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Food Chemistry 75 (2001) 37–42

Food Chemistry

www.elsevier.com/locate/foodchem

Comparative studies of different heat treatments on quality of fried shallots and their frying oils

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Received 9 April 1999; received in revised form 9 March 2001; accepted 9 March 2001

Abstract

The objectives of this study were to compare the quality of shallot-flavoured frying oil from microwave heat treatment with that from gas heat treatment. Frying of shallot pieces by the microwave treatment required shorter heating time to obtain the same colour quality as through gas treatment. The amount of total volatile compounds of shallot-flavoured frying oil obtained from microwave treatment was greater than that from gas treatment. Oil-frying of shallots by microwave heating showed better oil quality, with lower acid and peroxide values than after frying by gas heating. In storage tests these two differently treated oils at 25°C, the acid value (AV) showed no significant increase during storage for 80 days. However, the peroxide value (PV) of these two oils increased in parallel as storage time increased. The effect of moisture content, of the shallots, on the quality of resultant shallot-flavoured frying oil was studied. Slight moisture reduction of shallot pieces from 72 to 63%, by a toasting pretreatment gave the highest amount of total volatile compounds of the shallot-flavoured frying oil. However, this total volatile compounds decreased if the moisture content of shallot pieces was less than 63%. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Frying oil; Gas heating; Microwave heating; Shallot-flavoured oil

1. Introduction

Shallot (*Allium cepa* L. var. *aggregatum*) is an important seasoning spice in Chinese dishes. Shallot seasoning is usually prepared by cutting shallots into pieces, followed by deep frying. Sulfur-containing compounds in shallots are responsible for the flavour production (Chou & Wu, 1985; Fenwick & Hanley, 1985). Shallot-flavoured frying oils, obtained from different heat treatments show some differences in the flavouring constituents (Wu, Chou, Chen, & Wu, 1982). However, all these oils, from baking or deep-frying of shallots, show increases in the amounts of dimethylthiophene, unsaturated alkyl trisulfides and some small high molecular weight compounds (Ho, 1989). Boelens, de Valois, Wobben, and van der Gen (1971) described the aroma of 2,4- and 3,4-dimethylthiophens as being “distinctly that of fried onions”. These compounds should contribute greatly to the flavour of deep-fried shallots. During frying, higher temperatures favour the formation of sulfur-containing compounds. Although shallot-flavoured frying oil is normally obtained by deep-frying through gas heat treatment, in this study, other heat treatments, including toasting pretreatment and deep-frying of shallots through microwave heating are investigated, and we compare the quality of shallot pieces and shallot-flavoured frying oils obtained from different heat treatments.

2. Materials and methods

2.1. Materials

Shallots were purchased at a local market in Hsinchu, Taiwan. Commercial soybean oil product was purchased from a local market.

2.2. Methods

2.2.1. Sample preparation

Shallots were sliced into pieces with a thickness of 5 mm by a Moulinette chopper blender (Italy). Twenty four grams of shallots and 88 g of soybean oil were prepared for each experimental trial. Toasting of shallots was conducted in a 60°C oven for 0.5, 1, 2, and 3 h. Deep oil-frying of toasted or fresh shallot pieces was

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PII: S0308-8146(01)00180-7

conducted by microwave or gas heat treatments, in this study. Microwave heating was accomplished with a National unit (Taipei, Taiwan) equipped with a revolving carousel. The shallot pieces in the cold soybean oil, weighed in a 200-ml Pyrex glass, were microwaved for 3 min 35s at 720 W–2450 MHz to obtain golden-coloured shallots, the final oil temperature was 135°C for each trial. For gas treatment, shallot pieces were initially fried in a stainless steel pan until the oil reached 130°C, and then the frying was continued for 5 min 30 s to obtain the same golden-coloured shallots as those from microwave heating.

2.2.2. Analysis

Acid value (AV), peroxide value (PV) and oil colour [R/Y; R (redness), Y (yellowness)] of shallot-flavoured frying oil were determined according to American Oil

Table 1
Colour of shallot pieces and shallot-flavoured frying oil

Colour analyses	Heating time (min:s)		
	Microwave		Gas
	3:35	3:50	5:30
Chroma value of shallots[a]			
L	52.09	56.56	52.03
a	5.26	8.91	4.39
b	15.48	22.89	15.83
Colour of shallot oil[b]			
R	0.1	0.1	0.1
Y	0.6	0.6	0.6

[a] Chroma value: *L* (lightness), *a* (redness), *b* (yellowness).

[b] Oil colour: R (redness); Y (yellowness).

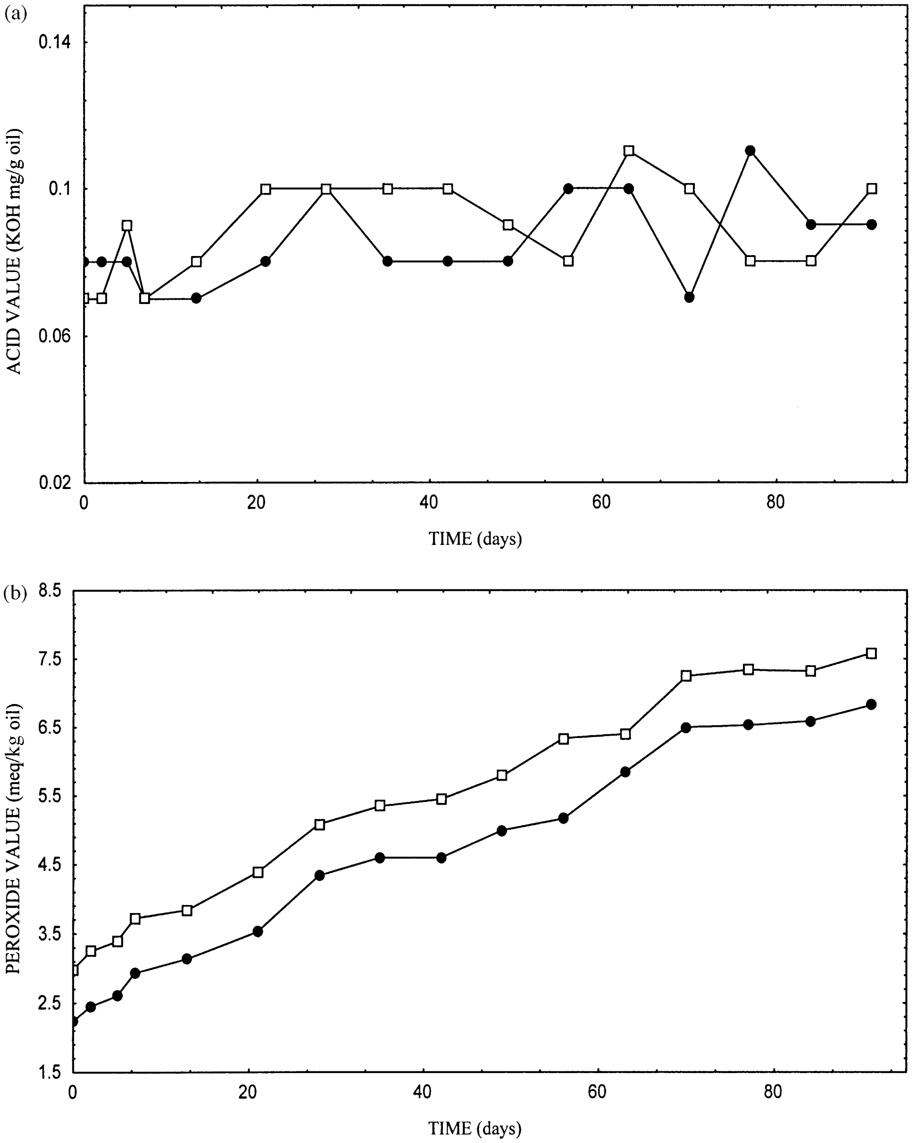

Fig. 1. (a) AV change of shallot oil at 25°C, (b) PV change of shallot-flavoured frying oil at 25°C (— ● — , microwave; — □ — , gas).

Chemists' Society (AOCS, 1993) Methods Cd 3a-63, Cd 8-53 and Cc 13e-92, respectively.

A Minolta Chroma Meter CR-200 (Minolta Camera Co. Japan) was used to measure the *L* (lightness), *a* (redness) and *b* (yellowness) of fried shallots.

Gas chromatography–mass spectrometry (GC–MS) analysis of shallot-flavoured frying oils was conducted. The volatile compounds of shallot-flavoured frying oil were analyzed by static headspace using a 7694 Hewlett-Packard headspace sampler coupled to a 5890 Hewlett-Packard gas chromatograph and a 6890 Hewlett-Packard mass selective detector (Hewlett-Packard, Palo Alto, CA). An aliquot of 1 g of oil sample was weighed into a 5 ml headspace vial and capped with Teflon seal. The oil sample was equilibrated at 110°C for 15 min and pressurized with carrier gas (helium) at 5 psi for 30 s before injection into a capillary column DB-Wax (60 m×0.32 mm, ID 0.5 mm film; J&W Folsom, CA). The oven temperature programme was run at 40°C for 10 min, and raised by 2°C/min to 200°C holding it there for 15 min. The flow-rate of carrier gas (helium) was 1 ml/min. At the end of the capillaries, the effluent was passed into a mass detector. The mass spectra were recorded at a scan rate of 3 s/decade, a source temperature of 180°C and an ionization energy of 70 eV.

Table 2
AV, PV and total volatile compounds of shallot-flavoured frying oil

Treatment	Total volatile compounds (peak area)	AV (mg KOH/g)	PV (meq/kg)
Microwave	1 880 678	0.08[a]	2.24[b]
Gas	1 763 555	0.07[a]	2.99[b]

[a] Values are not significantly different at $P<0.05$ in the same column.
[b] Values are significantly different at $P<0.01$ in the same column.

3. Results and discussion

3.1. General

The fried shallot pieces with golden colour and the oils with fried shallot flavour after frying for 5 min 30 s at 130°C by gas heat treatment were used as a control group to compare with the qualities of fried shallots and frying oils from microwave heat treatment.

3.2. Effect of microwave heat treatment on qualities of shallot-flavoured frying oil

Shallot pieces were oil-fried for 3 min 35 s by microwave heat treatment. The *L*, *a* and *b* values of fried shallot pieces were 52.09, 5.26, 15.48, respectively, which were close to those values of the control group as shown in Table 1. As microwave heating time increased up to 3 min 50 s, burning and darker coloured shallot pieces occurred with a higher chroma value which resulted in an undesirable appearance of the shallots. The AV of shallot-flavoured frying oils, from microwave and gas heat treatments, showed no significant differences ($P>0.05$). However, the PV of shallot-flavoured frying oil, from gas heating, increased 33% as compared with that of oil from microwave heating ($P<0.01$; Table 2). These results indicated that quick evaporation of water by frying of shallot pieces with microwave heating gave a less-oxidized oil. In addition, the longer oil frying of shallots by gas heating might result in a higher PV of oil. In the determination of total volatile compounds, shallot-flavoured frying oil from microwave heating gave 6.6% more total volatile compounds than the oil from gas heating. The higher amount of the total volatile compounds in shallot-flavoured frying oil, from microwave heating, caused a

Table 3
Effects of toasting pretreatment of shallots on qualities of shallots and shallot-flavoured frying oil

Toasting time (h) at 60°C	Moisture content of shallots (%)	Heating time (min:s)	Chroma of shallots			Shallot oil			
			L	*a*	*b*	AV	PV	Colour	
								R	Y
Microwave heating									
0	71.86±0.20	3:35	52.09	5.26	15.48	0.04±0.00	1.91±0.01	0.1	0.6
0.5	63.49±0.42	3:10	52.14	4.62	15.16	0.04±0.01	1.90±0.09	0.1	0.6
1	56.01±0.22	2:25	51.68	4.72	13.09	0.06±0.01	1.86±0.05	0.1	0.6
2	21.35±1.22	2:00	50.55	4.43	12.76	0.05±0.01	1.90±0.07	0.1	0.6
3	8.50±0.72	1:15	49.64	4.94	12.42	0.04±0.01	1.95±0.03	0.1	0.6
Gas heating									
0	71.86±0.20	5:30	52.03	4.39	15.83	0.05±0.02	2.32±0.14	0.1	0.6
0.5	63.25±1.12	4:10	52.47	4.45	14.95	0.08±0.01	2.09±0.01	0.1	0.6
1	55.23±0.87	4:00	49.89	3.79	13.03	0.05±0.01	2.12±0.02	0.1	0.6
2	20.02±0.53	3:00	49.98	3.87	9.77	0.05±0.01	2.12±0.04	0.1	0.6
3	10.59±0.92	1:35	48.79	3.55	8.93	0.04±0.01	1.96±0.01	0.1	0.6

Table 4
Total peak area of volatile compounds of microwave-treated and gas-treated shallot-flavoured frying oils from shallots toasted at 60°C for various times

Heat treatment	Toasting time (h)	Peak area of total volatile compounds[a]
Microwave	0	1 308 984
	0.5	1 519 799
	1	1 302 587
	2	1 171 772
	3	1 088 832
Gas	0	1 234 569
	0.5	1 249 654
	1	1 154 639
	2	994 307
	3	982 685

[a] Determined with a Hewlett Packard 5890 gas chromatography.

Table 5
Identity of volatile compounds of microwave-treated shallot-flavoured frying oils from shallots pretreated with various toasting times

Flavour compound[a]	Peak area				
	0 (h)	0.5 (h)	1 (h)	2 (h)	3 (h)
2-Butenoic acid	247 625	332 457	259 547	224 882	218 585
Acetic acid	67 862	61 893	67 446	62 735	74 198
2-Methyl-(E)-1,3-pentadiene	70 020	72 970	45 586	40 110	39 907
2-Propenal	160 204	156 698	106 752	93 663	92 825
2-Methyl-2-propenal	30 571	32 522	19 218	16 558	15 087
Ethyl alcohol	30 327	32 374	20 504	18 395	17 543
Chloroform	34 753	37 413	21 475	19 022	18 363
2,4-Pentadienal	71 549	59 771	45 182	44 725	44 016
2-Pentyl furan	11 413	9042	7979	7548	7495
2,4-Dimethyl thiophene	5686	6540	5534	5393	5086
3-Methyl-1-propene	23 638	18487	14 300	13 262	7959
Pyrrolidine	48501	37176	32576	29743	28 291
3-Methyl- 2-butenal	54134	44959	37438	33952	32 563
2,4-Heptadienal	15 430	16 393	11 269	10 221	9913
2-(1-Methylethoxy)-ethanol	13 070	16 535	14937	12 786	12 428
Total peak area	884 784	935 229	709 744	631 995	624 259
Heptyl acetate (IS)	111 520	109 144	117 073	115 335	118 743

[a] Determined with a Hewlett Packard 5890 gas chromatograph, coupled to a mass selective detector, 6890.

stronger flavour intensity than that from gas heating. In the storage tests of these two differently treated oils at 25°C, the AV of both oils showed no significant increase during storage for 80 days (Fig. 1). However, the PV of these two oils increased, in parallel, as storage time increased.

3.3. Effect of moisture content of shallot on oil qualities

Shallot pieces were deep-fried by microwave heating using a frequency of 2450 MHz to excite the water molecules of shallots first, then to induce them to rotate and, eventually evaporate. As microwaves can penetrate further into samples (~1.2 cm in foodstuffs), the frying time tends to be shorter. Due to the high moisture content (72%) of shallots, toasting pretreatments of shallot pieces at 60°C, before either microwave or gas heat treatment, was conducted to study the effects of the moisture content on the quality of shallot-flavoured frying oil. From the determinations of chroma value of shallot pieces, from either microwave or gas heating, as shown in Table 3, the value of *L*, *a* and *b* decreased as toasting time increased more than 0.5 h ($P<0.05$). With respect to the quality of shallot-flavoured frying oil, all the results showed a similar trend as those from the shallots without toasting. The AV and colour of the oils from microwave and gas heat treatments were not significantly different. However, the PV of the oil from

Table 6
Identity of volatile compounds of gas-treated shallot-flavoured frying oils from shallots pretreated with various toasting times

Flavour compound[a]	Peak area				
	0 (h)	0.5 (h)	1 (h)	2 (h)	3 (h)
2-Butenoic acid	208 150	200 610	185 280	168 651	160 645
Acetic acid	60 159	64 373	66 670	56 707	66 578
2-Methyl-(E)-1,3-pentadiene	41 047	55 609	47 030	36 632	36 692.
2-Propenal	144 639	133 274	114 462	103 202	100 393.
2-Methyl-2-propenal	18 892	17 040	16 207	13 749	14 730
Ethyl alcohol	23 337	26 596	25 067	19 535	19 016
Chloroform	25 879	33 011	26 052	23 329	22 806
2,4-Pentadienal	66 092	81 461	70 682	57 075	56 272
2-Pentyl furan	10 289	13 147	11 780	10 494	6149
2,4-Dimethyl thiophene	5232	5346	5130	4980	4935
3-Methyl-1-propene	19 259	23 106	19 381	15 107	15 079
Pyrrolidine	47 648	61 971	43 9893	40 706	39 502
3-Methyl- 2-butenal	45 825	62 625	51 867	46 196	45 906
2,4-Heptadienal	14 054	16 319	15 375	14 520	13 491
2-(1-Methylethoxy)-ethanol	15 401	14 765	14 956	14 333	17 026
Total peak area	745 904	809 254	713 833	622 216	619 222
Heptyl acetate (IS)	117 661	117 722	113 158	111 376	117 613

[a] Determined with a Hewlett Packard 5890 gas chromatograph, coupled to a mass selective detector, 6890.

microwave treatment was lower than that from gas treatment.

The toasting effect, of shallots, on the amount of total volatile compounds of shallot-flavoured frying oils, from both microwave and gas heat treatments was also studied. All the total volatile compounds of shallot-flavoured frying oils from both microwave and gas heat treatments, increased as the moisture content of shallots was lowered to 63% by toasting at 60°C for 0.5 h. Nevertheless, if the toasting process of shallots exceeded 0.5 h, the amount of total volatile compounds decreased. Longer toasting of shallots might cause more loss of some volatile compounds in the shallots. The lower the total amount of volatile compounds, the lower the flavour intensity of shallot oils. By comparing the amount of total volatile compounds of shallot-flavoured frying oils with the same colour intensity, more total volatile compounds were found in the shallot-flavoured frying oil obtained from microwave heating than from gas heating (Table 4). This result might be due to rapid heating and active pumping of water from the interior to the surface of the shallots during microwave heating, which might favour interactions between the water-soluble compounds of the shallots and the frying oil.

In the analysis of GC mass spectra, some differences were found in the flavour compounds of shallot-flavoured frying oils between microwave and gas heat treatments. The amounts of 2-butenoic acid, 2-methyl-(E)-1,3-pentadiene, 2-methyl-2-propenal and 2,4-dimethyl thiophene were higher for the oils from microwave heat treatment of both fresh shallots and 0.5 h-toasted shallots. 2,4-Dimethyl thiophene has been reported to be one of the major compounds contributing to the desirable flavour of fried shallots (Boelens et al., 1971). Toasting of shallots at 60°C for 0.5 h, before frying, increased the amount of 2,4-dimethyl thiophene of shallot-flavoured frying oils during microwave- or gas heat-treatment. For microwave heat-treatment (Table 5), the amount of 2,4-dimethyl thiophene increased by 15%, as shallots were toasted for 0.5 h, as compared with the control group (without toasting). When toasting time was prolonged for 3 h, the amount of 2,4-dimethyl thiophene was 10% less. With gas heat-treatment, Table 6 shows that 2,4-dimethyl thiophene increases by 2% for the frying oil from 0.5 h-toasted shallots. Where toasting of shallots exceeded 0.5 h, 2,4-dimethyl thiophene of shallot-flavoured frying oil decreased as the toasting time increased. Aside from 2,4-dimethyl thiophene, other compounds might also influence the total flavour of shallot-flavored frying oil. With soybean oil as a heat medium, aldehydes, such as 2,4-pentadienal and 2,4-heptadienal (Tables 5 and 6) are produced. According to Wu et al. (1982), sulfur-containing compounds, including disulfides, trisulfides, and thiophenes, played an important role in contributing to the flavour of shallot-flavoured frying oil. Our results show that only 2,4-dimethyl thiophene was determined by the GC–MS analysis by the headspace method, which might be due to the low concentrations of sulfur-containing compounds in the headspace of 1 g sample oil/5 ml. However, by comparing the changes of total volatile compounds and 2,4-dimethyl thiophene, shallot-flavoured frying oil, obtained from microwave heating, had a higher flavour intensity and quality than that from gas heating.

In conclusion, this study shows that the moisture reduction of shallots from 72 to 63%, by the toasting pretreatment, increases the total volatile compounds and 2,4-dimethyl thiophene of the resultant shallot-flavoured frying oil during microwave or gas heating. If the moisture content of shallots is reduced below 63%, by prolonged toasting, the flavour intensity and 2,4-dimethyl thiophene content decreases. Oil frying of shallots by microwave heating gives lower PV and higher flavour intensity than by gas heating.

Acknowledgements

This research was supported by the Ministry of Economic Affairs, Taiwan, the Republic of China (project no. 87-EC-2-A-17-0237). Our thanks go to S.C. Chou for providing technical assistance.

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