Heating Reduces Vitamin E Content in Palm and Soy Oils

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Abstract

Heating palm oil for 10 minutes (PO1H) caused significant reduction in α-tocopherol (α-tf), α-tocotrienol (α-tt), γ-tocotrienol (γ-tt) and δ-tocotrienol (δ-tt) compared to fresh palm oil (POF). Heated five times palm oil (PO5H) also caused a further reduction in α-tf, α-tt, γ-tt and δ-tt. Up to 98% of the three most abundant vitamin E fractions in the palm oil, namely α-tf, α-tt and γ-tt, were destroyed by repeated heating. Similarly, heating soy oil for five times (SO5H) also significantly lowered the concentration of all three tocopherols, namely α-tf, γ-tocopherol (γ-tf) and δ-tocopherol (δ-tf), compared to fresh soy oil (SOF) and heated once soy oil (SO1H). However, the latter only managed to significantly lower the level of α-tf without affecting levels of γ-tf and δ-tf. Up to 60% of γ-tf, which is the most abundant variety of vitamin E in soy oil, was lost upon heating repeatedly for five times. The findings of this study suggest that the extent of vitamin reduction was not only affected by the frequency of heating but varied according to the different vitamin E fractions. Heating appears to have more effect on α-tf, α-tt, γ-tt and γ-tf but less effect on δ-tt and δ-tf.

Keywords: Heating, palm oil, soy oil, vitamin E

Introduction

Vitamin E, a naturally occurring antioxidant is an essential lipid soluble vitamin. The term vitamin E is now considered to be a generic name describing bioactivities of both tocopherol and tocotrienol derivatives. Both tocopherols and tocotrienols consist of a chromanol head and a side chain at the C-2 position. Tocopherol has a saturated phytyl tail while tocotrienol has an unsaturated isoprenoid side chain. Both of them are further separated into individual compounds assigned by the Greek letter prefixes (α, β, γ and δ) depending on the number and position of methyl substitution on the chromanol ring [1, 2]. In general, tocopherols and tocotrienols are considered to have beneficial health effects. The main sources of vitamin E-active compounds in the human diet are vegetable fats and oils and products derived from them. While tocopherols are generally present in nuts and common vegetable oils such as soy oil and sunflower oil [3], tocotrienols are mainly concentrated in palm oil [4].

These oils are available to be used in the preparation of food during cooking. Even though vitamin E is a vital nutrient, it is unstable during processing and cooking. During heating, an interrelated series of reactions of hydrolysis, oxidation of the oil and polymerisation of fats occurs [5, 6]. Adverse changes occur in the structure of fat, which is primarily dependent on the temperature, the time of exposure, the amount of oxygen present [7] and the chemical composition of the oil, such as degree of its saturation and presence of pro-oxidants and antioxidants [8]. In the literature, much information is available on the adverse effects of oxidized dietary fats on experimental animals [9-11].

In many parts of the world including Malaysia, there is a tendency for the oil to be used repeatedly in frying and cooking. Such a practice appears to cut the cost of cooking, albeit without due consideration to its effect on health. The harmful effect of the thermally oxidized oil on health may be due to several causes which include nutritional factors like vitamin deficiency. Several studies have demonstrated the adverse effects of vitamin E deficiency such as angina [12], cystic fibrosis [13] and cerebral ataxia [14]. Besides, some studies on deterioration of frying oils have been carried out [6, 8, 15-18]. We undertake this study to determine whether heating has an effect on the various fractions of vitamin E in both palm and soy oils and to investigate whether repeated heating will cause further effects on the stability of vitamin E.

Materials and Methods

Heating process

The vegetable oils used were palm oil (Lam Soon Edible Oil, Malaysia) and soy oil (Yee Lee Edible Oil, Malaysia). The oils used were fresh, heated once or heated five times, as described by Owu et al. [9]. Heating involved 2500 ml of the vegetable oil to fry 25 pieces of ‘keropok lekor’ (fish-flavored chips) in a metal wok. The temperature of the heated oil reached about 180°C, and the cooking process lasted for 10 minutes. To heat the
oil five times, the oil was cooled for five hours in between heating, then the whole frying process was repeated with a fresh batch of ‘keropok lekor’. No fresh oil was added between batches to make up for the loss due to uptake of the oil by the frying material.

**HPLC analyses**

The concentration of vitamin E in the fresh, heated once and heated five times palm and soy oils were determined by HPLC (Hewlett Packard HP1100). HPLC analysis was performed using YMC 5U silica column 150 x 6 mm I.D. The mobile phase used was composed of 0.5% IPA/hexane and the flow rate was 1 ml/min. Total runtime for each standard and sample was 40 minutes. The injection volume was 20 µL. Detection was performed using a fluorescence detector at excitation 295 and emission 330. All standards were obtained from the Malaysian Palm Oil Board (MPOB). The standard concentration was 40 ppm for each component. Samples were injected directly without any processing after being cooled from the heating process. Quantification of vitamin E was done by using the following formula:

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\chi \text{ ppm} = \frac{V_s \times A_s \times V_{Istd} \times C_{std}}{W_s \times A_{std} \times V_{Is}} 
\]

where: 
- \(V_s\) = volume of sample
- \(W_s\) = weight of sample
- \(A_s\) = area of sample
- \(A_{std}\) = area of standard
- \(V_{Istd}\) = volume of standard injected
- \(V_{Is}\) = volume of sample injected
- \(C_{std}\) = concentration of standard

Measurement of the various fractions of vitamin E in the palm or soy oils was done for six samples (n=6) for each of the three corresponding groups; fresh, heated once and heated five times.

**Statistical analyses**

The results are expressed as mean ± S.E.M. Data was analysed using Mann-Whitney U test. A value of \(p<0.05\) was considered significant. All statistical analyses were conducted using the Statistical Product and Service Solutions (SPSS) software.

**Results**

Heated once palm oil (PO1H) caused significant reduction in \(\alpha\)-tf, \(\alpha\)-tt, \(\gamma\)-tt and \(\delta\)-tt (Figure 1). Heated five times palm oil (PO5H) caused a further reduction in \(\alpha\)-tf, \(\alpha\)-tt, \(\gamma\)-tt and \(\delta\)-tt compared to both fresh palm oil (POF) and PO1H.

Five times heated soy oil (SO5H) significantly reduced the concentration of \(\alpha\)-tf, \(\gamma\)-tf and \(\delta\)-tf compared to fresh soy oil (SOF). The level of \(\alpha\)-tf, \(\gamma\)-tf and \(\delta\)-tf also were reduced in SO5H compared to soy oil that was heated once (SO1H). However, SO1H only significantly lowered the level of \(\alpha\)-tf, but not \(\gamma\)-tf and \(\delta\)-tf when compared to SOF. (Figure 2).

**Discussion**

The concentration of \(\alpha\)-tf is significantly higher in palm oil compared to soy oil. In the palm oil, only the \(\alpha\)-variety of the tocopherol was present in abundance (± 178 ppm), which is about 2\(\frac{1}{2}\) times that found in soy oil. This was reduced by both heating once (by about 56%) and heating five times (by about 98%) (Table 1). Heating also reduced \(\alpha\)-tt, \(\gamma\)-tt and \(\delta\)-tt in the palm oil. The reduction in \(\alpha\)-tt, \(\gamma\)-tt and \(\delta\)-tt were observed after both single and repeated heating. However, the reduction was more drastic with repeated heating. The \(\gamma\)-tt was reduced 57% and 98% by heating once and five times, respectively from its original level of 189 ppm. Similarly, the \(\gamma\)-tt was reduced 26% after heating once and 88% after heating five times from its original level of 261 ppm. Palm oil also contained only a smaller amount of \(\delta\)-tt (± 70 ppm) and it was also reduced 14% and 49% by heating once and five times, respectively.

In contrast to palm oil, soy oil contains only tocopherol, mainly \(\gamma\)-tf (± 247 ppm). As for the soy oil, repeated
heating reduced all the three tocopherols, namely the α-tf, γ-tf and δ-tf. γ-tf was reduced by about 60% by heating five times, but was unaffected when heated only once (Table 2). The level of δ-tf, which was the second most abundant (≈ 123 ppm) vitamin E fraction was also unaffected after heating once and decreased by about 34% on upon five times heating. α-tf was only present in about 66 ppm in the soy oil. On the other hand, a reduction in α-tf was observed with both once (62%) and repeated heating (83%).

The finding of this study suggests that heating reduces the various vitamin E fractions in palm and soy oils. Andrikopoulos et al. reported that antioxidants were lost during frying [8]. They also proved that greater loss of antioxidants occurred during pan-frying compared to deep-frying as a result of higher surface-to-volume ratio and contact of the food with atmospheric oxygen. The reduction in vitamin E concentration was seen more with repeated heating. The effect of heating process on the vitamin E fractions was not equal. The percentage of reduction in α-tf and α-tt appear to be higher in heated once and heated five times for both oils compared to other isomers. Gordon and Kourimská also reported that α-tf was consumed significantly faster than other isomers in heated rapeseed oil [16]. Our result was also in agreement with the results of Izaki et al. which showed that tocopherol in liver and serum of rats was considerably decreased in proportion to the degree of heating of the supplied oil [19]. These data have shown that a considerable degree of loss of vitamin E fractions indeed has taken place during heating.

The relative decomposition rates of tocopherols in soy oil after five times heating were α > γ > δ (Table 2). The results are in agreement with those of Tsaknis and Lalas, who reported the decomposition rates of tocopherols after 25 fryings of potatoes using olive oil [17]. Similarly, the relative decomposition rates of palm oil after five times heating were α-tf > α-tt > γ-tt > δ-tt. However, Rossi et al. observed that the rates were γ-tt > α-tt > α-tf > δ-tt after 9 hours of frying using palm super olein [18].

Vitamin E is an important antioxidant that plays an important role in prevention of chronic diseases [20]. The major biological role of vitamin E is to protect unsaturated fatty acids contained in vegetable oils from oxidation by free radicals. When the oils are heated, vitamin E is consumed by reacting with lipid free radicals, originally formed by the action of oxygen on unsaturated fatty acids, to form relatively stable products which interrupt the propagation stage of oxidative chain reactions [16]. In the case of soy oil, which has higher levels of polyunsaturated fatty acids (PUFA) compared to palm oil [4], the double bonds which determine unsaturation compete with the antioxidants as substrates for oxidation. Since palm oil has lower levels of PUFA, antioxidants constitute the major substrates that are more easily reactive with oxygen [18]. The present results proved that heating caused bigger reduction of α-tf in the palm oil compared to soy oil.

We conclude that heating reduces the various vitamin E fractions in palm and soy oil as a function of degree of heating. The stability of the vitamin E isomers varies during heating. It depends on the type of oils that are used, which reflects the PUFA content and the vitamin E isomers present. There is not much research regarding the changes of vitamin E, especially tocotrienols subsequent to heating process. We feel that further study is needed to clarify the changes of vitamin E due to heating process. The possibility of any detrimental effect of heated oil on health should be done which may be related to the reduction in the concentration of these protective vitamin E fractions, apart from toxic effect due to thermally oxidized products in the oil.

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