

# Effects of microwave vs. convection oven heating on the formation of oxidation products in canola (*Brassica rapa* subsp. *oleifera*) oil

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Received 5 January 2017 – Accepted 13 March 2017

**Abstract** – Research on the effects of microwave vs. “conventional” heating of dietary oils on lipid oxidation has been very limited. In this study, canola oil (*Brassica rapa* subsp. *oleifera*) was heated in either convection or microwave oven to compare the effects of heating methods on triacylglycerol (TAG) oxidation. Peroxide and *p*-anisidine values (PV and *p*-AV, respectively) were determined and liquid chromatography–mass spectrometric (LC–MS) analysis of non-oxidized and oxidized TAG molecular species was performed. Neither of the heat treatments caused any considerable changes in PV of the oil samples. However, increase in *p*-AV was observed. The change was higher in the oil heated in microwave oven, demonstrating a higher increase in the amount of secondary oxidation products. The changes were accompanied by a decrease in the polyunsaturated TAG molecular species ACN:DB (acyl carbon number: number of double bonds) 54:7 and 54:6, this change also being higher in the oil heated in microwave oven.

**Keywords:** fat / heating / microwave / oxidation / canola oil

**Résumé** – Effets d'un chauffage par microondes vs. un chauffage par convection sur la formation de produits d'oxydation dans l'huile de colza (*Brassica rapa* subsp. *oleifera*) ? Il existe relativement peu de travaux portant sur l'effet d'un chauffage poussé des huiles alimentaires par microondes comparé au chauffage conventionnel. Dans cette étude, de l'huile de canola (*Brassica rapa* subsp. *oleifera*) a été chauffée comparativement dans un four à convection ou un four à microondes pour suivre l'oxydation des triglycérides (TG). Les valeurs de l'indice de peroxyde et de para-anisidine (IP et IPA, respectivement) ont été déterminées et des analyses par chromatographie liquide – spectrométrie de masse des TG oxydés et non oxydés ont été effectuées. L'IP n'a pas été affecté significativement par les traitements tandis que l'IPA a augmenté. Ce changement a été plus important pour l'huile chauffée dans un four à microondes, ce qui se traduit par une production plus importante de produits d'oxydation secondaire. On retrouve cette différence au niveau des espèces moléculaires polyinsaturés. Les triglycérides ayant les ratios carbones acylés sur nombre de double liaisons 54:7 et 54:6 diminuent plus fortement dans l'huile chauffée aux microondes que dans l'huile chauffée conventionnellement.

**Mots-clés :** graisse / chauffage / four microonde / oxydation / huile de canola

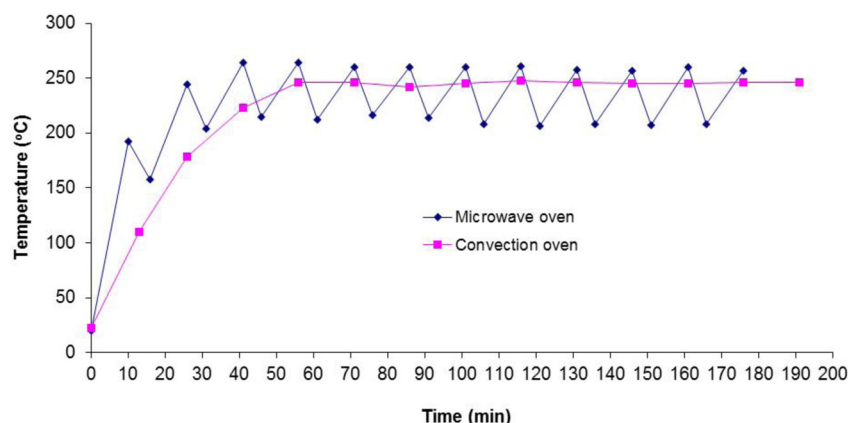
## 1 Introduction

Fat oxidation, resulting in the formation of various primary and secondary oxidation products, takes place in dietary oils during prolonged storage and heating. Dietary oxidized lipids are a potential risk factor for atherosclerosis and their amount in food should be kept in minimum (Ahotupa *et al.*, 2010).

Foods with a high fat and low water content absorb microwave energy rather quickly and are intensely heated

(Yoshida and Kajimoto, 1994). However, due to lower dielectric constant and hence more limited absorption of microwave energy, the heating process is slower compared with water. Comparisons of the effects of microwave vs. “conventional” heating of dietary oils on lipid oxidation and on the formation of lipid oxidation products have been scarce. Only a few comparative studies have been performed using sunflower oil, high oleic sunflower oil, virgin olive oil, olive oil and lard (Albi *et al.*, 1997), refined cottonseed oil and hydrogenated palm oil (Farag *et al.*, 1991) as well as cocoa fat (Krysiak, 2011). In all these studies, microwave heating appeared to modify the fats more even if the temperature of the

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**Fig. 1.** Temperatures of the canola oil during heating.

oils during heating was fairly similar. However, in a study on New Zealand King Salmon (*Oncorhynchus tshawytscha*) (Larsen *et al.*, 2010), the fatty acid profile showed only minor differences between the heating methods with a good preservation of omega-3 fatty acids.

To further compare the effects of the two heating methods, canola oil (*Brassica rapa* subsp. *oleifera*), an important oil seed in Northern Europe, was heated for ~3 h either in convection or microwave oven so that its average temperature was retained close to 240 °C; the temperature is within a typical range of oven cooking. Peroxide and *para*-anisidine values (PV and *p*-AV, respectively) were determined, and liquid chromatography–mass spectrometric (LC–MS) analysis of non-oxidized and oxidized TAG molecular species was performed.

## 2 Materials and methods

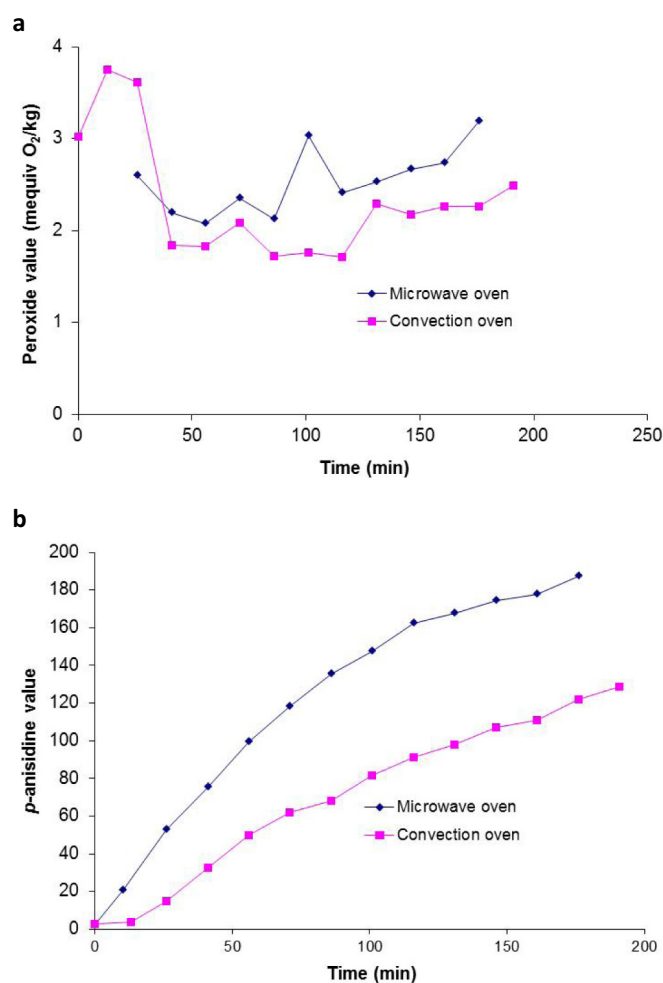
### 2.1 Sample treatment

All solvents were of HPLC grade and used without further purification. Fully refined, commercial canola oil was purchased from a local store. 500 ml of the oil was added to two round glass containers (diameter 18 cm) placed in a convection (260 °C) and a microwave oven (800 W; the frequency of the radiation 2450 MHz) (Cylinda EuroLine 7M, Sweden). The oils were stirred, their temperature was measured and samples were taken in an interval of 15 min. After each heating period of 10 min, microwave oven was set off for 5 min to avoid excessive heating of the oil. After each 5 min pause, temperature was measured anew (see Fig. 1).

### 2.2 Sample analysis

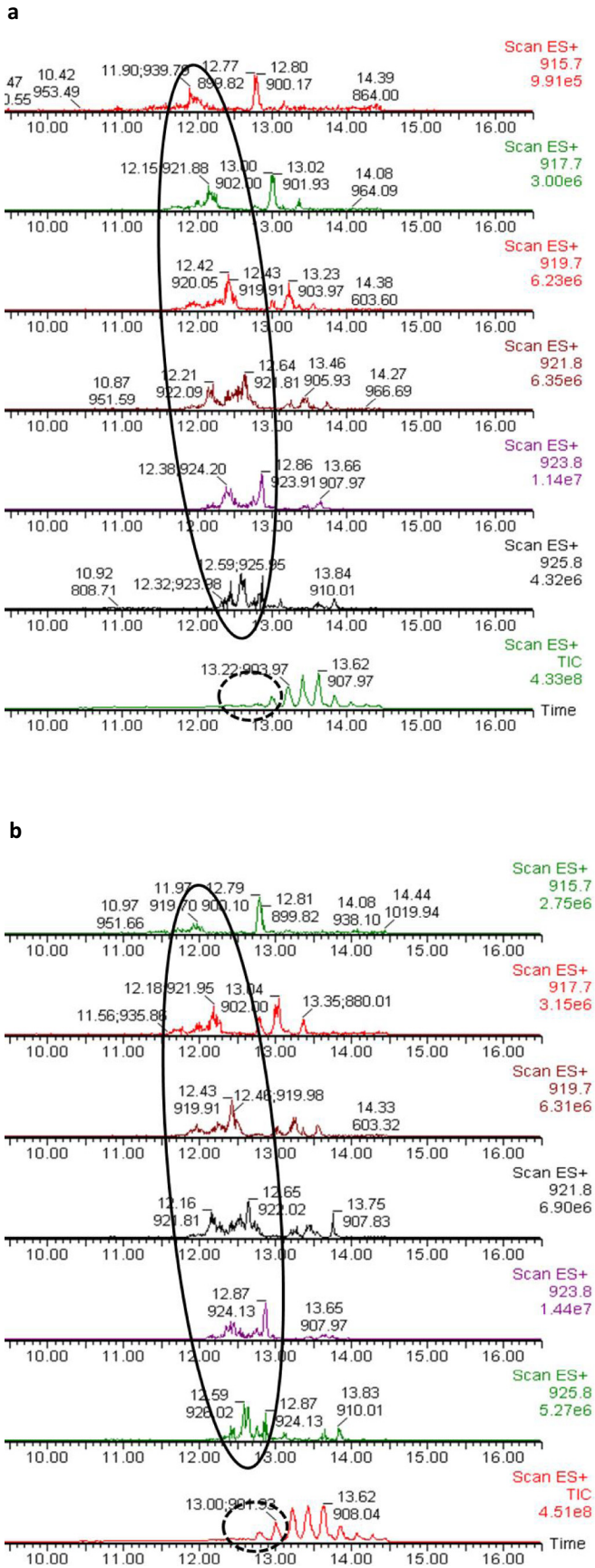
PV and *p*-AV were measured using IUPAC standard methods 2.501 and 2.504, respectively. In case of *p*-AV, duplicate measurement was performed.

The UHPLC system consisted of a Kinetex™ C18 column (100 mm × 2.1 mm i.d., 1.7 μm particle size) (Phenomenex, Torrance, CA) equipped with a 0.2 μm in-line filter and Acquity Ultra Performance LC equipment (Waters Co., Milford, MA). A binary solvent gradient consisted of 0.1% formic acid in acetonitrile/water (50:50, by vol) (designated A)



**Fig. 2.** (a) Peroxide values and (b) *p*-anisidine (avg,  $n=2$ ) values of the canola oil samples collected at different time points.

and 0.1% formic acid in isopropanol (designated B). The gradient program was as follows: initial A/B (90:10, v/v), linear from 0 to 14 min to A/B (15:85). The run duration was 16.5 min including an equilibration time of 2.5 min. The flow rate was 0.5 ml/min and the column was kept at 60 °C. The injection volume was 3 μl.



MS analyses were performed with a Quattro Premier tandem quadrupole mass spectrometer (Waters Co., Milford, MA) using positive ESI. The scan range was  $m/z$  150–1500. The capillary was set at 4.8 kV and the sample cone at 350 V. The source and the desolvation temperatures were set at 80 and 350 °C, respectively. Nitrogen was used as the desolvation and cone gas, and the flows were set at 500 and 300 L/h, respectively.

### 3 Results and discussion

Temperatures of the oils during heating are shown in Figure 1. Neither of the heat treatments caused any considerable changes in PV of the oil (Fig. 2a). This is probably due to the fast secondary reactions in the high heating temperatures. *p*-AV of the oil increased more when it was heated in microwave oven, demonstrating a higher increase in the amount of secondary oxidation products (Fig. 2b; SD between measurements were very small and hence not visible). It is noteworthy that air circulation in microwave oven was weaker compared with convection oven. On the other hand, the oil heated in microwave oven was stirred more frequently because its temperature was measured in both the beginning and the end of the 5 min period when the microwave oven was set off (Fig. 1).

Interesting differences were found between the mass chromatograms of the samples prepared with the different heating techniques. In the oil samples oxidized in microwave oven, the peaks representing some of the polyunsaturated triacylglycerol (TAG) molecular species, especially ACN:DB 54:7 and 54:6, were noticeably decreased, whereas the changes in the samples oxidized in convection oven were clearly smaller (dashed circles in Fig. 3a and b, respectively). Of all TAG peaks, the relative proportion of the combined integrated areas of the peaks representing ACN:DB (acyl carbon number: number of double bonds) 54:7 and 54:6 was 17.6% in case of non-heated oil (data not shown). This proportion was 13.6% in case of the oil sample heated in microwave oven for 175 min, and 16.8% in case of the oil sample heated in convection oven for 190 min. The decrease in the polyunsaturated TAG molecular species seemed not to be reflected as a noticeable increase in the peaks representing slightly oxidized (addition of a single oxygen) TAG molecular species (Fig. 3a and b).

It can be calculated based on the power of the microwave oven and the amount of oil heated that the estimated thermal yield in the microwave heating process was 37% (calculated required heat during each 10 min heating step was 175,000 J whereas the calculated microwave energy produced was 480,000 J), leaving rest of the microwave energy non-absorbed. This non-absorbed microwave energy could

**Fig. 3.** Total ion chromatograms (TIC) and single ion chromatograms showing some ions representing oxidized TAG molecular species of 54 acyl carbons (addition of single oxygen to the molecule; solid circles) found in the canola oil samples. Dashed circles demonstrate the differences in the amounts of polyunsaturated TAG molecular species ACN:DB 54:7 and 54:6 between the samples. (a) Oil heated in microwave oven for 175 min and (b) oil heated in convection oven for 190 min.

enhance undesirable reactions like oxidation. It needs to be taken into account that in foods traditionally heated in domestic microwave ovens over shorter periods and in presence of water, it is likely that the microwave energy is mostly absorbed. It can also be hypothesized that, compared with heating in convection oven, the rapid movement of TAG molecules during microwave heating predisposes them more readily to reactions with oxygen molecules present.

## 4 Conclusions

Compared with convection oven heating, microwave heating of canola oil seemed to result in greater increase in *p*-AV and more pronounced decrease in the amount of highly desaturated TAG molecular species. Thus, like in the other studies comparing the effects of microwave vs. “conventional” heating (Farag *et al.*, 1991; Albi *et al.*, 1997; Krysiak, 2011), the former treatment appeared to modify the fats more. If not fully unexpected, the results are rather interesting taking into consideration the low dielectric constant of oils. The results show that further work on practical effects of microwave treatment on fat quality during food processing (*e.g.* drying processes involving microwave treatment) and food preparation is needed.

*Acknowledgements.* This work has been supported by the Academy of Finland (Kallio 116408). Hannele Jokioinen is acknowledged for her help in LC–MS analyses.

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**Cite this article as:** Suomela J-P, Tarvainen M, Kallio H. 2017. Effects of microwave vs. convection oven heating on the formation of oxidation products in canola (*Brassica rapa* subsp. *oleifera*) oil. *OCL* 24(3): A301