Potential Nutritional Effects of Replacing Fresh Fruits and Vegetables in the Diets of Americans with Frozen Counterparts

Objective: To determine and compare the status of targeted nutrients in selected fresh, fresh-stored, and frozen fruits and vegetables, while mimicking typical consumer purchasing and storage patterns of the produce.

Design: Over a two-year period, fresh and frozen produce – namely blueberries, strawberries, broccoli, green beans, corn, spinach, cauliflower, and green peas – were purchased from six local supermarkets; the frozen produce was private-label. A composite sample of each fruit or vegetable was prepared with equal quantities of the produce from each supermarket. Representative samples were taken from the composite and analyzed by approved, standardized analytical methods for vitamin C (as ascorbic acid), vitamin A (as β-carotene), folate, and minerals. Furthermore, analyses included a quality control plan for each nutrient involving the use of certified standard reference materials. Analyses of each nutrient were performed in triplicate, with six repetitions for each fruit and vegetable over the period of study. Fresh produce was analyzed for the nutrients of interest on the purchase day and then again after five days of storage in a kitchen refrigerator. The later fruits and vegetables, denoted as fresh-stored, were intended to mimic typical purchasing and storage habits of fresh produce by the consumer.

Statistics: All data was analyzed by one-way ANOVA to determine the presence of significant difference in nutrient contents according to treatment (α=0.05). Data transformation was applied when necessary to adequately meet the assumption of normal distribution for ANOVA, and the Weighted Least Squares method was employed in the instances in which the equal variance assumption of the ANOVA was violated. All necessary statistical diagnostic checks (e.g. residuals versus predicted value plot, Q–Q plot of residuals, and histogram plot of residuals) were performed to verify acceptability of ANOVA implementation. In the cases in which a statistically significant difference was observed among the three treatments, the Tukey's Studentized Range multiple comparisons test was performed to determine which specific pairs of treatments (*i.e.*, fresh vs. frozen, fresh vs. fresh-stored, and fresh-stored vs. frozen) showed significant differences from one another (α=0.05).

Results: Vitamins C, A, and folate were shown to be susceptible to degradation by enzymatic and oxidative mechanisms, whereas minerals were not. In all cases, the absolute mean content of the fresh produce was greater than its fresh-stored counterpart; albeit, not always statistically different ($p > 0.05$). In terms of ascorbic acid content, there was no significant

difference between levels in fresh, fresh-stored, and frozen produce with the exception of spinach and green peas. For fresh spinach, there was a decrease in vitamin C content for the fresh-stored and frozen samples. Unlike its fresh counterparts, frozen spinach had been blanched prior to freezing and owing to the large surface area of the chopped product, this could potentially account for its lower vitamin C content (*i.e.,* 25.2 ± 3.5 mg ascorbic acid/100 g vs. 14.5 ± 5.7 for fresh and frozen samples, respectively). In the case of green peas, the level of vitamin C in blanched, frozen samples was significantly greater ($p < 0.05$) than the fresh-stored samples. In terms of vitamin A, frozen produce for the most part was not statistically different from its fresh analog, and in some cases surpassed the level of the fresh-stored samples. Only for blueberries were the vitamin A levels significant different for the fresh, fresh-stored, and frozen samples; that is, 196 ± 43 μg trans-β-carotene/100 g vs. 136 ± 26 vs. 74 ± 24, respectively. The most interesting results were for green peas in which the frozen samples 973 ± 122 μg trans-β-carotene/100 g fresh weight performed better than the means of the fresh and fresh-stored counterparts; that is, 859 ± 290 and 597 ± 185, respectively. In terms of folate, the frozen produce performed equally well relative to its fresh counterparts in all cases except for broccoli (*i.e.*, 61.7 ± 9.3 μg folate/100 g, fresh weight vs 72.6 ± 7.7). In some produce (blueberries, corn, and green peas) the folate means for the frozen products were significantly greater ($p < 0.05$) than their fresh-stored counterparts. For minerals, there were no differences between fresh and frozen samples.

Conclusions: The consumers' assumption that fresh food has significantly greater nutritional value than its frozen counterpart is misplaced; in fact, it is fundamentally wrong. Fresh produce can spend up to a month in the chain of producers, wholesalers, and retailers before consumers have access to them. Over this period, significant deterioration occurs to the extent that they can and do, in some cases, have lower nutritional value than their frozen counterpart. The findings of the present study, which were intended to mimic consumers' purchasing and handling practices of fresh produce, clearly demonstrate that fresh produce loses vitamins upon refrigerated storage over time while frozen samples retain their nutrients equally so or better.

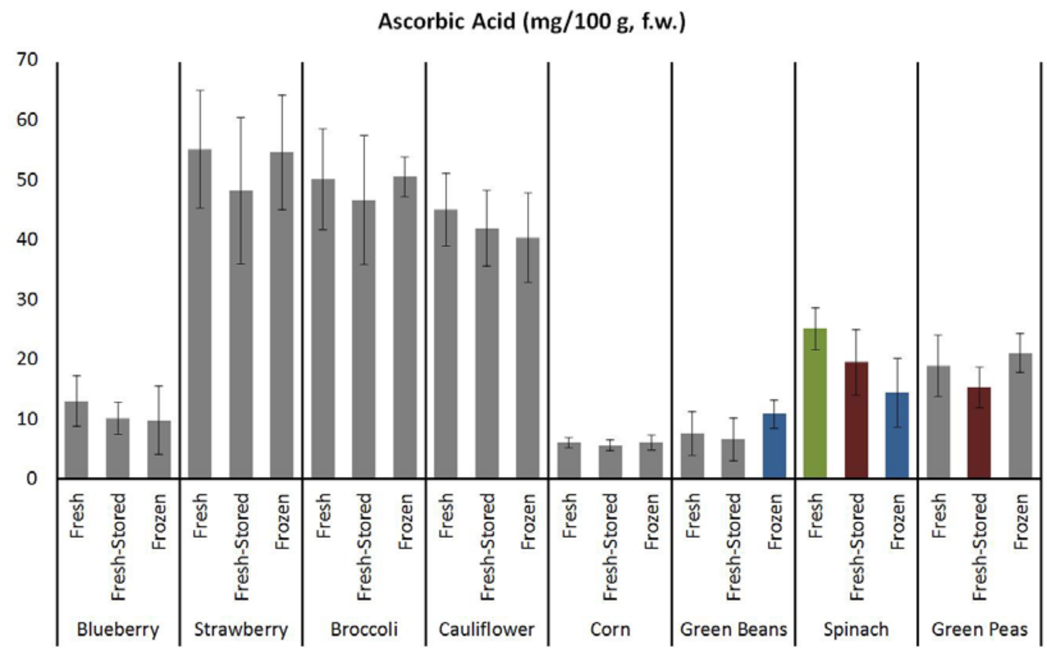

Figure 1. Ascorbic acid content (mg AA/100 g, fresh weight) in selected fresh, fresh-stored, and frozen fruits and vegetables.

Green, red, and blue bars signify fresh, fresh-stored, and frozen produce, respectively. Gray bars denote that there is no significant difference (p <0.05) between treatments. Where color is evident, this indicates a significant difference in at least one of the treatments against another.

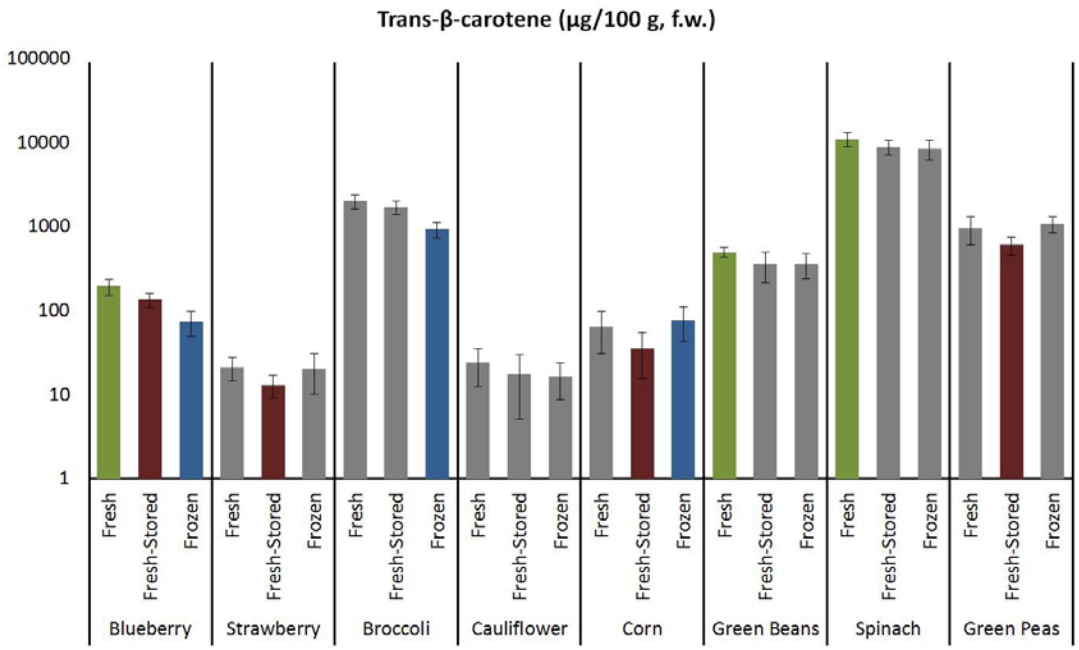

Figure 2. 1 *Trans*-β-carotene content (µg/100 g, fresh weight) in selected fresh, fresh-stored, and frozen fruits and vegetables.

Note that the *y*-axis is logarithmic in order to present broccoli and spinach results in the same figure. Green, red, and blue bars signify fresh, fresh-stored, and frozen produce, respectively. Gray bars denote that there is no significant difference (p <0.05) between treatments. Where color is evident, this indicates a significant difference in at least one of the treatments against another.

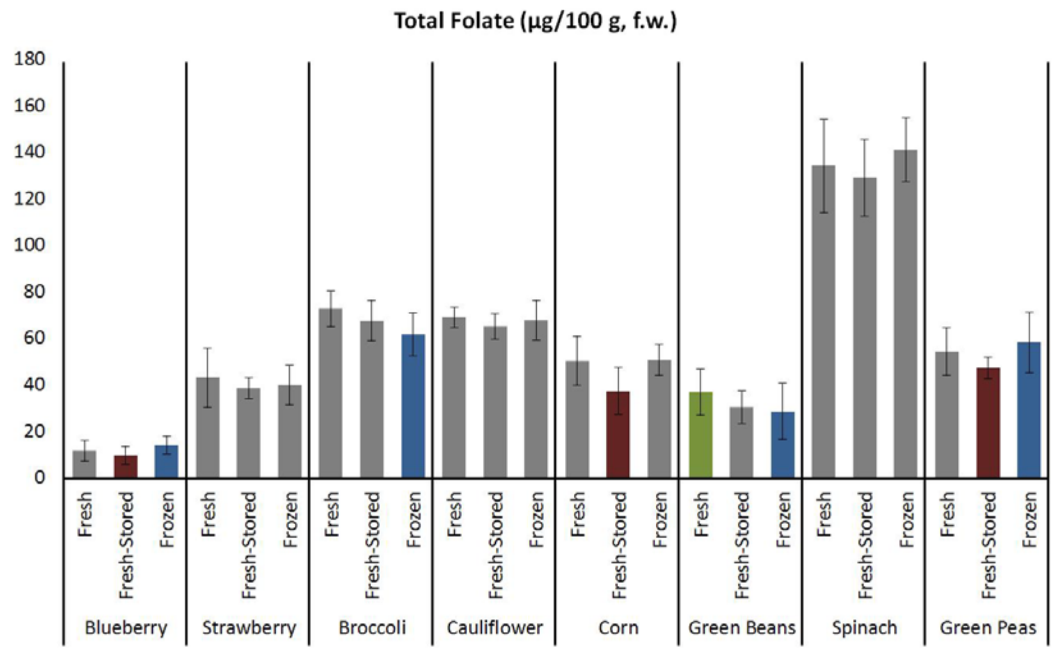

Figure 3. Food/total folate content (µg/100 g, fresh weight) in selected fresh, fresh-stored, and frozen fruits and vegetables.

Green, red, and blue bars signify fresh, fresh-stored, and frozen produce, respectively. Gray bars denote that there is no significant difference (p <0.05) between treatments. Where color is evident, this indicates a significant difference in at least one of the treatments against another.