Nutrition and Cost Comparisons of Select Canned, Frozen, and Fresh Fruits and Vegetables

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Abstract: *A common call to action for addressing public health concerns of both obesity and hunger is improving access to and consumption of fruits and vegetables. Previous research has examined the nutritional merits of fresh, frozen, and canned fruits and vegetables. However, there are limited data on the cost-effectiveness of fresh compared with processed—that is, canned and frozen—food. This study examined the nutrition delivered in 8 common vegetables and 10 common fruits across multiple packaging options (fresh, frozen, and canned) relative to average costs. A method of scoring based on nutrient intake recommendations was used to calculate the nutrients per calorie, and average costs were obtained from the US Department of Agriculture's Economic Research Service. Nutrient scores for the vegetables were similar across the 3 packaging options, whereas canned vegetables had a lower cost per edible cup compared with frozen and fresh. Nutrient scores were variable for the fruits across the 3 packaging options, and canned fruits were either lower or comparably priced per edible cup. The evidence from this study suggests that fruits and vegetables packaged as frozen or canned are cost-effective and nutritious options for meeting daily vegetable and fruit recommendations in the context of a healthy diet.*

Keywords: fruits; vegetables; nutrients; cost; canned; fresh; frozen

> . . .purchase of packaged fruits and vegetables for delayed consumption is a viable option for low-income households trying to consume adequate amounts of fruits and vegetables.

Introduction

Over the past decade, the United States has struggled with the paradox of an overweight and undernourished population, of which a growing number have limited access and financial means to purchase healthful foods. Whereas approximately 68% of Americans are overweight or obese, more than 14% received aid from a Supplemental Nutrition Assistance Program in 2011,[1] and more than 23 million people live in areas known as "food deserts," with little or no accessibility to healthy and affordable food.[2] Added to this bleak nutrition environment is a turbulent economy that has driven up food prices and rates of unemployment.

Helping Americans incorporate more nutrient-dense foods into their diets is just one strategy for addressing the current obesity crisis. Health and nutrition advocates, public policy leaders, and the food industry have made commitments to reduce rates of overweight and obesity, which are posing a significant threat to public health. From the US Department of Agriculture's (USDA's) MyPlate to the

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food industry's Healthy Weight Commitment Foundation, the prescription is the same: reduce calories and increase consumption of nutritious foods, including fruits and vegetables. At the same time, there is increasing pressure for consumers to select fresh fruits and vegetables. The White House vegetable garden and the growing number of farmer's markets in communities across the country are examples of the pervasive push for fresh fruits and vegetables as the "healthier" option.

Addressing the nation's hunger crisis is also a major public health concern. Because of current rates of obesity, an overwhelming majority of Americans are at risk for diet-related ailments, but those at greatest risk are the poor, who have documented barriers to healthful food options.[3] This population tends to have lower mobility, with limited access to grocery stores relative to fast food restaurants and convenience stores.[4] When fresh fruits and vegetables are purchased, they must last until the next visit, which may limit daily consumption. In contrast, purchase of packaged fruits and vegetables for delayed consumption is a viable option for low-income households trying to consume adequate amounts of fruits and vegetables.

Whereas school food programs are under increasing pressure to provide healthful food options, such programs are under increasing fiscal pressures to reduce program costs. At the same time, the role of school food programs across many districts has expanded beyond the traditional role of providing lunch for students to meeting wider health and nutrition policy objectives, especially for low-income children and families, and increasingly, they have "buy-local" mandates. As such, school lunch programs are burdened in providing multifaceted services with minimal resources, where proper budgeting is a key component of meeting nutritional objectives.

Nutrition and health programs and campaigns aiming to increase consumption of fruits and vegetables must address seasonality, quality, and cost in their objectives. Canned fruits and vegetables are often identified as nutritious options available year-round at a competitive cost to fresh and frozen ones.[5] However, the literature seldom addresses the cost-effectiveness of fresh versus processed fruits and vegetables (into canned or frozen packaging). Some research has studied the nutrient content of food groups relative to cost, but there are limited data available specific to canned fruits and vegetables compared with fresh or frozen.[6] A recent study that compared the nutritional content relative to the economic and time cost for preparing and serving edible portions of fruits and vegetables in various forms concluded that canned foods had the lowest total cost per edible portion and a lower or comparable cost-per-nutrient compared with fresh and frozen.[7] The purpose of this study was to examine how canned fruits and vegetables uniquely address the issues of obesity, nutrient quality, and hunger using a method of scoring canned, frozen, and fresh fruits and vegetables based on an overall ratio of nutrient content to recommended daily amounts, relative to calories provided and cost per edible cup.

Fruits and Vegetables in Dietary Guidance

Increasing fruit and vegetable intake is a key behavior recommended by the 2010 *Dietary Guidelines for Americans* (DGA) to improve the nutrient density of eating patterns while controlling calories.[8] When prepared without added fats or sugars, most fruits and vegetables are relatively low in calories and can be important sources of several nutrients that are underconsumed in the United States, including folate, magnesium, iron, potassium, fiber, and vitamins A, C, and K.[8,9] Among these, fiber and potassium are identified as nutrients of public health concern for the general public, whereas folate and iron are considered additional nutrients of concern for women of childbearing age.[8] The 2010 DGA point out that consumption of at least 2½ cups of fruits and vegetables per day is associated with reduced risk of cardiovascular disease, including heart attack and stroke, and certain types of cancer.[8] The typical American diet falls short of meeting DGA recommendations of 2½ cups of vegetables and 2 cups of fruit per day for a 2000-calorie diet, with usual intakes at about 59% and 42%, respectively, of daily intake recommendations.[10,11] Increased access to fruits and vegetables may contribute to reaching such DGA goals.

The 2010 DGA recognize canned and frozen fruits and vegetables, in addition to fresh, as options for increasing consumption, with emphasis on reduced sodium or no-salt-added canned vegetables and fruits canned in 100% juice.[8] However, there is a perception by some consumers that food packaged in cans is less nutritious than fresh or frozen food.[12] A recent survey also revealed that some consumers might be unaware that canned foods count toward the USDA's food group goals depicted by MyPlate.[12] The body of evidence suggests that although the canning process may compromise the nutritive value of fruits and vegetables, a similar effect is observed with increasing length of storage of fresh and even frozen produce.[13-15] Fruits and vegetables undergo various transformations in preparation for consumption, and extensive research has pursued the impact of food processing on food quality in relation to sensory quality. Although largely seen as decreasing food nutritional and aesthetic quality, recent research suggests that through preservation, thermal processing of fruits and vegetables can contribute positively to nutritional and sensory quality.[16]

Canned and frozen varieties of fruits and vegetables provide a convenient and cost-effective alternative to fresh in improving intakes of these typically underconsumed foods. Canned and frozen fruits and vegetables have a shelf life that is longer than that of their fresh counterparts and are ready to eat and easy to use in meal preparation. These features make canned and frozen fruits and vegetables valuable options for busy and cost-conscious consumers. Additionally, big-box grocery stores,

wholesale clubs, and supercenters are increasing the geographic isolation of many shoppers and decreasing the number of trips to buy food goods.[17] As a result, food consumption is increasingly directed at prepackaged and low-priced bulk food items with longer shelf lives.

Summary of Nutrition Comparison Research

A great deal of research has reported the effects of processing, storage, and cooking on the nutritional quality of fruits and vegetables. Most recently, a 2-part review of the literature examined the effects of freezing and canning on specific vitamins, minerals, phenolic compounds, and fiber.[14,15] Evidence from this review suggests that freezing and canning may preserve overall nutrient value. However, variations in experimental processing techniques, changes in moisture content during measurement, and differences in methods of reporting have produced varying results.

Heat treatment during processing of canned and frozen fruits and vegetables has been shown to cause initial loss of water-soluble vitamin C and the B vitamins, but nutrients remain stable over time in can-sealed containers.[14] Whereas frozen products initially lose fewer nutrients than canned products, they lose more nutrients over time as a result of oxidation.[14] The amount of vitamin C in fresh vegetables begins to decline immediately after harvest and continues to decline during storage. In addition, the amount of vitamin C lost during heating or cooking is higher for fresh produce compared with canned.[14] Other studies have confirmed that canned and frozen foods have lower levels of vitamin C because of blanching, but the amount of vitamin C loss also depends on the length of blanching time, crop varieties, and grower processes that directly influence vitamin C content.[13,18] Much of the vitamin C lost during the canning process may be found in the canning liquid, and the level of vitamin C remains stable during the 1- to 2-year shelf life of the product.[19] The relative amounts of water-soluble vitamin losses in canned, frozen, and fresh fruits and vegetables can also be influenced by the temperature of storage. Little vitamin C was lost in canned fruit and vegetable juices when the juice was stored at temperatures of 41°F (5°C) or less; more was lost if the storage temperature was higher.[20]

Canned fruits and vegetables tend to have slightly lower levels of B vitamins than fresh cooked, except for folate, which tends to remain stable.[19] Tomatoes often have higher levels of B vitamins but not folate. Fruits and vegetables that are packed in brine or syrup tend to lose phenolic compounds and those that are vacuum packed or canned without liquids or with skin tend to retain their levels of phenolic compounds.[14]

Amounts of vitamin A and carotenoids, vitamin E, minerals, and fiber are generally similar in fresh and processed forms.[15,19] Very little of fat-soluble vitamins A and E and carotenoids are lost in blanching, but some nutrient loss can occur during canning depending on the commodity.[15] For example, cooked fresh green beans contained higher levels of β-carotene than cooked frozen and cooked canned green beans, whereas cooked frozen green peas contained higher amounts than cooked fresh and cooked canned. Canned tomato products generally have higher levels of β-carotene and lycopene than fresh tomatoes. In a study of provitamin A carotenoids in fresh and processed fruits and vegetables, canning was found to increase the amount of measured provitamin A carotenoids by 16% to 50% across several fruits and vegetables.[21] The apparent increases may be a result of changes in moisture content during processing, the result of increased extraction efficiency during heat processing, or the inactivation of enzymes capable of degrading carotenoids.[15,21]

In research that studied the antioxidant activity of fresh, frozen, and canned vegetables, fresh vegetables showed declines in antioxidant activity over time, whereas it tended to remain stable in canned products[22,23] or increase with longer thermal processing time.[24] A recent study of the antioxidant activity of canned relative to fresh vegetables found limited declines in many vegetables, whereas in canned garlic, corn, peas, and leek, the decline in antioxidant activity can be more substantial, with declines of 18% to 35%.[25]

Mineral values tend to be dependent on commercial processing techniques and the mineral content of water used by the processing facility. For example, mineral content in canned items may reflect increases resulting from the uptake from hard water or the addition of brines.[15] Researchers further note that processing does not effectively reduce the fiber content of edible portions[15,26] but may increase fiber availability by making the fiber more soluble.[19] Canning has also been shown to destroy illness-causing microorganisms and may improve digestibility, suggesting that properly processed and prepared canned fruits and vegetables can be as healthful, if not more healthful, than their fresh counterparts.[13]

Methods

This section describes the methods used to evaluate the cost-effectiveness of competing packaging options for fruits and vegetables. Methods used in this research to report metrics of nutrient content are consistent with approaches widely seen in nutrition research[27,28] but reflect broader nutritional perspectives with less emphasis on water-soluble vitamins that typically degrade with thermal processing. This analysis largely used existing USDA data.

Sample

Nutrient and cost data were collected for 8 commonly consumed vegetables and 10 fruits across packaging options, including unprocessed foods in fresh form and processed foods in frozen and canned forms. Vegetables included in the analyses were white corn, yellow corn, carrots, spinach, turnip greens, green beans, peas, and asparagus. Fruits included were tomatoes, peaches,

strawberries, blueberries, blackberries, raspberries, cherries, apricots, pineapples, and pears. Frozen data for tomatoes, pears, pineapples, and apricots were not collected because these fruits are typically not offered in this form; thus, nutrient and cost data were not available. Commodities selected reflect those with high availability in all 3 packaging forms, including fresh, frozen, and canned.

Measure of Cost Across Packaging Options

The USDA Economic Research Service (ERS) provides periodic consumer price references for fruits and vegetables across multiple packaging options. The most recent estimate of 153 commonly consumed fresh and processed fruits and vegetables was published in February 2011 using 2008 Nielsen Homescan price data, which provide purchase data from a panel of 61 440 households, with sample weights for extrapolating across the entire US population of households.[29] The Homescan panel uses scanners to record purchase quantity, price, weight, date, and type of retail facility using the Universal Product Code (UPC label) in identifying purchased items. The accuracy of the Nielsen Homescan data was found to be consistent with most survey data used in research.[30]

ERS data include each product's average retail price per pound and per edible-cup equivalent (the unit of measurement for federal fruit and vegetable consumption recommendations). Researchers adjust the Homescan price data to reflect the price per edible portion to allow for an accurate comparison of relative costs of consumption. This includes adjusting for the removal of inedible parts, such as seeds, pits, and stems, and for cooking losses. In their price comparison, the ERS reduced purchase weight of fresh produce by USDA factors published in the report, *Food Yields Summarized by Different Stages of Preparation*,[31] making all prices equally comparable. Price per edible cup was used in this study to compare costs for the fresh, frozen (as available), and canned fruits and vegetables included in the analysis.

Measure of Nutritional Content Across Packaging Options

The USDA's Food and Nutrient Database for Standard Reference, Release 24 (SR24)[32] was used to collect nutrient data for fruits and vegetables across packaging options. The SR24 is a searchable online database of food composition for more than 7500 food items and provides nutrient data for up to 143 components, including vitamins, minerals, amino and fatty acids, and other components. Because the nutrient content of fresh fruits and vegetables degrades over time, fresh produce analyzed for inclusion in the database was stored for at least 2 days before analysis.[33] Nutrient amounts are reported on a per-portion basis, where portions are measured in cups, gram weight, or serving size (whole items). For the purposes of this analysis, portions were measured as 1 cup or as 100-g weight depending on the coarseness of the food item. This allows for coarse fruits and vegetables, such as sliced carrots, to be weighed because amounts may not be consistently measured using a cup measure. Data were recorded for 29 vitamins and minerals and for calories per portion.

Analysis

There is currently no standardized measure of the nutrient density of foods.[23,34] When comparing nutritional value across food processing options, researchers often focus on water-soluble nutrients, such as vitamin C and B complexes, because these are most susceptible to degradation under heat.[35] Doing so risks not recognizing the nutritional contribution of some processing methods to the nutritional content of processed foods.[36] Drewnowski[27,28] has an extensive discussion of indices for measuring and comparing nutritional density; however, such indices are generally limited in the number of nutrients tracked. The current analysis expands the number of nutrients used in estimating the nutritional content across various fruits and vegetables under different packaging options. A normalized measure, or nutrient score, was adopted comparing the content of 29 vitamins and minerals for each fruit or vegetable packaging option with the average adult dietary reference intake (DRI), or total recommended daily intake, for each corresponding vitamin or mineral.[37] To control for differences in energy content across packaging options, calorie data from SR24 were used in the calculation. The nutrient index, or score, was calculated using the following equation:

$$\mathrm{INDEX}_i = \left(\sum_{n}^{29} \mathrm{SR24}_{i,n} / \mathrm{DRI}_{i,n} \right) / \mathrm{Cal}_i,$$

where i is the food package, which can be fresh, frozen or canned; SR24 is the nutrient content, DRI is the recommended daily amount of vitamin or mineral n in packaging i, and Cal is the calories per unit. The nutrient score was calculated for each fruit or vegetable in each packaging option as follows: (1) nutrient content reported by SR24 was divided by the recommended dietary allowance or adequate intake level for each of the 29 vitamins and minerals, resulting in a ratio of nutrient content to daily nutrient requirement for each vitamin and mineral; (2) the ratios for the 29 vitamins and minerals were added; and (3) the sum was then divided by the energy content of the corresponding portion. Higher scores reflect greater nutrient density or nutrient content per calorie. The resulting standardized values, combining nonequal nutrient amounts, are comparable across fresh, frozen, and canned foods of the same commodity.

Results

Table 1 shows the combined nutrient scores and prices per edible portions of the 8 vegetables studied. The findings show that nutrient scores for the 8 common vegetables are remarkably similar across the 3 packaging options: fresh with no or minimal processing, and canned and frozen processed packaging. There are some exceptions. For 2 leafy

Table 1.

Nutrient Scores and Prices for Vegetables.

	Indices of Nutrient Content Per Calorie Consumed[a]			Price Per Edible Cup[b]		
	Canned	Frozen	Fresh	Canned	Frozen	Fresh
White corn	0.013	0.011	0.014	$0.69	$1.40	$1.17
Yellow corn	0.013	0.012	0.014	$0.69	$1.40	$1.17
Carrots, whole	0.061	0.048	0.049	$0.69	$1.19	$0.77
Spinach	0.298	0.221	0.334	$0.84	$1.51	$3.92
Turnip greens	0.096	0.079	0.177	$0.81	$1.48	$2.11
Green beans	0.049	0.035	0.039	$0.67	$1.22	$3.23
Peas	0.023	0.027	0.030	$0.74	$1.34	$1.83
Asparagus	0.083	0.075	0.084	$2.09	$3.61	$1.83

[a]Sources: Author's calculation using US Department of Agriculture's (USDA's) Food and Nutrient Database for Standard Reference, Release 24, and National Academies Institute of Medicine, Food and Nutrition Board, Recommended Dietary Allowances and Adequate Intakes for Vitamins and Elements.
[b]Sources: Stewart et al.[30] Other source includes Reed J, Frazao E, Itskowitz R. *How Much Do Americans Pay for Fruits and Vegetables?* Washington, DC: US Department of Agriculture, Economic Research Service; 2004. *Economic Information Bulletin*; vol 790.

green vegetable items, spinach and turnip greens, fresh provides a more nutritious option relative to frozen and canned. For green beans and carrots, canned packaging offers a preferred nutritional option. For the remaining 4 vegetables, either option provides comparable nutrient amounts.

Whereas nutrient scores across packaging options suggests that no packaging option has a clear nutrient advantage, systematic differences are found when comparing prices. For 7 of the 8 vegetables in this study, the consumer prices per edible cup of canned vegetables are lower than the prices of frozen or fresh-packaged counterparts. More so, consumer costs for canned vegetables can be as low as 50% of the costs of frozen alternatives and as low as 20% of the cost of fresh alternatives based on the cost per edible portion. Frozen packaging affords cost savings over fresh vegetables for 4 of the 8 vegetables represented here but command higher prices than canned vegetables for all 8.

Both canned and frozen packaging provides for deferred consumption, but canned vegetables afford comparable nutritional content with lower consumer costs, longer shelf life, and lower energy costs for consumer storage. With few exceptions, nutritional content is comparable across all packaging options. Canned vegetables afford households greater access through lower costs. For example, household food budgets can be stretched by nearly 50% with canned sweet corn over fresh and nearly 500% with canned green beans over fresh. Similar savings are found by comparing canned vegetables to frozen. In several cases, the savings are accompanied by increased nutrient content of canned packaging.

Nutrient scores and prices of 10 common fruits across packaging options are compared in Table 2. Because many fruit varieties do not have frozen packaging options or those options are uncommon, the report omits frozen nutrient scores and prices where reliable measures are not available. As shown in Table 2, the nutrient scores for fruits are comparable across packaging options for several of the fruits. However, the nutrient scores for fresh strawberries and raspberries significantly exceed that of the canned counterpart. In fact, for all fruits compared besides peaches, fresh provides the greatest nutrient score. For those fruits than can be frozen, frozen packaging also tends to provide greater nutrient scores relative to canned.

Compared with vegetables, nutrient scores for fruits tend to exhibit larger variation across packaging options. Much of this variation may reflect variation in caloric density across packaging options. Because scores are based on nutrient content per calorie, packaging options that are higher in calories may lower the nutrient scores. Several canned fruit options are packaged with added sugars (as syrup) to preserve the texture and flavor of delicate fruits, including strawberries, blackberries, blueberries, cherries, raspberries, and apricots. This is illustrated in the example of strawberries. A 100-g portion of canned strawberries delivers 92 kilocalories relative to 25 for frozen and 32 for fresh.

Table 2.

Nutrient Scores and Prices for Fruits.

	Index of Nutrient Content Per Calorie Consumed[a]			Price Per Edible Cup Equivalence[b]		
	Canned	Frozen	Fresh	Canned	Frozen	Fresh
Tomatoes	0.037	NA	0.043	$0.41	NA	$1.28
Peaches	0.014	0.016	0.013	$0.58	NA	$0.66
Strawberries	0.009	0.030	0.041	$0.66	$1.14	$0.89
Blueberries	0.005	0.011	0.014	$1.60	$1.35	$1.31
Cherries	0.247	0.520	0.703	$1.50	NA	$1.22
Raspberries	0.007	0.010	0.025	$0.69	$0.54	$0.64
Blackberries	0.010	0.023	0.031	$1.51	$1.13	$1.71
Pineapples	0.017	NA	0.031	$0.49	NA	$0.70
Apricots	0.005	NA	0.016	$0.37	NA	$0.25
Pears	0.016	NA	0.035	$0.58	NA	$0.42

[a]Sources: Author's calculation using US Department of Agriculture's (USDA's) Food and Nutrient Database for Standard Reference, Release 24, and National Academies Institute of Medicine, Food and Nutrition Board, Recommended Dietary Allowances and Adequate Intakes for Vitamins and Elements.
[b]Sources: Stewart et al.[30] Italicized values are from Reed J, Frazao E, Itskowitz R. *How Much Do Americans Pay for Fruits and Vegetables?* Washington, DC: US Department of Agriculture, Economic Research Service; 2004. *Economic Information Bulletin*; vol 790.

In the absence of the calories from packaging liquids, the nutrient scores of canned strawberries would be comparable with fresh and frozen varieties.

Prices are comparable across the 3 packaging options for most fruits. However, only 4 of the 10 common fruits have comparable frozen price data. Canned tomatoes, apart from providing greater nutrient intake, are also substantially less expensive than fresh. Additionally, canned blackberries and pineapples are significantly less expensive compared with fresh, whereas canned peaches and strawberries are marginally less expensive. Whereas many of the remaining canned fruit items are comparably priced relative to fresh, canned blueberries and cherries tended to be substantially more expensive. In sum, price comparisons across packaging options indicate no clear delineation for fruit packaging options.

Discussion

This study set out to estimate the consumer cost relative to nutrients per calorie for fruits and vegetables across fresh, frozen, and canned packaging options. The issue of food costs and healthy food choices is relevant to current food policy discussions in the United States, where affordability and availability of healthful food options have become key issues in the dialogue around both obesity and hunger.[38-40] Whereas some researchers and public health campaigns emphasize the importance of access to fresh produce, much of the literature suggests that low-income households have limited access to quality grocery stores with fresh options and that shelf life is an important factor in food selection. Canned and frozen packaging extends the effective life of fruits and vegetables, and this study shows that in the case of vegetables, they are also price competitive with regard to nutrient content and allow financially constrained consumers greater access to the nutrients provided by fruits and vegetables.

For the 8 common vegetables, no systematic reduction in the nutrient scores was found for fresh vegetables in regard to process. However, from a cost perspective, canned vegetables tend toward the most economical package options for nutrients per calorie of the vegetables reviewed in this study. Based on the ERS cost data, canned vegetables may provide households cost savings of up to 20% relative to fresh and afford longer shelf life. Frozen packaging also tends to be price competitive, but in some cases, affords lower shelf life and may compete for limited freezer space. The analysis shows that cost savings for canned and frozen vegetables are not at the expense of nutrient content.

Compared with vegetables, processed fruits show greater variation in nutrients per calorie between processed and fresh options. Much of this variation can be

attributed to methods and additives introduced in processing. Some of the canned fruit data included in the USDA database are only available as packaged in syrup rather than water or juice, and some fresh fruit items are not amenable to freezing. Although fresh fruits may have greater nutrient scores than canned and frozen for most of the fruits studied, households may find it challenging to acquire fresh fruit year-round because of limited off-season availability and higher off-season costs. Some people, especially those living in low-income communities, also may have limited access to fresh produce throughout the year, regardless of seasonality.[41] Frozen and canned packaging options help remedy the seasonal availability of fruits, though frozen fruits are limited to certain fruit items amenable to freezing. Households tend to have greater utilization of canned fruits relative to frozen for year-round consumption, and in some cases, canned is the only option for off-season consumption of fruits. Generally, this study found that processed fruits tend to be price competitive with fresh fruits. Of the 10 fruit items reviewed in this study, canned packaging provided the lowest cost for 4 items; frozen packaging provided the lowest cost for 2 and fresh for the remaining 4.

A potential concern with canned vegetables relative to current dietary guidelines on sodium is the addition of salt in the canning process. The canned vegetables included in this study contained salt as a standard ingredient. Canned fruits and vegetables tend to have higher levels of sodium relative to fresh and frozen as a by-product of processing because salt helps preserve flavor and texture in canned vegetables. The literature notes a high correlation between sodium intake and hypertension, but consumer directives on sodium intake are mostly directed toward at-risk individuals, and food marketing is increasingly targeting consumers concerned about their sodium uptake, including low-sodium or "no-salt-added" processing of canned vegetables.

The push for greater consumption of fresh fruits and vegetables is pervasive. From a consumer perspective, fresh is associated with better aesthetic and sensory quality and often considered the healthier option. It is also associated with higher costs. Foods processed for canning and freezing have the benefit of availability year-round and lower costs, but processed foods are also associated with lower quality. Recent research, however, suggests that thermal processed foods have comparable nutritional values and, in some cases, can contribute to the nutritional and sensory appeal of fruits and vegetables.[16,35]

This study adds to the body of knowledge on the impact of processing on the nutritional value of fruits and vegetables. However, several factors impede precise measurements and evaluations of the effect on nutrient value of processing fruits and vegetables, including the type of fruit and vegetables, differences in nutrient analysis methodologies and practices, and the effects of food storage and preparation. For example, fresh produce loses its nutrient value faster than processed, and cooking and other handling practices may also alter nutrient content. Limitations in comparing per-portion cost of fruits and vegetables across packaging options include variability in costs as a result of seasonality, region, brand, store, and type of retail outlet.

Conclusions

A common call to action for addressing the public health concerns of both obesity and hunger is improving access to and consumption of fruits and vegetables. Many low-income households have limited access to quality and nutritious foods. For some, fresh is perceived as too expensive or too difficult to prepare. For others, geography limits stable access to fresh produce, requiring deferred consumption and at-home storage between shopping opportunities. Previous research examined the nutritional merits of fresh, frozen, and canned fruits and vegetables, but the issue of cost-effectiveness of fresh compared with processed foods remains unresolved. Although studies have attempted to compare cost-effectiveness based on nutritional uptake, these studies rely on ad hoc methods of measuring nutritional content or focus on key nutritional values. This study expands on existing studies with consideration of more comprehensive measures of recommended daily intakes or DRI recommendations.

We compared 8 common vegetables and 10 common fruits across multiple packaging options, including fresh, frozen, and canned in terms of average costs. Nutrient scores for the vegetables were similar across the 3 packaging options, whereas canned vegetables largely had lower costs per edible cup compared with frozen and fresh. Nutrient scores were somewhat variable for the fruits studied across the 3 packaging options. These findings have important implications for households seeking to maximize their purchasing dollar while maintaining healthy diets and have important policy implications for government-sponsored food services, including school lunch programs, government and NGO-based supplemental nutrition programs, as well as USDA-sponsored nutrition education programs such as SNAP-Ed and the Expanded Food and Nutrition Education Program (EFNEP).

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