CONSUMPTION OF TOMATO PRODUCTS WITH OLIVE OIL BUT NOT SUNFLOWER OIL INCREASES THE ANTIOXIDANT ACTIVITY OF PLASMA

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Abstract—Health benefits of lycopene from tomato products have been suggested to be related to its antioxidant activity. Dietary fat may influence the absorption and hence the plasma levels and antioxidant activity of lycopene. In the present study, we have compared the effect of consumption of tomato products with extra-virgin olive oil vs. tomato products plus sunflower oil on plasma lycopene and antioxidant levels. Results show that the oil composition does not affect the absorption of lycopene from tomato products because similar levels of plasma lycopene (mean ± SD) were obtained on feeding tomatoes (providing approximately 46 mg lycopene/d) for 7 d with either olive oil (0.66 ± 0.26 µmol/l, p < .002) or sunflower oil (0.67 ± 0.27 µmol/l, p < .001). However, consumption of tomato products with olive oil significantly raised the plasma antioxidant activity (FRAP) from 930 ± 150 to 1118 ± 184 µmol/l, p < .01) but no effect was observed when the sunflower oil was used. The change (supplementation minus start values) in FRAP following the consumption of tomato products with oil was significantly higher for olive oil (190 ± 101) than for sunflower oil (−9.6 ± 99, p < .005). In conclusion, the results of the study show that consumption of tomato products with olive oil but not with sunflower oil improves the antioxidant activity of the plasma. © 2000 Elsevier Science Inc.

Keywords—Tomato, Lycopene, Antioxidant, FRAP, Olive oil, Sunflower oil, Free radicals

INTRODUCTION

The protective effect of the Mediterranean diet against the risk of cancer and cardiovascular disease has been attributed to various dietary components, e.g., carotenoids from fruits and vegetables, flavonoids from the red wine and monounsaturated and polyphenolic components of the olive oil [1,2]. In vivo supplementation studies on human subjects with “Mediterranean foods” have shown protective effects on several risk factors linked to cardiovascular disease [3–6]. In case of carotenoids, it has been suggested that the dietary fat can influence the absorption and also the antioxidant effects of these compounds [7,8]. Lycopene, a major carotenoid present in tomatoes, has been reported to show antioxidant activity both in vitro and in vivo [9,10]. Heating tomatoes with fat is suggested to increase the bioavailability of lycopene [8] but it is not known whether the composition of fat can affect the bioavailability and plasma antioxidant activity when consumed with tomato products. Both mono- and polyunsaturated fats are considered “healthier” than saturated fat since the latter is associated with higher blood cholesterol concentrations [11]. In addition, in human supplementation studies, monounsaturated fatty acids have been shown to reduce [6] and polyunsaturated fatty acids to increase the oxidation of low-density lipoprotein (LDL) [12,13].

The present study was conducted to determine whether cooking of tomatoes with different oils (olive oil vs. sunflower oil) affects the plasma lycopene concentration and total plasma antioxidant activity.

METHODS

Subjects and study design

Eight healthy subjects (5 female, 3 male), average age 22 years (range 20–24) were recruited for the study.
Subjects’ lipid profile, blood count, and liver function were within the normal range. Average weight and body mass index of the subjects were 60 ± 2.1 Kg and 22 ± 2.6 Kg/m², respectively. Ethical approval for the study was obtained from the University of Ulster Ethical Committee and all subjects gave signed informed consent prior to participation in the study. Two subjects withdrew at the beginning of the study: one did not turn up for the baseline blood sample and a second subject withdrew for personal reasons. Six subjects (5 female and 1 male) completed the study. Subject number was considered sufficient for the study as several studies have shown a significant effect of treatment with a smaller number (5–7) of subjects [5,14,15]. Subjects were allowed to continue their normal dietary habits but asked to incorporate an additional intake of tomato products with either olive or sunflower oil.

The study period was 5 weeks. Blood samples were obtained from subjects following an overnight fast of at least 10 h. At the baseline, 15 ml blood sample (10 ml in heparinized, 5 ml in plain tubes) was obtained with Vacutainers (Becton Dickinson Vacutainer Systems, Cedex, France) and subjects were asked to consume 200 g of tomato soup (Heinz Co. Ltd., Uxbridge, UK) providing approximately 33 mg lycopene, and 230 g canned tomatoes (Safeway, Middlesex, UK) providing approximately 13 mg lycopene, with 20 ml of olive oil (Greek extra-virgin olive oil, Safeway, Middlesex, UK) every day for 7 d. Tomato soup was heated with oil prior to consumption and most subjects either consumed it on its own or with bread. Canned tomatoes were also consumed after heating with oil and mixed with other food (i.e., meat, pasta, lasagne, vegetables, etc.). At the end of the first supplementation period, a second blood sample was obtained. Subjects were asked to return after a 3 week washout period and were supplemented for a further 7 d with the similar amounts of tomato products plus 20 ml sunflower oil (Flora sunflower oil, Crawley, UK) and blood samples were obtained before and after the supplementation. Fatty acid composition and vitamin E content of the oils is shown in Table 1.

Subjects were asked to complete food diaries 2 d prior to the supplementation and during the supplementation weeks. These food diaries were used to check compliance and to calculate the exact intake of lycopene using the database on lycopene content of tomato-based products [16,17]. All subjects consumed the specified amounts of tomato products and oils, and other dietary habits of subjects remained consistent during the course of the study.

### Blood collection and analysis

The following analyses were done on the blood: Serum samples were analyzed for triglycerides (TG) and cholesterol (total, LDL, and HDL) at the local health authority laboratory. Li-heparin blood was used to measure plasma lycopene levels using high performance liquid chromatography (HPLC) [18], and the antioxidant activity of the plasma was measured on COBAS FARA centrifugal analyzer using the test to assay ferric-reducing ability of the plasma (FRAP, total antioxidant activity) [19].

Lipid analysis and antioxidant activity measurements were done on the fresh samples. For the plasma lycopene analysis, all samples were stored at −80°C and the analysis of the whole batch of samples was done on the same day and completed within 6 weeks of completion of the study.

A pooled plasma sample stored at −80°C was used to measure the precision of the HPLC and FRAP assay. Within-assay precision calculated from five measurements of the same sample was 0.18% for the FRAP assay and 6% for the plasma lycopene levels. Between-assay precision calculated from the analysis of the stored plasma at each blood sampling time was found to be 4% for the FRAP assay.

### Statistical analysis

The data was found to be skewed. The statistical analysis was therefore done on the log_{10} transformed data with the level of significance set at \( p < .05 \). Following a significant effect of time with ANOVA repeated measures analysis, within-subject comparisons were done using paired t-test to detect which time periods were different. The results are shown as the geometric mean (antilog of logarithm data) and standard deviation (antilog [log mean plus standard deviation] – geometric mean).

### RESULTS AND DISCUSSION

In our previous study [17,20] we have shown that an increase in the dietary intake of carotenoid to 30 mg/d for one week increases the resistance of LDL to oxidation. A
supplementation period of 7 d was selected in the present study because in our previous study we did not find a significant difference in plasma carotenoids between d 7 and 14 of supplementation. In the present study, the mean dietary intake of lycopene was increased from < 5 mg/d to 46 mg/d during the supplementation period. The consumption of similar amounts of tomato products with olive oil and sunflower oil produced respectively approximately 80% and 70% increase in the plasma lycopene levels, but the percent increase was not significantly different between the two oils used during the supplementation period. Although both olive oil and sunflower oil contained vitamin E (Table 1), no change in the plasma α-tocopherol was observed during the supplementation period. Polysaturated fatty acid rich oil is reported to have a larger impact on reducing triglyceride concentration than monounsaturated fatty acid rich oil [21]. However, in the present study a reduction in triglycerides was observed only following olive oil supplementation (p = 0.01). Supplementation with both oils failed to show an effect on the plasma cholesterol levels. Most studies that show a lipid lowering effect of sunflower oil contained vitamin E [21,22]. It is therefore possible that the feeding of tomato products with olive oil for 1 week was followed by a 3 week washout period and a further supplementation with sunflower oil and tomato products. The plasma lycopene returned to the baseline after the washout period but the plasma antioxidant activity remained significantly higher than the baseline (p = .01, Table 1). It has been reported that oil supplementation can have prolonged effects [26] and effects of induced fatty acid modifications remain for a long time in the biological systems [27,28]. Unfortunately it was

<table>
<thead>
<tr>
<th>Tomato products with olive oil</th>
<th>Mean ± SD</th>
<th>Tomato products with sunflower oil</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietary lycopene mg/d</td>
<td>&lt;5</td>
<td>46 ± 10</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Plasma lycopene μmol/l</td>
<td>0.66 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.20 ± 0.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.67 ± 0.27&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Plasma α-tocopherol μmol/l</td>
<td>19.0 ± 3.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.4 ± 3.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.5 ± 5.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Triglycerides mmol/l</td>
<td>0.88 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.68 ± 0.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.97 ± 0.33&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total cholesterol mmol/l</td>
<td>3.78 ± 0.53</td>
<td>3.91 ± 0.35</td>
<td>3.90 ± 0.66</td>
</tr>
<tr>
<td>LDL cholesterol mmol/l</td>
<td>1.85 ± 0.54</td>
<td>2.10 ± 0.37</td>
<td>1.85 ± 0.62</td>
</tr>
<tr>
<td>HDL cholesterol mmol/l</td>
<td>1.49 ± 0.20</td>
<td>1.47 ± 0.18</td>
<td>1.55 ± 0.23</td>
</tr>
<tr>
<td>Total: HDL ratio</td>
<td>2.53 ± 0.47</td>
<td>2.66 ± 0.47</td>
<td>2.52 ± 0.59</td>
</tr>
<tr>
<td>FRAP μmol/l</td>
<td>930 ± 150&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1118 ± 184&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1049 ± 186&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Effect of supplementation was measured using paired-t-test on log<sub>10</sub> transformed data. Results shown are geometric means and standard deviation. Those not sharing a common superscript<sup>abc</sup> were significantly different at p < .05.
not possible to do fatty acid and polyphenol analysis to confirm whether the effects seen following the washout period were related to the oil consumption. The consumption of tomato products with sunflower oil produced no further increase in the FRAP and if anything, plasma antioxidant activity tended to decrease and was significantly lower than that measured following the olive oil supplementation (p = .007, paired t-test). The change in plasma FRAP (supplementation minus start values) was also significantly different when tomato products were consumed with olive oil or sunflower oil (p = .002, Table 3).

In conclusion, the preliminary results indicate that the oil composition (olive oil vs. sunflower oil) does not affect the bioavailability of lycopene from tomato products. The oil composition however, may affect the antioxidant activity of the plasma. Further studies are needed to provide clarification on whether the antioxidant effects seen in the present study were related to the olive oil or the combination of olive oil and tomato products.

REFERENCES


