Effect of a blueberry nutritional supplement on macronutrients, food group intake, and plasma vitamin E and vitamin C in US athletes

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Effect of a blueberry nutritional supplement on macronutrients, food group intake, and plasma vitamin E and vitamin C in US athletes

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Abstract
Antioxidants from a blueberry beverage may impact plasma vitamins. We examined vitamins/food selection in 12 college athletes during 30 days compared with placebo. Blood was collected before and after exercise at the beginning of the study (day 1) and then after a 30-day period of taking a daily supplemental beverage (day 30). The six trials involved blood that was drawn pre-beverage ingestion/pre-exercise (trials 1 and 4), post-beverage ingestion/pre-exercise (trials 2 and 5), and post-beverage ingestion/1 h post-exercise (trials 3 and 6), on day 1 (trials 1, 2, and 3) and day 30 (trials 4, 5, and 6). Analysis of variance revealed non-significant differences for macronutrient or γ-tocopherol and vitamin C intakes by food frequency questionnaire or plasma vitamins by liquid chromatography. There was a trend (P = 0.083) in the group × time interaction for α-tocopherol intake by repeated-measures analysis of variance. Blueberry α-tocopherol (23.91 ± 9.31 mg) was significantly (P < 0.05) higher than placebo α-tocopherol intake (7.59 ± 0.95 mg) on day 1, but not on day 30 (blueberry, α-tocopherol = 9.04 ± 2.35 mg, placebo, α-tocopherol = 11.46 ± 3.65 mg) by pairwise comparisons. Blueberry supplementation did not affect plasma vitamin C.
vitamin concentrations or γ-tocopherol and vitamin C intakes, and may reduce α-tocopherol intake in those starting with a higher α-tocopherol intake, yet not altering athletes’ eating habits.

**Keywords:** Blueberry antioxidants, food selection assessment, endurance exercise

**Introduction**

Free radicals are involved with the deterioration of biological systems leading to pathogenesis and the aging process (Yu and Chung 2006). Antioxidants have been demonstrated to inactivate free radicals both *in vitro* and *in vivo*. A study involving diet modulation with high antioxidant-containing wild lowbush blueberries (*Vaccinium angustifolium* L.) has shown great promise in preventing the damaging effects on neurons from free radicals (Joseph et al. 1999). The antioxidant polyphenols found in blueberries have been shown to reverse age-related declines in neuronal and brain function (Lau et al. 2005). Blueberries also contain anthocyanins, a class of phytochemicals that can modify antioxidant pathways in human subjects (Lampe 1999) and may have overlapping mechanisms of action as synergistic or inhibitory with other phytochemicals that are present in fruit, including antioxidant vitamins. Blueberries have one of the highest oxygen radical absorbance capacities levels of all fruits and vegetables at 24.0 μmol Trolox equivalents/g (Prior et al. 1998; Sánchez-Moreno et al. 2003).

The influence of anthocyanins on biological systems might be due to their ability to form complexes with macromolecules (Mazza et al. 2002). Dietary supplementation with freeze-dried blueberry powder increased the postprandial plasma antioxidant status in humans with high fat intake (Kay and Holub 2002). Anthocyanins, along with other phenolic compounds within the blueberry extract, may regenerate oxidized lipid-soluble antioxidants in the plasma, similar to how vitamin C regenerates vitamin E (Niki et al. 1989). Less documented is the interactive role of anthocyanins with plasma antioxidant vitamins E and C, and the intake of these vitamins on nutritionally supplemented diets. Vitamin E isoforms and vitamin C have been evaluated as antioxidants in the diet (Martin et al. 1996; Martin and Frei 1997). The biochemical effect of blueberry-rich diets may effect the regulation of antioxidants.

If antioxidants can increase memory and prevent aging in humans, blueberry-supplemented diets may help increase human lifespans. Young adults and teenagers often have irregular and nutritionally unbalanced diets, so this study was conducted to assess the intake of the basic food groups in college student athletes in response to daily intake of a natural blueberry beverage, or a blueberry-flavored, pigmented and textured placebo beverage for a period of 30 days. This study aimed to examine the antioxidant benefits that blueberry phytochemicals would offer by measuring representative plasma antioxidants.

We hypothesize that taking a 30-day antioxidant-supplemented diet of wild blueberries in beverage form may consequently increase plasma antioxidant vitamin E isoforms and vitamin C, and may change their dietary intake levels. These plasma levels may lead to altered cravings and satiation, and therefore, in turn, may alter subsequent intake of macronutrients, particular food groups, along with antioxidant vitamins in college student athletes.
Subjects and methods

Subjects

A convenience sample of 12 (six male/six female) University of Detroit Mercy/Oakland University student athletes, active in cross-country or basketball teams, or engaging in regular endurance activities, 18–24 years of age, were eligible and enrolled for this prospective study, during 30 days. This sample size was first estimated to be sufficient for significant differences at $P < 0.05$ based upon common metabolic variances that are found within the population studied. The University of Detroit Mercy and Oakland University Institutional Review Boards approved the proposal and informed consent; furthermore, the study was conducted in compliance with Health Insurance Portability and Accountability Act guidelines. All subjects signed informed consent forms prior to commencement of the study. Subjects were randomly allocated into experimental (blueberry beverage) or control (placebo beverage) groups. The subjects completed current and past health status forms. Subjects completed medical history forms for study participation. A 24-h trial period was conducted to observe whether any of the screened participants experienced any allergic responses to the beverages (edema, erythema or hive). Other exclusion criteria included tobacco or medication use, chronic conditions such as thyroid disease, diabetes mellitus, asthma, recent infections and a pregnant state. A pregnancy test for urinary human chorionic gonadotropin (Rapidvue; Quidel, San Diego, CA, USA) was conducted. No subjects were excluded from the commencement of the study.

Beverage intervention

On day 1, the subjects in both groups (blueberry and placebo groups) were asked to avoid blueberry-containing foods apart from the blueberry beverage, and also to not intentionally change any other dietary habits for the duration of this study (30 days). Investigators delivered beverages to the residences of each of the participants three times per week, and did not know until the end of the study to what beverage they were assigned. The subjects drank the chilled beverages (237 ml) daily at their noon meal until the end of the intervention (day 30).

The natural blueberry beverage, using nearly 45 kg wild blueberries, and the placebo beverage were prepared in a co-investigator’s kitchen, verbally approved by the Oakland County Board of Health (Michigan) with recipes as described in Table I. The recipes were developed at and the blueberries supplied by the Metabolic Research Laboratory at the USDA Jean Mayer Human Nutrition Research Center on Aging (HNRCA), Tufts University, Boston, MA. The HNRCA analyzed the blueberry and placebo beverages for fats, protein, carbohydrates, vitamin C, and α-tocopherol and γ-tocopherol content (Table II).

Nutritional status assessment

To assess the nutritional status and macronutrient intake of subjects, food frequency questionnaires (FFQs) are often employed. The Block FFQ is based on over 11,000 US nationwide respondents to the Second National Health and Nutrition Examination Survey (NHANES II) (Block et al. 1986). This dietary assessment is also known as the National Cancer Institute’s Health Habits and History Questionnaire (HHHQ), and the modified version used in this study is the Fred Hutchinson Cancer
Research Center FFQ (Kristal et al. 1994). After consent and before any other testing took place, we used this modified Block FFQ (Form N-1, revised 6/10/1988) to assess daily intake of the macronutrients (fats, protein and carbohydrates) on day 1 and day 30. Participants took approximately one-half-hour to complete this self-administered eight-page questionnaire. The FFQ on day 1 was taken without previous exposure to either beverage, while the FFQ on day 30 had 30 days of exposure to either beverage. FFQ responses were analyzed by the Dietary Assessment Department at the HNRCA using the Statistical Analysis System (2000; Cary, NC, USA), which calculated the crude weight intakes as absolute values and not adjusted for energy intake. Specialized food groups categorized on the FFQ as fruits and juices, vegetables, meats and restaurant foods were analyzed for each subject’s frequency of intake as medium-sized servings per 30 days, because all subjects maintained an average of medium-sized portion intake throughout the study, as documented by the FFQ.

**Physiologic determinations**

The subjects exercised after 1 h of beverage digestion. Blood was collected before and after exercise at the beginning of the study (day 1) and then after a 30-day period of taking a daily supplemental beverage (day 30). The six trials involved blood that was

<table>
<thead>
<tr>
<th>Blueberry beverage</th>
<th>Placebo beverage</th>
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<tbody>
<tr>
<td>1 230.0 g blueberries (containing 14.3 g fructose)</td>
<td>1 3.5 g Kool-Aid ‘Blastoff’ flavor</td>
</tr>
<tr>
<td>2 2.0 g Kool-Aid ‘Blastoff’ flavor (dry, unsweetened powder)</td>
<td>2 1.0 g coarse wheat bran</td>
</tr>
<tr>
<td>3 303.0 g water</td>
<td>3 5.5 g fine wheat bran</td>
</tr>
<tr>
<td>4 6.0 g fructose</td>
<td>4 31.0 g fructose</td>
</tr>
<tr>
<td>5 302.0 g water</td>
<td>5 2.0 g pectin</td>
</tr>
<tr>
<td>6 302.0 g water</td>
<td>6 1.0 g aspartame (brand name Nutrasweet)</td>
</tr>
<tr>
<td>7 100.0 g water</td>
<td>7 100.0 g water</td>
</tr>
<tr>
<td>8 697.0 g water</td>
<td>8 697.0 g water</td>
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<tr>
<td>9 Food coloring to match blueberry beverage that one will experiment with</td>
<td>9 Food coloring to match blueberry beverage that one will experiment with</td>
</tr>
</tbody>
</table>

Blend blueberries thoroughly, approximately 2 min. Add Kool-Aid, fructose and 303.0 g (about half) of the water—blend. Add remaining water (302.0 g) and blend again. Serve chilled. Make a serving of 237 ml

Combine ingredients 1–7 in a large saucepan. Heat to a boil, and boil for 1 min. Add remaining water (697.0 g) and stir. This placebo beverage should approximate similar flavor, color, and texture of the blueberry beverage. Serve chilled. Make a serving of 237 ml

Table I. Placebo and blueberry ingredients and recipes.

<table>
<thead>
<tr>
<th>Table II. Nutrient content for the two beverages.</th>
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<tr>
<td>Beverage contents</td>
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<td>-------------------</td>
</tr>
<tr>
<td>Fats (g)</td>
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<tr>
<td>Protein (g)</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
</tr>
<tr>
<td>Vitamin E-α (mg)</td>
</tr>
<tr>
<td>Vitamin E-γ (mg)</td>
</tr>
</tbody>
</table>

*Nutrient Data System for Research (VR 4.02/30); 230 g blueberries per 237 ml beverage were used.*
drawn pre-beverage ingestion/pre-exercise (trials 1 and 4), post-beverage ingestion/ pre-exercise (trials 2 and 5), and post-beverage ingestion/1 h post-exercise (trials 3 and 6), on day 1 (trials 1, 2, and 3) and day 30 (trials 4, 5, and 6). In all the plasma samples, the levels of \( \alpha \)-tocopherol and \( \gamma \)-tocopherol and vitamin C were analyzed. Body mass indices were also determined. Subjects exercised on a Monark bicycle ergometer for a 15 min warm-up and then directly into 30 min at 85\% of their age-predicted maximum heart rates on days 1 and 30. Power outputs were recorded in watts and kilopound meters per minute.

**Blood sample preparation**

For vitamin E and vitamin C levels, 10 ml blood samples were drawn from a forearm vein with an indwelling plastic catheter three times on each subject—pre-237 ml beverage intake/pre-exercise, post-beverage intake/pre-exercise, and post-beverage intake/1 h post-exercise—on day 1 and day 30 of the study. Blood samples were collected in heparin-coated tubes and centrifuged at 2,000×g for 15 min at 4°C. After plasma was collected, aliquots in triplicate were immediately mixed with an equal volume of cold 60 g/l metaphosphoric acid containing 1 mmol/l metal ion chelator diethylenetriaminepentaaacetic acid for vitamin C analysis. The rest of the plasma was stored at −80°C for vitamin E analysis. Samples were packaged in dry ice and sent to Tufts University (Neuroscience Laboratory) for vitamin E and vitamin C analysis as described.

**Plasma measurements of vitamin E (\( \alpha \)-tocopherol and \( \gamma \)-tocopherol)**

The tocopherol concentration of plasma was measured by reverse-phase high-performance liquid chromatography (HPLC). Tocol (a gift from Hoffmann-La Roche, Nutley, NJ, USA) was added to the mixture as an internal standard. Samples were centrifuged at 125×g for 5 min at 4°C. The supernatant was collected and dried under a stream of nitrogen gas, and reconstituted in 100 μl methanol. Tocopherols were separated by reverse-phase HPLC using a 3-mm C18 reverse-phase column (Perkin-Elmer, Boston, MA, USA). The mobile phase was delivered at a flow rate of 1.0 ml/min, consisting of 1% water in methanol, and containing 10 mmol/l lithium perchlorate. Samples were injected with an autosampler (1100 series; Hewlett-Packard, Wilmington, DE, USA). Eluted peaks were detected at an applied potential of +0.6 V by a LC 4B amperometric electrochemical detector (Bioanalytical Systems Inc., West Lafayette, IN, USA). Tocopherols were eluted as well-separated peaks with a retention time from 2 to 6 min. Peaks were integrated with a ChemStation (Hewlett-Packard) and tocopherol concentrations were expressed in micromoles per liter. Samples were analyzed for vitamin concentrations by reverse-phase HPLC (Sánchez-Moreno et al. 2004).

**Plasma measurements of vitamin C**

Ascorbate was analyzed in plasma by paired-ion, reverse-phase HPLC. Briefly, a 100-μl plasma sample was mixed with an equal volume of cold 6% (wt:vol) metaphosphoric acid containing 1 mmol/l metal ion chelator diethylenetriaminepentaaacetic acid (Sigma-Aldrich, St Louis, MO, USA). A portion of the sample was analyzed on a LC8 column (150 mm × 4.6 mm i.d., 3-μm particle size, Supelco; Sigma-Aldrich) using 99% deionized water and 1% methanol containing 40 mmol/l
sodium acetate and 1.5 mmol/l dodecyltriethylammonium phosphate (Q12 ion pair cocktail; Regis Technologies, Morton Grove, IL, USA) as the mobile phase delivered at a flow rate of 1 ml/min. Samples were injected with an autosampler (Agilent 1100 series; Hewlett-Packard). Ascorbate was detected at an applied potential of +0.6 V with the gain set at 100 nA by a LC 4B amperometric electrochemical detector (Bioanalytical Systems, Inc.). Ascorbate was eluted as a single peak with a retention time of 5.5 min. Peaks were integrated with a ChemStation (Hewlett-Packard). The ascorbate concentration was calculated on the basis of a calibration curve, and its concentration expressed in micromoles per liter (Sánchez-Moreno et al. 2004).

Statistics

Values are presented as the mean ± standard deviation or standard error of the mean when appropriate. The Statistical Package for the Social Sciences (SPSS VR11; Chicago, LC, USA) was used for univariate analysis of variance (ANOVA) with repeated measures—one-way ANOVA (group [placebo, blueberry] by time [day 1 – day 30]) with significance set at $P < 0.05$. If any significant (or trend: $0.05 \leq P \leq 0.10$) group effect or group × time or group × trial interactions were found, then pair-wise comparisons were used to find differences between beverage groups. For determining changes in the amount of servings in the food groups between time periods, a dependent $t$-test was used.

Results

The body mass index for the placebo group was $21.6 \pm 3.31$ kg/m$^2$ (mean ± standard deviation) and the experimental group was $22.1 \pm 1.53$ kg/m$^2$. The body mass index was not significantly different between the two groups, and did not change significantly during the study. Nine of the subjects were on the beverage for 29 days, while two of the subjects were on it for 28 days and one of the subjects for 30 days. ANOVA revealed no significant group or group × time differences between the blueberry and the placebo groups for fats, protein or carbohydrate intake by FFQ for day 1 and for day 30 (Table III). A dependent $t$-test demonstrated no significant differences within group changes for intake in servings per 30 days for any of the foods categories in either the blueberry or placebo beverage groups. However, a dependent $t$-test demonstrated a significant ($P < 0.05$) decrease in servings of lunchmeat when blueberry and placebo beverages were considered as a combined beverage intervention for 30 days. There was no significant difference in the intake of fruits and juices, vegetables and restaurant foods with the combined beverage intervention for 30 days.

A semi-quantitative assessment was performed by adding the daily intake of either of the two beverages as a supplement on day 1 and day 30 to either of the cumulative blueberry group’s or placebo group’s daily intake of fats, protein or carbohydrates. Intake at day 1 and at day 30 (Table II) demonstrated a decrease in fat, protein and carbohydrate intakes during the 30-day period of the experiment in both the blueberry and placebo groups, except for the increase in carbohydrate intake in the placebo group after 30 days.

The intakes of $\alpha$-tocopherol (Figure 1), $\gamma$-tocopherol (Figure 2) and vitamin C (Figure 3) are presented for day 1 and day 30 for both groups. Plasma $\alpha$-tocopherol
(Figure 4), plasma γ-tocopherol (Figure 5) and plasma vitamin C (Figure 6) levels are reported for day 1 (trials 1, 2 and 3) and day 30 (trials 4, 5 and 6) for both groups. ANOVA demonstrated no significant differences for vitamin intake. Furthermore, ANOVA revealed no significant variations for plasma vitamins. There was a trend ($P = 0.083$) in the group × time interaction for α-tocopherol intake by repeated-measures ANOVA. In addition, ANOVA and pair-wise comparisons revealed a trend ($P = 0.087$) in the effect over time for γ-tocopherol intake for both groups during 30 days.

All subjects achieved the targets of 85% of their age-predicted maximum heart rates for both day 1 and day 30 at peak exercise by cycle ergometry. Peak exercise resulted in averaged power outputs of 167 W (1,001 kp·m/min) for the experimental group and 162 W (972 kp·m/min) for the placebo group.

<table>
<thead>
<tr>
<th></th>
<th>Blueberry beverage group</th>
<th>Placebo beverage group</th>
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<tbody>
<tr>
<td></td>
<td>FFQ (g)</td>
<td>Beverage (g)</td>
</tr>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fats</td>
<td>101.80 ± 16.84</td>
<td>0.00</td>
</tr>
<tr>
<td>Protein</td>
<td>114.73 ± 16.54</td>
<td>0.00</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>326.23 ± 40.24</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Day 30</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fats</td>
<td>74.60 ± 15.54</td>
<td>0.87</td>
</tr>
<tr>
<td>Protein</td>
<td>84.24 ± 12.61</td>
<td>1.54</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>270.36 ± 34.37</td>
<td>40.5</td>
</tr>
</tbody>
</table>

Data presented as the mean ± standard error of the mean. 0.00 in columns indicate that the respective beverages were not yet taken by the day the FFQ was given.

Figure 1. There were no significant group or group × time differences for α-tocopherol intake by the FFQ, based on repeated-measures ANOVA. However, there was a trend ($P = 0.083$) in the group × time interaction for α-tocopherol intake. Values are means ± standard error of the mean.
Discussion

Dietary intake parameters

The nutritional components of the blueberry or placebo beverages had no influence to change the diet of college team athletes during 30 days as reflected by macronutrient intake changes by the FFQ. There were non-significant differences for fat, protein and carbohydrate intakes between day 1 and day 30. However, a type II error is possible because of our small sample size. The FFQ used in this study was designed to potentially reflect up to the last 3 months of the dietary intake by the subjects. Posthoc analyses and follow-up telephone calls demonstrated that no subject recorded the beverage in their FFQ. In as much as the students did not know whether they received blueberry or placebo beverages, there may be an influence on this knowledge by the different ingredients. This is based on a detectable but undefined taste, color and texture, of either beverage, characteristic of the ingredients present.

Figure 2. There were no significant group or group × time differences for \( \gamma \)-tocopherol intake by FFQ, based on repeated-measures ANOVA. However, ANOVA and pair-wise comparisons revealed a trend \( (P=0.087) \) in the effect over time for \( \gamma \)-tocopherol intake for both groups during 30 days. Values are means ± standard error of the mean.

Figure 3. There were no significant group or group × time differences for vitamin C intake by FFQ, based on repeated-measures ANOVA. Values are means ± standard error of the mean.
With the more detailed grouping of fruits and juices, vegetables, meats and restaurant categories on the FFQ, lunchmeat servings decreased significantly with beverage imbibement during 30 days. It is likely that the two beverages, although different in their composition, are dense or highly concentrated with dietary fiber bulk in the blueberries or in the wheat bran, the latter in the placebo beverage, and are thus very filling, as meat may be, so therefore satiation with dense foods may have occurred. The behavioral components of food selection may be influenced by specific plasma metabolites of the actual macronutrient intake. Future studies will attempt to relate these variables, which were not evaluated in this investigation. Appetite and satiety measurements can be accomplished through additional questionnaires and/or through physiologic determinations of actually measuring hunger or satisfaction upon energy loading over time, and have been thoroughly investigated (Bolton et al. 1981; Rodin et al. 1988; Rogers et al. 1988; Rodin 1990; Rolls et al. 1994; Lavin et al. 1997; Roberts 2003).

Figure 4. There were no significant group or group × trial differences for plasma α-tocopherol concentration, based on repeated-measures ANOVA. Values are means ± standard error of the mean.

Figure 5. There were no significant group or group × trial differences for plasma γ-tocopherol concentration, based on repeated-measures ANOVA. Values are means ± standard error of the mean.
In other studies, FFQ assessments have been utilized in relation to the laboratory measurements of physiologic variables such as plasma concentrations of vitamins and other antioxidants (Willett et al. 1987; Kristal et al. 2000; Block et al. 2001). FFQs are often employed to assess the nutritional status of a subject and the respective intake of macronutrients or micronutrients. In addition to the modified Block FFQ (Block et al. 1986; Kristal et al. 1994) that we used to assess food and beverage intake, others have employed motivation-based assessments for determining readiness to increase fruit and vegetable intake among 18–24 year olds (Ma et al. 2001).

Plasma vitamin concentration parameters

Daily intake of the blueberry beverage, containing higher concentrations of the vitamins E isoforms and vitamin C, may accelerate oxidative pathways in nutrient metabolism. The cellular metabolism of macronutrients may affect vitamin plasma levels, satiation and, hence, food selection toward intake of foods containing these vitamins (Cummings and Overduin 2007). Vitamin E is the most potent antioxidant that can break the propagation of the free radical chain reaction in the lipid part of the biological membrane. In addition, humans and other primates cannot synthesize vitamin C, whereas most mammals (e.g. rat and mouse) produce it endogenously in the liver (Champe and Harvey 1994; Gilgun-Sherki et al. 2001). Therefore, humans must consume antioxidant-rich foods, such as blueberries, to maintain a concentration sufficient enough to provide protection against oxidative stress. Overall, blueberry ingestion did not affect vitamin E isoforms and vitamin C intakes. Although the intake during 30 days of \( \alpha \)-tocopherol suggests that, by demonstrating a trend, the high plasma levels of this isoform prior to the study may have in some way caused the subjects to reduce the \( \alpha \)-tocopherol intake in their normal diet. \( \alpha \)-Tocopherol, bound by a protein, is the most abundant tocopherol in human tissue, and has a longer half-life in the plasma than vitamin C, which is not protein bound (Schwedhelm et al. 2003). Moreover, vitamin C regenerates vitamin E (Gilgun-Sherki et al. 2001) and, under oxidative stress, vitamin C spares \( \alpha \)-tocopherol (Joseph et al. 1999). Finally, nerve endings contain the highest concentrations of vitamin C in human tissue, while

Figure 6. There were no significant group or group \( \times \) trial differences for plasma vitamin C concentration, based on repeated-measures ANOVA. Values are means ± standard error of the mean.
among various vitamin E components only \( \alpha \)-tocopherol is involved in neuronal membranes (Bourre 2004), perhaps playing some role in the chemical pathways involved in satiety. This reasoning supports the results of our work, as well, in that \( \alpha \)-tocopherol is the lowest vitamin isoform concentration in the blueberry beverage of all three vitamins (\( \alpha \)-tocopherol, \( \gamma \)-tocopherol and vitamin C), and was the highest of the two vitamin E isoforms in the plasma. Vitamin C concentration was the highest in the blueberry beverage and in the plasma.

**Conclusions**

Blueberry supplementation may not affect plasma vitamin E isoforms and vitamin C levels before or after exercise and may not affect \( \gamma \)-tocopherol and vitamin C intake. In addition, blueberry supplementation may reduce the \( \alpha \)-tocopherol intake in those starting with a higher \( \alpha \)-tocopherol intake. Investigations on the effect of a fruit beverage on the intake of vitamins in active college students may support intervention programs on improving diets of young adults for enhancing fruit and vegetable consumption. At the very least, the blueberry beverage increases fruit consumption in this mode by one serving per day.

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