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The more that households prioritise healthy eating, the better they can afford to consume a sufficient quantity and variety of fruits and vegetables

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Abstract

Objective: To examine the variety of fruits and vegetables lower income households in the USA can buy while meeting Federal dietary recommendations at different levels of expenditure.

Design: Simulation techniques were used to create 3000 market baskets of fruits and vegetables. All baskets contained enough food for a four-person household to meet dietary recommendations for fruits and vegetables over 1 week. Each basket's retail value was estimated along with the ability of a representative household to afford each basket with different levels of expenditure.

Setting: We used data from the US Department of Agriculture's (USDA) Fruit and Vegetable Prices data product which reports a US household's costs to buy each of 157 different fruit and vegetable products per edible cup equivalent.

Participants: We consider the situation facing a lower income household that receives maximum benefits through the Supplemental Nutrition Assistance Program (SNAP). These benefits are enough for the household to obtain a nutritious and palatable diet without spending any of its own money on food if it approximately follows USDA's Thrifty Food Plan.

Results: Households receiving maximum SNAP benefits can buy a sufficient variety and quantity of fruits and vegetables if they allocate about 40 % of those benefits to these two food groups. However, if households spend less than that amount, the variety of products they can buy while still satisfying recommendations drops off quickly.

Conclusion: Households that move fruits and vegetables to the centre of their budgets can better afford to meet Federal dietary guidelines.

Keywords
Fruit and Vegetable Prices
Food budgeting
MyPlate
Nutrition education
Supplemental Nutrition Assistance Program
Thrifty Food Plan

Fruit and vegetable underconsumption is a problem in many countries including European Nations and the USA[1–3]. Several possible reasons exist. In the US case, research shows that households may lack the time and/or cooking skills necessary to prepare home-cooked meals rich in fruits and vegetables[4–6].

Another possibility is that some US households, especially lower income ones, cannot afford to meet Federal fruit and vegetable recommendations. Individuals in lower income households consume even less than individuals in higher income households do[7,8]. Moreover, in surveys and focus group analyses, lower income households often cite costs as a barrier to increased fruit and/or vegetable consumption[9–12].

Some research investigating why lower income Americans may believe fruits and vegetables are unaffordable focuses on food prices. It has been argued that such households rely on energy-dense grains, fats and sweets because these foods cost less than nutrient-dense foods including fruits and vegetables on a dollars-per-calorie basis ($/calorie)[13]. However, this argument depends on the unit in which food prices are measured. Many fruits and vegetables cost less than energy-dense foods if prices are instead measured on a dollars-per-edible grams basis ($/edible grams) or on a dollars-per-portion basis ($/average portion)[14].

Another relevant strand of research focuses on how American households budget their food dollars. In particular, when money is tight, households may prioritise certain types of foods over others[9,15]. Meats are often purchased first[9,15]. Grains, such as pasta and rice, may also be prioritised because households believe these foods are satiating and serve to 'stretch out' other foods (e.g. preparing meat

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with rice or pasta ensures that the meat can serve more people)[9]. Fruits and vegetables, by contrast, are not generally a priority[9]. Little money may be left over for them. For example, in one study of lower income households with children, a parent explained that, 'If we don't have the money . . . then a lot of the fresh fruit is cut out . . . ' [9].

In this study, using the US Department of Agriculture's (USDA) Fruit and Vegetable Prices data product[16], we investigate the mix of fruits and vegetables that a representative American household can afford at prevailing prices with different shares of its food budget. The household is assumed to participate in the Supplemental Nutrition Assistance Program (SNAP). It is also assumed to receive maximum SNAP benefits which are sufficient for the household to follow USDA's Thrifty Food Plan (TFP) without spending any of its own money on food. The TFP demonstrates how households can obtain a nutritious and palatable diet on a minimal budget[17]. Of course, households are not required to follow the TFP; rather they may allocate their money and/or SNAP benefits across different types of at-home foods as they see fit.

Previous studies confirm that households following the TFP can satisfy dietary recommendations for fruits and vegetables[18,19]. On the one hand, these two food groups represent about 40 % of a household's overall costs to follow the TFP which may seem reasonable since fruits and vegetables should account for half of everyone's plate[17,20]. On the other hand, American households allocate only 26 % of their food budgets to fruits and vegetables, on average[21]. We hypothesise that, if a household receiving maximum SNAP benefits budgets enough money for these two food groups, then it can afford to meet Federal dietary recommendations for them. However, if the same household allocates a substantially smaller share of its food dollars to fruits and vegetables than the TFP does, possibly because it perceives these foods as being 'too expensive', then the household will only be able to afford a very limited mix of fruits and vegetables. It may struggle to meet the same guidelines while also satisfying the tastes and preferences of household members and accommodating variation in types of meats, grains and other foods the household also eats. This may be especially true for vegetables. While many types of fruit are consumed as a stand-alone food and fruit consumption is associated with snacking[22], vegetables often serve as a side dish or as a needed ingredient and vegetable consumption is associated with preparing home-cooked meals[23].

Methods

We begin by examining what types of foods Americans typically consume with their fruits and vegetables. This examination and the roles played by each food group in the American diet provide context for the study's main empirical analysis which relies on a combination of descriptive techniques and a simulation. Data from USDA showing how much money American consumers pay at retail food stores for different fresh and processed fruits and vegetable products are used. All data used are publicly available including the price data which are accessible online through USDA's Economic Research Service.

Foods commonly consumed with fruits and vegetables

In order to identify what types of foods Americans typically consume with their fruits and vegetables, we use the 2015–16 National Health and Nutrition Examination Survey (NHANES)[24]. Participants report their food and beverage consumption for two separate, 24-h periods. USDA's 2015–16 Food Patterns Equivalents Database (FPED) can then be used to identify each type of food that a participant consumed[25]. This database disaggregates a food's components, whether a stand-alone item like an apple or a glass of milk, or a multi-ingredient item like pizza, into cup equivalents of fruit, vegetables, and dairy products; ounce equivalents of grains and protein foods; teaspoon equivalents of added sugars; and gram equivalents of solid fats and oils.

Fruit and Vegetable Prices data

Data on how much different fruit and vegetable products cost at retail food stores are available through USDA's Fruit and Vegetable Prices data product[16]. These data report national-average retail prices for 157 commonly consumed and purchased foods. Prices are reported in cup equivalents to be consistent with Federal dietary recommendations. In general, a cup equivalent is the amount of the edible portion of a fruit or vegetable (e.g. minus pits or peels) that will fit in a standard 8-ounce measuring cup. However, because some foods are more concentrated and some are airier or contain more water, there are exceptions. A cup equivalent for raw leafy vegetables is two cups; for raisins and other dried fruits, it is one-half cup.

USDA's fruit and vegetable cost estimates are based on 2016 retail scanner data from Information Resources Incorporated (IRI), a market research company. IRI collects sales data from grocery stores, supermarkets, supercentres and other types of food retailers. USDA researchers use these data to calculate average retail prices per pound (or per pint for juices) for each food product across different types of retail outlets, package sizes, brand names and seasons. These prices are then adjusted to account for the weight of inedible parts and cooking loss that may occur prior to consumption. For example, fresh potatoes when baked in their skins lose about 19 % of their weight. For a fresh orange, weight adjustments were made to account for the inedible peel and seeds.

Fruits and vegetables are available at a wide range of prices. Figures 1 and 2 show how many fruits and vegetables are available within each of five price intervals, respectively. The first interval in both histograms was defined to

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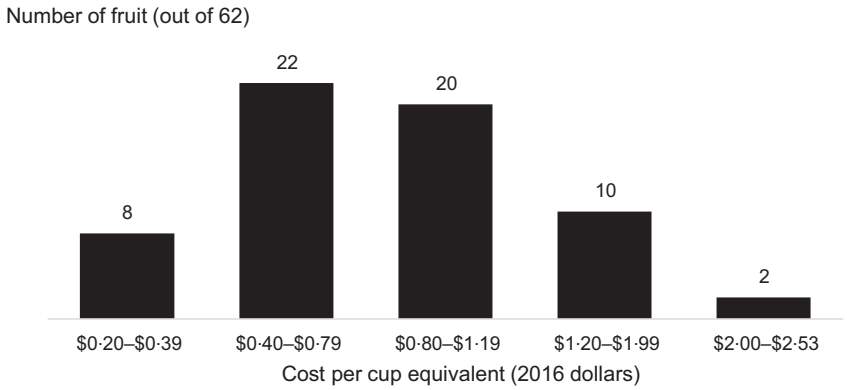

Fig. 1 The cost of fruit ranges from $0·20 to $2·53 per edible cup equivalent
Source: US Department of Agriculture, Economic Research Service. Fruit and Vegetable Prices data set. 2016 Average Retail Prices.

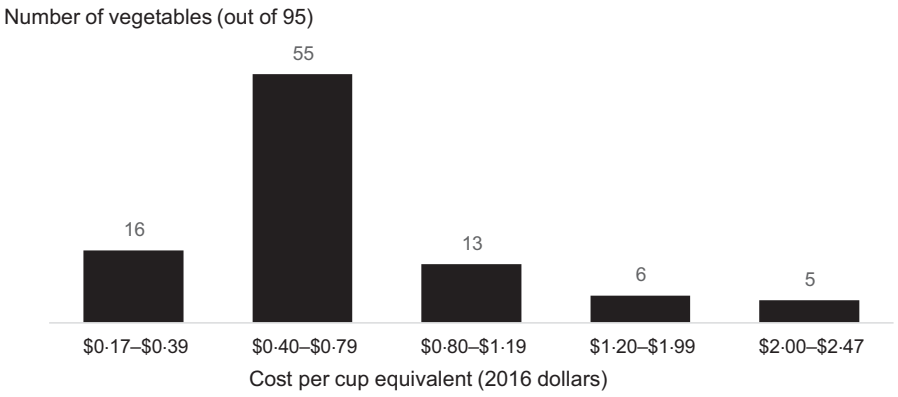

Fig. 2 The cost of vegetables ranges from $0·17 to $2·47 per edible cup equivalent
Source: US Department of Agriculture, Economic Research Service. Fruit and Vegetable Prices data set. 2016 Average Retail Prices.

include products costing less than $0·40 per cup equivalent. This made it possible to include at least one product from both food groups and each vegetable subgroup. Vegetable subgroups include dark green vegetables, red/orange vegetables, legumes, starchy vegetables and other vegetables. The second interval in both histograms was then defined to include products costing between $0·40 and $0·80 per cup equivalent. This made it possible to include many of the remaining, top-consumed products as discussed below.

Among all 62 fresh and processed fruits priced by USDA, only 8 cost less than $0·40 per cup equivalent in 2016 (Fig. 1, first price interval). These are watermelon ($0·20 per cup equivalent), bananas ($0·28), cantaloupe ($0·38) and five types of juice (all made from frozen concentrate and costing between $0·26 and $0·38 per cup equivalent). A much greater variety of fruits are available for $0·40 to $0·80 per cup equivalent (Fig. 1, second price interval). These include apples ($0·44), oranges ($0·66), grapes ($0·77), raisins ($0·59) and canned fruit cocktail packed in 100 % juice ($0·76), among others.

The situation is similar for vegetables. Among all 95 fresh and processed vegetables examined by USDA, 16 cost less than $0·40 per cup equivalent in 2016 (Fig. 2, first price interval). Romaine lettuce ($0·33) is the only dark green vegetable. Whole carrots ($0·24 if eaten fresh and $0·30 if boiled) are the only orange/red vegetable. Other products available for less than $0·40 per cup equivalent in 2016 include baked potatoes eaten with the skin ($0·20), fresh green cabbage ($0·26), iceberg lettuce ($0·28), cucumbers eaten with the peel ($0·34), canned green beans ($0·38) and eight types of legumes (all in dried form and costing between $0·17 and $0·34 per cup equivalent). A much greater variety of vegetable products cost between $0·40 and $0·80 per cup equivalent (Fig. 2, second price interval). Items in this second interval include baby carrots ($0·40), green bell peppers ($0·48), canned tomatoes ($0·49), frozen green peas ($0·66), frozen broccoli ($0·71), red bell peppers ($0·75) and fresh kale ($0·79). Eight types of canned legume also cost between $0·48 and $0·56 per cup equivalent. Onions ($0·41), used for flavouring a wide variety of dishes, further fall into the second price interval.

Together, the first and second price intervals in Figs 1 and 2 include most of the top fruits and vegetables consumed by Americans in at least one form[26,27]. Asparagus, avocados, cherries, strawberries and other types of berries are exceptions. These cost more than $0·80 per cup equivalent.

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Simulations

To investigate how well lower income Americans can afford to satisfy dietary recommendations for fruits and vegetables at prevailing prices, we begin by creating baskets of foods that contain enough of these products to meet the needs of a representative household over 1 week. Creating baskets that include different shares of products from the first and second price intervals (< $0·40 and $0·40 to $0·80) will allow for variation in the cost of each basket at retail food stores. Baskets that include more products from the second price interval will cost more money for the same overall amount of food but also contain a greater variety of products. Households that can afford one of these more expensive baskets should be better able to cook meals and satisfy household members' preferences, all else constant. Even if a household cannot afford all products, those who can afford a wide variety should still be able to consume meals with different types of meats, grains and other foods. Substitutions are generally possible even when recipes call for specific types of vegetables. Moreover, since each basket will represent 1 week of purchases, being able to afford a greater percentage of all baskets at all cost levels would suggest that a household can enjoy more week-to-week variation in its food choices.

The representative household considered in this study is a four-person, moderately active household with one male (31–45 years old), one female (31–45 years old) and two children (one aged 6–8 years and another aged 9–11 years old). According to the *2015–2020 Dietary Guidelines for Americans*, this household needs 122·5 cup equivalents of fruits and vegetables per week[28]. Vegetable consumption is divided among dark green vegetables (7 cup equivalents), red/orange vegetables (22 cup equivalents), legumes (6·5 cup equivalents), starchy vegetables (21 cup equivalents) and other vegetables (17 cup equivalents). Whole fruit must account for at least half of all fruit consumed (49 cup equivalents).

Maximum SNAP benefits for this same four-person household are based on its cost to follow the TFP. In June 2016, the family needed $147·76 per week to follow the TFP. Fruits and vegetables accounted for about 40 % of these costs[17,29].

Baskets of fruits and vegetables with a sufficient quantity and variety of items for our household to satisfy Federal guidelines over 1 week were created at each of three different cost levels. To further allow for food loss due to spoilage and other factors that can lower consumption, we follow the TFP and add an additional 5 % more food on top of the minimum in each basket (129 cup equivalents in total). First, we created 1000 baskets by drawing a roughly equal mix of fruits and vegetables that cost less than $0·40 per cup equivalent and the other half cost between $0·40 and $0·80, on average. We consider these baskets to be 'moderately priced' since they contain no foods costing more than $0·80 per cup equivalent. Secondly, we created another 1000 'low-priced' baskets by drawing about 70 % of all items from the first price interval and the other 30 % from the second price interval. Thirdly, we created 1000 'very low-priced' baskets by drawing 90 % of all items from the first price interval in Figs 1 and 2, and the remainder from the second price interval. A total of 3000 were thus created.

The Gauss statistical software package version 19 and probability sampling were used to select the products included in each basket. Fruits and vegetables costing less than $0·80 per cup equivalent were sampled with replacement one-half of a cup equivalent at a time using sample weights to determine the share of those items costing less than $0·40 per cup equivalent. This process continued until we had drawn 258 half cup equivalents including the first 103 units of fruit, the first 15 units of dark green vegetables, the first 46 units of red/orange vegetables, the first 14 units of legumes, the first 44 units of starchy vegetables and the first 36 units of other vegetables selected. Juice never accounted for more than 50 % of all fruit in any basket. Simple random sampling could not be used. Among all products in Figs 1 and 2 costing less than $0·80 per cup equivalent, 23·8 % (24 out of 101) cost less than $0·40 per cup equivalent and 76·2 % (77 out of 101) cost between $0·40 and $0·80 per cup equivalent. When selecting products for our low-priced priced baskets, for example, we set our sample weights equal to 2·94 (= 0·7/0·238) for items in the first price interval and 0·39 (= 0·3/0·762) for items in the second price interval. This ensured that about 70 % of sampled products would cost less than $0·40 per cup equivalent.

Results

Analysis of NHANES 2015–16 data and the FPED 2015–2016 confirms that variety in fruit and vegetable consumption is not only important for the purpose of satisfying individuals' unique preferences and desires for variety but also to accommodate variation in the other types of foods households also eat (see online supplementary material, Additional file 1). On eating occasions when Americans ate fruit, 51·4 % also consumed some amount of a dairy product, 61·6 % consumed some amount of a grain product, and 28·1 % consumed some amount of a protein food. For vegetables, these shares are 59·5, 80·1 and 74·6 %. Thus, while both fruits and vegetables are generally consumed with other foods, vegetable consumption is particularly allied with meat and grains consumption, consistent with past research showing that vegetables often serve as needed ingredients and side dishes, and vegetable consumption is associated with preparing home-cooked meals[23].

Shown in Table 1 are the number of each basket type (moderate, low and very-low cost) that our four-person household could afford with 25, 30, 35 and 40 % of its food budget (SNAP benefits), along with measures of our baskets' costs and contents. Finally, we supplemented our simulation with examples to better illustrate what our

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Table 1 US households receiving maximum Supplemental Nutrition Assistance Program (SNAP) benefits can afford to meet fruit and vegetable recommendations at one of three different cost levels depending on share of budget allocated to those foods

Basket cost level	Total cup equivalents	Share costing less than $0·40 per cup equivalent (%)	Average retail value of basket	Average cost per cup equivalent	Average number of different foods in basket	Share affordable with 25 % of budget (%)	Share affordable with 30 % of budget (%)	Share affordable with 35 % of budget (%)	Share affordable with 40 % of budget (%)
Moderate	129	50	$57·29	$0·44	83	0	0	0	92·0
Low	129	70	$50·56	$0·39	72	0	0	83·5	100
Very low	129	90	$43·27	$0·34	49	0	87·4	100	100

Results of simulation using USDA's Fruit and Vegetable Prices data product. The author generated 1000 baskets at each of 3 cost levels (moderate, low and very low). Each basket contained enough food to satisfy Federal dietary recommendations for fruits and vegetables for a four-person household (one male and one female aged 31–45 years, 1 child aged 10 years and one child aged 8 years) over 1 week. Less costly baskets included a greater share of products available for less than $0.40 per cup equivalent. All other products cost between $0.40 and $0.80 per cup equivalent. The household's total food budget equals the value of its SNAP benefits ($147.76/week).

Table 2 Example of how a four-person family spending 25 % of the Thrifty Food Plan (TFP) budget on fruits and vegetables can satisfy Federal dietary recommendations for both food groups over 1 week

	Cup equivalents	Retail cost		Cup equivalents	Retail cost
Fruit			Starchy vegetables		
Bananas	13	$3·69	Potatoes	22	$4·33
Watermelon	13	$2·62			
Frozen concentrated orange juice	26	$8·57	Other vegetables		
			Cucumber, eaten with skin	9	$3·08
Dark green vegetables			Green beans, canned	9	$3·40
Romaine hearts	7	$2·31			
			Beans and Peas		
Red and orange vegetables			Lentils, dry	7	$1·55
Whole carrots, consumed raw	23	$5·51			
Total cost:	$35·06				
Average cost per cup equivalent	$0·27				

Family of four includes a male and a female aged 31–45 years, one child aged 10 years and one child aged 8 years. In June 2016, the household's weekly food budget and costs to follow the TFP are assumed to have been $147.76 of which about 25 % was earmarked for fruits and vegetables. Costs of products are from the US Department of Agriculture's Fruit and Vegetable Prices data product. Prices are 2016 average retail prices.

representative four-person household can buy with different shares of its food budget. The first of these hypothetical baskets included a mix of fruits and vegetables affordable with 25 % of the family's SNAP benefits. We then showed how that affordable bundle of foods might change with incremental increases in budget share. These baskets were not among the simulated 3000 baskets. However, this approach allowed us to better illustrate the incremental benefits that can come with allocating more money to fruits and vegetables or, conversely, the types of trade-offs a household might face at successively lower budget shares. Tables 2–5 illustrate what baskets affordable with 25, 30, 35 and 40 % budget shares might look like.

While variety in fruit and vegetable consumption is important, our simulations reveal that lower income households cannot likely meet recommendations for these two food groups with only a quarter of their food budgets. If our four-person household receiving maximum SNAP benefits allocated $36·94 to fruits and vegetables (25 % of its overall costs for following the June 2016 TFP), it could not afford any of the 3000 baskets generated for this study. The household could technically satisfy Federal guidelines by relying exclusively on the 8 cheapest fruit and 16 cheapest vegetables as shown in Table 2. However, it may not have enough variety to cook meals featuring the different types of meats and other foods the household would also like to eat. Whole carrots and Romaine lettuce would be the only affordable orange/red and dark green vegetables, respectively. Week-to-week variety in vegetable consumption would be driven largely by selecting among the eight types of dried legumes available for less than $0·40 per cup equivalent, while variety in fruit consumption would be similarly driven by selecting among the five types of frozen concentrated juice available also available in this price range.

Encouraging the household to increase its fruit and vegetable budget share to 30 % would create room for some genuine variety in consumption. With $44·33 (30 % of its costs for following the June 2016 TFP), our four-person household receiving maximum SNAP benefits can purchase 87·4 % of the 1000 very low-priced baskets created in this study. About 90 % of the items in those baskets came from the first price interval in Figs 1 and 2. The baskets contained 49 different products, on average, and had a mean retail value of $43·27.

The variety of fruits and vegetables our household can afford with 30 % of its budget is still very limited. Shown in Table 3 is an example of what it could buy. In order to

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Table 3 Example of how a four-person family spending 30 % of the Thrifty Food Plan (TFP) budget on fruits and vegetables can satisfy Federal dietary recommendations for both food groups over 1 week

	Cup equivalents	Retail cost		Cup equivalents	Retail cost
Fruit			Starchy vegetables		
Apples	**7**	**$3·05**	Sweet corn, canned	**3**	**$1·43**
Bananas	7	$1·99	Green peas, canned	**3**	**$1·61**
Watermelon	6	$1·21	Potatoes	16	$3·15
Cantaloupe	**6**	**$2·30**			
Frozen concentrated orange juice	26	$8·57	Other vegetables		
			Green cabbage	**6**	**$1·59**
Dark green vegetables			Cucumber, eaten with skin	6	$2·05
Romaine hearts	5	$1·65	Green beans, canned	6	$2·26
Broccoli, frozen	**2**	**$1·41**			
			Beans and Peas		
Red and orange vegetables			Lentils, dry	5	$1·11
Whole carrots, consumed raw	6	$1·44	Red kidney beans, canned	**2**	**$1·02**
Whole carrots, boiled	**5**	**$1·20**			
Sweet potato	**6**	**$3·44**			
Tomatoes, canned	**6**	**$2·96**			
Total cost:	$43·43				
Average cost per cup equivalent	$0·34				

Family of four includes a male and a female aged 31–45 years, one child aged 10 years and one child aged 8 years. In June 2016, the household's weekly food budget and costs to follow the TFP are assumed to have been $147.76 of which about 30 % was earmarked for fruits and vegetables. Highlighted items have been added to the basket above what was included in Table 2. Costs of products are from the US Department of Agriculture's Fruit and Vegetable Prices data product. Prices are 2016 average retail prices.

create this basket, we started with the basket in Table 2 and raised the overall level of variety by substituting more expensive products for less expensive ones (items added to the basket in Table 3 above what was included in Table 2 are printed in bold). Among other changes, we substituted some frozen broccoli for some Romaine lettuce. We also added some canned tomatoes and sweet potatoes in exchange for fewer whole carrots. Canned beans were further added in place of some dry lentils. However, the household continues to rely predominately on products costing less than $0·40 per cup equivalent. This may be problematic from the standpoint of taste satisfaction and meal preparation because many items, such as frozen green peas ($0·66 per cup equivalent), frozen broccoli ($0·71), red bell pepper ($0·75) and fresh kale ($0·79), are popular vegetables, commonly used in meal preparation, and lend variety to the diet.

Our representative household receiving maximum SNAP benefits must allocate at least 35 % of its food budget to fruits and vegetables in order to enjoy a somewhat wide variety of these foods. With $51·72 (about 35 % of the household's overall costs for following the June 2016 TFP), our family of four could purchase 83·5 % of the 1000 low-priced baskets generated in this study. About 70 % of all items in these baskets are drawn from the first price interval in Figs 1 and 2. Their average retail value was $50·56 and they contain 72 different products, on average. Table 4 shows what one of these baskets could look like. In order to create this basket, we started with the basket in Table 3 and further increased variety in fruit consumption by adding grapes and canned fruit cocktail. We also increased variety in vegetable consumption by adding some fresh onions and Roma tomatoes.

Finally, if our household allocates 40 % of its budget to fruits and vegetables as the TFP does, it can afford an equal share of items selling for less than $0·40 per cup equivalent (first price interval in Figs 1 and 2) and items selling from $0·40 to $0·80 per cup equivalent. Simulation results show that our 1000 moderately priced baskets had an average retail value of $57·29 and contained 83 different products, on average. Moreover, our four-person household receiving maximum SNAP benefits can purchase 92·0 % of these baskets with $59·10 (about 40 % of its overall costs for following the June 2016 TFP). To illustrate, we created the basket shown in Table 5. By choosing items from the first price interval, such as potatoes bought fresh and baked in their skins ($0·20 per cup equivalent), the household can also buy a number of higher cost items like frozen broccoli ($0·71), red bell peppers ($0·75) and fresh kale ($0·79) and stay within budget.

Discussion

Study results confirm that households receiving maximum SNAP benefits can meet Federal fruit and vegetable recommendations at prevailing prices if they allocate about 40 % of their food budget to these two food groups. This is consistent with previous studies[18,19] and the TFP[17]. However, when it comes to budgeting for fruits and vegetables, there is little room for flexibility. If households do not to prioritise these foods, then the variety they can afford while still satisfying recommendations drops off quickly.

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Table 4 Example of how a four-person family spending 35 % of the Thrifty Food Plan (TFP) budget on fruits and vegetables can satisfy Federal dietary recommendations for both food groups over 1 week

	Cup equivalents	Retail cost		Cup equivalents	Retail cost
Fruit			Starchy vegetables		
Apples	7	$3·05	Sweet corn, canned	4	$1·91
Bananas	7	$1·99	Green peas, canned	4	$2·14
Grapes	**6**	**$4·62**	Potatoes	14	$2·76
Fruit Cocktail, canned, packed in juice	**6**	**$4·57**			
Frozen concentrated orange juice	26	$8·57	Other vegetables		
			Green cabbage	6	$1·59
Dark green vegetables			Radish	**1**	**$0·45**
Romaine heads	5	$1·65	Cucumber, eaten with skin	5	$1·71
Broccoli, frozen	2	$1·41	Green beans, canned	5	$1·89
			Onions	**1**	**$0·41**
Red and orange vegetables					
Whole carrots, consumed raw	5	$1·20			
Whole carrots, boiled	5	$1·52	Beans and peas		
Sweet potato	4	$2·29	Lentils, dry	5	$1·11
Tomatoes, canned	5	$2·47	Red kidney beans, canned	2	$1·02
Roma tomatoes	**4**	**$2·13**			
Total cost	$50·44				
Average cost per cup equivalent	$0·39				

Family of four includes a male and a female aged 31–45 years, one child aged 10 years and one child aged 8 years. In June 2016, the household's weekly food budget and costs to follow the TFP are assumed to have been $147.76 of which about 35 % was earmarked for fruits and vegetables. Highlighted items have been added to the basket above what was included in Table 3. Costs of products are from the US Department of Agriculture's Fruit and Vegetable Prices data product. Prices are 2016 average retail prices.

Table 5 Example of how a four-person family spending 40 % of the Thrifty Food Plan budget on fruits and vegetables can satisfy Federal dietary recommendations for both food groups over 1 week

	Cup equivalents	Retail cost		Cup equivalents	Retail cost
Fruit			Starchy vegetables		
Apples	7	$3·05	Sweet corn, canned	4	$1·91
Oranges	**7**	**$4·61**	Green peas, frozen	4	$2·62
Grapes	6	$4·62	Potatoes	10	$1·97
Fruit Cocktail, canned, packed in juice	6	$4·57	Succotash, frozen	**4**	**$2·68**
Frozen concentrated orange juice	26	$8·57	Other vegetables		
Dark green vegetables			Green cabbage	3	$0·79
Romaine heads	2	$0·66	Radish	1	$0·45
Broccoli, frozen	2	$1·41	Cucumber, eaten with the skin	5	$1·71
Kale, fresh	**3**	**$2·36**	Green beans, canned	5	$1·89
			Onions	1	$0·41
Red and Orange Vegetables			Green bell pepper	**3**	**$1·45**
Whole carrots, consumed raw	5	$1·20			
Whole carrots, boiled	5	$1·52			
Red bell pepper	**4**	**$2·99**	Beans and Peas		
Sweet potato	2	$1·15	Lentils, dry	2	$0·44
Tomatoes, canned	3	$1·48	Red kidney beans, canned	5	$2·56
Roma tomatoes	4	$2·13			
Total cost	$59·18				
Average cost per cup equivalent	$0·46				

Family of four includes a male and a female aged 31–45 years, one child aged 10 years and one child aged 8 years. In June 2016, the household's weekly food budget is assumed to have been $147.76 of which about 40 % was earmarked for fruits and vegetables. Highlighted items have been added to the basket above what was included in Table 4. Costs of products are from the US Department of Agriculture's Fruit and Vegetable Prices data product. Prices are 2016 average retail prices.

While households can meet fruits and vegetables recommendations for less than 40 % of what maximum SNAP benefits would be for them, these households will have to rely heavily on less expensive types of fruits and vegetable. This may be problematic from the standpoint of meal preparation and taste satisfaction.

Demonstrating how households can meet their needs with less expensive options is one way that nutritionists can promote fruit and vegetable consumption. That some products may be too expensive for a household should not prevent it from consuming meals with a variety of meats and grains if the household has access to a wide variety of different products. Substitutions are generally possible even when recipes call for a specific type of vegetable.

The perception that fruits and vegetables are expensive is not based on prices alone. In a study of low-income

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households in Boston, MA, parents primarily worried about getting through each month until the next month's food assistance benefits became available[10]. Salient characteristics of food products identified by the research included how quickly family members would consume the food, how quickly it might spoil and how satiated family members might feel after consuming the food. Fruits and vegetables compared less favourably than grains, when judged by these product characteristics. This, in turn, added to perceptions that fruits and vegetables were costly.

Allocating more money to fruits and vegetables will also require households to spend less money elsewhere. Americans, on average, allocate a larger share of their food budgets to meats and other protein foods than the TFP does (31·6 % *v.* 21·9 %)[21,30]. The same is true for miscellaneous foods including fats, oils and sweets, such as salad dressings, gravies, sauces and soft drinks, among other things (17·2 % *v.* 6·9 %)[21,30]. On the one hand, it is possible that some households could free up additional money for fruits and vegetables by spending less money on both groups of foods. On the other hand, meats are particularly important to households, provide key nutrients, and pairing meats with vegetables is one way to improve vegetable consumption[23]. Nutritionists working with households to adjust their food budgets might therefore focus on encouraging them to curtail spending on miscellaneous foods rather than meats.

Food assistance programmes can lower a household's costs for acquiring fruits and vegetables which, in turn, can reduce their need to curtail spending on other foods. Double Up Food Bucks programmes, for one, lower a SNAP-participating household's costs for buying locally grown fruits and vegetables at participating farmers markets, Community Supported Agriculture locations and grocery stores. USDA also provides nutritious meals that include fruits and vegetables to children through its National School Lunch and School Breakfast Programs. Children from families with incomes at or below 130 % of the Federal poverty level are eligible for free meals. Those with incomes between 130 and 185 % of the Federal poverty level are eligible for reduced price meals.

Limitations and generalisability of findings

This study considers a four-person household with two adults and two children that receives maximum SNAP benefits, faces average retail prices and can prepare home-cooked meals rich in fruits and vegetables. Additional research is needed to understand how results would vary for other types of households. Below, we consider some factors that could exacerbate or alleviate the situation for a particular household.

Federal dietary recommendations vary across individuals based on their energy requirements which, in turn, depend on age, level of physical activity and gender. For example, according to the Healthy US-Style Eating Pattern, individuals at the 2000-calorie level need 2·5 cup equivalents of vegetables and 6 ounce equivalents of grains per day, whereas individuals at the 3000-calorie level need 4 cup equivalents of vegetables and 10 ounce equivalents of grains per day[28]. It follows that some modest variation exists in the relative amounts of fruits, vegetables, dairy products and other types of foods that households should consume, depending on their composition. This study focuses on a family with a mix of adults and children. In 2018, 40·9 % of all SNAP households included children, 25·9 % included an elderly individual and 20·7 % included a non-elderly person living with disabilities[31]. To check how results might vary, we re-ran our simulation for an elderly couple without children that again receives maximum SNAP benefits (see online supplementary material, Additional file 2). Results show that this couple can afford a wide variety of fruits and vegetables for a somewhat smaller share of its food budget than our four-person household with children can. The couple can buy baskets with a roughly equal mix of products from the first and second price intervals in Figs 1 and 2 for no more than 35 % of its food budget.

Households also spend different amounts of money on food in general. The household in our simulation receives maximum SNAP benefits which are just enough for it to follow the TFP. This is close to what the median SNAP-eligible household spends. In 2018, half of US households with an income-to-poverty ratio under 1·30, which is the income cut-off for SNAP eligibility, spent more than 104 % of their costs to follow the TFP[32]. These households can better afford to meet fruit and vegetable recommendations than the household in our simulation. The opposite is true for households spending less money on food than they would need to follow the TFP. These households would need to allocate an even higher share of their food budgets to fruits and vegetables to meet the guidelines. This includes some SNAP households receiving less than maximum benefits. In 2018, only 37 % of all SNAP participants received maximum benefits[31]. A household's SNAP benefits are reduced as its income increases because the household is expected to spend some of its own money on food. It also includes some SNAP-eligible households that do not participate in the programme. In 2018, 85 % of eligible Americans participated[33].

Variation in households' cooking skills and time constraints should also be considered. In this study, we focus on fruits and vegetables purchased outside of multi-ingredient dishes which is largely consistent with the TFP[17]. However, many households lack the time to prepare meals rich in fruits and vegetables as frequently as following the TFP can require[6]. This includes time for planning meals, developing shopping lists, searching for lower-priced foods, travelling to stores, cooking foods and, finally, cleaning up. They may also lack the necessary cooking skills[4,5]. Such households may rely more heavily than the TFP does on convenience foods, including

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restaurant foods, and face higher food costs to the extent that these foods are more expensive. It is unlikely that such households can satisfy Federal dietary guidance without spending more money on food than their costs to follow the TFP.

Fruit and vegetable cost estimates used in the study are also broad averages. They do not reflect what individual households pay for specific products at specific stores. Some product prices vary seasonally and annual averages may disproportionately reflect in-season prices in these cases. Retail food prices also vary across different types of stores with bulk supermarkets typically charging lower prices than traditional supermarkets and smaller food stores [34,35]. Researchers in Chico, California, for example, developed and priced menus for a representative family[34]. Menus were based on what people within the community would typically eat during a week and the amount of time they could commit to meal preparation. Prices were then collected at 13 stores around the city. Results show that lower income households can afford to eat healthily, but only if they have access to lower-priced, bulk supermarkets. Households that do not have access to bulk supermarkets may face higher prices and struggle to eat healthily.

Conclusions

Food prices, time constraints, cooking skills and other factors all affect how well a lower income household can afford to meet Federal dietary recommendations for fruits and vegetables. However, it also matters to what extent a household prioritises healthy eating by budgeting enough money for these food groups. Those that move fruits and vegetables to the centre of their budgets will fare better. In this study, we show that, if a representative household receiving maximum SNAP benefits allocates about 40 % of its total food spending to fruits and vegetables as the TFP does, then it can afford a sufficient quantity and wide variety of both types of foods. However, if the same household allocates a substantially smaller share of its food dollars to fruits and vegetables than the TFP does, possibly because it perceives these foods as being 'too expensive', then the variety it can afford drops off quickly. The household may be unable to meet Federal dietary recommendations, satisfy members' preferences and desires for variety and accommodate variation in other types of foods eaten.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020004929

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