

# Nutritional content of fresh and canned peaches

Robert W Durst<sup>a\*</sup> and George W Weaver<sup>b</sup>

## Abstract

**BACKGROUND:** The objective of this study was to assess whether canned peaches could deliver nutrient levels comparable to fresh peaches. Fresh freestone peaches, fresh cling peaches and canned cling peaches were analyzed for vitamins A, C and E, folate, antioxidants, total phenolics and total carotenoids to assess how these nutrients were affected by the canning process and whether storage further changed these components.

**RESULTS:** The vitamins and phytochemicals measured in this study were found to be present in canned cling peaches versus fresh freestone at statistically significantly higher levels (vitamin C, antioxidants and folate); higher but not statistically different levels (vitamin A); or lower, but not statistically different levels (vitamin E, total phenolics and total carotenoids). There were no statistically significant changes in nutrient content during storage for 3 months.

**CONCLUSIONS:** The nutritional content of canned peaches has been shown in this study to be comparable to that of fresh peaches. There were no statistically significant decreases in those nutritional parameters measured in this study between fresh freestone peaches and canned cling peaches. Vitamins A and E along with total carotenoids decrease immediately upon processing, but appear to stabilize after the processing step, showing minimal additional changes upon storage for 3 months. This study shows that canned peaches can provide comparable nutrient levels to the consumer as fresh peaches, meaning that consumers can enjoy peaches year round without worrying about loss of nutrients in their diet.

© 2012 Society of Chemical Industry

**Keywords:** peach; nutrition; processing; vitamins; antioxidants

## INTRODUCTION

There is consensus among nutritionists and medical professionals that increased consumption of fruits and vegetables will result in improved health for many individuals in the Western world. Many consumers also believe this to be true, however, they also have the perception that processed products have lower levels of vitamins, minerals and phytochemicals and are thus nutritionally inferior to fresh products.

There is considerable information in today's popular press about the need for increased consumption of fruits and vegetables. In fact, the USDA recently launched their 'Half Your Plate Campaign' (ChooseMyPlate.gov) aimed at getting Americans to increase their servings of fruits and vegetables. Running concurrent with this call for healthier food choices is a consumer perception that processed fruits and vegetables do not deliver the same level of nutrients that fresh products do. While it is clearly desirable, considering the extent of compelling scientific evidence, to have consumers eat more fruits and vegetables, the commonly held belief that 'fresh is best' may not be the case.<sup>1,2</sup> This misperception may limit consumers' food choices considering that many products, such as peaches, are seasonal, which limits their availability. Another challenge to the 'fresh is best' mentality is the strong push by the Institute of Medicine (IOM)<sup>3</sup> and other health and nutrition experts to provide more fruits and vegetables to children as part of their school lunch program. In the case of peaches this is nearly impossible, as the fresh season barely overlaps with the school year, so there is little chance of fresh peaches being on

the menus of schools. This paper describes the nutrient content of canned peaches compared to fresh peaches. It demonstrates the ability of the processing industry to deliver high quality, nutrient-dense foods on a year-round basis, instead of the limited seasonal availability of fresh peaches. In addition, these processed peaches, while not necessarily local (a poorly defined term, but another of popular interest with consumers), are available from domestic sources and as such should prove to be more appealing to consumers than foreign sourced products.

The objective of this study was to assess whether canned peaches could deliver nutrient levels comparable to fresh peaches. Fresh freestone peaches, fresh cling peaches and canned cling peaches were analyzed for several vitamins and nutritional parameters to assess how these nutrients were affected by the canning process and whether storage further changed these components. Fresh peaches are seasonally available from mid-summer through early fall. All fresh market peaches are freestone varieties, whereas cling peach varieties are specifically grown for the canning industry and are harvested over approximately the same time frame as freestones. Peaches are unusual among

\* Correspondence to: Robert W Durst, Linus Pauling Institute, Oregon State University, Corvallis, OR 97331, USA. E-mail: Bob.Durst@OregonState.edu

<sup>a</sup> Linus Pauling Institute, Oregon State University, Corvallis, OR 97331, USA

<sup>b</sup> Statistics Department, Oregon State University, Corvallis, OR 97331, USA

processed fruits as varieties are grown specifically for processing, versus other processed fruits that are more often sort-outs from the fresh market stream. Since the fresh season is short, freestone peaches are stored in a controlled atmosphere and cold storage to extend their shelf life and their season, but they do not store well, again limiting their seasonal availability.

## MATERIALS AND METHODS

### Samples

Ten samples of fresh cling peaches were taken from the processing line of commercial canners over the processing season and shipped overnight to Oregon State University (OSU). Ten canned samples packed in light syrup ( $^{\circ}$ Brix ranged from 8.99 to 16.80 with an average of 10.98) and prepared from the same lot of fresh cling peaches sampled above were shipped overnight to OSU. Sample preparation was done 1 or 2 days after canning/sampling as described below. This constituted the 'canned T 0' sample (T0) and 'fresh cling' sample (FC), respectively. A sampling of five of the ten canned cling samples at 3 months from canning date was also performed (T3).

Ten 'fresh freestone' samples (FF) were shipped overnight and held in cold storage ( $4^{\circ}$ C) for a few days and then held at room temperature for a day or two until considered fully ripe and ready to eat, at which point they were prepared as described below.

### Materials

All solvents (methanol, tetrahydrofuran, hexane) were high-performance liquid chromatography (HPLC) grade purchased from Merck (Whitehouse Station, NJ, USA). Potassium phosphate monobasic ( $\text{KH}_2\text{PO}_4$ ), dithiothreitol (DTT), potassium hydroxide (KOH), ascorbic acid (vitamin C), Folin–Ciocalteu's phenol reagent, and gallic acid were reagent grade and purchased from Sigma-Aldrich (St. Louis, MO, USA). Authentic carotenoid pigment standards (lutein, zeaxanthin,  $\beta$ -cryptoxanthin,  $\alpha$ -carotene,  $\beta$ -carotene, and *trans*-lycopene) were purchased from Sigma.

### Sample preparation

Canned samples were prepared by draining the liquid from the fruit (kitchen strainer), dicing and subsequently treated for the various analyses as described below.

Peaches from two different cans (same lot) and from three to four fresh peaches were used for each sample. Two separate samples (duplicates) were prepared from these diced samples.

All sample preparations and analyses were performed in duplicate. Since all commercial canned peaches are peeled, and it is widely reported that peels have a different composition than flesh,<sup>4–6</sup> the fresh cling and fresh freestone samples were also peeled as follows: fresh peaches were immersed in a hot lye bath [approx.  $88^{\circ}$ C ( $190^{\circ}$ F) water containing 2% KOH] for 1 min and then submerged in a slushy ice bath for less than 1 min. The peels were fully removed by the abrasive action of the slush without damaging the flesh. This process closely mimics the commercial peeling process. The lye treatment is the same, but in the commercial setting, water spray bars over a conveyor belt would cool and rinse the peel fragments and lye solution off the fruit. After peeling, samples were then diced and further prepared for the various analyses as described below.

Diced samples were accurately weighed into separate test tubes and then buffer or extraction solvent was added depending on the analyte. For vitamin C,  $\sim 5$  g tissue plus 5.0 mL buffer (0.5%

$\text{KH}_2\text{PO}_4$  w/v, pH 2.5 with  $0.5 \text{ g L}^{-1}$  DTT) was used. For vitamin E,  $\sim 5$  g tissue plus 5.0 mL extraction solvent (1% ascorbic acid) was used. For folate, phenolics and antioxidants,  $\sim 30$  g plus 30.0 mL MilliQ water was used (EMD Millipore, Billerica, MA, USA).

The above samples were all ground using an Omnimax stick mixer (Omni International, Kennesaw, GA, USA) for approximately 30 s until fully homogenized. Samples were sonicated (5 min), centrifuged (5 min at  $4000 \times g$ ) and the supernatant was portioned out into 2 mL micro-vials and stored at  $-80^{\circ}$ C until analysis.

For carotenoids, the extraction procedure was adapted from Rodriguez.<sup>7</sup> Approximately 10 g tissue plus 25 mL extraction solvent [MeOH–THF 1:1, containing 10% (v/w) magnesium carbonate] was homogenized as above, sonicated and centrifuged as above. The solvent was poured off and the pellet was re-extracted two more times with 10 mL MeOH–THF (1:1), vortexed, sonicated and centrifuged. All supernatants were combined and evaporated at  $40^{\circ}$ C to near dryness on a rotary evaporator (Buchi Rotovapor R; Buchi Analytical, Flawil, Switzerland). Carotenoids were re-dissolved in hexane and diluted to 10.0 mL. Autosampler vials were filled, sealed and samples stored in the dark at  $-80^{\circ}$ C until analysis.

HPLC analyses were performed on an HP (Agilent) 1090 equipped with a diode-array detector and processed with Chemstation A.08.03 software (Agilent Technologies, Santa Clara, CA, USA).

The ferric reducing antioxidant power (FRAP)<sup>8</sup> assay was used to measure antioxidant levels using a Gemini SpectraMax plate reader (Molecular Devices, LLC Sunnyvale, CA, USA). Spectrophotometric analyses were performed on a Beckman DU-640 spectrophotometer (Beckman–Coulter Inc., Brea, CA, USA).

### Carotenoid analysis (vitamin A)

Carotenoid samples were analyzed by HPLC<sup>9</sup> using a gradient separation with a Develosil RP Aqueous C-30 column ( $150 \times 2$  mm,  $3 \mu\text{m}$  particle size) and by absorbance at 450 nm.<sup>10</sup> Quantification was by an external standard method against authentic standards (lutein, zeaxanthin,  $\beta$ -cryptoxanthin,  $\alpha$ -carotene,  $\beta$ -carotene, and *trans*-lycopene) using HPLC to separate and quantify individual compounds. Those compounds with pro-vitamin A activity [ $\alpha$ -cryptoxanthin (quantified as  $\beta$ -cryptoxanthin),  $\beta$ -cryptoxanthin, 13-*cis*- $\beta$ -carotene (quantified as  $\beta$ -carotene),  $\alpha$ -carotene,  $\beta$ -carotene] were summed with appropriate conversion factors ( $\div 24$ ,  $\div 24$ ,  $\div 12$ ,  $\div 24$ ,  $\div 12$ , respectively) and reported as RAE  $\text{kg}^{-1}$  fresh fruit (retinol activity equivalents). Total carotenoids were measured spectrophotometrically by absorbance at 450 nm, using  $\beta$ -carotene as the standard<sup>10</sup> and reported as  $\text{mg kg}^{-1}$  fresh fruit.

### Vitamin E analysis

The analysis of  $\alpha$ - and  $\gamma$ -tocopherol was performed by a modification of the method by Podda *et al.*<sup>11</sup> Briefly,  $\approx 50$  mg of tissue was saponified with alcoholic KOH, extracted with hexane, dried under nitrogen, re-suspended in 1:1 ethanol–methanol, then injected into an HPLC system. The HPLC system consisted of a Shimadzu LC-10ADvp controller (Shimadzu, Columbia, MD, USA), and a SIL-10ADvp auto injector with a 50  $\mu\text{L}$  sample loop. Tocopherols were detected using a LC-4B amperometric electrochemical detector (Bioanalytical Systems Inc., West Lafayette, IN, USA) with a glassy carbon working electrode, and a silver chloride reference electrode. The column used was a Waters Spherisorb ODS2 C-18 column ( $100 \times 4.6$  mm,  $3 \mu\text{m}$  particle size) with a Waters Spherisorb

ODS precolumn (10 × 4.6 mm, 5 μm particle size). An isocratic mobile phase delivery system was used, flow 1.2 mL min<sup>-1</sup> with a total run time of 6 min. The mobile phase used was 99:1 (v/v) methanol–water containing 0.1% (v/w) lithium perchlorate. The electrochemical detector was in the oxidizing mode, potential 500 mV, full recorder scale at 500 nA. Peak areas were integrated using Shimadzu Scientific 4.2 Class VP software package, and tocopherols were quantified using authentic standards and reported as mg α- and mg γ-tocopherol kg<sup>-1</sup> fresh fruit. The total was by summation.

### Total phenolics analysis

Total phenolics were measured by a modification of the Folin–Ciocalteu spectrophotometric method<sup>12</sup> and reported as mg gallic acid equivalents (GAE) kg<sup>-1</sup> fresh fruit.

### Vitamin C analysis

Vitamin C was measured by HPLC. Column: Spherisorb ODS-1; flow 0.7 mL min<sup>-1</sup>; detector: 243 nm; mobile phase: 0.5% KH<sub>2</sub>PO<sub>4</sub> w/v, pH 2.5 with 0.5 g L<sup>-1</sup> DTT and reported as mg kg<sup>-1</sup> fresh fruit.

### Antioxidant measurement

Samples were analyzed for antioxidant activity by the FRAP assay<sup>8</sup> and reported as μmol L<sup>-1</sup> Trolox equivalents kg<sup>-1</sup> fresh fruit.

### Folate measurement

Samples were analyzed by the VitaFast folic acid microbial assay kit from R-Biopharm, Darmstadt, Germany (AOAC method 2004.05).<sup>13</sup> Samples were preincubated with pig pancreatin enzyme (Sigma P1750) as recommended in the assay kit as follows: 0.3 mL sample was diluted with 10.5 mL phosphate buffer (7.8 g NaH<sub>2</sub>PO<sub>4</sub>·2H<sub>2</sub>O 100 mL<sup>-1</sup>, pH 7.2, containing 1% w/w ascorbic acid: the buffer was prepared daily) plus 1.2 mL pig pancreatin solution (5.0 mg mL<sup>-1</sup> phosphate buffer). This was incubated for 2 h in the dark at 37 °C with occasional shaking. The sample was then boiled for 30 min and then placed in an ice bath to rapidly bring it to room temperature, and centrifuged for 5 min at 10 000 × *g*. The sample was then appropriately diluted as instructed in the assay kit. Enzyme blanks (water instead of sample) were run and used to subtract background readings from samples. Results are reported as μg folic acid kg<sup>-1</sup> fresh fruit.

### Statistical analyses

For each response variable (total carotenoids, Folin–Ciocalteu, etc.), two paired *t*-tests were used. The first compared the fresh cling and canned cling peaches using data from 10 sample lots. The second compared canned cling peaches to the canned and stored cling peaches. This second test used only samples from five lots. The paired *t*-test was used to take advantage of the natural pairing that came from the sampling design. We expected peaches sampled from the same lot to be more alike than peaches from different lots, and so analyzed the differences between peaches from within the same lot. This gave us a more precise comparison of the differences between the various peach processing procedures. We used the differences between the, for example, fresh cling peaches and canned cling peaches from the same lot, and analyzed these 10 differences, or pairs, to determine if the average difference was significantly different from 0.

There was no pairing in the case of comparing the canned cling and fresh freestone peaches, therefore a standard *t*-test was used to compare the mean of the 10 samples from each group.

For each variable, the *P*-value for the statistical test was determined. If it was less than 0.05, this was interpreted as evidence that the difference was significant. Estimates of the mean and a 95% confidence interval (95% CI) for the mean are given.

## RESULTS AND DISCUSSION

### Carotenoids (vitamin A)

The carotenoids were analyzed by two different methods. HPLC analysis allows changes in the carotenoid profile to be monitored, and to also specifically identify and quantify each of the active vitamin A analogues. The second method, spectrophotometric absorbance, gives a total value but does not measure the individual carotenoids.

Figure 1 shows the results for the HPLC carotenoid analysis of fresh clings, which had an average of 150 RAE kg<sup>-1</sup> with a range of 75–225 RAE kg<sup>-1</sup>. The fresh freestones had an average of 105 RAE kg<sup>-1</sup> with a range of 61–149 RAE kg<sup>-1</sup>. The IU values were obtained by summing those carotenoids that are vitamin A precursors from their concentrations (in μg kg<sup>-1</sup>) as follows: α and β-cryptoxanthine/24; 13-*cis*-β-carotene/12; α-carotene/24; β-carotene/12. Lutein was an additional carotenoid identified, but not included in the total since it has no vitamin A activity.

The canned clings (T0) had an average of 115 RAE kg<sup>-1</sup> with a range of 61–169 RAE kg<sup>-1</sup>. The canned and stored clings (T3) had an average of 110 RAE kg<sup>-1</sup> with a range of 33–177 RAE kg<sup>-1</sup>.

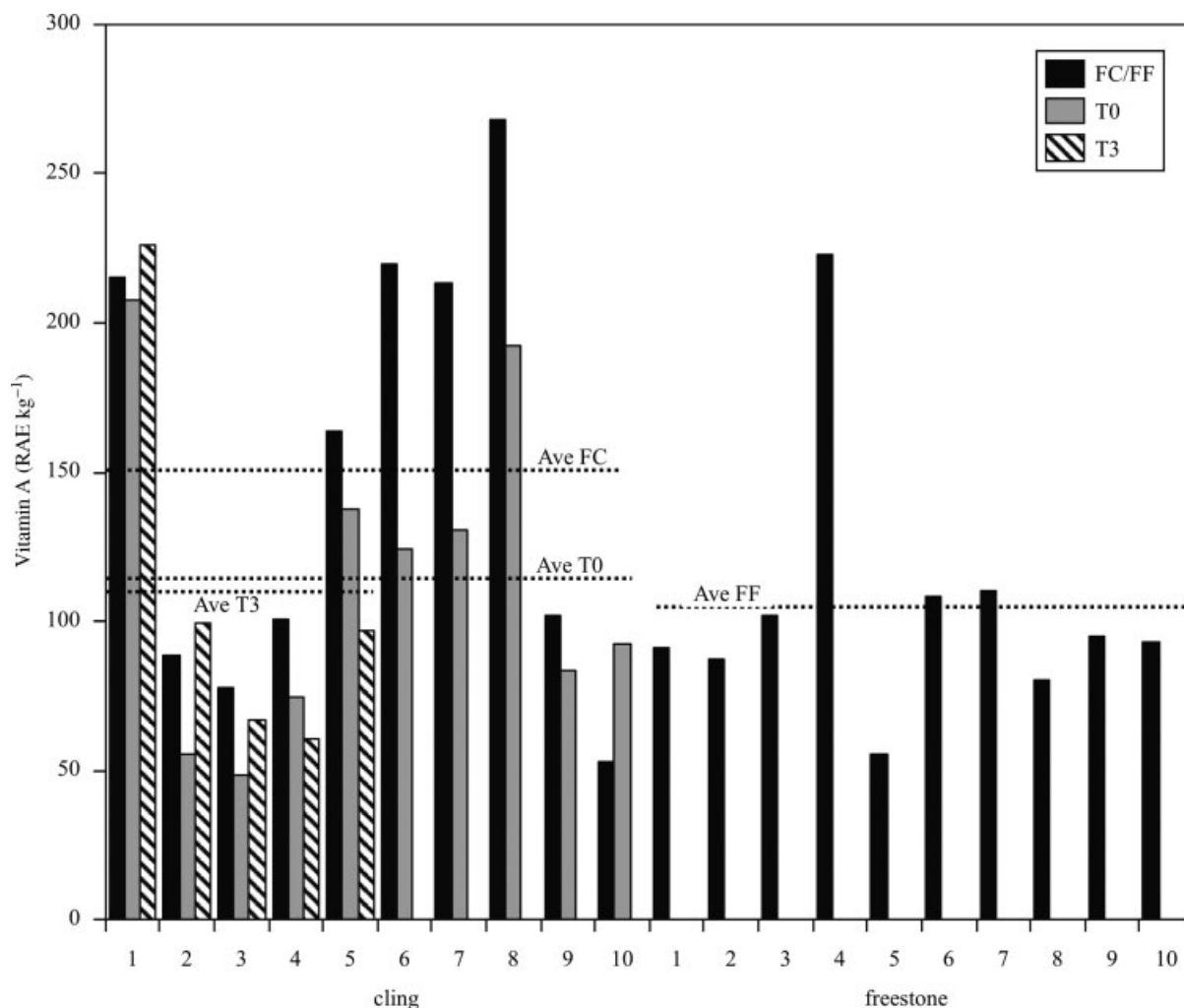
Table 1 shows that the average difference in carotenoids between canned (T0) and fresh cling (FC) peaches is significantly different from 0 (paired *t*-test, *P* = 0.021, *n* = 10) with an average difference (fresh minus canned) of 3.6 and a 95% CI for the difference of (0.7–6.5). The average difference in carotenoids between canned (T0) and canned and stored (T3) cling peaches was not significantly different from 0 (paired *t*-test, *P* = 0.74, *n* = 5).

Comparison of average carotenoids between the canned cling peaches (T0) and a sample of fresh freestone peaches (FF) was not significant (*t*-test, *P* = 0.56, *n* = 10).

The levels of vitamin A provided by the fresh freestones would constitute 3.9–8.7% of the RDA, while the canned clings would provide 4.2–9.6%. There is a range because the RDA is age and gender dependent.

Figure 2 shows that, based on spectrophotometric analysis, fresh clings (FC) had an average of 16.7 mg kg<sup>-1</sup> as (β-carotene) with a range of 11.2–22.9 mg kg<sup>-1</sup>. The fresh freestones (FF) had an average of 16.3 mg kg<sup>-1</sup> with a range of 1.33–30.1 mg kg<sup>-1</sup>. The canned clings (T0) had an average of 13.3 mg kg<sup>-1</sup> with a range of 6.6–22.6 mg kg<sup>-1</sup>. The canned and stored clings (T3) had an average of 13.3 mg kg<sup>-1</sup> with a range of 8.6–20.6 mg kg<sup>-1</sup>. The average difference in total carotenoids between canned cling and fresh cling peaches is significantly different from 0 (paired *t*-test, *P* = 0.026, *n* = 10) with an average difference (fresh minus canned) of 3.5 mg kg<sup>-1</sup> and a 95% CI for the difference of (0.5 mg kg<sup>-1</sup>, 6.4 mg kg<sup>-1</sup>). The difference in total carotenoids between canned (T0) and canned and stored cling peaches (T3) is not significantly different from 0 (paired *t*-test, *P* = 0.0559, *n* = 5). Comparison of average total carotenoids between the canned cling peaches and a sample of fresh freestone peaches is not significant (*n* = 10, *t*-test, *P* = 0.213).

The HPLC and spectrophotometric analysis showed similar trends, but the ability to compute a vitamin A value from the HPLC data indicates that, although more complicated to perform, it does provide additional information. The values measured in

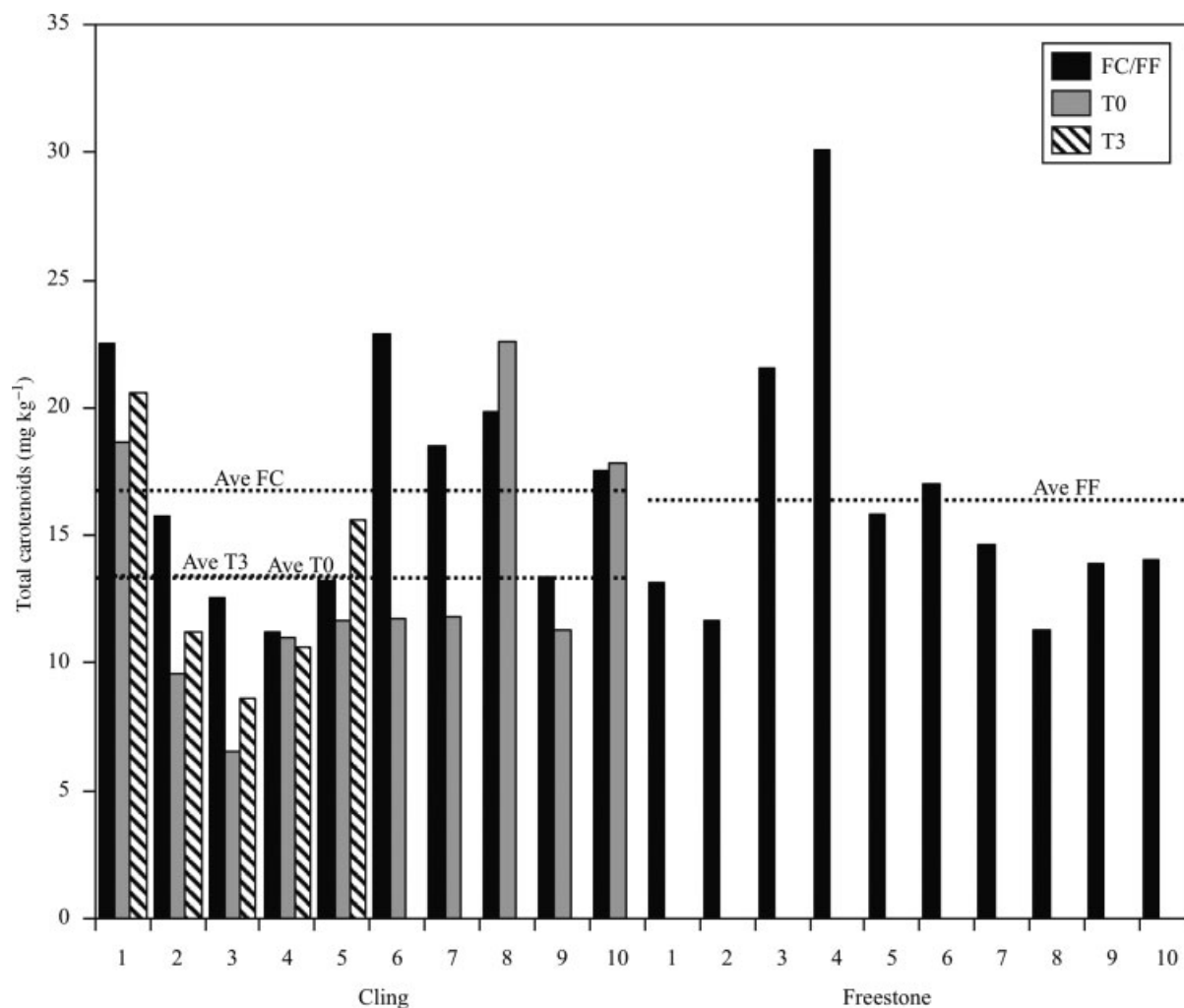


**Figure 1.** Vitamin A content of canned and fresh peaches. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

**Table 1.** Comparison of fresh freestone with fresh and canned cling peaches

Analyte and method	Fresh freestone (FF)	FF vs FC	Fresh cling (FC)	FF vs T0	FC vs T0	Canned cling (T0)	T0 vs T3	Canned cling (T3)
<b>Carotenoids</b>								
HPLC (RAE kg <sup>-1</sup> )	105 ± 44	NS	150 ± 75	NS	S	115 ± 54	NS	110 ± 67
Spectrophotometric (mg kg <sup>-1</sup> )*	16.3 ± 5.7	NS	16.7 ± 4.2	NS	S	13.3 ± 4.9	NS	13.3 ± 4.8
<b>Vitamin E</b>								
Alpha (mg kg <sup>-1</sup> )	1.42 ± 0.42	NS	1.68 ± 0.24	NS	S	1.12 ± 0.31	NS	0.93 ± 0.10
Gamma (mg kg <sup>-1</sup> )	0.11 ± 0.01	NS	0.13 ± 0.02	S	NS	0.13 ± 0.07	NS	0.14 ± 0.02
Total (mg kg <sup>-1</sup> )	1.53 ± 0.42	NS	1.82 ± 0.24	NS	S	1.24 ± 0.35	NS	1.06 ± 0.11
<b>Total phenolics</b>								
Folin-Ciocalteu (mg kg <sup>-1</sup> ) <sup>†</sup>	281 ± 92	NS	306 ± 73	NS	NS	265 ± 73	NS	227 ± 39
<b>Vitamin C</b>								
HPLC (mg kg <sup>-1</sup> )	9.5 ± 4.5	NS	19.5 ± 18.3	S	NS	34.1 ± 24.1	NS	55.0 ± 17.1
<b>Antioxidants</b>								
FRAP (μmol L <sup>-1</sup> Trolox equivalent kg <sup>-1</sup> )	9620 ± 5700	NS	11990 ± 3840	S	NS	15580 ± 5450	NS	12 180 ± 3400
Folate (μg kg <sup>-1</sup> )	2.0 ± 0.8	S	5.9 ± 4.3	S	S	22.4 ± 4.2	NS	24.3 ± 3.0

Results are given as the average ± standard deviation. NS, not significant ( $P \geq 0.05$ ); S, significant ( $P < 0.05$ ). Comparisons were made using the two-sample *t*-test.  
 \* As β-carotene.  
 † As gallic acid equivalents.



**Figure 2.** Total carotenoid content of canned and fresh peaches, determined by spectrophotometric analysis. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

this study compare favorably with other studies<sup>14</sup> and the USDA food composition values<sup>15</sup> for raw fruit of 160  $\mu\text{g RAE kg}^{-1}$  (150  $\mu\text{g RAE kg}^{-1}$  in this study). While the processed value of 115  $\mu\text{g RAE kg}^{-1}$  is lower than reported by USDA (180–250  $\mu\text{g RAE kg}^{-1}$ ), it is comparable to the value of others<sup>14</sup> who report a total of approximately 20  $\text{mg kg}^{-1}$ .

### Vitamin E

The fresh clings (FC) had an average of 1.8  $\text{mg kg}^{-1}$  vitamin E with a range of 1.3–2.2  $\text{mg kg}^{-1}$ . Total vitamin E (80–90%  $\alpha$ -tocopherol with 10–20%  $\gamma$ -tocopherol) are used for all summaries and statistics unless otherwise noted.

Figure 3 shows that fresh freestones (FF) had an average of 1.5  $\text{mg kg}^{-1}$  with a range of 1.2–2.3  $\text{mg kg}^{-1}$ . The canned clings (T0) had an average of 1.2  $\text{mg kg}^{-1}$  with a range of 1.0–2.0  $\text{mg kg}^{-1}$ . The canned and stored clings (T3) had an average of 1.1  $\text{mg kg}^{-1}$  with a range of 0.9–1.2  $\text{mg kg}^{-1}$ .

Table 1 compares the average difference in vitamin E between canned (T0) and fresh cling (FC) peaches and found that it was significantly different from 0 (paired *t*-test,  $P = 0.004$ ,  $n = 10$ ) with an average difference (fresh minus canned) of 0.06 and a 95% CI for the difference of (0.02, 0.09). The average difference in vitamin E between canned (T0) and canned and stored (T3)

cling peaches was not significantly different from 0 (paired *t*-test,  $P = 0.28$ ,  $n = 5$ ).

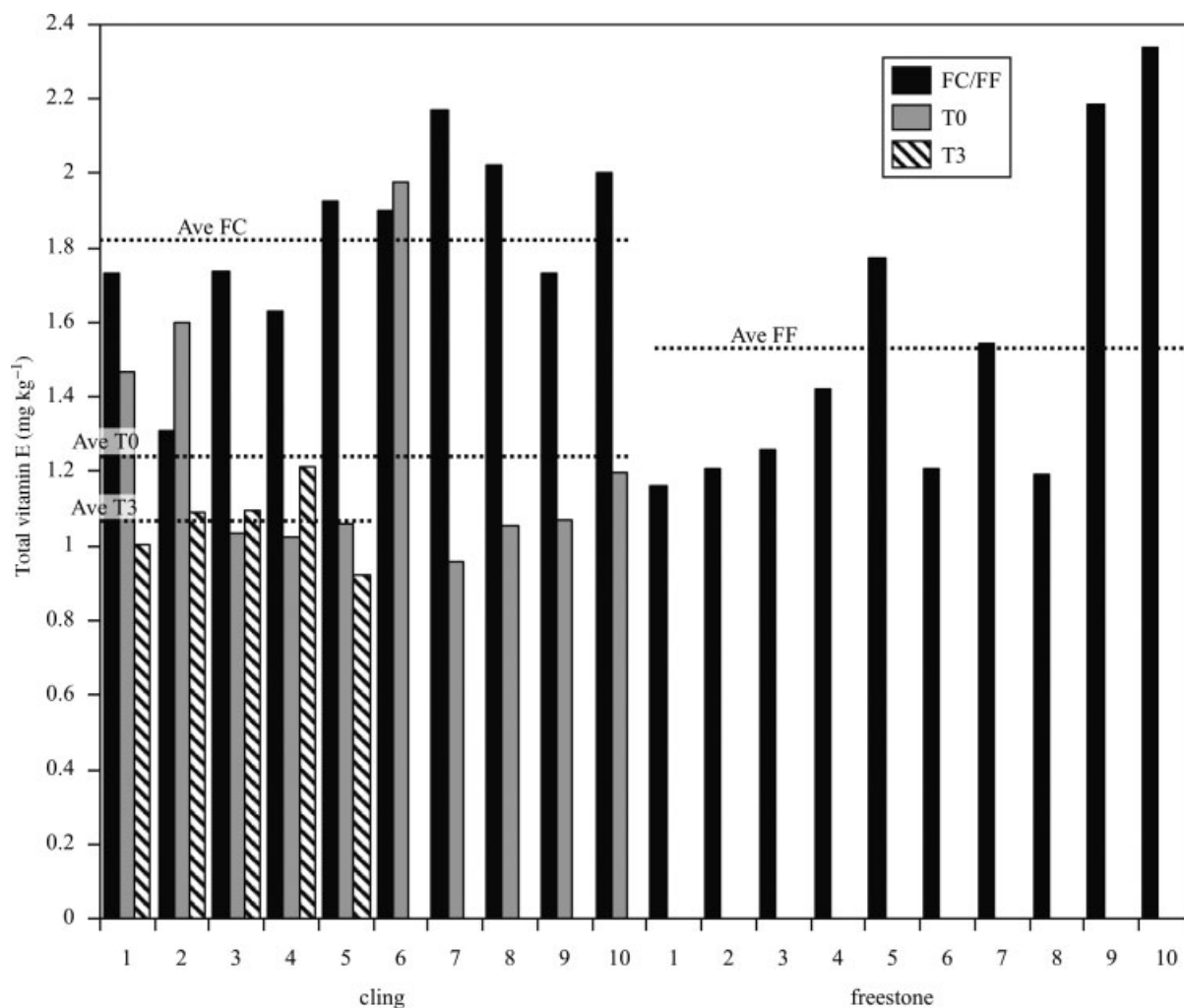
Comparison of average vitamin E between the canned cling (T0) peaches and the sample of fresh freestone (FF) peaches was not significant (*t*-test,  $P = 0.44$ ,  $n = 10$ ).

Table 1 shows that the average difference in  $\alpha$ -tocopherol between canned cling (T0) and fresh cling (FC) is significantly different from 0 (paired *t*-test,  $P = 0.003$ ,  $n = 10$ ) with an average difference (FF minus T0) of 0.57 and a 95% CI for the difference of (0.24, 0.89). The average difference in  $\alpha$ -tocopherol between canned (T0) and canned and stored (T3) cling peaches is not significantly different from 0 (paired *t*-test,  $P = 0.203$ ,  $n = 5$ ).

Comparison of average  $\alpha$ -tocopherol between the canned cling (T0) peaches and the sample of fresh freestone (FF) peaches was not significant (*t*-test,  $P = 0.397$ ,  $n = 10$ ).

Table 1 shows that the average difference in  $\gamma$ -tocopherol between canned (T0) and fresh cling (FC) peaches was not significantly different from 0 (paired *t*-test,  $P = 0.80$ ,  $n = 10$ ). The average difference in  $\gamma$ -tocopherol between canned (T0) and canned and stored (T3) cling peaches was not significantly different from 0 (paired *t*-test,  $P = 0.91$ ,  $n = 5$ ).

There is evidence of a difference in average  $\gamma$ -tocopherol between the canned cling peaches and a sample of fresh freestone



**Figure 3.** Total vitamin E content of canned and fresh peaches. Sum of  $\alpha$ -tocopherol plus  $\gamma$ -tocopherol. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

peaches (*t*-test,  $P < 0.001$ ,  $n = 10$ ). Estimated mean  $\gamma$ -tocopherol is 0.13 for canned cling peaches and 0.11 for fresh freestone peaches; 95% CIs are (0.08, 0.18) for canned cling and (0.10, 0.12) for freestone.

The levels of vitamin E provided by the fresh freestones (FF) would constitute 1–2.2% of the RDA (for ages 4–18 years), while the canned clings (T0) would provide 0.8–1.8%.

**Total phenolics**

Figure 4 shows that the fresh clings had an average of 306 mg kg<sup>-1</sup> GAE with a range of 205–420 mg kg<sup>-1</sup>. The fresh freestones had an average of 281 mg kg<sup>-1</sup> with a range of 158–479 mg kg<sup>-1</sup>. The canned clings (T0) had an average of 265 mg kg<sup>-1</sup> with a range of 143–404 mg kg<sup>-1</sup>. The canned and stored clings (T3) had an average of 227 mg kg<sup>-1</sup> with a range of 186–281 mg kg<sup>-1</sup>. The average difference in total phenolics between canned cling (T0) and fresh cling (FC) is not significantly different from 0 (paired *t*-test,  $P = 0.0693$ ,  $n = 10$ ). The average difference in total phenolics between canned (T0) and canned and stored (T3) cling peaches is not significantly different from 0 (paired *t*-test,  $P = 0.775$ ,  $n = 5$ ).

Comparison of average total phenolics between the canned cling (T0) peaches and a sample of fresh freestone (FF) peaches is shown in Table 1, and was not significant ( $n = 10$ , *t*-test,

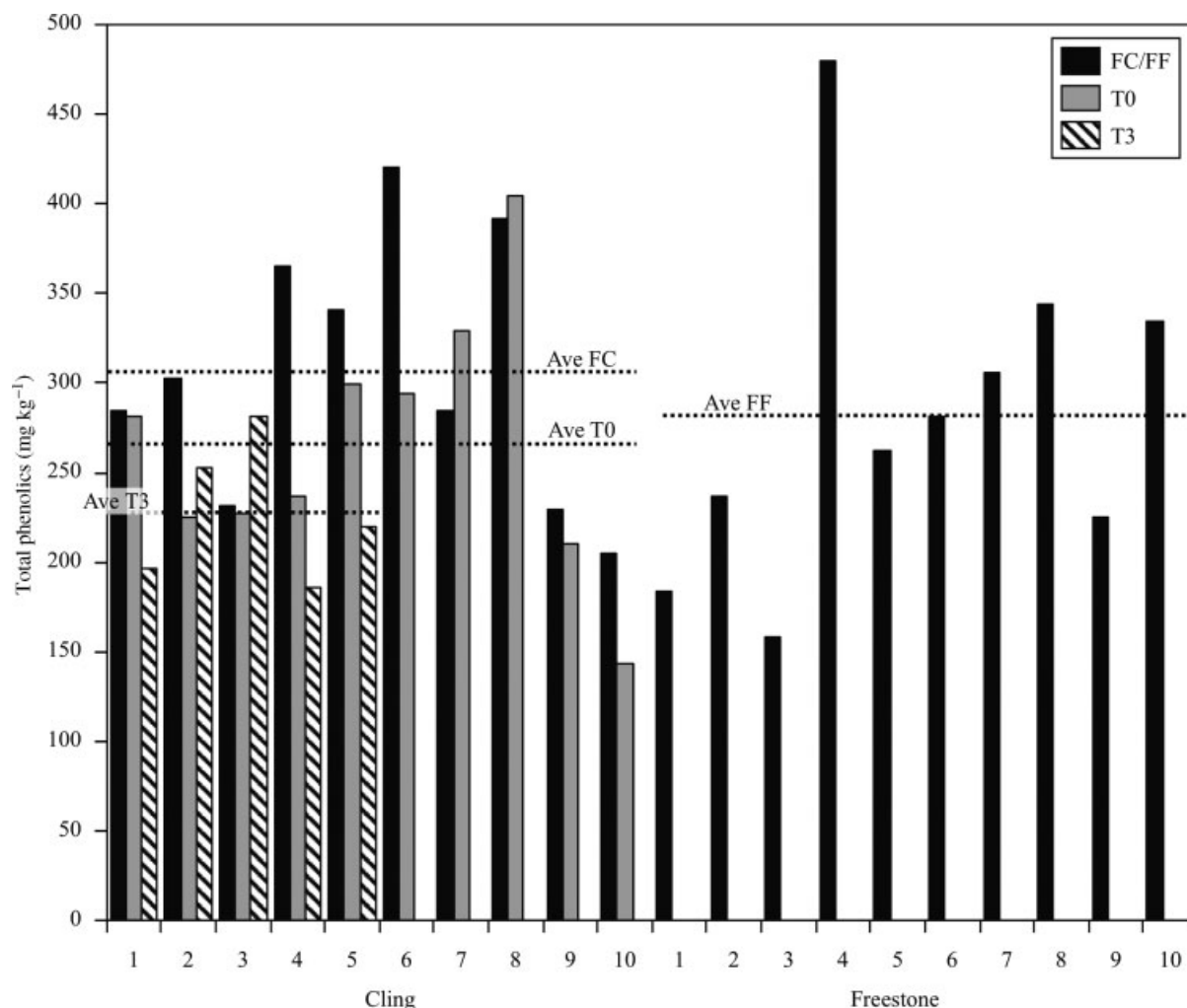
$P = 0.684$ ). This is comparable to the findings of others<sup>4</sup> of 274 mg kg<sup>-1</sup> (lye peeled fresh cling) and 398 mg kg<sup>-1</sup> (processed) and 230 mg kg<sup>-1</sup> (stored for 3 months).

**Vitamin C**

Figure 5 shows that the fresh clings (FC) had an average of 19.5 mg kg<sup>-1</sup> with a range of 10.1–70.4 mg kg<sup>-1</sup>. The fresh freestones (FF) had an average of 9.5 mg kg<sup>-1</sup> with a range of 3.9–15.9 mg kg<sup>-1</sup>. The canned clings (T0) had an average of 34.1 mg kg<sup>-1</sup> with a range of 7.0–75.9 mg kg<sup>-1</sup>. The canned and stored clings (T3) had an average of 55.0 mg kg<sup>-1</sup> with a range of 7.0–75.9 mg kg<sup>-1</sup>.

Table 1 shows that the average difference in vitamin C between canned (T0) and fresh cling (FC) peaches was not significantly different from 0 (paired *t*-test,  $P = 0.237$ ,  $n = 10$ ). The average difference in vitamin C between canned (T0) and canned and stored (T3) cling peaches was not significantly different from 0 (paired *t*-test,  $P = 0.31$ ,  $n = 5$ ).

The difference in average vitamin C between the canned cling (T0) peaches and the sample of fresh freestone (FF) peaches was significant (*t*-test,  $P \leq 0.0001$ ,  $n = 10$ ). Estimated mean vitamin C is 34 for canned cling peaches and 9 for fresh freestone peaches; 95% CIs are (17, 51) for canned cling and (6, 13) for freestone.



**Figure 4.** Total phenolics of canned and fresh peaches as measured by Folin–Ciocalteu reagent. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

The observed apparent increase of vitamin C with processing is likely due to the inactivation of native ascorbate oxidase during canning, which was not inactivated in the preparation of the fresh samples.<sup>1</sup> Subsequent tests have shown that the addition of a small amount of 10% PCA (containing 10 mmol L<sup>-1</sup> DTPA) to the extraction buffer should be used to bring the samples to ~pH 1.0 to protect and preserve ascorbic acid during sample extraction.

The average values reported here (9.5–55 mg kg<sup>-1</sup>) are comparable to that reported by others (40–130 mg kg<sup>-1</sup>, reported by Gil *et al.*<sup>16</sup> and 12–91 mg kg<sup>-1</sup>, reported by Cantin *et al.*<sup>17</sup>). Fresh peaches contribute a small portion of the RDA of vitamin C ranging from 1.1% to 3.8%, whereas canned peaches contribute over three times as much (3.8–13.6%).

### Antioxidants

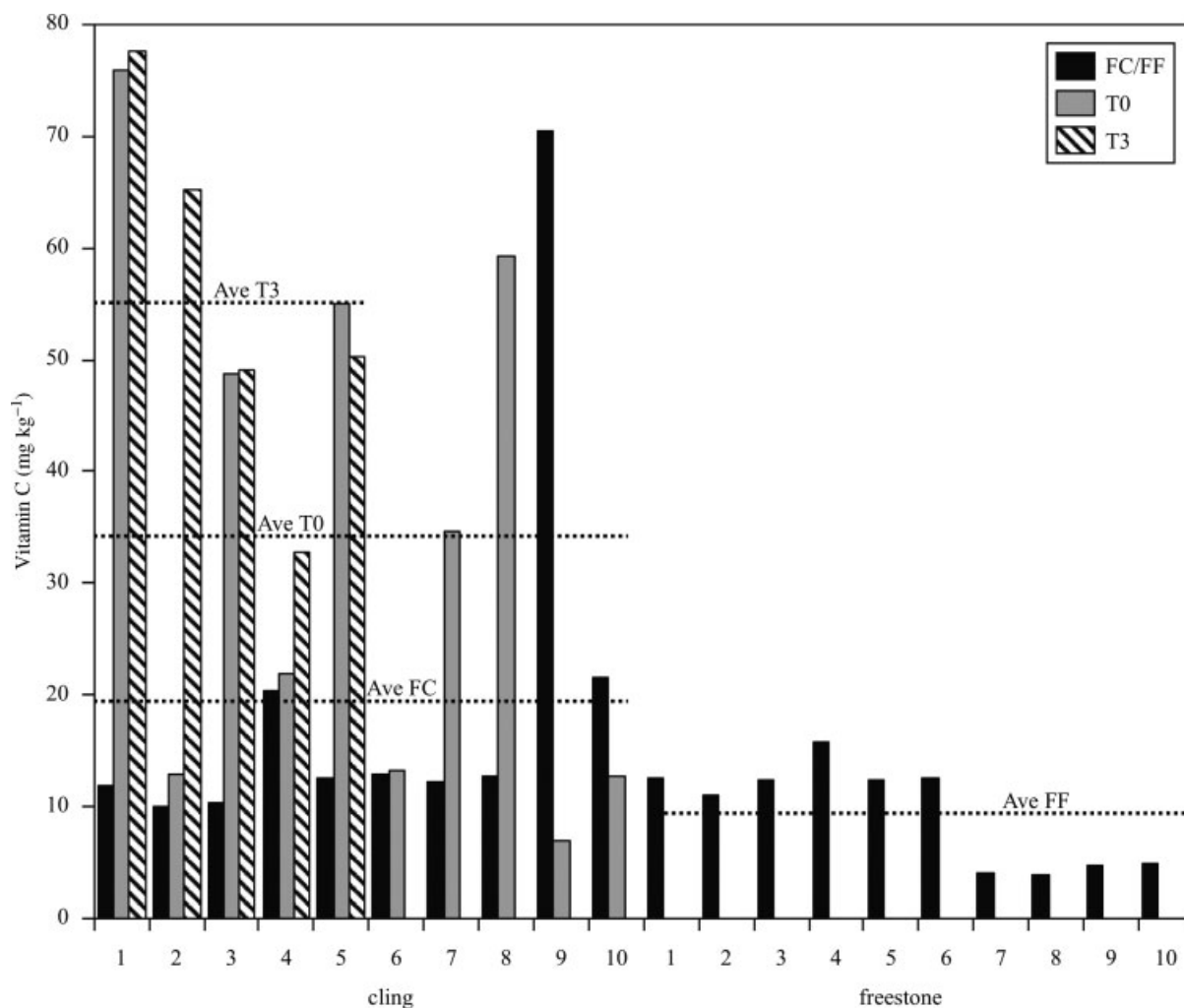
Figure 6 shows the results of the FRAP measurement. The fresh clings (FC) had an average of 11 990  $\mu\text{mol L}^{-1}$  Trolox equivalent (TE) kg<sup>-1</sup> with a range of 6250–18 620  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup>. The fresh freestones (FF) had an average of 9620  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup> with a range of 3540–23 500  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup>. The canned clings (T0) had an average of 15 580  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup> with a range of 6520–23 730  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup>. The canned and stored clings

(T3) had an average of 12 180  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup> with a range of 7680–16 610  $\mu\text{mol L}^{-1}$  TE kg<sup>-1</sup>.

The average difference in FRAP values between canned (T0) and fresh cling (FC) peaches was not significantly different from 0 (paired *t*-test,  $P = 0.106$ ,  $n = 10$ ). The average difference in FRAP values between canned (T0) and canned and stored (T3) cling peaches was not significantly different from 0 (paired *t*-test,  $P = 0.136$ ,  $n = 5$ ).

Table 1 shows that the difference in average FRAP values between the canned cling (T0) peaches and a sample of fresh freestone (FF) peaches is significant (*t*-test,  $P = 0.028$ ,  $n = 10$ ). Estimated mean FRAP is 15 580 for canned cling peaches and 9620 for fresh freestone peaches; 95% CIs are (11 680, 19 480) for canned cling and (5540, 13 700) for freestone.

The processed samples all had higher apparent levels of antioxidants than the fresh samples. This is most likely due to increased solubilization and/or inactivation of degradative enzymes during the canning process.<sup>1,2</sup> The canned cling sample (T0) had over 1.5 times the antioxidant level that the fresh freestone (FF) had, and was the only antioxidant comparison that was statistically significant (see Table 1). We found, as other researchers have, that there are wide variations in antioxidant measurements, some of which is due to genetic variability. Kader



**Figure 5.** Vitamin C content of canned and fresh peaches. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

*et al.*<sup>16</sup> found up to a 4.4-fold difference with variety and a three- to six-fold increase when the peel was included, which it was not in this study. Cantin *et al.*<sup>17</sup> found up to a three-fold difference with variety. Both found a good correlation between antioxidant level's and total phenolic content, but not with vitamin C levels.

**Folate**

The results of the folate measurement are summarized in Fig. 7. Fresh clings (FC) had an average of 5.9 μg kg<sup>-1</sup> with a range of 2.2–14.5 μg kg<sup>-1</sup>. The fresh freestones (FF) had an average of 2.0 μg kg<sup>-1</sup> with a range of 0.1–2.7 μg kg<sup>-1</sup>. The canned clings (T0) had an average of 22.4 μg kg<sup>-1</sup> with a range of 11.8–25.9 μg kg<sup>-1</sup>. The canned and stored clings (T3) had an average of 24.3 μg kg<sup>-1</sup> with a range of 20.3–27.4 μg kg<sup>-1</sup>.

Table 1 shows that the average difference in folate between canned cling (T0) and fresh cling (FC) is significantly different from 0 (paired *t*-test, *P* < 0.001, *n* = 10) with an average difference (fresh minus canned) of –16.56 and a 95% CI for the difference of (–20.5, –12.6). The average difference in folate between canned (T0) and canned and stored (T3) cling peaches is not significantly different from 0 (paired *t*-test, *P* = 0.213, *n* = 5).

Table 1 shows that the difference in average folate between the canned (T0) cling peaches and fresh freestone (FF) peaches

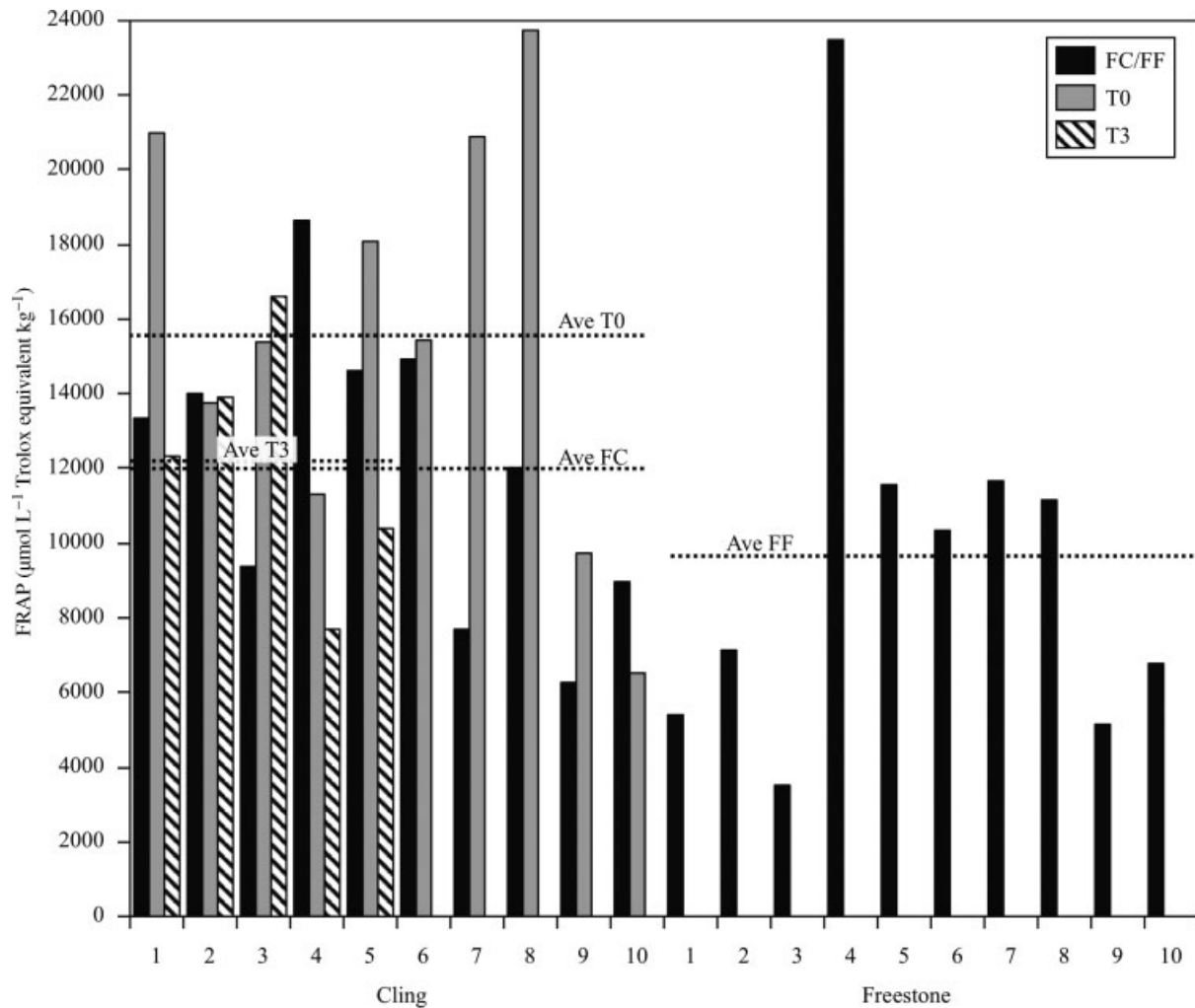
is highly significant (*n* = 10, *t*-test, *P* < 0.001). Estimated mean folate is 22.4 μg kg<sup>-1</sup> for canned cling (T0) peaches and 2.0 μg kg<sup>-1</sup> for fresh freestone (FF) peaches. 95% CIs are (19.4, 25.4) for canned cling (T0) and (17.6, 23.2) for freestone (FF).

The processed clings had more than 10 times the amount of folate compared to the fresh freestones. This may be due to solubilization of folate from the tissue matrix due to heating during the canning process, as the fresh clings had quite low levels also. The USDA nutritional database<sup>15</sup> lists values of 30–80 μg kg<sup>-1</sup> for canned peaches and 30–40 μg kg<sup>-1</sup> for raw peaches. From this study, canned peaches would be considered a minor source of folate, contributing only 0.5–1% of the daily requirement, and fresh peaches contributing almost nothing to the daily requirement (<0.1%).

**DISCUSSION**

The objective of this study was to assess whether canned peaches could deliver nutrient levels comparable to fresh peaches. It is impossible to directly compare changes in compositional and nutritional values between fresh and processed fruit, because there are varietal differences between peaches destined for fresh market (freestones) and those used for canning (clings). The pertinent





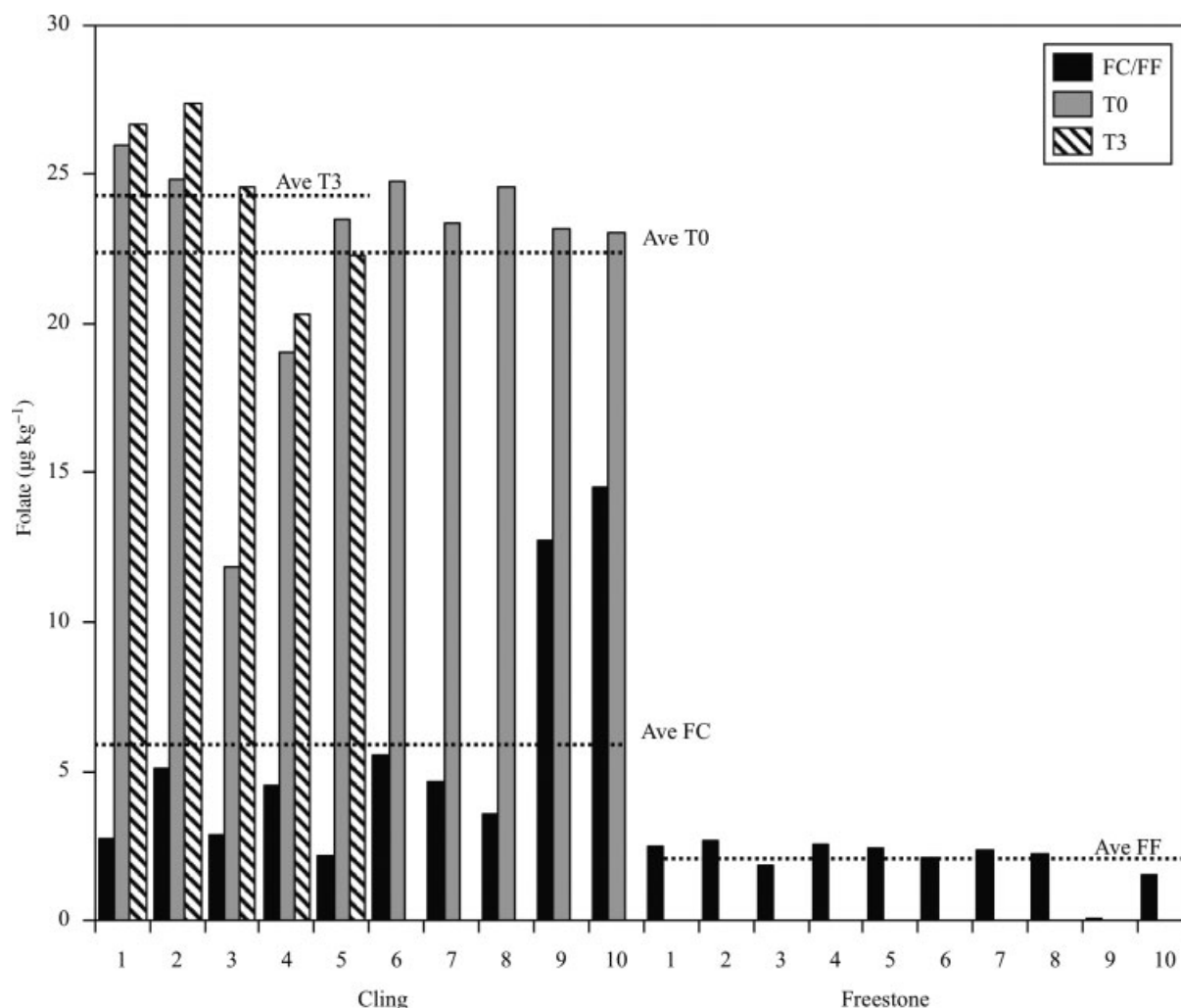
**Figure 6.** Antioxidant content of canned and fresh peaches as measured by the FRAP assay. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

comparisons are fresh freestones (FF) values versus canned cling (T0) to determine the nutritional differences in what the consumer is eating. In addition, the comparison of canned cling (T0) and canned and stored cling (T3) shows the stability during storage of the canned product.

The vitamins and phytochemicals that were measured in this study were found to be present in canned cling peaches (T0) at statistically significantly higher levels (vitamin C, antioxidants and folate); higher but not statistically different levels (vitamin A); or lower, but not statistically different levels (vitamin E, total phenolics and total carotenoids) than in fresh freestone peaches (FF). Vitamin C levels were found to be almost four times higher in canned (T0) than in fresh freestones (FF) and T0 retained those levels during the 3 month storage period (T3). Vitamin C was found in fresh cling (FC) to be two times greater than in fresh freestone (FF). Folate was found to be over 10 times higher in canned product (T0) than fresh freestones (FF) and again T0 retained that level during the storage period (T3). Folate was found in fresh cling (FC) to be three times higher than in fresh freestone (FF). Antioxidants were over 1.5 times higher in canned (T0) than fresh freestone (FF) and after 3 months storage (T3) still remained slightly higher than the fresh freestones (FF). The vitamin A level of the canned product (T0) dropped 30% during the canning process (T0 vs. FC) but was

retained at that level during the storage period (T0 vs. T3). The fresh freestones (FF) had a comparable level of vitamin A to the processed clings (T0). Total carotenoids showed a similar but not statistically significant trend. The vitamin E levels of the canned product (T0) dropped 20% during the canning process (T0 vs. FC) and dropped slightly during the storage period (15%) as has been shown by others.<sup>2</sup> The fresh freestones (FF) had a comparable level of vitamin E to the processed clings (T0). Total phenolics showed losses on canning (10%) and during storage (25%), but they were not statistically significant. This is likely explained by losses to the canning syrup as seen by others.<sup>1,18</sup>

In addition to the nutrient differences between canned cling and fresh freestone peaches, two other characteristics can be deduced from this study. First, were the changes due to processing by comparing fresh cling with canned cling measured immediately after canning (FC vs. T0); and, second, the retention of those nutrients in product stored for 3 months (T0 vs. T3). In the comparison of fresh cling (FC) with canned cling (T0) folate had statistically significant increases and antioxidants, total phenolics and vitamin C increased, but not significantly. Vitamins A and E, as well as total carotenoids, had statistically significant decreases and total phenolics decreased but not significantly. The effects of processing, especially on those vitamins and phytochemicals that



**Figure 7.** Total folate content of canned and fresh peaches. Fresh cling (FC), fresh freestone (FF), canned cling immediately after processing (T0) and canned cling after 3 months storage (T3).

**Table 2.** Contribution of peaches to the Recommended Dietary Allowance (RDA, %)

Vitamin/folate	Children (4–8 years)		Children (9–13 years)		Adolescents (14–18 years)		Adults	
	Fresh freestone	Canned cling	Fresh freestone	Canned cling	Fresh freestone	Canned cling	Fresh freestone	Canned cling
Vitamin A	8.7*	9.6	5.8	6.4	3.9	4.2	3.9	4.2/5.5 <sup>†</sup>
Vitamin E	2.0	1.6	1.3	1.0	1.0	0.8	1.0	0.8
Vitamin C	3.8	13.6	2.1	7.6	1.3	4.6/5.3	1.1	3.8/4.6
Folate	0.10	1.12	0.07	0.75	0.05	0.56	0.05	0.56

\* %RDA from a 100 g serving.

<sup>†</sup> Results are given for males/females when there is a difference in the RDA based on gender.

increased over fresh, may be due to unknown factors associated with processing, such as enzyme inactivation or tissue disruption leading to increased solubilization as has been reported by others.<sup>19</sup> One factor not taken into account in the decreases in some of these analytes is the diffusion of the analyte from the peach flesh into the canning medium as has been shown to occur,<sup>20</sup> but which was not measured in this study. In addition, there were no statistically significant changes in nutrient content upon storage for 3 months (T0 vs. T3). All of the other changes

appeared at processing. Since a number of different varieties were included in this study and it is known that there are wide varietal variations in composition, it is of interest to note that there were no statistically significant differences between fresh cling (FC) and fresh freestone (FF) except for folate, which was three times higher in FC than FF.

The nutritional content of canned peaches has been shown in this study to be comparable to that of fresh peaches. There were no statistically significant decreases in those nutritional parameters

measured in this study between fresh freestone peaches (FF) and canned cling peaches (T0). Vitamins A and E along with total carotenoids decrease immediately upon processing, but appear to stabilize after the processing step, showing minimal additional changes upon storage for 3 months. This may be due to the combined effects of processing conditions, dilution effect and equilibration with the canning syrup.<sup>21</sup> Any nutrients that leached out of the peach tissue into the syrup would not have contributed to these analyses, since the syrup was not measured. For those vitamins with established RDAs, the difference between eating a serving of canned peaches versus a serving of fresh peaches is small. See Table 2 for a comparison of the %RDA dietary contribution of canned versus fresh peaches according to this study.

## ACKNOWLEDGEMENTS

This work was funded by a grant from the California Cling Peach Board. Thanks to Scott Leonard (LPI) for assistance with the vitamin E analyses.

## REFERENCES

- Rickman JC, Barrett DM and Bruhn CM, Review nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds. *J Sci Food Agric* **87**:930–944 (2007).
- Rickman JC, Bruhn CM and Barrett DM, Review nutritional comparison of fresh, frozen and canned fruits and vegetables. Part II. Vitamin A and carotenoids, vitamin E, minerals and fiber. *J Sci Food Agric* **87**:1185–1196 (2007).
- Institute of Medicine, *Child and Adult Care Food Program: Aligning Dietary Guidance for All*. The National Academies Press, Washington, DC (2011).
- Andreotti C, Ravaglia D, Ragaini A and Costa G, Phenolic compounds in peach (*Prunus persica*) cultivars at harvest and during fruit maturation. *Ann Appl Biol* **153**:11–23 (2008).
- Tomás-Barberán FA, Gill MI, Cremin P, Waterhouse AL, Hess-Pierce B and Kader AA, HPLC-DAD-ESIMS analysis of phenolic compounds in nectarines, peaches, and plums. *J Agric Food Chem* **49**:4748–4760 (2001).
- Asami DK, Hong Y-J, Barrett DM and Mitchell AS, Processing-induced changes in total phenolics and procyanidins in clingstone peaches. *J Sci Food Agric* **82**:56–63 (2002).
- Rodriguez GA, *Handbook of Food Analytical Chemistry: Pigments, Colorants, Flavors, Texture, and Bioactive Food Components*, ed. by Wrolstad RE. John Wiley & Sons, New York, pp. 71–80 (2005).
- Benzie FF and Strain JJ, Ferric reducing antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods Enzymol* **299**:15–23 (1999).
- Scott KJ, *Handbook of Food Analytical Chemistry: Pigments, Colorants, Flavors, Texture, and Bioactive Food Components*, ed. by Wrolstad RE. John Wiley & Sons, New York, pp. 81–90 (2005).
- Craft NE, *Handbook of Food Analytical Chemistry: Pigments, Colorants, Flavors, Texture, and Bioactive Food Components*, ed. by Wrolstad RE. John Wiley & Sons, New York, pp. 91–105 (2005).
- Podda M, Weber C, Traber C, Traber MG and Packer L, Simultaneous determination of tissue tocopherols, tocotrienols, ubiquinol and ubiquinones. *J Lipid Res* **37**:893–901 (1996).
- Waterhouse AL, *Handbook of Food Analytical Chemistry: Pigments, Colorants, Flavors, Texture, and Bioactive Food Components*, ed. by Wrolstad RE. John Wiley & Sons, New York, pp. 463–470 (2005).
- Official Methods of Analysis (2005) AOAC International, Gaithersburg, MD, USA, Method 2004.05.
- Aczel A, Change of the carotenoid contents of yellow peach during the canning process and storage. *Lebensm-Wiss Technol* **10**:120 (1977).
- US Department of Agriculture, National Nutrient Database for Standard Reference, Release 23, NDB Nos: 09438, 09240, 09236 (2010).
- Gil MI, Tomas-Barberan FA, Hess-Pierce B and Kader AA, Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. *J Agric Food Chem* **50**:4976–4982 (2002).
- Cantin CM, Moreno MA and Gogorcena Y, Evaluation of the antioxidant capacity, phenolic compounds, and vitamin C content of different peach and nectarine [*Prunus persica* (L.) Batsch] breeding progenies. *J Agric Food Chem* **57**:4586–4592 (2009).
- Chaovanalikit A and Wrolstad RE, Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. *J Food Sci* **69**:FCT67–FCT72 (2004).
- Lessin WJ, Catigani GL and Schwartz SJ, Quantification of *cis-trans* isomers of provitamin A carotenoids in fresh and processed fruits and vegetables. *J Agric Food Chem* **45**:3726–3732 (1997).
- Sharma KD, Kaushal M and Kaushal BBL, Canning of peach halves in fruit juice. *J Sci Ind Res* **61**:823–827 (2002).
- Hong Y-J, Barrett DM and Mitchell AE, Liquid chromatography/mass spectrometry investigation of the impact of thermal processing and storage on peach procyanidins. *J Agric Food Chem* **52**:2366–2371 (2004).