

Squeezing Fact from Fiction about 100% Fruit Juice^{1–3}

Roger Clemens,⁴ Adam Drewnowski,⁵ Mario G Ferruzzi,⁶ Cheryl D Toner,⁷ and Diane Welland^{8*}

⁴Horn, La Mirada, CA; University of Southern California School of Pharmacy, Los Angeles, CA; and California State University, Northridge, CA;

⁵Center for Public Health Nutrition, University of Washington, Seattle, WA; ⁶Department of Food Science and Department of Nutrition Science, Purdue University, West Lafayette, IN; ⁷CDT Consulting, LLC, Herndon, VA; and ⁸Juice Products Association, Washington, DC

ABSTRACT

Total fruit intake in the United States is ~1 cup equivalent per day, or one-half of the 2010 Dietary Guidelines for Americans recommendation for adults. Two-thirds of the fruit consumed is whole fruit and one-third is 100% juice. The nutritional value of whole fruit, with the exception of fiber and vitamin C, may be retained with appropriate juice production methods and storage conditions. One-hundred percent fruit juice consumption is associated with a number of health benefits, such as improved cardiovascular health and decreased obesity, although some of these and other potential benefits are controversial. Comprehensive analyses of the evidence by the Academy of Nutrition and Dietetics in 2014, the US Dietary Guidelines Advisory Committee in 2010, and the Australian Dietary Guidelines of 2013 concluded that 100% fruit juice is not related to adiposity in children when consumed in appropriate amounts for age and energy needs. However, some reports suggest the consumption of fruit juice contributes to unhealthful outcomes, particularly among children. A dietary modeling study on the best ways to meet the fruit intake shortfall showed that a combination of whole fruit and 100% juice improved dietary density of potassium and vitamin C without significantly increasing total calories. Notably, 100% juice intake was capped at amounts consistent with the 2001 American Pediatric Association guidance. The preponderance of evidence supports the position that 100% fruit juice delivers essential nutrients and phytonutrients, provides year-round access to a variety of fruits, and is a cost-effective way to help people meet fruit recommendations. *Adv Nutr* 2015;6:236S–243S.

Keywords: dietary guidelines, phytochemicals, fruit, nutrition, juice, 100% juice

Introduction

The 2010 Dietary Guidelines for Americans recommend that Americans consume more fruits and vegetables (1). MyPlate translates the message as, “Make half your plate fruits and vegetables,” and specifies 1–2 cups (the units of measure are based on the US Dietary Guidelines, which do not include metric) of fruit per day depending on age, gender, and physical activity level (2). Although in the past fruits and vegetables were often counted together, both for education and in dietary intake surveys, researchers have recently called for separation of these food groups, as well as their subgroups, such as 100% fruit juice vs. whole fruit (3, 4). In keeping with this approach, a recent analysis of the

2003–2010 NHANES revealed that usual daily mean fruit consumption by Americans ≥ 4 y old is ~1 cup equivalent, one-third of which is 100% fruit juice (5). A majority (79.6%) of Americans ≥ 2 y old do not meet fruit recommendations (6). Among 19- to 30-y-old women, 92.7% do

³ Author disclosures: R Clemens has served as a consultant to numerous food, beverage, and ingredient companies; some international humanitarian organizations; and several law and public relations firms. He serves as a pro bono speaker for American Society for Nutrition, Institute of Food Technologists, University of Southern California, and numerous media outlets. A Drewnowski has received research grants from Danone (France), Beneo (Belgium), Ajinomoto, and McDonald's (United States) and has also received grants, honoraria, and consulting fees from numerous food, beverage, and ingredient companies and other commercial and nonprofit entities with interest in nutrient density of foods. Analyses of federal databases described in this review were supported by the Juice Products Association. MG Ferruzzi has served as an advisor to Alliance for Potato Research and Education Scientific Advisory Council, General Mills, Sensient Technologies, and Welch's Nutrition Advisory Panel. MGF is supported by research funding from Conserve Italia, General Mills, McCain Foods, Ltd., Mead Johnson Nutrition, and PepsiCo. CD Toner is a consultant to numerous food, beverage, and health organizations, including Juice Products Association, Cranberry Institute, Calorie Control Council, California Walnut Commission, International Food Information Council Foundation, Mushroom Council, Sports, Cardiovascular and Wellness Nutrition Practice Group of the Academy of Nutrition and Dietetics, and Tate & Lyle. D Welland is the Nutrition Communications Manager for the Kellen Company, which provides management services to the Juice Products Association.

*To whom correspondence should be addressed. E-mail: dwelland@kellencompany.com.

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not meet fruit recommendations (6, 7), and 60% of 1- to 18-year-old children are falling short (8). Although 1 cup of 100% fruit juice is equivalent to 1 cup of whole fruit according to MyPlate communications (2), controversy and confusion abound for this nutrient-packed beverage. This paper reports the proceedings of a satellite session sponsored by the Juice Products Association on 29 April 2014 at the Experimental Biology meeting in San Diego, CA, which explored both the controversy surrounding 100% fruit juice and the evidence for its relation to health.

100% Juice beyond Sugar and Calories

Fruit juice comes from whole fruit, a complex group of foods with respect to both sensory and nutritional qualities. According to the US Code of Federal Regulations, “juices directly expressed from a fruit or vegetable (i.e., not concentrated and reconstituted) shall be considered to be 100% juice and shall be declared as ‘100% juice.’” However, when reconstituted from juice concentrate, the US FDA defines 100% juice according to Brix concentrations representative of those originally expressed from the fruit (Figure 1) (9). Many factors affect overall 100% juice quality including physical properties such as Brix concentration (Table 1), acidity, Brix:acid ratio, color, and flavor (10). Maturity and ripeness of the fruit used to make juice drives accumulation of innate sugars, aroma compounds, and, therefore, flavor, as well as changes in acidity, color, and texture (11). Nutritional and functional attributes of juice include typical macronutrients, many micronutrients, and an array of phytonutrients such as flavonoid glycosides found in orange juice and related compounds innate to pomegranate juice (12, 13).

Nutritional content may vary within fruits, as it does among different forms of a fruit. Nutritional differences in the forms of a food are related at least in part to cultivar variations and in the weights of each of those food forms. Nevertheless, with the exception of fiber and vitamin C, 1 small fruit or 0.5 cup of whole fruit is similar in vitamin and mineral content to 0.5 cup of 100% fruit juice (Table 2) (14). The nutrient profiles of several forms of orange juice are compared relative to energy content (Table 3). This comparison indicates whole fruit and juice are similar except for some nutrients, such as dietary fiber, calcium, and vitamin C.

Phytonutrients, or phytochemicals, are plant metabolites broadly distributed in fruit and fruit juice. As defined by the National Cancer Institute, these components of plants are thought to promote human health but unlike traditional nutrients are not considered essential for life (15). Carotenoids, particularly xanthophylls such as lutein, and carotenes such as β -carotene

and lycopene, are commonly found in a wide variety of fruit juices. Polyphenols are also found in many fruit juices, including phenolic acids, stilbenes, ellagic acid, and, particularly, the flavonoids. The flavonoids found most commonly in fruits and fruit juice include anthocyanins, flavan-3-ols, flavonols, flavones, and flavanones (16). Although juice contains these and related polyphenols, their metabolic consequences, biologic properties, and clinical significance remain under study (17).

Maximizing Nutrient Retention in Juice Production

Fresh whole fruits are nutrient-dense, healthful foods that are inherently perishable. Processing fruit, especially when nonthermal technologies are used, into 100% fruit juice can protect nutrient and phytonutrient content. For example, high hydrostatic pressure, sonication technologies have been shown to deactivate degradative enzymes innate to fruit, thereby maintaining product quality and nutritional qualities in watermelon and grapefruit juices while assuring product safety (18–20).

The first critical step in juice production is to select mature, ripe, high-quality fruit that can be processed typically within a day. Ripening is important to full color, flavor development, and nutrient content (11, 21). In contrast, select fruits, e.g., apples, pears, peach, banana, and mango, destined for fresh consumption are often picked mature but allowed to fully ripen in storage or during transit to retail locations. Although optimal quality is achieved often when allowed to ripen on the plant, this early harvest allows the fruit to endure the postharvest handling and transport (11, 22).

Different fruits require different juicing procedures (Figure 2) primarily because of the physical characteristics of the fruit and the desired attributes for the finished product (10). Phytonutrient structure and distribution throughout the fruit vary among different fruits (23). These variables affect the availability of these bioactives in fresh fruits and have implications for optimal juicing procedures to ensure retention in the juice product. For example, 77.3% of the phytonutrients in grapes are found in the seed, 21.6% in the skin, and only 1.1% in the pulp (24). Most of the phenolic and flavonoid compounds in the orange are located in the peel, which includes the flavedo and albedo layers (25–27). Commercial squeezing (juicing) of oranges typically separates 3 fruit into peel and seeds, but through this process, many of the phenolic compounds from these sections are transferred to the juice (28). Compared with home juicing this process allows for some contact between albedo and

According to the U.S. Code of Federal Regulations, “juices directly expressed from a fruit or vegetable (i.e., not concentrated and reconstituted) shall be considered to be 100% juice and shall be declared as ‘100% juice.’” Juice from concentrate is also considered “100%” if it is reconstituted to contain the minimum Brix levels specified in the regulations. Federal regulations importantly require that a beverage containing less than 100% juice be identified as a juice “drink” or “beverage” or “cocktail.”

FIGURE 1 The US regulatory definition of 100% juice vs. other juice-containing beverages. Reproduced from reference 9 with permission.

TABLE 1 Minimum Brix concentrations required for labeling juice from concentrate as 100% juice¹

Fruit	100% Juice, minimum Brix concentrations
Apple	11.5
Banana	22.0
Blueberry	10.0
Cranberry	7.5
Grape	16.0
Grapefruit	10.0
Lemon	4.5
Mango	11.8
Orange	11.8
Peach	10.5
Pear	12.0
Pomegranate	16.0

¹Reproduced from reference 9 with permission.

juice sacks, thus resulting in higher content of phenolics in commercial juice than typically found in home-squeezed products extracted from oranges with minimal extraction of peel and seed components products such as cranberries, apples, and grapes, which are typically crushed, creating a higher amount of contact with phytonutrient-rich skin and seeds that are, in fact, subsequently carried into the juice (29, 30). Despite the presence of many phytonutrients in juice, the bioavailability of the most common polyphenols is quite variable (31).

Heat and pectinase/cellulase enzyme treatments are often applied to aid in extraction, as is common for grapes and cranberries. Enzyme treatments are used with most fruits to extract even more juice from the fiber and juice sacs. The juice is then clarified through filtration and additional enzyme treatments that hydrolyze cellulose and other complex carbohydrates. The juice may be concentrated, usually through evaporation, which facilitates long-term storage and/or blending (32, 33).

Pasteurization, a critical step for reducing microbiologic contamination risk, is used regardless of fruit variety. A thermal treatment of ~90–95°C for 30 s in a hot-fill-hold process can be applied as well as other forms of thermal treatment including canning (sterilization) or aseptic processing (28). This treatment inactivates pathogenic and spoilage microorganisms, as well as degradation enzymes such as pectinases and polyphenol oxidase. Polyphenol oxidase and other innate enzymes must be controlled, either by thermal or non-thermal processing, to ensure the stability of fruit juices and to maintain product quality (34).

Association of Fruit Juice Consumption with Diet Quality and Health

Many reports suggest fruit juice consumption is positively associated with diet quality (35–38). Based on data collected from the 2003–2006 NHANES, the Healthy Eating Index (HEI)⁹ 2005 score (designed to measure compliance with the Dietary Guidelines for Americans) was significantly higher ($P < 0.0001$) for consumers vs. nonconsumers of

100% juice across age groups (2–5 y, 6–12 y, 13–18 y, and 19+ y) (39). A more recent analysis for NHANES 2007–2010 data found a significant trend ($P < 0.0001$) toward higher HEI 2010 scores for children who consumed 12 oz of juice/d (HEI = 52.3) than those who did not consume juice (HEI = 43.8) (40).

There are reports that argue fruit juice consumption is comparable with consuming sugar-sweetened beverages that contribute to overweight and obesity, particularly among children (41–43). Important to this argument are quality studies, as noted by the 2010 US Dietary Guidelines for American, which indicate sugar per se does not contribute to weight gain (1, 44).

The total (poly)phenolic content of citrus fruit juices depends on cultivar and stage of ripeness (45). Typically, for citrus fruit, the phenolic content tends to be less in ripe fruit vs. unripe fruit. As a class, flavonoid and phenolics found in fruit juice at concentrations of 51–968 $\mu\text{mol/L}$ have been shown to modulate oxidative stress, inflammatory stress, and microbial growth and activity (46–48). The variability of structure, concentrations, and classic pharmacodynamics of these substances challenges the clinical relevance of some of these compounds at typically consumed concentrations (49, 50). Our understanding of pharmacokinetics, including absorption, distribution, metabolism, and excretion, is critical to ascribe doses and specific health benefits to the spectrum of polyphenols innate to 100% fruit juice typically consumed. Although not the focus of this article, these findings have been thoroughly reviewed elsewhere (51, 52).

Limited epidemiologic evidence suggests an association between certain fruit juices, such as Concord grape, citrus, and cranberry; their polyphenolic compounds; and cardiovascular health (53–55). Possible mechanisms that explain these potential benefits include increased blood flow (56, 57) and blood pressure (58–60), improved endothelial function (56, 57, 61), reduced LDL cholesterol oxidation susceptibility (56), decreased platelet aggregation (62–64), and attenuated inflammation (61, 65).

Fruit Juice and Cognition

The extent to which different polyphenol forms, or their metabolites, may impart specific cognitive benefits is currently a subject of intensive investigation. This includes anthocyanins, flavan-3-ols, and resveratrol, all polyphenol forms common to fruit and juices. Anthocyanin-rich blueberry, strawberry (66–68), blackberry (69), and grape (70) products have demonstrated the ability to attenuate age-related cognitive decline in animal models of aging. Apple, grape, and wine extracts rich in anthocyanins and flavan-3-ols have also demonstrated the ability to minimize cognitive decline in rodent models of Alzheimer's disease (71).

Our understanding of the metabolic fate of these and other polyphenols often remains speculative with respect to cognitive decline among humans. One of the major hurdles in this arena is the low bioavailability of anthocyanins and related compounds and the rapid plasma clearance of most of the respective metabolites (23). A recent review of 17 epidemiologic studies and several intervention studies

⁹Abbreviations used: AAP, American Academy of Pediatrics; HEI, Healthy Eating Index; IPR, income:poverty ratio; UTI, urinary tract infection.

TABLE 2 Amounts and %DV of vitamins and minerals per serving of oranges in whole, sliced, and juice forms¹

	0.5-cup Sections (USDA 09203)		0.5 cup, 100% Orange juice ² (USDA 09209)		1 Medium whole (USDA 09203)		0.5 cup, Canned 100% orange juice (USDA 09207)	
		%DV		%DV		%DV		%DV
Weight of servings, g	90.5		124.5		131		124.5	
Energy, kcal	43		61		62		59	
Carbohydrate, g	11.5	3.8	14.4	4.8	16.3	5.4	13.7	4.5
Total sugars, g	9.1	—	10.4	—	12.9	—	10.9	—
Total dietary fiber, g	2.4	9.6	0.4	1.6	3.4	13.6	0.4	1.6
Calcium, mg	43	4.3	14	1.4	61	6.1	12	1.2
Magnesium, mg	10	2.5	14	3.5	14	3.5	12	3
Potassium, mg	169	4.8	222	6.3	238	6.8	229	6.5
Vitamin A, µg RAE	11	—	2	—	16	—	11	—
Vitamin C, mg	45	75	41.8	70	63	105	37	62
Folate, µg DFE	17	4	24	6	24	6	30	7.5

¹Reproduced from reference 14 with permission. %DV, percent daily values; DFE, dietary folate equivalent; RAE, retinol activity equivalent.

²Includes orange juice from concentrate.

suggests there are limited data in this area of interest. Results from intervention studies among those who are >45 y old presenting mild cognitive decline indicate potential improvement in several assessment tools, including word recognition and verbal memory (72). However, these studies indicated considerable variability in fruit juice consumption patterns and cognitive benefits.

Substantial evidence is available to support the effect of cranberry juice on reduced risk of urinary tract infections (UTIs); however, that evidence is insufficient to justify a health claim in Europe or the United States (52, 73). Proanthocyanidin A, a flavan-3-ol particularly high in cranberry, appears to play a key role in UTI protection. Depending on the cause, it appears many women with recurrent UTIs may benefit most (74). Limited evidence suggests that cranberry juice may reduce both UTI incidence and antibiotic use in children (75). A dose of 120 mg of this polyphenol, equivalent to about four 4-oz servings of cranberry juice consumed daily for 3–6 mo supports these types of outcomes based on reduced bacterial adhesion to uroepithelial cells (52).

100% Fruit Juice as an Affordable Component of Dietary Fruit Intakes

Studies of the relation between the nutritional quality and cost of foods have shown that foods with higher nutrient

density can cost more per calorie, although not necessarily per nutrient (76–79). The calculations in these studies were based on analyses of energy and nutrient composition of foods and retail price data. For US studies, data were derived from the USDA Food and Nutrient Database for Dietary Surveys and the USDA Center for Nutrition Policy and Promotion. For French studies, data were derived from French national food composition and retail price databases. The US and French studies indicated fruit had the highest energy cost (cost/100 kcal) (38). However, energy density (kcal/100 g) was negatively correlated with energy cost for combined fresh and processed fruits and vegetables. Fresh fruits and vegetables, canned and frozen vegetables, and fruit juices had high nutrient adequacy scores/cost compared with other food categories. In addition, vegetables and fruits were the least-expensive sources of vitamin C, and vegetables and beans were the lowest-cost sources of potassium.

Whole fruit appears to have a greater impact on diet cost than the overall fruit category, including 100% juice, according to an analysis of the relation between diet quality (as measured by HEI 2005) and per calorie diet cost among participants in the 2001–2002 NHANES database (80). Total fruit and whole fruit consumption are important components of the HEI 2005. At higher consumption amounts of total fruit (including both whole fruit and 100% fruit juice)

TABLE 3 Select nutrient content of oranges and juice forms expressed per 43 calories of a serving of oranges in 0.5-cup sections isocalorically¹

	0.5-cup Orange sections (USDA 09203)	100% Orange juice ² (USDA 09209)	Canned 100% orange juice (USDA 09207)
Calorically equivalent weight, g	90.5	87.8	91
Energy, kcal	43	43	43
Carbohydrate, g	11.5	10.2	10
Total sugars, g	9.1	7.3	9
Total dietary fiber, g	2.4	0.3	0.3
Calcium, mg	43	10	9
Magnesium, mg	10	10	9
Potassium, mg	169	158	167
Vitamin A, µg RAE	11	1	8
Vitamin C, mg	45	29	3
Folate, µg DFE	17	17	22

¹Reproduced from reference 14 with permission. DFE, dietary folate equivalent; RAE, retinol activity equivalent.

²Includes orange juice from concentrate.

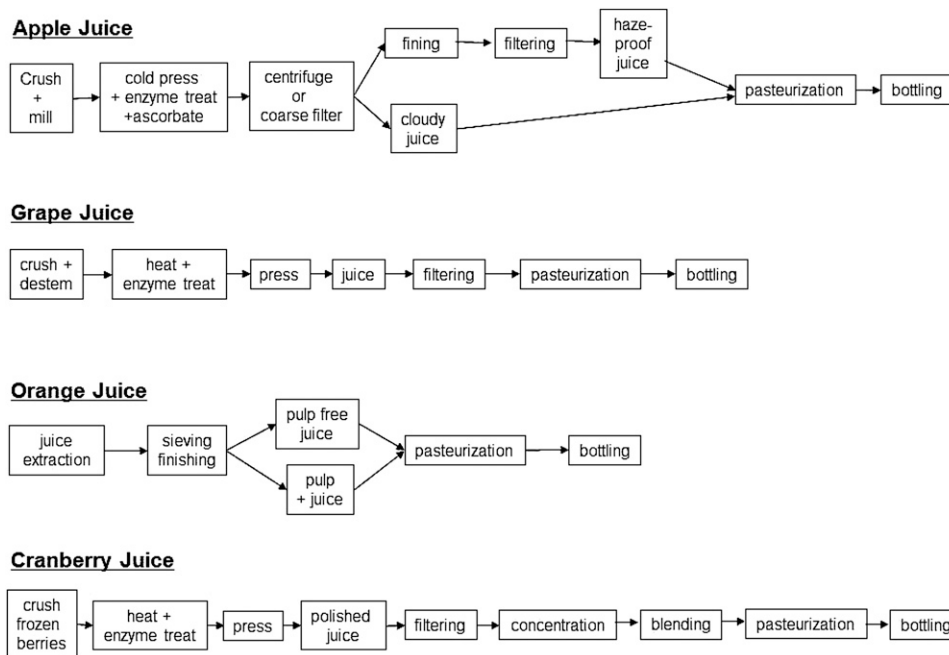


FIGURE 2 Juice processing customized for apple, grape, orange, and cranberry (MG Ferruzzi, personal communication, 2014). Adapted from reference 10 with permission.

and whole fruit, total diet quality was higher than at lower consumption amounts, but so was per calorie diet cost for both men and women. Overall, the consumption of whole fruit was more strongly associated with a higher diet cost than was the consumption of total fruit.

A dietary modeling study in which all 100% fruit juice was replaced with whole fruit showed a decrease in calories and fiber, as well as an increase in diet cost. In the same study, replacing only the 100% fruit juice that was in excess of the American Academy of Pediatrics (AAP) recommendations with whole fruit resulted in a lower increase in diet cost, while still allowing for a caloric reduction. The lowest-cost model involved replacement of 100% fruit juice with the lowest-cost whole fruit, but potassium was also lowest in this model (81).

Analysis of 2009–2010 NHANES data points to a strong socioeconomic gradient in consumption of whole fruit vs. 100% juice (82). The income:poverty ratio (IPR) is defined by the US Census Bureau as a family’s income divided by the poverty threshold (83). Except for children 4–13 y old, those with the lowest IPR (<1.3) consumed less whole fruit than those with a midrange (1.3–3.5) or high (>3.5) IPR. For children 4–13 y old, the lowest intakes were observed in the 1.3–3.5 IPR group. Within IPR groups, whole fruit consumption across the age groups was distributed in either a u- or j-shaped curve. One hundred percent fruit juice made up ~60% of total fruit consumption but was a lower proportion of the total among those with a higher IPR.

Given the cost barrier to increased whole fruit consumption for those with the least financial resources, modeling was used to assess the roles for whole fruit and 100% juice in helping 4- to 13-y-old children ($n = 1071$) to meet total fruit intake recommendations of 1–2 servings/d (presented by Adam Drewnowski on 29 April 2014 at Experimental

Biology, San Diego, CA). Approximately 70% of children aged 4–13 y in the 2009–2010 NHANES cohort were consuming <1.5 servings/d and 85% were consuming <2 servings/d.

One model met the fruit shortfall with whole fruit alone (presented by Adam Drewnowski on April 29, 2014 at Experimental Biology, San Diego, CA). Increasing total fruit consumption to recommended values was associated with significantly higher intakes of dietary fiber, potassium, and vitamin C ($P < 0.001$). However, total diet cost was also significantly increased above baseline amounts. In the second model, the fruit shortfall was met by a combination of whole fruit and 100% fruit juice. The permitted amounts of 100% fruit juice were capped at the daily intake limit recommended by the AAP (84). The combination of fruit and 100% juice was associated with significantly higher intakes of potassium, calcium, and vitamin C, but not fiber. On the other hand, daily diet costs were not significantly above baseline amounts. Calories were not substantially increased in either model.

Fruit Juice Challenges and Solutions

From a nutrition perspective, fruit is favored by some over 100% fruit juice because of concerns regarding excess consumption and obesity. The 2010 Dietary Guidelines Advisory Committee reviewed longitudinal studies on the relation between 100% fruit juice and adiposity in children and concluded the following: “Limited and inconsistent evidence suggests that for most children, intake of 100 percent fruit juice is not associated with increased adiposity, when consumed in amounts that are appropriate for age and energy needs of the child” (1). This finding is consistent with the conclusion noted by the 2013 Australian Dietary Guidelines committee (85).

The 2010 Dietary Guidelines specifically note that the consumption of 100% fruit juice is not associated with body weight in most children and adolescents (1). However, limited evidence suggests that increased intake of 100% juice has been associated with higher body weight in children and adolescents who were already overweight or obese (1).

The Academy of Nutrition and Dietetics Evidence Analysis Library evaluated the available cross-sectional and longitudinal studies and concluded, “There doesn’t appear to be a link between weight and fruit juice consumption in children” (86). The strength of evidence was graded as fair (grade II), which indicates studies were of strong design, but the results and conclusions were inconsistent. Both of these exhaustive reviews indicate that more research is needed on this topic (87).

Although some recommendations limit 100% juice to control calories, the continually mounting evidence for reduced risk of chronic diseases with adequate fruit and vegetable consumption (1, 88) is the rationale for recognizing 100% juice as an important option for individuals striving to meet dietary recommendations. The 2010 Dietary Guidelines for Americans recommends 1–2 cup equivalents of fruit per day, with a cup equivalent of fruit defined as 1 cup fresh, 1 cup 100% juice, or 0.5 cup dried fruit (1). The Dietary Approaches to Stop Hypertension diet recommends 4–5 servings of fruit, with 0.5 cup 100% fruit juice noted to be equivalent to 0.5 cup fresh or frozen fruit (89). The AAP guidance for individuals who are 1–6 y old is to limit 100% fruit juice to 4–6 oz/d and for individuals who are 7–18 y old is to limit 100% fruit juice to 8–12 oz/d (83). Finally, the Robert Wood Johnson Foundation acknowledges that 100% juice fits into a healthful diet and advises limits of 4 oz at 2–4 y, 6 oz at 5–10 y, and 8 oz at ≥ 11 y (90). Around the globe in countries such as Australia, Ireland, and Spain, dietary recommendations similarly include 100% juice as part of a healthful diet (83, 91, 92).

Conclusions

Further research documenting the nutritional value of 100% juice in comparison with whole fruit, both at harvest and throughout a typical period of time from harvest to consumption, would help to improve nutrition communications and inform consumers. Directly examining the impact of 100% juice consumption on health outcomes and physiologic processes such as inflammation will also help to build on existing evidence regarding its role in the human diet and human health, including areas such as cardiovascular health, cognition, and urinary tract health.

It is important to communicate the health benefits of fruit, including 100% juice, more clearly to consumers. Such guidance should incorporate the findings that 100% juice in appropriate amounts can help individuals to meet fruit recommendations without a substantial impact on energy intake or food costs.

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