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Journal of Food Composition and Analysis 19 (2006) 330–339

JOURNAL OF FOOD COMPOSITION AND ANALYSIS

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Original Article

Microwave roasting effects on the oxidative stability of oils and molecular species of triacylglycerols in the kernels of pumpkin (*Cucurbita* spp.) seeds

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Received 1 April 2004; received in revised form 24 August 2004; accepted 21 October 2004

Abstract

Pumpkin (*Cucurbita* spp.) seeds of the two cultivars were exposed to microwaves for 6, 12, 20 or 30 min at a frequency of 2450 MHz using a microwave oven. After the kernels were separated from the whole pumpkin seeds, the quality characteristics and composition of the oils, i.e., their tocopherol distributions and the molecular species of the triacylglycerols (TAGs) were investigated. These results were compared with those of an unroasted oil sample for the two cultivars. Only minor increases ($P<0.05$) in chemical changes of the oils, such as peroxide value, carbonyl value, *p*-anisidine value and thiobarbituric acid reactive substances (TBARS), occurred after a prolonged roasting period. Compared to the original level, more than 85% tocopherols remained after 20 min of roasting. Therefore, significant differences ($P<0.05$) in fatty acid distributions were observed in the pumpkin seeds roasted for 20 min or more. A modified AgNO3-TLC procedure provided 11 different groups of TAG, based on both the degrees of unsaturation and the total fatty acid chain-length. With a few exceptions, microwave roasting for 12 min caused no significant ($P>0.05$) loss or changes in the content of tocopherols and polyunsaturated fatty acids (PUFAs) in the kernels. These results contribute to further investigation of the functional properties of pumpkin seed products.

Keywords: Carbonyl value; Fatty acid distribution; Kernels; Microwave roasting; Oxidative stability; Pumpkin (*Cucurbita* spp.) seeds; Triacylglycerols; Tocopherols

1. Introduction

Much attention has been recently focused on the utilization of food-processing byproducts and wastes, as well as on underutilized agricultural products. The value of pumpkin (*Cucurbita* spp.) seeds as a useful source of oils and proteins has been reviewed by a few workers (Tu et al., 1978; El-Adawy and Taha, 2001). Therefore, pumpkin seeds are utilized in several countries as snacks after salting and roasting (Al-Khalifa, 1996) for human consumption.

Microwaves are a non-ionizing energy that can generate heat deep inside the penetrated medium by the ''molecular friction'' in an alternating electromagnetic field (Lewandowicz et al., 1997). Since it is quite competitive in cost compared to other methods of heating, it has been used for thawing of frozen foods, drying, baking, rendering, pasteurization, and sterilization. Penetration and heating of foods by microwave energy are instantaneous (Decareau, 1986). Microwave energy effects on various food components, could differ significantly from those of conventional cooking. For example, it has been speculated that reactive free radicals may be formed by exposure to microwave

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doi:10.1016/j.jfca.2004.10.004

energy (Michael et al., 1991), especially in those applications that result in abnormally high temperatures (100–200 °C). It was found that the higher the amount of polyunsaturated fatty acids (PUFAs) in vegetable oils, the greater the rate of quality deterioration of the oils exposed to microwave energy (Yoshida et al., 1990). Yoshida et al. (1992) reported that the levels of free fatty acids (FFAs) also increase in vegetable oils heated in a microwave oven.

Some reports suggest that nutrient retention, such as vitamins in microwave foods, is improved because roasting time is shortened (Gould and Golledge, 1989; Newsome, 1987). However, other researches indicate that nutrient retention in microwave processing is not much greater than that in conventional cooking (Thompson, 1982). Tocopherol homologues are phenolic antioxidants that occur naturally in vegetable oils and provide some protection against oxidation by terminating free radicals. The determination of the tocopherol homologues in the kernel oils is important owing to their antioxidative effects and their positive nutritional influences in human metabolism as biological antioxidants. Until now, there has been no information on how microwave roasting affects, not only the oxidative stability of lipids, but also the distribution of tocopherols of the kernels in pumpkin seeds.

In the present work, we examined the interrelation between the oxidative stability of oils and the molecular species of triacylglycerols (TAGs) in the kernels of pumpkin seeds when roasted for different time periods in a microwave oven.

2. Materials and methods

2.1. Sample seeds

Commercially available pumpkin (*Cucurbita* spp.) seeds used in this study were from two Japanese cultivars—*Yatsuko* and *Kuriebisu*—that were grown in Japan during the summer of 2003 (Kyoto, Japan). Cultivars were purchased from Takii Seed Co. (Kyoto, Japan) and selected for uniformity based on seed weights of 120–150 mg for *Yatsuko*, and 150–200 mg for *Kuriebisu*. The seeds were hand-selected to eliminate damaged seeds. All the seeds were stored in stainless steel containers at 4 °C and 52% relative humidity until needed.

2.2. Reagents and standards

All reagents and solvents were of the required purity grade (Nacalai Tesque, Kyoto, Japan). Vitamin E homologues (α, β, γ, and δ) were purchased from Eisai Co. (Tokyo, Japan). All tocopherols were of the D-form (*RRR*-), and the purity of each tocopherol was >98.5% as determined by HPLC using 2,2,5,7,8-pentamethyl-6-hydroxychroman as internal standard (compared *2.5 HPLC*). Thin-layer chromatography (TLC) pre-coated Silica Gel G 60 plates (100×200 or $200 \times 200\,mm^2$, 25 μm layer thickness) were purchased from Merck (Darmstadt, Germany).

TLC standard mixture, containing diacylglycerols (DAGs), FFAs, TAGs and steryl esters (SEs), was from Nacalai Tesque (Kyoto, Japan). Standard TAGs (trimyristin, tripalmitin, tristearin, triolein, trilinolein and trilinolenin) were obtained from Sigma Chemical Co. (St. Louis, MO, USA). Fifty milligrams of methyl pentadecanoate (C15:0, Merck) were dissolved in *n*-hexane and used as internal standard. Boron trifluoride (BF_3) in methanol (14%; Wako Pure Chemical Inc., Osaka, Japan) was used to prepare fatty acid methyl esters (FAMEs) according to the method of Morrison and Smith (1964).

2.3. Chemical analysis

AOAC methods were used to determine the chemical composition of the kernels of pumpkin seeds before roasting (AOAC, 1997). The kernel was analyzed in triplicate for fat, protein and moisture content according to the standard methods. Fat was determined by solvent extraction (Method 991.36), protein by a Kjeldahl method (Method 981.10) and moisture by oven drying to constant weight at 105 °C (Method 925.40). Nitrogen factor 6.25 was used in this work.

2.4. Roasting of pumpkin seeds

Whole pumpkin seeds were arranged a single layer in Pyrex Petri dishes (12.0 cm diameter). Three dishes, containing 100 seeds each, were placed on the turntable plate in a commercial microwave oven (Model R-5550, Sharp, Osaka, Japan). The total weight of the 100 seeds thus treated was 106.4 ± 2.3 g. After covering the dishes, the contents were then roasted at a frequency of 2450 MHz (high-power setting; capable of generating 0.5 kW power) for 6, 12, 20 or 30 min in the turntable mode based on previous results (Yoshida et al., 2001). As soon as they were removed from the oven after each treatment, the internal temperature of the treated seeds was determined as previously described (Yoshida and Kajimoto, 1989). The roasted whole pumpkin seeds were allowed to cool to ambient temperature before homogenization for lipid extraction.

2.5. Lipid extraction

After microwave roasting of pumpkin seeds, the seed samples (200 kernels) were extracted using a Maxim homogenizer (Nihonseiki Kaisha Ltd. Tokyo, Japan) at high speed for 10 min at 0 °C with 150 mL of

chloroform/methanol (2:1, v/v) fortified with 0.01% butylated hydroxytoluene (BHT), which was added to inhibit the oxidative degradation of lipids during analysis.

The homogenate was vacuum-filtered through defatted filter papers on a Buchner funnel, and the filter residue re-homogenized with a second volume of chloroform/methanol. The filtrates were combined and dried in a rotary vacuum evaporator at 35 °C. The residue was dissolved in 100 mL of chloroform/methanol (2:1, v/v), 20 mL of a 0.75% aqueous potassium chloride solution was added (Folch et al., 1957), and the phases were vigorously mixed. After phase separation, the chloroform layer was withdrawn, dried with anhydrous sodium sulphate and filtered. The organic phase was concentrated under vacuum. Finally, the chloroform was completely removed under a stream of nitrogen. The extract lipids were weighed to determine the lipid content of the kernels and then transferred to a 25-mL brown glass volumetric flasks with chloroform/methanol (2:1, v/v) solution, and stored under nitrogen in the dark at −25 °C until further processing and analysis. Samples of unroasted pumpkin seeds were extracted by the same procedures and used as control.

2.6. HPLC

The tocopherol content was determined by direct injection of the oil samples into an HPLC following the method as previously described (Yoshida and Kajimoto, 1989). Briefly, oil samples weighing 500 mg were dissolved in a 2-mL brown volumetric flask with the mobile phase for the HPLC (as described below) and 10 μL of this solution was injected into the column. The chromatographic system consisted of a normal-bonded phase Shim-pack CLC-SIL (M) column (5 μm, 250 × 4.6 mm i.d.; Shimadzu, Kyoto, Japan) protected by a 10-mm guard column (Shim-pack G-SIL).

A mixture of *n*-hexane/1,4-dioxane/ethanol (490:10:1, v/v/v) was used as the mobile phase at a flow rate of 2.0 mL/min. The tocopherols were monitored with a fluorescence detector (Shimadzu RF-535; Shimadzu Instruments Inc., Kyoto, Japan). The relative amounts of each tocopherol were calculated using an external standard method that uses reference samples of tocopherols (Eisai Co., Tokyo, Japan). A Shimadzu C-R6A integrator (Shimadzu, Kyoto, Japan) was used to calculate the peak areas.

2.7. Analysis of lipids

AOCS Official Methods (AOCS, 1990) were used to determine the peroxide value (Method Cd 8-53) and the amount of 2-thiobarbituric acid reactive substances (TBARS, Method Cd 19-90). The TBARS were expressed as malonaldehyde equivalents mg/kg oil. The *p*-anisidine value and carbonyl value of the oils were measured according to IUPAC and JOCS (Japanese Oil Chemists' Society) standard methods (IUPAC, 1987; JOCS, 1986).

2.8. Lipid class analysis and TAG composition

The total lipids were fractionated by TLC into following six fractions as previously described (Yoshida et al., 1995): SEs, TAGs, FFAs, 1,3- and 1,2-DAGs, and polar lipids (PLs). The phospholipids were isolated from total lipids by multiple-development TLC: neutral lipids were removed by developing with *n*-hexane/diethyl ether/formic acid (80:30:1, v/v/v), and glyceroglycolipids were further removed by developing with acetone/acetic acid/de-ionized water (100:2:1, v/v/v). Zones corresponding to the each lipid class were scraped separately into a tube (105 × 16 mm) fitted with poly(tetrafluoroethylene)-coated screw caps, respectively.

Methyl pentadecanoate (C15:0) was added as internal standard to the total lipids and to each fraction at ca. 10% (esters). FAMEs were prepared from the isolated lipids by heating the samples to 80 °C for 90 min with boron trifluoride (14%) in methanol (Morrison and Smith, 1964) on an aluminium block bath. The samples were cooled to 0 °C in an ice bath, then 5 mL of *n*-hexane was added and vigorously stirred for 30 s using a Vortex mixer. The organic layer with the FAMEs was isolated, washed several times with de-ionized water and dried over anhydrous sodium sulphate. The solvent was removed under a stream of nitrogen and the residue quantified on a Shimadzu Model GC-14A gas chromatograph (Shimadzu, Kyoto, Japan) as described (Yoshida et al., 2001). The detection limit was 0.05% of total fatty acids for each fatty acid in a FAME mixture, and the results are expressed as % of total FAMEs.

On the other hand, TAGs isolated by TLC was analyzed by GC following the method of Matsui et al. (1973), using a Shimadzu Model GC-14A equipped with a hydrogen flame ionization detector. TAG peaks were identified by co-chromatography with standards. Peak areas were calculated by addition of a known weight (50 μg) of trimyristin internal standard using an electronic integrator (Shimadzu C-R4A).

2.9. TAG species analysis

Molecular species separation of total TAG was carried out by silver nitrate–silica gel TLC according to the method of Bilyk et al. (1991). Briefly, TAG classes differing in unsaturation were separated by argentation TLC using 1.8% (v/v) methanol in chloroform, depending on their degree of unsaturation (Blank et al., 1965). This system was varied according to temperature and humidity conditions. Individual bands were visualized by spraying with 0.1% 2′,7′-dichlorofluorescein (Nacalai

Tesque, Kyoto, Japan) in methanol and detected under UV-radiation. Bands were recovered from the plates by extraction with 10% aqueous HCl in diethyl ether. The combined extracts were purified by alumina column chromatography (5.0×30 mm; alumina column) to remove the 2′,7′-dichlorofluorescein. The identity and purity of each band was verified by analytical silver nitrate–silica gel TLC after co-chromatography with the reference TAG mixture. Determination of relative amounts of each TAG subfraction was made by comparison of FAMEs with a known amount (25 μg) of methyl pentadecanoate as internal standard. Each subfraction was converted into FAMEs and quantified by GC as described above.

2.10. Statistical analyses

All experiments were done in triplicate, and then the results were analyzed by one-way ANOVA with a randomized complete block design to partition (Steel et al., 1995). Significant differences ($P<0.05$) between means were determined by applying Duncan's multiple range test (SAS Institute, 1990).

3. Results and discussion

Proximate analyses showed the composition of the kernels before roasting to be as follows: moisture 4.3–5.2%, fat 47.3–48.6%, and protein 28.5–29.8%. There were no significant differences ($P>0.05$) in these contents between the two cultivars.

3.1. Microwave roasting and oxidative stability of lipids

The internal temperature of the pumpkin seeds at the end of each roasting period was compared (data not shown). The temperature of the seed sample was 25 °C before microwave treatment and increased to 93.2, 117.5, 124.3 and 132.5 °C, at 6, 12, 20 and 30 min of roasting, respectively. The qualities and characteristics of the oils prepared from the kernels of pumpkin seeds roasted in the range of 6–30 min are shown graphically in Fig. 1 and are compared with those of an unroasted oil sample.

The peroxide value serves as an indicator of the extent of primary oxidation products in the oils, whereas the carbonyl value, the anisidine value and the TBARS value reflect the degree of secondary products (Augustin and Berry, 1983). Therefore, it is necessary to determine the primary oxidation products but also their secondary products in the pumpkin seeds when roasted in a microwave oven. There were only minor increases ($P<0.05$) in parameters such as peroxide, carbonyl, anisidine and TBARS values of the kernel oils prepared until 12 min of roasting. With the progress of microwave roasting, a significant change in these values was exhibited at 20 min of roasting, while more pronounced differences ($P<0.05$) were observed at 30 min (Fig. 1). These trends were more pronounced ($P<0.05$) in

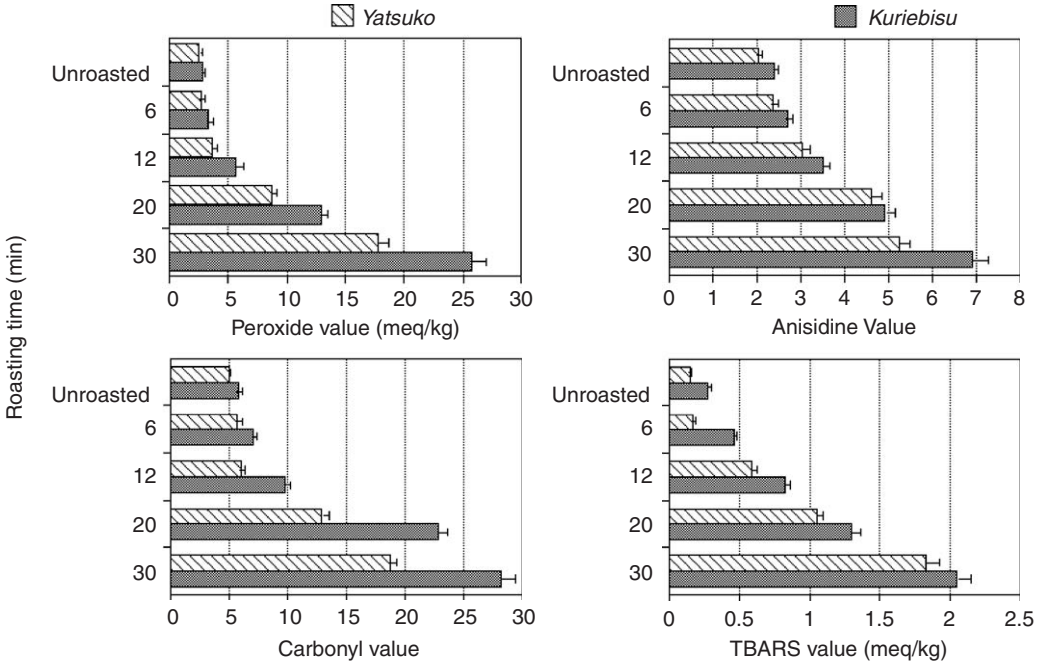

Fig. 1. Changes in selected quality parameters of the oils prepared from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Each value represents the average of three replicates, and horizontal bars show the S.D. of the mean value.

Kuriebisu than in *Yatsuko*, which would be attributed to the differences in the fatty acid distributions between the two cultivars (as described below).

3.2. Tocopherol distributions and lipid components

The influence of microwave roasting on the total and individual tocopherol contents in the kernel oils is compared in Fig. 2. Whereas β-, γ-, and δ-tocopherols were the predominant component (over 97.0%), α-tocopherol was only detected at small amounts (level; 2.2%). The distribution patterns of tocopherol homologues were very similar to each other for the two cultivars. However, the amount of β-tocopherol was higher than other oilseeds such as soybeans, sesame seeds and sunflower seeds (Yoshida and Kajimoto, 1989; Yoshida et al., 1995, 2002). After 20 min of roasting, the amount of tocopherol homologues was reduced to $<15\%$ of the original levels.

Profiles of the different lipid classes in the kernel oils before and during microwave roasting are shown in Table 1. The major lipid components were TAGs (above 93%), whereas FFAs and phospholipids were minor proportions (2.7% and 1.9%, respectively). Microwave roasting caused a significant increase ($P<0.05$), not only FFAs as well as 1,3- and 1,2-DAGs at 12 min of roasting, while even more pronounced differences ($P<0.05$) were observed at 20 min or more. It was also suggested that TAGs were randomly and gradually hydrolyzed by microwaves to produce FFAs or DAGs (Cossignani et al., 1998). Conversely, the amount of phospholipids was reduced to two-third of its initial

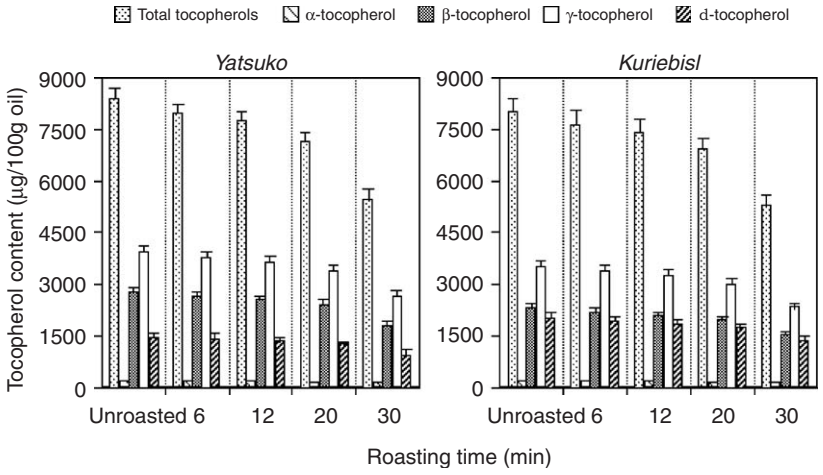

Fig. 2. Changes in total and individual tocopherols in the oils prepared from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Each value represents the average of three replicates, vertical bars show the S.D. of the mean value.

Table 1
Lipid components in the oils prepared from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz*

Cultivar	Roasting time (min)	Triacylglycerols		Free fatty acids		Phospholipids		1,3-diacylglycerols		1,2-diacylglycerols		Steryl esters	
		(mg)	(%)	(mg)	(%)	(mg)	(%)	(mg)	(%)	(mg)	(%)	(mg)	(%)
Yatsuko	Unroasted	5793.2^{e}	(93.48)	181.2^{a}	(2.93)	122.3^{f}	(1.97)	30.6^{a,b}	(0.49)	33.2^{a,b}	(0.54)	36.6^{c}	(0.59)
	6	5612.6^{e,f}	(93.11)	197.8^{b}	(3.28)	115.7^{g}	(1.92)	31.3^{b,c}	(0.52)	33.6^{b}	(0.56)	36.5^{c}	(0.61)
	12	5457.1^{f,g}	(92.82)	214.6^{c}	(3.65)	104.4^{h}	(1.78)	32.8^{c}	(0.56)	35.0^{c}	(0.59)	35.3^{c}	(0.60)
	20	5289.6^{g,h}	(91.79)	271.2^{d}	(4.71)	93.2^{i}	(1.62)	35.7^{d}	(0.62)	37.6^{d}	(0.65)	35.2^{c}	(0.61)
	30	5067.0^{h}	(91.05)	300.8^{e}	(5.41)	78.6^{j}	(1.41)	42.6^{e}	(0.77)	40.8^{e}	(0.73)	35.0^{c}	(0.63)
Kuriebisu	Unroasted	11797.1^{a}	(93.90)	335.7^{d}	(2.67)	236.2^{a}	(1.88)	39.2^{e}	(0.31)	43.5^{f}	(0.35)	111.8^{a}	(0.89)
	6	11341.3^{a,b}	(93.49)	375.9^{e}	(3.10)	220.8^{b}	(1.83)	40.3^{e}	(0.33)	43.8^{f}	(0.36)	108.6^{a,b}	(0.90)
	12	11053.9^{b,c}	(93.30)	402.8^{f}	(3.40)	197.9^{c}	(1.67)	41.5^{e}	(0.35)	44.7^{g}	(0.38)	106.7^{b}	(0.90)
	20	10646.4^{c,d}	(92.33)	513.7^{g}	(4.45)	172.9^{d}	(1.50)	45.2^{f}	(0.39)	48.6^{i}	(0.42)	104.5^{b}	(0.91)
	30	10242.9^{d}	(91.26)	632.0^{h}	(5.63)	146.7^{e}	(1.31)	48.0^{g}	(0.43)	50.3^{j}	(0.45)	103.6^{b}	(0.92)

*Each value is the average of three determinations and expressed as mg lipid in 200 kernels. Value in the same column with different indices are significantly different from those values in raw seeds ($P<0.05$). Values in parentheses are relative contents of the individual lipids within total lipids.

levels. The reduction of phospholipids following microwave treatment may be due to the decomposition of phospholipids and/or formation of a complex with protein or carbohydrate.

3.3. Effect of microwave roasting on fatty acid compositions

The fatty acid distribution (expressed in terms of the esters by weight) of TAGs, FFAs and phospholipids isolated by TLC in the oils prepared from the kernels was compared between the two cultivars as shown in Figs. 3, 4 and 5, respectively. The principal fatty acids for each genotype were: oleic, linoleic, palmitic and stearic acids. However, significant differences ($P<0.05$) occurred in the fatty acid compositions among these lipid classes when comparing *Yatsuko* and *Kuriebisu*. The percentage of oleic acid was lower ($P<0.05$) in the *Kuriebisu* than in the *Yatsuko*, and the value was compensated by an increase ($P<0.05$) in linoleic acid (Figs. 3–5). Especially, these trends were more pronounced ($P<0.05$) in the phospholipids than in the TAGs or FFAs. Low percentages were detected for myristic, palmitoleic, linoleic and arachidic acids, and they are shown as "others" in Figs. 3–5. Longer microwave processing caused higher roasting temperatures that resulted in a lower percentage of linoleic acid and higher percentages of oleic, palmitic and stearic acids (Figs. 3–5).

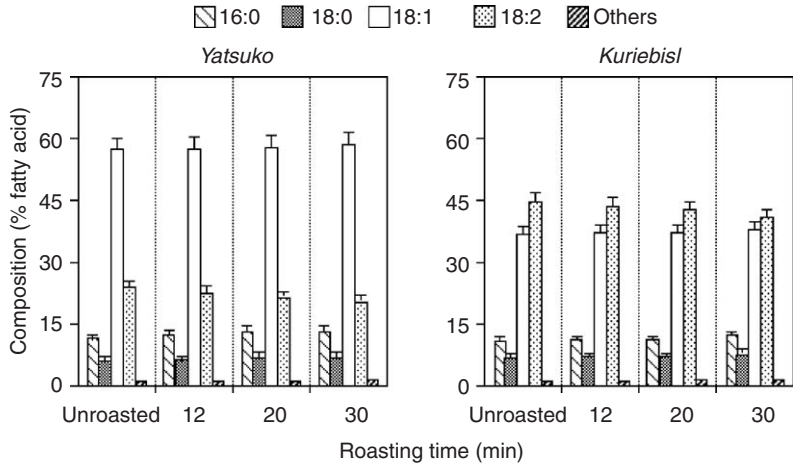

Fig. 3. Changes in fatty acid distribution of triacylglycerols obtained from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Each value represents the average of three replicates, and vertical bars show the S.D. of the mean value. "Others" contained 14:0, 16:1, 18:3 and 20:0.

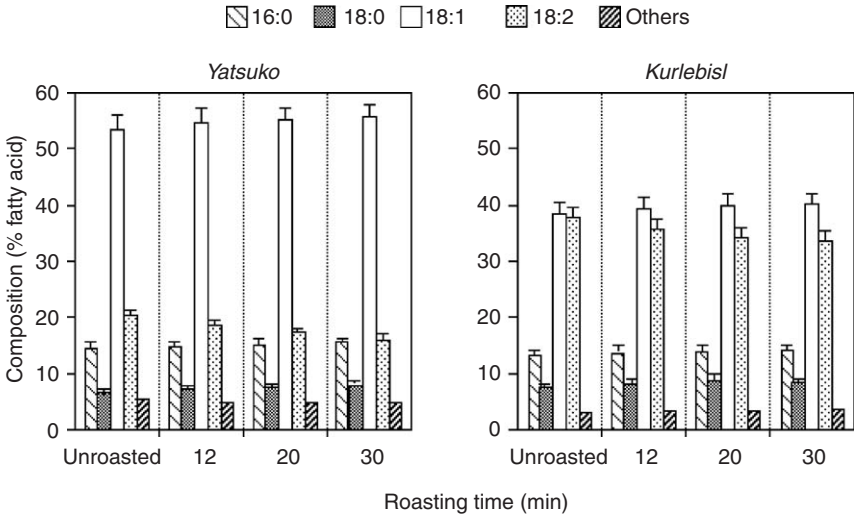

Fig. 4. Changes in fatty acid distribution of free fatty acids obtained from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Each value represents the average of three replicates, and vertical bars show the S.D. of the mean value. "Others" contained 14:0, 16:1, 18:3 and 20:0.

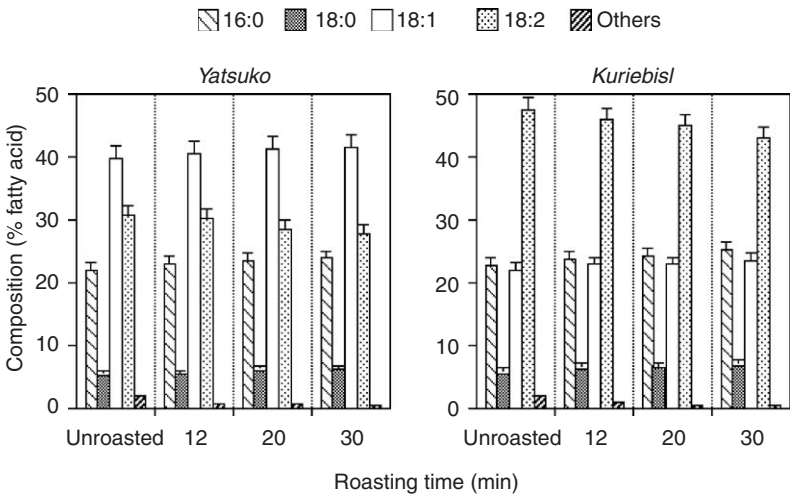

Fig. 5. Changes in fatty acid distribution of phospholipids obatined from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Each value represents the average of three replicates, and vertical bars show the S.D. of the mean value. "Others" contained 14:0, 16:1, 18:3 and 20:0.

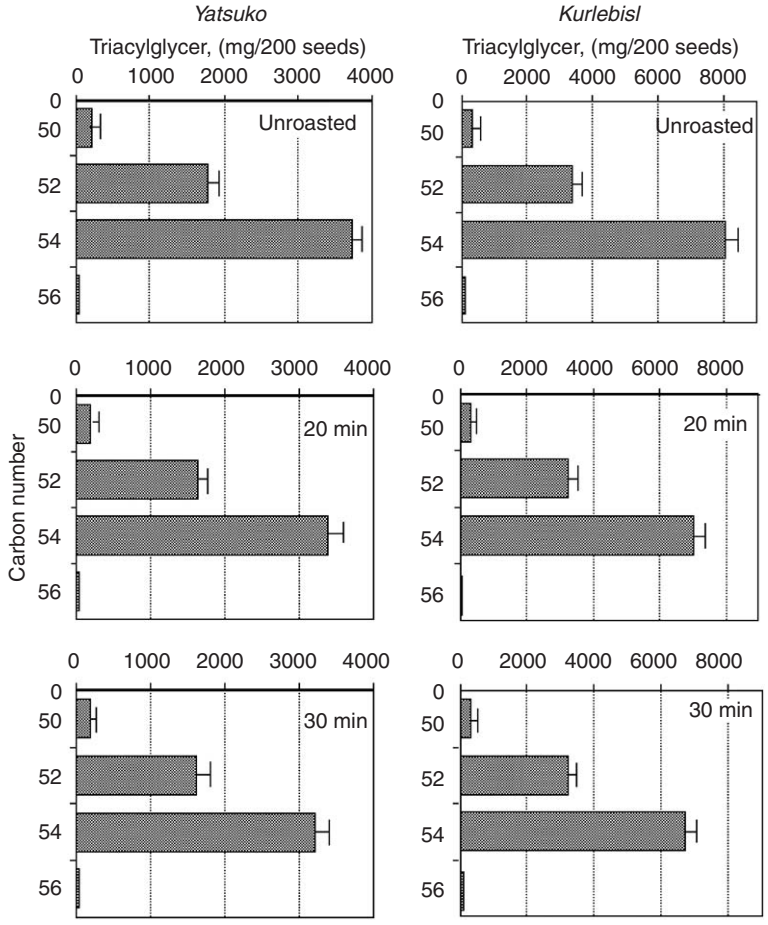

Fig. 6. Changes in the triacylglycerols content of the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Carbon number shows length of total acyl chains in a triacylglycerols. Each value represents the average of three replicates, and horizontal bars depict the S.D. of the mean value.

3.4. Effect of microwave roasting on major TAG content and distribution of these species

The kernels of pumpkin seeds contained even-numbered carbon TAGs for C44–C56 before microwave roasting (Fig. 6). Dominant components consisted of C52 and C54 TAGs, with much smaller amounts of C50 and C56 TAGs. Minor amounts (6.8 mg) of C44, C46 and C48 TAGs were omitted from Fig. 6 because the samples were too small to obtain reliable results. With increased microwave roasting time, a significantly greater loss ($P<0.05$) was observed for C54 TAGs compared to the other TAGs. The amount of C54 TAGs decreased after 30 min substantially by 3200 mg for *Yatsuko* and 6700 mg for *Kuriebisu*. These results would depend on the differences in the amounts of TAGs composed of oleic and linoleic acids (Fig. 3).

Fig. 7 depicts the typical changing profiles in the TAG molecular species isolated from the kernels of pumpkin seeds microwaved for different time periods. Eleven different molecular species were detected in the oils extracted from the kernels of unroasted pumpkin seeds. The three-letter designation does not suggest fatty acyl positional isomers in the TAGs (P, palmitic; St, stearic;

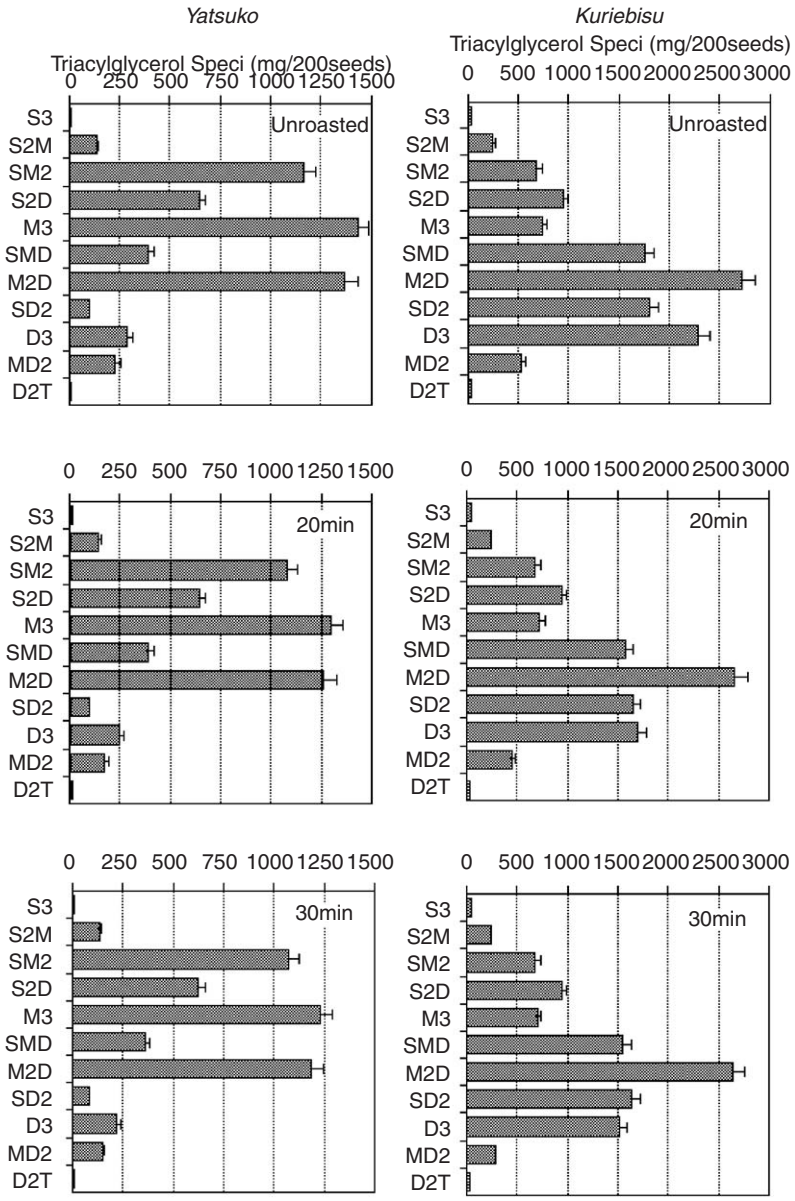

Fig. 7. Characteristics of molecular species of triacylglycerols extracted from the kernels of pumpkin seeds roasted for different time periods in a microwave oven at a frequency of 2450 MHz. Saturated fatty acids (S) consist of myristic (C14:0), palmitic (C16:0) and stearic (18:0) acids. Unsaturated fatty acids, oleic (C18:1) and linoleic (C18:2) acids are denoted as monoene (M) and diene (D). Each value represents the average of three replicates, and horizontal bars depict the S.D. of the mean.

O, oleic; L, linoleic). Major TAG species were POO or StOO (SM_2), PPL, PStL or StStL (S_2D), OOO (M_3), POL or StOL (SMD), and OOL (M_2D) between the two cultivars, and further StLL or PLL (SD_2) and OLL (MD_2) for *Kuriebisu*. These results would reflect the differences in the composition and distribution of fatty acids composed of TAGs (Fig. 3). The other species (S_3, S_2M, D_3 or D_2T) were detected as minor components (Fig. 7).

With increased microwave roasting time, a significant loss ($P<0.05$) was apparent in the TAG molecular species having more than four double bonds. These trends became more pronounced ($P<0.05$) after 20 min of roasting. The rate of fatty acid breakdown is related to the number of double bonds in the carbon chain of the molecule. As the number of double bonds increases, the rate of oxidation increases, the ratios of the rates of oxidation of oleate to linoleate to linolenate are reported to be 1:10:20 (Fatemi and Hammond, 1980). These results are in agreement with those obtained by Wada and Koizumi (1983), and by Yoshida and Alexander (1984) for fatty acid thermal oxidative degradation.

4. Conclusions

The results of the experiments presented here show that the exposure of pumpkin seeds to microwaves for 12 min caused no significant loss or change in the content of tocopherols and linoleic acid in the kernels. This information may indicate that a short exposure to microwaves to retard seed deterioration is technically feasible at oilseed processing mills. Further studies are necessary to discuss a relationship between the content of antioxidants and oxidative stability of the kernel oils of pumpkin seeds during microwave roasting. We undertake to expand these results to factory circumstances, because the laboratory-scale experimental design methodology is easily extendible to factory scale as well.

Acknowledgements

This research was partly financially supported by a research grant for Health Science of Kobe Gakuin University.

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