicken Bites, 8-piece	Fat	1.56	2.46	3	3		3	2.6	3									
Side Salad	Sugar	3	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3
	Sugar			0.03		0.15			0.51	0.9	0.05							
Strawberry Banana Smoothie, extra-large	Sugar	0.36	0.61	1.18	1.56	1.58	1.56	1.3		2.47	2.95	2.55	2.06					
	Del Taco																	
Bean & Cheese Cup	Fat	0.33	0.52	0.48	1.1	0.87	1.1	1.34	0.21	0.24	0.44	0.47	0.87					
	Sodium	2.66																
Caramel Cheesecake Bites, 4-piece	Sugar	1.24	1.54	1.65	2.25	2.09	2.25	2.43	1.36	1.48	1.92	1.92	2.09					
	Fat																	
Chocolate Shake, large	Sugar																	
	Sugar				0.23							0.52	0.52					
Chocolate Shake, regular	Fat											0.18	0.18	0.23				
	Fat											0.05	0.67					
Crinkle Cut Fries, macho	Fat																	
	Fat																	
Cruncheitada Tostada	Fat	2.31	2.67	3	3	3	3	2.96	3	3	3	3	3	3	3	3	3	3
	Sodium	0.05																

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	M	M	M	M	M	M	
		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
Del Beef Burrito	Sugar	0.44	0.42	0.32	0.3	0.18	0.3	0.36	0.36	0.21				0.18
	Fat												0.09	
Hot Coffee	Fat	2.32	2.19	2.28	2.12	2.33	2.12	1.92	2.29	2.46	2.16			2.33
	Sodium	2.32												
	Sugar	0.13												
Mini Churros	Fat			1.58	1.47	3	1.47		1.04	3	3		2.84	3
Simply Orange Juice	Fat	0.68	0.81	0.72	0.88	0.67	0.88	1.08	0.71	0.54	0.84		0.75	0.67
	Sodium	0.68												
Strawberry Shake, mini	Sugar	2.87	3	3	3	3	3	3	3	3	3		3	3
Dunkin Donuts	Sugar	0.37	2.03	2.09	2.77	2.09	2.09	0.93	1.53	2.83	2.3		2.3	2.77
Chicken Bacon Sandwich	Sodium					0.41								0.41
Chicken Salad Croissant Sandwich	Fat					0.3								0.3
Cinnamon Raisin Bagel	Fat	1.31	1.37											
	Sodium	0.16	0.52											
	Sugar			0.06										
Egg and Cheese Sandwich, english-muffin	Sugar	0.09	0											
English Muffin	Fat	3	3	2.85	1.85	3	1.85	2.06	3				3	
	Sodium	3	3	2.2	0.74	1.15	0.74	2.2	3	0.74	2.17		2.17	1.15
	Sugar	3	3	1.79	1.7	1.79	1.79	1.88	3	2.92	1.79	1.91	1.79	1.7
Everything Bagel	Sodium					2.47					0.99		0.99	2.47
	Sugar	0.62	0.87											
French Roll	Fat			0.15	1.15		1.15	0.94						

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	F	F	M	M	M	M
	Sodium	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	1.85
	Sugar			0.8	2.26	1.85	2.26	0.8			2.26	0.83	0.83	1.85	
	Fat			0.99	2.18	3	2.18	1.12	1.18			1.09	1.21	1.3	
Glazed Old Fashioned Munchkin	Sugar														3
	Sodium														
Ham and Cheddar Sandwich	Sodium														
	Fat														
Multigrain Bagel	Sodium	0.43	0.79	3	3	3	3	1.83	2.46						3
	Sodium	1.39	1.66	2.29	2.52	0.53	2.52	2.29	1.94	2.52					0.53
	Sugar	0.98	1.39	2.36	2.62	2.97	2.62	2.26	2	2.72	3	3	3	2.97	
Pineapple Coolatta, small	Sugar														
Plain Bagel	Fat	0.04	0.21					1.17							
	Sodium			0.71	0.48		0.48	0.71	0.48	2.01	2.01	2.01	2.01	2.01	
	Sugar			0.58	0.38	0.03	0.38	0.74	0.28						
	Fat			0.33	0.3	0.28	0.3	0.49	0.28						
Strawberry Dragonfruit Dunkin' Refreshers, medium	Sodium	0.32	0.24	0.48	0.6	0.72	0.6	0.48	0.15	0.6	0.56	0.56	0.56	0.72	
	Sugar			1.19	1.54	2.89	1.54	0.2	0.89	2.55	3	3	3	2.89	
Tuna Salad Sandwich	Fat							0.19							0.19
Five Guys	Fat														
Cajun Style Fries	Fat	0.99	1.13	1.4					1.42	1.64					
Cattlemen's BBQ Sauce	Fat	0.63	0.69						0.33						
Little Hamburger	Fat			0.42						0.35					
Mushrooms	Fat			2.11											
Onions	Fat	2.37	2.31	0.89					2.67	3					
Veggie Sandwich	Fat			0.12	0.08					0.08					

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	M	M	M	M	M	
Godfather's Pizza		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
Calzone, cheese	Fat											0.02		
Cheese, jumbo	Fat	0.32	0.89	2.09	1.3	2.44	1.3			1.03	2.44	2.32	2.4	2.37
Cheese, large	Fat	0.31	0.18		1.17		2.24			1.45				
Cheese, medium	Sugar								1.64					
Cheesesticks, medium	Fat											0.34		
Cherry Streusel, small	Fat									0.07		1.7	0.43	0.71
Chicken Wings, bbq	Fat												1.19	1.34
Coffee	Fat	2.09	1.92	1.61	1.52	1.36	1.52	1.71	1.78	1.48	1.2	1.06		
Cottage Cheese	Sugar	2.07												
	Fat	0.17	0.09	0.02	0.11		0.11	0.38						
	Sugar	0.18	0.45											
Dr. Pepper	Fat	0.91	1.08	1.39	1.48	1.64	1.48	1.29	1.22	1.52	1.8	1.94	1.81	1.66
	Sugar	0.93	2.7											
Mellow Yellow	Sugar		0.3											
Pears	Fat	2.83	2.91	2.98	2.89	3	2.89	2.62	3	3	3	3	3	3
Potato Wedges	Sugar	2.82	2.55											
Veggie Pie Golden Crust Pizza, mini	Fat						0.64				1.63	0.94	1.34	0.05
Veggie Pie Golden Crust Pizza, small	Fat								0.56					
Jersey Mike's	Fat	0.29	0.35	0.44	0.53	0.56	0.53	0.45		0.52	0.56	0.68	0.6	0.63
	Sugar	0.29	0.43											

Table 7 (continued)

Menu item	Objective	Age-sex group																
		M/F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M
Agave Vanilla Cream Soda, giant	Sugar	0.4	0.52															
BBQ Beef, giant	Fat	0.15	0.24	0.2	0.42	0.21	0.42	0.58	0.16	0.04	0.05						0.05	0.21
Baked Lay's Sour Cream & Onion Chips	Sugar	0.35	0.45	0.5	0.72	0.63	0.72	0.73	0.41	0.41	0.54	0.48	0.54	0.63				
	Fat	3	3	3	2.44	3	2.44	0.72	3	3	1.41	3	3	3				
Grilled Portabella Mushroom & Swiss, giant	Sugar			0.64	0.07	1.19	0.07	0.53	1.76	2.32	3	2.32	1.19					
	Fat			0.2	0.15	0.53	0.15	0.06	0.5	0.84	0.93	0.84	0.53					
Miss Vickie's Sea Salt Chips	Fat	1.57	1.94	2.6	2.43	2.25	2.43	1.17	2.78	2.46	2.11	2.07	2.11	2.25				
	Sugar										0.09							
Sierra Mist, giant	Sugar			0.84	0.87	1.24	0.87	0.67	1.2	1.61	2	1.61	1.24					
Sun Chips, original	Fat				0.56		0.56	2.28		1.59								
Tossed Salad	Fat	0.39	0.47	0.76	0.72	0.94	0.72	0.48	0.69	0.97	1.16	1.36	1.16	0.94				
	Sugar	2.22	2.41	3	3	3	3	1.95	3	3	3	3	3	3				
KFC																		
Apple Turnover	Fat			0.74	1.18	1.78	1.18	0.1	1.7	2.34	2.91	2.34	1.78					
BBQ Baked Beans, family-size	Sugar				0.03		0.03											
Country Fried Steak without Peppered White Gravy	Fat																	
Crispy Twister without Sauce	Fat					0.75			0.2	0.9	0.7		0.75					
Extra Crispy™ Tenders (1) - Kids	Fat																	
Green Beans, family-size	Fat	0.19																
Grilled Chicken-Breast	Fat																	
Hidden Valley The Original Ranch Fat Free Dressing	Fat	0.98	0.91															
	Sugar	2.09	1.68	0.03	0	0	0	1.36	0.45									
Honey BBQ Sandwich	Fat			0.08	0.24			0.66	0.12									
	Sugar																	

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	M	M	M	M	M	M	
	Sugar	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
		0.64	2.21	2.82	2.82	2.82	2.04	1.48						
Honey Sauce Packet	Fat		1.09					1.48						
House Side Salad without Dressing	Fat		2.09	0.93	1.2	0.93	1.08							1.2
	Sugar	0.01	1.32	2.97	3	3	1.64	2.55						
Nashville Hot Extra Crispy Tender	Fat									0.2	0.35	0.2		
Original Recipe Chicken-Breast without skin or breading	Fat	1.02	1.85	1.91	2.69	1.29	2.49	1.52	0.26					1.29
	Sugar	0.54	0.47	0.05			0.22	0.21						
Parmesan Garlic Croutons	Fat		3	2.07	1.8	2.07	1.92	3	3	3	3	3	3	1.8
Sweet Kernel Corn, family-size	Fat	2.81	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	3	3	3	2.97	2.97	3	3						
Long John Silver's	Sugar								0.01					
Baja Fish Taco	Fat	0.21	0.61	0.45	1.29	1.29	1.87	0.32						
Baked Cod	Sodium	0.26	2.82				2.82	1.54						
	Sugar	0.56	1.02	1.91	1.13	1.91	2.01	0.5	0.93					
	Fat	3	3	3	3	3	3	3						
Baked Potato	Sodium	2.55	3	3			3	3						
	Sugar	2.96	3	3	3	3	3	3	3					
Corn Cobbette, w-butter-oil	Sugar	0.04												
Corn Cobbette, wo-butter-oil	Sodium	0.45												
	Sugar				0.15	3	0.15		0.12					
Marinara	Fat	0.01	0.44	1.4	1.62	1.62	1.1	1.13						
Pecan Pie	Sodium	0.43	0.58	0.72			0.72	0.65						

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	M	M	M	M	M	M
	Sugar	0.11	0.57	0.77	0.85	0.96	0.85	0.85	0.74	0.68	0.88				
Popcorn Shirimp	Fat			0.31	0.33		0.33								
Ranch	Sugar	0.45													
Strawberry Iceflow Lemonade	Fat	0.33	0.24						0.14	0.02					
	Sodium	0.11	0.17	0.32					0.32	0.24					
McDonald's	Sugar	0.03	0.03	1.13	1.37	2.21	1.37	1.37	0.68	0.72	1.82				
	Fat	0.55	0.53	0.63	0.69	0.54	0.69	0.69	0.85	0.37	0.47	0.47	0.42	0.47	0.54
Artisan Grilled Chicken Sandwich	Sugar	0.33	0.22	0.7	0.98	1.25	0.98	0.7	0.35	0.88	1.42	1.54	1.42	1.25	
Basket of French Fries	Fat										0.4	0.88	0.4		
	Sugar			1.03	1.06	1.08	1.06	1.06	1.03	0.52					1.08
Fruit & Maple Oatmeal w/ Brown Sugar	Fat	0.93	1.12	1.67	1.72	2.11	1.72	1.34	1.5	2.05	2.46	2.82	2.46	2.11	
Fruit & Maple Oatmeal w/o Brown Sugar	Sugar	2	2.67	1.97	1.94	1.92	1.94	1.97	2.48	3	3	3	3	1.92	
	Sugar		0.01							0.53	0.52	0.34	0.52		
Hotcake Syrup	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	0.6													
Large Strawberry Banana Smoothie	Sugar														2.3
	Sugar	2.76	2.99	3	3	3	3	3	3	3	1.8	2.14	2.14	3	
Marinara Sauce	Sugar	1.43	1.67	2.37	2.46	2.92	2.46	2	2.13	2.83	2.6	2.12	2.6	2.92	
	Fat														
Medium French Fries	Sugar			0.63	1.36	2.08	1.36	0.63	0.32	1.45	2.91	0.7	2.91	2.08	
	Sugar											0.02			
Premium Asian Salad w/o Chicken	Fat	0.06	0.3	0.28	0.66	0.68	0.66	0.63	0.33	0.31	0.61	0.52	0.61	0.68	
Premium Southwest Salad w/ Grilled Chicken	Sugar	2.4	3	2.37	1.64	0.92	1.64	2.37	2.68	1.55	0.09				
	Sugar														

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
Side Salad	Fat	1.57	1.33	0.63	0.54	0.08	0.54	0.54	0.54	1	0.87	0.17	0.08	0.08
	Sugar	3	3	3	3	3	3	3	3	3	3	3	3	3
Olive Garden	Fat								1.06					
Linguine di Mare	Fat								0.17					
Shrimp Scampi	Fat								1.13					
Zeppoli	Fat													
Panda Express	Fat												1.18	1.18
Cream Cheese Rangoon	Fat					0.25	0.25	0.25	0.74				0.98	0.98
Firecracker Shrimp	Sugar				1.24	1.24	1.24	1.06						
Fortune Cookies	Fat			1.98	2.75	3	2.75	2.26		3	2.02		2.02	2.05
	Sugar				1.76	1.76	1.76	1.94						
Kids Brown Steamed Rice	Sodium	2.98	1.42											
Kids Mixed Veggies (Side)	Fat	1.12	0.7						0.12	0.28				
	Sugar	0.02	0.06	0.01	1.36	1.36	1.36	0.59		0.73				
Lipton Brisk Raspberry®, kids	Fat	0.25	0.6	0.88	0.88	0.98	0.88	0.74	0.84	0.88	1.12		1.12	0.98
	Sugar			1.41	1.87		1.87	2.12		2.39				
Mug Root Beer®, medium	Sugar				1.13	1.13	1.13					0.61		
Mug Root Beer®, small	Sodium											0.08		
Plum Sauce	Fat	2.42	1.05										0.61	
	Sugar													2.17
Soy Sauce	Fat	0.58	1.95	1.02						2.39				
	Sugar			3						2.87				0.83

Table 7 (continued)

Menu item	Objective	Age-sex group											
		M/F	F	F	F	F	F	F	F	M	M	M	M
Steamed Brown Rice	Fat	0.13	1.3	3	2.64	1.99	2.64	2.88	2.47	2.56	2.85	2.85	2.29
	Sodium		1.58					2.94					
Steamed White Rice	Sugar	2.19	2.62	2.99	1.64		1.64	2.4	2.87	2.27			
	Fat	1.75	1	0.36	1.01	0.36	0.25	0.44	0.15	0.15	0.71		
	Sodium						0.06						
	Sugar						0.01	0.13					
Super Greens	Fat	3	3	3	3	3	3	3	3	3	3	3	3
	Sodium	1.69	2.14				2.75						
Veggie Spring Roll	Sugar	1.72	2.09	3	3	3	3	3	2.8	3			
	Fat		0.25	1.3	2.76	1.3	0.06	1.44	1.82	1.82	2.22		
	Sugar		0.25	0.69		0.69		0.03	1				
Popeyes													
Blackened Ranch	Fat	2.46	2.83	3	3	3	3	2.92	2.94	3	3	3	2.86
	Sodium						0.22			0.07	0.79	1.41	0.68
	Sugar	0.09	0.38	0.9	1.18	1.47	1.18	0.9	0.67	1.18	1.76	3	1.76
Chicken Blackened Tenders (3 Pcs)	Fat		0.19	0.75	0.81	0.75	0.74	0.48	0.86	1.02	0.9	0.97	
	Sodium		0.12	0.55	0.49	0.55	0.6	0.06	0.66	0.75	0.82	0.9	
	Sugar	1.84	1.88	2.32	2.36	2.4	2.36	2.32	1.92	2.36	2.44	1.75	2.44
	Fat	2.74	2.66	2.78	2.53	2.6	2.53	2.5	2.68	2.69	2.66	2.62	2.65
Corn On The Cob	Sodium	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	3	3	3	3	3	3	3	3	3	3	2.84	3
Grits	Fat	0.21	0.62	1.37	1.72	2.17	1.72	1.29	1.05	1.77	2.62	3	2.61
	Sodium	0.89	1.38	2.31	2.58	3	2.58	2.11	1.86	2.78	3	3	2.89

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
	Sugar	0.29	0.71	1.43	1.86	2.29	1.86	1.43	1.14	1.86	2.71	3	2.71	2.29
Hawaiian Punch	Fat			0.09	0.51	0.09				0.12	0.94		0.72	
Hot Cinnamon Apple Pie	Fat									0.12				
	Sodium				0.04					0.35	0.69	0.3		
	Sugar									0.19				
Jalapenos, 6-piece	Fat	0.26	0.34	0.22	0.47	0.4	0.47	0.5	0.32	0.31	0.34	0.38	0.35	0.44
	Sugar									0.16				
Loaded Chicken Wrap	Sugar									0.1				
Orange Juice	Fat	0.75	0.91	1.23	1.28	0.83	1.28	1.24	1.07	1.23	0.38		0.39	0.84
	Sodium			0.69	0.42		0.42	0.89		0.22				0.11
Sweet Tea	Fat											1.24	0.21	0.49
	Sodium	0.56	0.67	0.33	0.68	1.1	0.68	0.12	0.78	0.85	1.11	1.12	1.13	1.03
Raising Cane's														
1% Milk Box	Fat	0.71	1.52	2.96	1.35		1.35	2.35	2.33	1.05				0.68
3 Chicken Finger Combo	Fat			0.1	0.69				0.4					
Apple Juice	Fat	1.25	0.85	0.04					0.45	1.92				
Box Combo	Fat				0.33		0.33	0.18						0.58
Chicken Fingers	Fat							0.19						
Crinkle-Cut Fries	Fat	1.83	2.33	3	3	3	3	2.81	2.83	3				3
Lemonade, jug	Fat			0	0.04	0.07	0.04			0.02				0.02
Texas Toast	Fat	1.17	0.67						0.17					
Red Lobster														
Alotta Colada	Sugar			0.1	0.48	1.37	0.48		0.96	2.45		2.44		1.5

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M
Asparagus	Sodium	0.93													
	Sugar	0.72	0.43	0.66	0.26	0.66	0.73	0.78	0.36						
Baked Potato	Sodium	1.69	1.91												
	Sugar	0.31	0.01	0.43					0.14						0.17
Bar Harbor Lobster Bake, Berry Mango Daiquiri	Sugar						0.05								
	Sodium	0.29													
	Sugar	1.53	2.9	2.52	1.63	2.52	2.53	2.58	2.04	0.55				0.35	1.5
Broccoli	Sodium	1.25	0.16												
	Sugar	2.39	2.26	2.57	2.34	2.34	2.27	2.22	2.64	2.86				3	2.83
Caesar Dressing	Sodium	0.27													
	Sugar	0.41	0.42	0.65	0.51	0.65	0.58	0.44	0.55	0.37				0.19	0.27
French Fries	Sodium	0.06													
	Sugar	0.3													
Lighthouse Maple-Glazed Chicken	Sugar									0.42				0.53	0.2
Lighthouse Rock Lobster Tail	Sodium	0.07													
	Sugar		0.18	0.7	0.72	0.7	0.72	0.27	0.32					0.28	0.71
Lobsterita, raspberry Manhattan	Sugar													0.21	
	Sodium	2.48													
	Sugar	1.88													
Old Fashioned	Sodium	2.71													
	Sugar	1.47													
Roasted Maine Lobster Bake	Sodium	0.1													
	Sugar	0.11	0.05				0.47	0.42							

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	F	M	M	M	M
Shrimp Linguini Alfredo, full-portion	Sodium	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
		0.03												
	Sugar	0.09	0.09	0.2	0.04	0.04	0.04	0.04	0.11	0.12				
Strawberry Daiquiri	Sodium	0.2												
	Sugar	1.1												
Sonic	Fat													
Burger, w-mayonnaise	Fat				0.14						0.45	0.21	0.64	0.47
Burger, w-mustard	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3
Caramel Topping, medium	Sugar	3	3	3	2.15	2.85	2.15	1.24	3	3	2.82	3	2.51	2.28
Chocolate Fudge Topping, route-44	Sugar				0.15						0.18		0.49	
Cinnasnacks, 3-piece-wo-frosting	Fat											1.04	0.23	
Coffee, large	Fat							3						
Coffee, regular	Sugar	0.54	1.37	1.14	0.01	0.01	0.01	0.46		0.04				2.79
Diet Cherry Limeade, route-44	Fat				0.12		0.12						2.61	
	Fat	3	3					0.1						
	Sugar	2.46	1.44					1.92						
Diet Cherry Syrup, route-44	Sugar				0.85		0.85	1.76						0.72
Diet Limeade, medium	Fat			2.59	2.88	2.56	2.88		1.72	2.28	2.38		2.56	
French Fries - Small	Fat			1.03	0.44	0.55	0.44		0.7	0.74	0.03			
French Fries, large	Fat											0.11		
French Fries, medium	Fat			0.38	0.25	1.33	0.25		1.74	2.76			2.42	1.81
French Fries, small	Fat											2.89		
Grilled Chicken Wrap	Fat	0.29	0.25					0.22						

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
	Sugar	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
	Sugar	0.21	0.38	0.42	0.52	0.66	0.52	0.5	0.46	0.57	0.79	0.64	0.79	0.66
Lemonade Slush, route-44	Sugar									0.21				
Milk (1)	Fat			1.97	2.38	2.45	2.38	1.78		2.26	2.97	3	3	3
	Sugar			1.73	3	2.45	3	3		1.07	2.73	3	3	3
Minute Maid Apple Juice Box	Sugar				0.55					0.27				
Minute Maid Orange Juice, large	Sugar											0.94	0.51	1.84
Nut Topping	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	3	3	3	3	3	3	3	3	3	2.79	3	3	3
Soft Pretzel Twist	Fat	0.88	1.29	2.75	1.67	2.75	2.75	2.27	1.66	0.46	0.24			0.74
	Sugar								0.16	0.26		0.46		
Sweet Green Iced Tea, gallon	Sugar											0.25	0.05	
Sweet Iced Tea, small	Fat			0.41	0.44				1.18	0.72	0.62	0.39	0.44	0.21
	Sugar	0.19	1.86	2.99	3	2.99	2.99	2.54	1.08	2.96	3	1.81	2.45	1.16
Syrup	Fat	1.21	1.2					0.29						
	Sugar	1.76	3	3	3	3	3	3	3	3	3	3	3	3
Subway														
6" Harvest Bread	Fat	3	2.23	3	3	3	3	3	3	3	3	3	3	3
	Sodium	0.94	1.26	1.9	2.22	2.54	2.22	1.9	1.58	2.22	2.41	2.12	2.41	2.54
	Sugar	0.71	0.77	2.46	2.26	2.34	2.26	0.77	2.23	0.95	0.9			2.34
6" Hearty Italian Bread	Sugar							0.82						
6" Honey Oat Bread	Fat		0.69											
	Sodium	0.29	0.3	0.34	0.35	0.37	0.35	0.34	0.32	0.35	0.59	0.88	0.59	0.37
	Sugar	2.29	2.23		0.74		0.74		1.45		1.45		1.45	

Table 7 (continued)

Menu item	Objective	Age-sex group														
		M/F	F	F	F	F	F	M	M	M	M	M	M			
6" Sourdough Bread	Fat	2-3	4-8	9-13	14-18	19-30	31-50	51+	2.78	2-3	4-8	9-13	14-18	19-30	31-50	51+
Apple Slices - 1 package	Sugar							1.41								
	Fat		0.82	0.21	0.92	0.21	0.69	0.9	1.53	1.15	1.15	1.15	1.15	1.15	1.15	0.92
	Sodium									0.16	0.39	0.16	0.39	0.16	0.16	0.16
	Sugar	0.77	0.11	2.8	0.18	2.55	0.18	2.78	1.96	1.63	1.39	1.63	1.39	1.63	2.55	2.55
Avocado	Fat	0.2	2.14	0.16	2.66	0.16	2.34	3	3	3	3	3	3	3	3	2.66
Baked Lay's@Chips	Sodium									1.14	2.71	1.14	2.71	1.14	1.14	1.14
	Sugar						3				0.42					
Caramel Apple Cookie	Sugar		0.2		0.45			0.22	1.04	1.37	1.61	1.37	1.61	1.37	1.37	0.45
Chocolate Chunk Cookie	Fat									0.22	1.3	0.22	1.3	0.22	0.22	0.22
FUZE Black Tea with Lemon Sweet	Sugar									0.43	2.1	0.43	2.1	0.43	0.43	0.43
Mini Italian (White) Bread	Fat		0.08					0.22								
Minute Maid@Fruit Punch (100% Juice)	Sodium	1.78	1.44	0.77	0.43	0.09	0.43	0.77	1.1	0.43	2.05	1.12	1.12	1.12	1.12	0.09
	Sugar			0.54	0.66			0.77	2.56	3	3	3	3	3	3	0.66
Olive Oil Blend (1 tsp)	Fat															
Onions	Fat	0.38	3	0.86	2.84	0.34	2.84	0.66								0.34
	Sodium	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugar	3	3					3								3
Spinach	Fat							3								
Sunchips Harvest Cheddar Chips	Fat														2.2	
Tomato	Fat	2.42														
	Sugar		3	3	3	3	3	3	3	3	3	3	3	3	3	3
Veggie Delite, 6	Fat							1.64								

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	M	M	M	M	M	
Veggie Deluxe, footlong	Fat	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
		0.31	0.91	2.07	2.07	2.07	2.07	1.36	0.21	0.91	2.02	0.54	2.02	2.07
Veggie Deluxe, kids-mini-sub	Sodium	0.16	0.7	1.77	2.31	2.85	2.31	1.77	1.24	2.31	3	3	3	2.85
	Sugar		0.47	1.21	2.16	2.41	2.16	0.46	0.65	2.02	3	3	3	2.41
	Fat	1.89	2.69	2.09	0.93	0.93	0.93	2.79	2.09	0.98	2.46	0.98	0.93	0.93
	Sodium	2.84	2.3	1.23	0.69	0.15	0.69	1.23	1.76	0.69				0.15
	Sugar	2.5	2.53	1.79	0.84	0.59	0.84	2.54	2.35	0.98				0.59
	Fat					0.78			0.83	1.11	0.43			
Black Bean Chalupa	Sugar													0.22
	Sugar				1.96		1.96	2.64						
Black Beans & Rice	Fat	1.88	2.89	2.12	2.3	2.49	2.3	2.13	3	1.82	1.23	0.14	0.55	0.8
	Sodium	1.48	2.78						3					
	Sugar	3	3	1.26	1.04	0.97	1.04	0.36	3	1.14			1.92	3
	Fat							0.47						
Chalupa Supreme - Chicken	Fat													
	Fat			1.16	1.45	1.82	1.45	0.53	0.88	2.57	3	1.08		
	Sugar			0.35	0.84	0.35								
	Fat			0.88	0.7	0.51	0.7		1.18	1.77	2.86	2.45	1.08	
	Sodium	0.45	0.16											
Cinnabon Delights, 2-pack Crunchy Taco	Sugar									0.71				
	Fat										0.35	0.92		
	Fat												0.25	0.33
	Sugar					0.09								
	Fat	2.98	2.93	2.87	2.84	2.81	2.84	2.88	2.88	2.84	2.82	2.84	2.8	2.83

Table 7 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M
	Sodium	2.96	2.92												2.9
	Sugar	2.31	2.93	1.84	0.71	0.88	0.71	0.16	2.5	1.3					
Fresco Bean Burrito	Fat								0.03						
	Sodium								0.83						
Fresco Burrito Supreme - Chicken	Sugar	0.11	0.19						0.16						
Fresco Chicken Soft Taco	Sugar							0.51							
	Fat	0.5	0.68	0.57	1.24		1.24	2							
	Sodium	0.56	0.69												
	Sugar	0.35	2.56	3	3	3	3	2.49	0.28	2.55					
Iced Coffee	Sugar	0.69	0.07												
Mountain Dew Baja Blast, 40-oz	Fat	0.02	0.07												
	Sodium								0.1						
Mug Root Beer, 40-oz	Fat			0.13	0.16	0.19	0.16	0.12	0.12	0.16	0.18	0.16	0.2	0.17	
	Sodium	0.04	0.08												
	Sugar			1.16	1.56	2.12	1.56	1.23	0.5	1.7					
Nachos BellGrande, chicken	Fat													0.14	
Orange Juice	Sugar							1.61							
Pizza Sauce	Fat	2.71	1.35		0.73		0.73								
	Sodium								1						
Steak Power Bowl	Sugar														
Veggie Power Bowl	Sugar	0.02													
Wendy's															
Apple Slices	Sodium		0.67												0.17

Table 7 (continued)

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	M	M	M	M	
Barbecue Nugget Sauce	Fat	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
		0.68	1.62	1.68	1.62	1.68	1.62	1.68	2.24	2.28	2.28	2.24	2.1	1.17
Barq's Root Beer, medium	Fat		1.47	1.6	1.73	1.6	1.06	1.06	1.65	1.79	1.88	1.74	1.61	
	Sodium								0.78			0.59		
	Sugar	0.07	0.84	1.36	1.47	1.69	1.47	1.3	1.52	2.32	2.12	1.67		
Brown Sugar	Fat								0.5					
Chocolate Milk	Fat		0.59	1.4	1.27	1.4	1.4	1.4	1.07	1.21	0.76	1.26	1.39	
	Sodium											0.13		
	Sugar											0.42		
Cold Brew Iced Coffee, large	Fat		0.94				1.94	1.94						
	Sugar	1.89	1.64	1.53	1.31	1.53	1.7	1.7	1.48	0.68	0.46	1.33		
French Fries, junior	Sugar	1.11	1.14	0.59	0.24	0.24	0.59	0.79	0.24					
Grilled Chicken Sandwich	Fat		0.2				0.63	0.63						
Honey Roasted Sunflower Seeds	Sodium	2.78	2.67	2.91	1.78	0.09	1.78	2.6	1.31	2.23			0.3	
Large Coffee	Fat		0.49											
Lemonade,	Fat	2.25	2.51						3	0.37				
	Sodium	1.61	2.25	2.3	2.53	3	2.53	1.96	3	2.82	2.22	2.29	2.83	
	Sugar	1.67	0.27						2.38					
Milk	Sodium		0.7	0.47	0.47	0.47	1.04	1.04	0.18				0.17	
Oatmeal Bar	Sodium		0.1	0.56	1.26	0.56			0.84	0.05			1.01	
Orange Juice	Fat		0.49				0.79	0.79			0.6			
	Sodium	0.32	0.46	0.42	0.29	0.42	0.44	0.44	0.31	1.04	0.98	0.42		
	Fat		0.25	0.13	0.25	0.25	0.15	0.15	0.13	0.13	0.24	0.36		
Parmesan Caesar Salad, full	Sodium		0.35	0.39	0.35	0.35	0.28	0.28	0.13	0.23	0.33	0.59		

Table 7 (continued)

Menu item	Objective	Age-sex group																						
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M									
	Sugar	2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+	0.22	0.42	0.34	0.42	0.49	0.15	0.27	0.33	0.56	
Plain Baked Potato	Fat	2.05	2.64	3	3	3	3	3	3	3	3	3	3	3										
	Sodium	1.83	2.33	2.67	3	1.97	3	3	2.83	3	3	3	3	3										
	Sugar	1.52	1.86	2.41	2.76	3	2.76	2.41	2.21	2.76	3													
Seasoned Potatoes, large	Sugar		0.11	0.45	0.57		0.57	0.18	0.43	0.84														
Seasoned Potatoes, medium	Sugar					0.97																	0.64	
Sour Cream & Chives Baked Potato	Sodium			0.33		1.03																		
Southwest Avocado Chicken Salad, full	Sodium			0.09																				
Strawberries	Fat	0.95	0.36																					
	Sodium	1.17																						
Taco Salad, full-size	Sodium																						0.58	
	Sugar					0.1																	0.41	
Taco Salad, half-size	Fat				0.15	0.56	0.15													0.33	0.9	1.29	0.84	0.42
	Sodium																						0.91	
	Sugar																						0.88	
Whataburger	Fat																						0.24	
Apple & Cranberry Chicken Salad, w-grilled-chicken	Fat	0.65	0.74	1.04	0.97	1.29	0.97	0.69	1.01	1.32	1.56	1.75	1.44	1.29										
Apple & Cranberry Salad	Fat	0.53	0.65	0.61	0.94	0.6	0.94	1.21	0.39	0.34	0.04													0.6
Apple Slices	Fat		0.05	0.08	0.32	0.26	0.32	0.35	0.02	0.05	0.19	0.12	0.17	0.26										
Chicken Garden Salad, w-grilled-chicken	Fat	1.79	1.4	0.76	0.13		0.13	0.3	1.23	0.59														
French Fries, small	Fat	0.03	0.16	0.51	0.64	0.85	0.64	0.45	0.35	0.71	1.08	1.13	1.06	0.85										
Garden Salad	Fat	0.03	0.28	0.27	0.56	0.4	0.56	0.64	0.19	0.18	0.05	0.59	0.1	0.4										
Grilled Chicken Sandwich	Fat																							

Table 7 (continued)

Menu item	Objective	Age-sex group														
		M/F	F	F	F	F	F	F	F	F	M	M	M	M	M	
Jalapeno & Cheese Whataburger	Fat	0.26	0.35	0.49	0.56	0.56	0.56	0.56	0.56	0.55	0.36	0.5	0.52	0.55	0.53	0.56
Minute Maid Light Lemonade, large	Fat												2.07		1.39	
Minute Maid Light Lemonade, medium	Fat					1.08										1.08
Pancake Platter with Bacon	Fat	0.05														
Unsweetened Tea, large	Fat	3	3	3	3	1.92	3	3	3	3	3	3	0.93		1.61	1.92
Zaxby's																
Brownie	Fat															
Crinkle Fries, large	Fat	1.26														
Insane Sauce	Fat	0.04														
Minute Maid Lite Lemonade	Fat	0.28														
Side Salad	Fat	1.74														

Table 8 Optimal solutions found for the combined menu

Menu item	Objective	Age-sex group												
		M/F	F	F	F	F	F	F	F	F	F	F		
		2-3	4-8	9-13	14-18	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
Blimpie/Popcorn, regular	Sodium			0.3	0.44	0.3					0.31	0.28	0.34	0.07
Blimpie/Pretzels Classic Thin Style	Sodium				0.56						2.72	2.66	2.93	0.38
Buffalo Wild Wings/Carrot Sticks	Fat	1.27	1.55	2	2.27	2.04	2.27	2	1.82	2.27	1.88	2.82	1.78	1.79
Burger King/Dried Fruit Topping	Sodium		0.07	0.75	0.54	0.75	0.46	1.07	1.27	0.51	0.72	1.14	1.59	2.05
Chick-fil-A/4 Piece Grilled Chicken Nuggets	Sugars	2.37	1	0.46	1.14	0.26	1.14	0.26	1.07	0.05				0.32
Chick-fil-A/ Kids Fruit Cup	Sodium			1.14	1.14	1.14	1.14	0.26	1.07		1.59	1.18	1.55	0.91
Chipotle/Black Beans	Sugars	3	3	3	3	3	3	3	3	3	3	3	3	3
Culvers/Almond	Sodium							0.22		0.5				
Culvers/Banana	Sodium	1	2.5	3	1.95	3	1.95	3	2.69	2.5	2.07	2.08	0.33	
DQ/Applesauce	Sodium		0.17		1.1		1.15	1.3						
Domino's Pizza/Caesar Dressing	Sugars		0.52	0.66	0.59	0.66	0.52	0.69	0.69	0.22				0.76
Domino's Pizza/Green Peppers	Fat	1.73	1.45	0.45	0.11	0.11	0.63	0.75						
Godfather's Pizza/Coffee	Sodium	2	0.5											
Godfather's Pizza/Kidney Beans	Sodium	1.07	0.68	2.82										
Godfather's Pizza/Mellow Yellow	Fat		1.66	3	3	3	2.46	0.12	2.64	3	3	3	3	3
	Sugars		0.7	1.04	0.7	1.52	1.41	2.17						2.09
	Fat	0.23												
	Sodium	0.04												
Godfather's Pizza/Mushrooms	Sodium										0.28	1.06	0.93	0.94
Hardee's/Natur-Cut French Fries, large	Sugars				0.22						0.72	0.91	0.44	

Table 8 (continued)

Menu item	Objective	Age-sex group																				
		M/F	F	F	F	F	F	F	F	F	M	M	M									
KFC/Nashville Hot Grilled Chicken, whole-wing	Sugars	0.78	0.32																			
McDonald's/Peanuts for Sundaes	Sodium																					
McDonald's/Regular Nonfat Latte	Fat	0.39	0.56	0.57	0.65	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
McDonald's/Side Salad	Fat							2.58														
Panda Express/Kids White Steamed Rice	Fat	1.82	2.67	3	2.73	3	2.73	3	2.73	3	2.73	3	2.73	3	2.73	3	2.73	3	2.73	3	2.73	3
	Sodium		0.2	2.83																		
	Sugars		0.32	2	2.54	3	2.54	3	2.54	3	2.54	3	2.54	3	2.54	3	2.54	3	2.54	3	2.54	3
Panda Express/Steamed White Rice	Fat				0.27		0.27		0.27		0.27		0.27		0.27		0.27		0.27		0.27	
	Sodium				1.86		1.86		1.86		1.86		1.86		1.86		1.86		1.86		1.86	
	Sodium	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Popeyes/Corn On The Cob	Fat																					
Red Lobster/Caesar Dressing	Fat																					
Sonic/Chocolate Fudge Topping, large	Fat					0.55	0.62	0.82	0.82	0.62	0.62	0.43	0.73	0.87	0.18	0.77	0.58					
Sonic/Grape Slush, large	Fat																					
Sonic/Nut Topping	Sodium																					
Sonic/Raspberry Syrup, medium	Fat																					
Subway/Apple Slices - 1 pack	Sodium																					
Subway/Avocado	Sodium																					
Subway/Cucumbers	Fat	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Subway/Onions	Sodium	3	3	1.24	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Sugars	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Taco Bell/Black Beans & Rice	Sugars																					1.04

Table 8 (continued)

Menu item	Objective	Age-sex group													
		M/F	F	F	F	F	F	F	F	M	M	M	M		
Taco Bell/Coffee		2-3	4-8	9-13	14-18	19-30	19-30	31-50	51+	4-8	9-13	14-18	19-30	31-50	51+
Wendy's/Lemonade		2.38	2.44	2.43	2.35	2.85	2.35	1.87	2.6	3	1.19	3	2.73	2.31	2.13
	Sodium														
	Fat														
	Sodium	1.89	2.32	0.18							1.81				
	Sugars	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Wendy's/Plain Baked Potato	Fat					0.42					1.21			1.4	0.88

Acknowledgements The authors would like to thank the two reviewers and associate editor for their helpful comments and suggestions.

Funding This work was supported by a grant from the Texas A&M Triads for Transformation (T3) program.

Data Availability All the data and codes used in this study are available online [18].

Declarations

Conflict of Interest The authors declare no competing interests.


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