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Influence of dimethylpolysiloxane addition to frying oils: performance of sunflower oil in discontinuous and continuous laboratory frying

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SUMMARY

Influence of dimethylpolysiloxane addition to frying oils: performance of sunflower oils in discontinuous and continuous laboratory frying

Conventional and high oleic sunflower oils were used to study the influence of dimethylpolysiloxane (DMPS) addition (2 mg/Kg) on discontinuous and simulated continuous laboratory frying. Analytical methods applied for a direct evaluation of oil degradation included determination of total polar compounds, polymers, oxidized triglyceride monomers and diglycerides. Results indicated that DMPS has a strong positive action in discontinuous frying as differences between samples with and without DMPS were very high and much more pronounced than those attributed to oil unsaturation. However, DMPS was not effective in simulated continuous frying. Comparison from results obtained for discontinuous and simulated continuous frying demonstrated that the surface was well protected from the penetration of oxygen when potatoes are being fried and, in consequence, protection by DMPS in discontinuous frying took place when the oil surface was unprotected.

KEY-WORDS: Continuous frying– Dimethylpolysiloxane– Discontinuous frying– High oleic sunflower oil– Polar compounds– Sunflower oil.

1. INTRODUCTION

Studies on the action of dimethylpolysiloxane (DMPS) during thermoxidation of oils in the absence of food (Jorge et al, 1996) clearly demonstrated that its addition at very low concentrations had a positive effect when samples were heated in plates, although no significant differences were found when they were prepared in an oven. These facts would be in favour of the importance of the convection currents created due to the temperature gradient which would be inhibited when DMPS was added (Freeman et al., 1973; Kusaka et al., 1985). Taking into account that deep fat frying is similar to heating in plates in that the interface air-oil is at a lower temperature than the oil close to the heating element, a positive effect should be also expected in practical frying when oils contain DMPS.

Nevertheless, results obtained in the industrial preparation of crisps (Sebedio et al., 1996) indicated that DMPS was not effective as no differences in degradation were found between oils with and without DMPS. Due to the good manufacturing frying practices applied, i.e., fryer design, high rate of production, low period of turnover, etc (Wester et al., 1996), the alteration level of oils after two days of frying was very low, and analytical deviations could explain why significant differences were obtained. Alternatively, the dynamic nature of the surface during frying might have contributed to the lack of DMPS action.

Experiments of laboratory frying may be very useful to clarify the results, as they permit selection of certain variables of the frying process in order to obtain high alteration levels which in turn can clearly define if the absence of effect in industrial trials was masked by the low alteration of the samples. In this paper, results obtained in discontinuous and simulated continuous laboratory frying under similar conditions are compared.

2. EXPERIMENTAL

2.1. Samples

Sunflower oil (SO), genetically modified high oleic sunflower seed oil (HOSO), both without and with 2 ppm of DMPS added, were the four initial oils . General characteristics have been reported previously (Jorge et al., 1996; Sebedio et al., 1996).

2.2. Frying Procedures

a) *Discontinuous frying*

4 commercial electric fryers each containing 1L of the four oils were used to prepare 4 lots of 2 Kg of fried potatoes.

Potatoes were peeled, cut into homogeneous strips and washed with water. 10 batches of 200 g were fried in each oil for 10 min and intervals of 20 min were established between frying operations. The initial temperature was 175°C and no replenishments of oil were made. Total heating period was 6 hours, which also included an initial heating period (50 min), to establish the same temperature in the fryers, and a final heating period (30 min). Surface-to- oil volume ratio changed from the initial 0.3 cm^{-1} to 0.4 cm^{-1} after the 10th frying operation. Samples of frying oils were taken out after the 1^{st}, 6^{th} and 10^{th} frying operations and stored at -30°C for further analyses.

b) *Simulated continuous frying*

Similar conditions to those described above for temperature, initial surface-to-volume ratio and total period of heating were applied. Continuous frying was simulated by using two baskets to maintain the presence of the food in the fryer during all the heating period . Thus, the main difference with discontinuous frying consists in that 6.4 Kg of potatoes were fried in each oil (32 lots x 10 minutes). A minimum initial heating period of 20 min and a final one of 20 min completed the 6 hour heating. Also, it was necessary to add 250 ml of oil after the 21^{st} frying operation to maintain a minimum amount of oil. Surface-to-oil volume ratio changed from the initial 0.3 cm^{-1} to 0.5 cm^{-1} after the 32^{nd} frying operation. Samples of frying oils and fried potatoes were taken out after the 1^{st}, 21^{st} and 32^{nd} frying operations and stored at -30°C for further analyses.

3. ANALYTICAL EVALUATION

– Quantitation and distribution of polar compounds were determined by a combination of adsorption and size exclusion chromatography (Dobarganes, 1988).

– Raw and fried potatoes were ground and freez-dried, and moisture was determined gravimetrically. Food lipids were obtained by 6 h Söxhlet extraction (AENOR, 1991), using diethyl ether as solvent. Dry lipid matter was calculated by subtracting the moisture and lipid content of each sample from 100.

– Oil stability index was evaluated by means of a Rancimat apparatus at 100°C (AOCS, 1994) using either 2.5 g of oil or 5g of freeze-dried potatoes.

– α-tocopherol was determined by HPLC and fluorescence detection (IUPAC, 1992)

4. RESULTS AND DISCUSSION

Table I shows the quantitative changes in the major components of the potatoes, to indicate general characteristics of the potatoes, intermediate between crisps and french fries. Results for fried potatoes were expressed as the food weight obtained from 100 g of raw potatoes. Thus, from the values shown in Table I, both the loss of moisture and the gain of oils can be determined directly by subtraction. Standard deviations of the means were high as the mean values corresponded to four samples obtained from the four fryers and they belonged to different frying operations. This random selection of fried products gives more complete information of the general differences in fried food composition. They are probably due to small variations in temperature during frying, as it was deduced previously that there were no significant differences due to oil unsaturation or alteration level of the oils. (Dobarganes et al., 1993).

Table I
Major changes during the frying of potatoes (wt% on initial food basis)

Treatment	Analysis	Before frying	After frying
Discontinuous frying	Moisture	81.2	7.7 (0.62)*
	Lipids	< 0.1	9.5 (1.24)
	Dry matter	18.7	18.6 (0.63)
	Total	100	35.8 (1.13)
Continuous frying	Moisture	82.6	7.2 (0.60)
	Lipids	< 0.1	10.7 (0.85)
	Dry matter	17.4	17.8 (0.90)
	Total	100	35.7 (1.30)

*SEM (n=4) are included between brackets

Table II shows the evolution of polar compounds in discontinuous frying. In these experiments, the effect of the addition of DMPS, oil unsaturation and period of frying can be analysed as the other variables, i.e., temperature, surface-to-oil volume ratio, food, etc, were kept constant. Samples of oils after 1, 3.5 and 5.5 hours corresponded to the 1^{st}, 6^{th} and 10^{th} frying operations, respectively. As can be observed, values for SO were always higher than for HOSO at any period of frying, independently of the DMPS addition. Nevertheless, differences due to oil unsaturation were less important than those previously found (Jorge et al., 1996). Thus, after 6 hour of frying, the highest difference found between SO and HOSO was 3.2% in polar compounds for samples without DMPS. However, differences between samples with and without DMPS in polar compounds were enormous since the first frying operation and they increased with the period of heating. After 6 hours, polar compounds for samples without DMPS were 3-fold higher than those obtained for oils with 2 mg/Kg DMPS added.

It is also interesting to observe that the time period required to obtain similar values of polar compounds clearly varied between samples containing DMPS or not. Thus, results for polar compounds were practically identical for SO after 1 h and SO DMPS after 5.5 h, and for HOSO after 1 h and HOSO DMPS after 5.5 h. The time ratio found (5.5) suggested a high increase in the frying oil life in discontinuous frying by adding DMPS at a low concentration. From these two pairs of samples it was also deduced that addition of DMPS did not affect the formation of any of the most significant groups of polar components specifically.

Table II
Evolution of total polar compounds (wt % on oil) and polar compound distribution (mg/g) in discontinuous frying

Samples	t (h)*	Total	Distribution				
			TGP	TGD	oxTGM	DG	FA
SO	0	3.2	n.d.	5.5	8.8	11.6	6.1
SODMPS	0	3.3	n.d.	5.7	9.1	12.0	6.2
HOSO	0	2.9	n.d.	2.1	6.1	14.4	6.4
HOSODMPS	0	2.9	n.d.	2.5	6.8	13.8	5.9
SO	1	6.1	2.3	24.8	19.5	9.6	4.8
SODMPS	1	3.7	1.1	11.4	9.1	10.2	5.2
HOSO	1	5.0	1.4	14.0	17.5	12.5	4.6
HOSODMPS	1	2.8	0.6	4.9	7.0	11.0	4.5
SO	3.5	13.0	11.2	62.3	41.3	10.1	5.1
SODMPS	3.5	5.0	1.6	19.2	13.9	10.1	5.2
HOSO	3.5	10.6	7.7	38.3	41.1	13.7	5.2
HOSODMPS	3.5	4.1	1.2	10.1	12.2	12.3	5.2
SO	5.5	18.7	24.1	89.2	58.7	10.1	4.9
SODMPS	5.5	6.4	2.9	28.2	18.0	10.0	4.9
HOSO	5.5	15.4	18.0	58.2	59.6	13.9	4.3
HOSODMPS	5.5	4.9	2.0	15.4	14.3	12.6	4.7
SO	6.0	20.4	27.3	94.9	66.3	10.6	4.9
SODMPS	6.0	7.2	3.2	32.2	20.7	10.6	5.3
HOSO	6.0	17.2	21.3	64.2	67.6	14.1	4.8
HOSODMPS	6.0	5.8	2.3	18.4	17.7	14.1	5.5

* Period of heating
n.d. not detectable
Abbreviations: SO, sunflower oil; HOSO, high oleic sunflower oil; DMPS, dimethylpolysiloxane; TGP, triglyceride polymers; TGD, triglyceride dimers; oxTGM, oxidized triglyceride monomers; DG, diglycerides; FA, fatty acids.

Values for triglyceride polymers, dimers, oxidized monomers, diglycerides and fatty acids were similar in samples with and without DMPS, confirming that the distribution of polar compounds depended mainly on the oil alteration, and, at a second level, on the oil unsaturation (Jorge et al., 1996). Finally, it was clearly deduced from the results in Table II that, under the conditions applied, the addition of DMPS would be much more beneficial than the selection of a less unsaturated oil, as polar compound contents for HOSO were always much higher than those obtained for SO DMPS at any period of heating.

Results for simulated continuous frying are shown in Table III where a very different profile for the evolution of polar compounds can be observed. Apart from the initial and final oils, results at 0.5, 3.8 and 5.7 hours corresponded to samples of oils taken out after the 1st, 21st and 32nd frying operations. Under continuous frying, only small differences between samples with and without DMPS were found and it was interesting to observe that the differences existed since the first frying operation. In consequence, it was deduced that the slightly lower alteration of samples containing DMPS could be due to the unavoidable initial period of heating (20 min), necessary to achieve the same initial temperature in the fryers. Beyond this point, the increase in polar compounds was practically identical, which indicated that DMPS was not effective. However, the low values for polar compounds could not be attributed in this case to a low turnover period as occurred in industrial frying (Sebedio et al., 1996), since only 250 mL of oil was added after the 21st frying operation to make frying possible.

There was a more important finding even, related to the changes in surface to volume ratio (S/V). In continuous frying, S/V varied from 0.3 to 0.5 cm^{-1}, while changes in discontinuous frying were from 0.3 to 0.4 cm^{-1}. From these changes and considering that the rest of the variables remained at the same values in both types of frying, higher alteration would have been expected in continuous frying given the high influence of S/V (Jorge et al., 1996). In consequence, the results

Table III
Evolution of total polar compounds (wt % on oil) and polar compound distribution (mg/g) in continuous frying

Samples*			Distribution				
	t (h)	Total	TGP	TGD	oxTGM	DG	FA
SO	0	3.2	n.d.	5.5	8.8	11.6	6.1
SODMPS	0	3.3	n.d.	5.7	9.1	12.0	6.2
HOSO	0	2.9	n.d.	2.1	6.1	14.4	6.4
HOSODMPS	0	2.9	n.d.	2.5	6.8	13.8	5.9
SO	0.5	4.6	0.9	10.4	14.9	12.7	7.1
SODMPS	0.5	3.3	0.5	7.6	8.6	10.1	6.2
HOSO	0.5	4.2	0.6	6.8	13.8	14.1	6.1
HOSODMPS	0.5	3.0	0.2	3.5	9.2	12.0	5.1
SO	3.8	7.2	3.1	29.0	25.6	9.4	4.9
SODMPS	3.8.	6.3	2.1	24.3	20.5	10.5	5.6
HOSO	3.8	6.1	2.1	18.5	22.2	13.1	5.1
HOSODMPS	3.8	4.4	0.9	9.9	14.5	13.3	5.4
SO	5.7	9.5	6.0	42.0	31.2	10.5	5.3
SODMPS	5.7	8.1	4.3	35.3	25.8	10.3	5.3
HOSO	5.7	6.8	3.0	21.6	24.8	13.4	5.2
HOSODMPS	5.7	5.3	1.6	14.7	18.4	13.2	5.1
SO	6.0	11.7	10.9	50.9	39.4	10.3	5.3
SODMPS	6.0	10.4	7.7	46.8	33.9	10.2	5.4
HOSO	6.0	7.0	2.9	22.1	26.3	13.4	5.3
HOSODMPS	6.0	5.8	1.9	16.5	20.8	13.5	5.3

* Period of heating
n.d. not detectable
For abbreviations, see Table II

obtained for samples without DMPS indicated a strong protection of the surface due to the continuous presence of the food. In other words, by comparing the results obtained for samples without DMPS in discontinuous and continuous frying, it was deduced that alteration occurred mainly when the food was not present and the surface was unprotected from the penetration of oxygen.

Contrarily to the results obtained in discontinuous frying, the shift to a less unsaturated oil would be more beneficial to decrease alteration than adding DMPS at low concentration, given that polar compounds values for HOSO were always lower than those obtained for SO at any time of heating.

Lipids from foods were also analysed and the results were very similar to those obtained for their counterpart oils in Tables II and III (data not shown). No significant differences were found, neither in total polar compound levels nor in polar compound distribution, as previously observed. For illustration, Figure 1 shows graphically the values found for total polar compounds in lipids from the potatoes fried in conventional sunflower oil as they reproduce very well

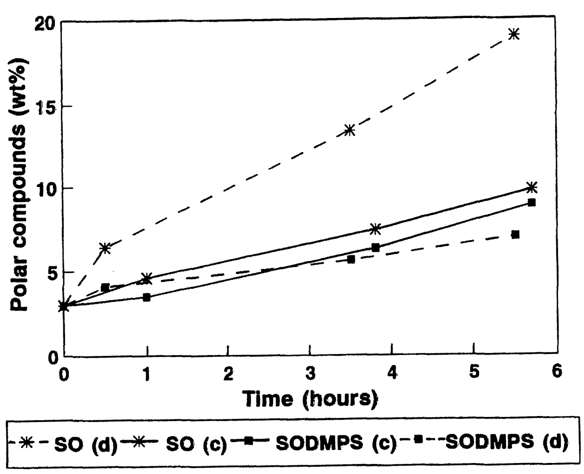

Figure 1
Evolution of total polar compounds in lipids extracted from potatoes fried in conventional sunflower oil (SO), with and without DMPS added, in continuous (c) and discontinuous (d) frying

Table IV
Total polar compounds (wt % on oil), α-tocopherol content (mg/Kg) and oil stability index (h) of frying oils and food lipids corresponding to the last frying operation.

Frying process	t(h)	Samples	Polar compounds Food lipids	Polar compounds Oil	α-tocopherol Food lipids	α-tocopherol Oil	Oil stability index Food lipids	Oil stability index Oil
Discontinuous	5.5	SO	19.0	18.7	185	155	4.5	3.8
		SO DMPS	7.0	6.4	543	584	9.0	8.8
		HOSO	16.0	15.4	10	tr.	2.5	1.2
		HOSO DMPS	5.5	4.9	535	569	29.7	22.5
Continuous	5.7	SO	8.8	9.5	320	345	6.6	5.4
		SO DMPS	7.9	8.1	394	414	7.5	6.2
		HOSO	6.6	6.8	168	185	16.1	10.5
		HOSO DMPS	4.9	5.3	362	417	21.0	18.4

For abbreviations, see Table II

what should be expected from a general interpretation of the results presented in Tables II and III. Evolution of samples with and without DMPS added is represented, dashed lines corresponding to discontinuous frying and unbroken lines to continuous frying. Differences between samples with DMPS can be attributed to changes in S/V, the only variable which differs due to the number of frying operations, while differences between samples without DMPS can be due to the distinct protection of the oil surface, higher in continuous frying. In general, these results would suggest that the higher the ratio of frying period-to-heating period, the lower the differences between samples with and without DMPS, i.e., minimum differences would correspond to continuous frying and maximum differences to thermoxidation in the absence of food. The influence of DMPS due to the existence of daily cooling/heating periods has not been defined but, considering the general results obtained, it is also a subject of interest and will be studied in the near future.

Finally, Table IV includes results for α-tocopherol contents and induction periods for samples of frying oils and food lipids corresponding to the last frying operation by both frying systems. It is observed that the loss of tocopherol from the initial oils (about 600 mg/Kg) depended on both the level of polar compounds and oil unsaturation, as previously found in the thermoxidative assays (Jorge et al, 1996). However, the tocopherol loss seemed to be more pronounced in continuous frying as the amounts found were lower when samples with similar polar compound levels from both frying systems were compared. Taking into account the differences between both frying procedures, the results would suggest a higher volatilization due to the steam water continuously produced during simulated continuous frying. This higher loss of natural antioxidants would consequently decrease the stability of the fried potatoes, as observed in the last column of the table. In this respect, induction times obtained were consistenly higher in dried potatoes than in oils, which could be due either to the different sample evaluated (5 g of dried fried potatoes) (Barrera-Arellano and Esteves, 1992) and/or to the presence of other active natural antioxidants in potatoes (Al-Saikan et al., 1995). Storage studies showing the influence of polar compound and tocopherol levels on the evolution of oxidation of the fried potatoes are being carried out to determine the influence of used frying oil quality on the shelf life of the fried product.

5. CONCLUSIONS

By comparing results from discontinuous and simulated continuous laboratory frying the following conclusions stand out:

1.- Surface during the continuous frying process was strongly protected, as deduced by comparing alteration of samples without DMPS in discontinuous and continuous frying. Even if the surface-to-volume ratio was higher at the end of the frying period in continuous frying, values for polar compounds were significantly lower for both SO and HOSO.

2.- No extra protection of DMPS during continuous frying was found as values for oils with and without DMPS were similar. The main consequence is that DMPS addition would not be necessary during continuous frying either because it has no action due to the physical characteristic of the surface or because of the protection already exerted by steam water from the potatoes.

3.- From the two previous conclusions, it was deduced that the positive action of DMPS was exerted when the oil surface was unprotected from the penetration of air. That would mean that addition of DMPS would be of particular interest in fried food shops where the fryers usually remain without food during significant periods of times, i.e. catering services, fast- food outlets, restaurants, etc.

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