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RESEARCH PAPER

Oxidative Stability of Edible Grade Crude Palm Oil Blends With Sunflower Oil or Groundnut Oil as Deep Frying Medium

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ABSTRACT

Oxidative stability of edible grade crude palm oil (CPO) blends with sunflower oil (SFO) and groundnut oil (GNO) in a ratio of 60:40 and 50:50 respectively was determined on 8h continuous heating with hourly frying of rice flakes for 4 min. Physico-chemical tests were performed on the two blends and CPO, initially and during frying regimen. CPO: SFO showed the highest unsaturated fatty acid content (65.3%) followed by CPO: GNO (65.0%), where as CPO had only 49% at the initial stage. Organoleptic evaluation of the rice flakes fried in all the three oils showed higher scores at 8h as compared to those fried at 1h in the respective oils. An increase in oil content of the rice flakes with increase in heating time was observed in all the three oils. The oils showed change in colour during heating. A steady increase in moisture, free fatty acids, peroxide value, anisidine value, total oxidation value and a decrease in ß-carotene and α-tocopherol contents was observed in the three oils during frying regimens. ß-carotene was totally lost within 4h in CPO and in 2h in the blends. α-tocopherol was destroyed completely within 1h in all the three oils. CPO showed maximum oxidative stability. CPO:SFO had better oxidative stability as compared to CPO:GNO. However, CPO and its blends can be promoted for the preparation of dishes requiring minimum heat treatment rather than as deep frying medium

Key words : edible grade crude palm oil, oil blends, deep frying, oxidative stability, ß-carotene, α-tocopherol

INTRODUCTION

Edible grade crude palm oil, an inexpensive, nutritious and abundantly produceable oil, with poor sensory attributes of colour, taste and aftertaste was improved by blending with conventionally accepted refined oils, groundnut or sunflower oil. Blending vastly improved the polyunsaturated fatty acids : saturated fatty acids (P:S) and saturated fatty acids : monounsaturated fatty acids : polyunsaturated fatty acids (SFA:MUFA:PUFA) ratios. Further the blends met the major objectives of storage stability and organoleptic acceptability and would be a good approach for promoting non-conventional crude palm oil as an edible oil in Indian dietaries (Padmavathy *et al.*, 2001).

A survey of various commercial food service establishments in Delhi showed that deep-fat frying is a widely used procedure in the preparation of a wide variety of foods. Further groundnut oil was the most popular frying medium followed by sunflower oil (Joshi *et al.*, 2001).

The oil used for frying becomes part of the food being fried. Further, quality of frying oil influences oil absorption and the types of by-products and residues absorbed by food (Kochar, 1999). Therefore it was of importance to determine the oxidative changes occurring in edible grade crude palm oil blends during deep-fat frying process and assess the organoleptic acceptance of fried food. It was also noteworthy to study the stability of the natural antioxidants present in palm oil like ß-carotene for its nutritional importance and α-tocopherol for its protective effect on frying oils.

MATERIALS AND METHODS

BLENDING OF OILS

Collection of oils: Edible grade crude palm oil (CPO) was obtained from Central Plantation Crops Research Institute, Research Centre (now NRC for Oil Palm, Regional Station) Palode, Thiruvananthapuram, Kerala in 50 l plastic can. Refined grade sunflower oil (SFO) and groundnut oil (GNO) were obtained from Super Bazaar outlet, each in two batches of 2 sl in green and yellow plastic cans. It was ensured that the different packs of each oil belonged to the same batch of production. All the three oils represents a single batch each. The inherent limitation was that the batch variation have not been studied.

Ratio of blending: Blends of CPO with SFO in a ratio of 60:40 and of CPO with GNO in a ratio of 50:50 were prepared. The basis of blending was to obtain a blend with a P:S ratio as near to the desirable value (0.8-1.0) as

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possible. This value has been recommended from a nutritional perspective (Ghafoorunissa, 1995). CPO on its own does not meet this requirement. Further blending also brought the SFA:MUFA:PUFA ratio of the blends nearer to the desirable value (1:1:1). As the fatty acid composition of SFO and GNO used for blending are different, the two blends prepared have unequal quantities of CPO. Blended and unblended CPO were transferred into 2 kg amber coloured PET bottles till used for frying trials. Each bottle was labeled and stored away from direct sunlight.

Deep-fat frying trials: The deep-fat frying (DFF) regimen was similar to that followed by Joshi *et al.* (2000), which was in accordance with the DFF practices observed in commercial food service establishments in Delhi (Joshi *et al.*, 2001). A thermostatically controlled deep-fat fryer with a 6 l capacity vessel was used for frying. For each frying regimen, the fryer was filled with 4.5 kg (approx. 5 l) of oil. The temperature control was set at 180°C and the oil was kept heated at this temperature throughout the 8 h trial. The oil was not replenished at any time during the experiment in order to assess the maximum deterioration possible in the heated oil.

DFF of rice flakes was conducted in 100 g batches, at hourly intervals. Each batch was fried for 4 minutes. Thus a total of 8 batches were fried during each 8 h frying regimen. After each batch of frying, an aliquot of 150 ml of the frying medium was taken for physico-chemical tests. The recovered oil samples were kept in food grade 180 ml amber coloured PET bottles at room temperature away from direct sunlight till analysis. Samples of rice flakes fried at 1 h, 4 h and 8 h were also stored in food grade amber coloured PET bottles separately for each batch. These were then presented for organoleptic evaluation. Duplicate frying trials, of 8 h each, were carried out with CPO, CPO:SFO and CPO:GNO. Thus a total of 6 frying trials with fresh oil were conducted.

Oil uptake by rice flakes: The oil absorbed by each batch of fried rice flakes was estimated by soxhlet fat extraction method (Anonymous, 1983).

Organoleptic/Sensory evaluation: A panel of 12 postgraduate collegiate women was selected for organoleptic evaluation of 1 h, 4 h and 8 h batches of the fried rice flakes. At one time 9 samples of the rice flakes, 3 from each of the 3 different oil types were presented. Water was provided as a palate-cleansing agent. The organoleptic evaluation sessions were conducted 1 h before lunch and conditions of temperature, humidity and illumination were adequate.

The panelists were asked to score the appearance, texture, colour, odour, taste, aftertaste and overall acceptability of the products on a scale of 1 to 5 where, 1 = very poor, 2 = poor, 3 = satisfactory, 4 = good and 5 = very good.

Changes in physico-chemical characteristics of the oils during DFF: Prior to DFF trials, the three oils, CPO, CPO:SFO and CPO:GNO were analyzed to obtain baseline data on their physico-chemical characteristics. After commencement of heating and frying the oil samples were again analyzed at 1h (colour, free fatty acids, peroxide value, anisidine value, totox value, ß-carotene and α-tocopherol), 4 h (moisture content, refractive index and specific gravity) and 8h (fatty acid composition) intervals.

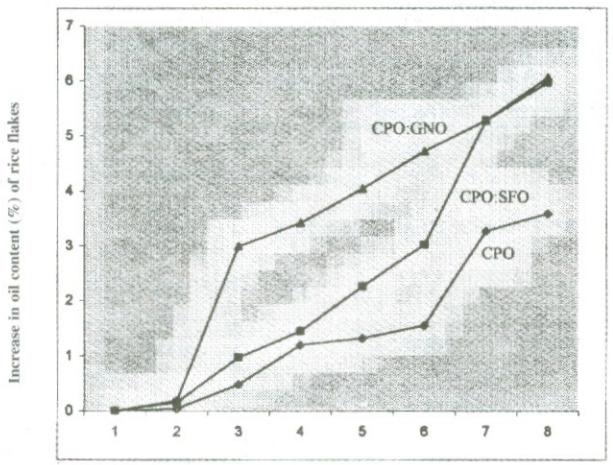
Physical tests: Colour of the oils was measured on a Lovibond tintometer. Moisture, refractive index and specific gravity were determined according to standard procedures (Anonymous, 1985).

Chemical tests: Fatty acid (FA) composition was determined by gas liquid chromatography (GLC). Fatty acid methyl esters were prepared using boron-trifluoride and methanol and were analyzed using a Nucon 5700-model gas chromatograph fitted with a flame ionization detector. Separation was done on a stainless steel column (6"x1/8") packed with 3% SP-2310 + 2% SP-2300 OW on Chromosorb-W (H.P. 100/200 mesh). Fatty acids in negligible amounts (<0.1%) was not considered. Further, 18:1 and 18:2 fatty acids were considered as MUFA and PUFA respectively. Free fatty acids (FFA), peroxide value (PV), anisidine value (AV) and total oxidation value (totox value) were determined according to standard procedures (Anonymous, 1985; Hamilton and Hamilton, 1992).

Beta-carotene was determined after alkaline saponification of oil and organic extraction. Non-aqueous reverse phase high performance liquid chromatographic (HPLC) analysis with a uv-vis detector at 450 nm was carried out (Manorama and Rukmini,1991). ß-carotene was separated by isocratic elution with acetonitrile, methanol and dichloromethane (60:35:5) at 1.5ml/ minute on a 25 cm C-18 column. Standard ß-carotene (crystalline, from carrots Code No. C-1026) was obtained from Sigma Aldrich, New Delhi. All the solvents were of HPLC grade. The HPLC system used was a Shimadzu LC-10 ATVP model fitted with Shimadzu UV-VIS spectrophotometric detector model SPD-10A Vp, rheodyne injection valve with 20*ul* loop.

Alpha-tocopherol was also estimated in the organic extract prepared for estimation of ß-carotene. HPLC analysis with a UV-VIS detector at 292 nm employing isocratic elution with acetonitrile, methanol and dichloromethane (60:35:30) at 2 ml/ minute on a 25 cm C-18 column was carried out. Standard α-tocopherol (Code No. T3251) was obtained from Sigma Aldrich, New Delhi.

Fig .1 : Increase in oil content (%)[a] of rice flakes fried in CPO, CPO:SFO and CPO:GNO



[a]Mean of two frying trials

All the solvents were of HPLC grade. All the data have been expressed as mean of two frying trials and percentages.

RESULTS AND DISCUSSION

The increase (Δ) in oil content of the rice flakes fried at each time point over a period of 8 h is given in Fig. 1. An increase in oil content of the rice flakes was observed with increased heating time of the oil. This increase in the 8 h batch of rice flakes fried in CPO, CPO:SFO and CPO:GNO was 3.6%, 6.0% and 6.1% respectively. The rice flakes fried in CPO, thus showed lowest oil pick up. Joshi *et al.*,(2000) observed that the oil pick up of rice flakes fried for 4 minutes at 8h time point was 7.6% and 9.8% in case of SFO and GNO respectively. The present study reveals that presence of CPO in the blends has helped in decreased retention of the oil by the rice flakes, hence ensuring lower fat consumption through fried foods.

The mean evaluation scores assigned to the fried rice flakes for each sensory attribute along with statistical significance for overall acceptability are presented in Table 1. There was a general increase in all the sensory attributes of the 8 h batch rice flakes fried in the three oils as compared to the 1h batch sample from the same oil. The overall acceptability of rice flakes fried in the three oils at 8 h was significantly greater than at the 4 h time point ($p<0.05$) and in 1h batch ($p<0.05$). The overall acceptability at 8 h was in the order of CPO:GNO>CPO:SFO> CPO. Table 1 further shows that none of the samples of rice flakes fried in CPO secured a score of 3 (satisfactory) for any of the sensory attributes. However both the CPO based blends were preferred to unblended CPO (very poor to poor scores). Further, CPO:GNO (poor to satisfactory scores) was marginally preferred to CPO:SFO (very poor to satisfactory scores). This may be attributed to a lower percentage of CPO (50%) in CPO:GNO blend. It is of concern to note here that even the two blends did not obtain

Table 1 : Sensory evaluation scores* for rice flakes fried for 4 minutes at 1, 4 and 8h in CPO, CPO:SFO or CPO:GNO

Frying medium	Time point of frying of rice flakes	Appearance	Texture	Colour	Odour	Taste	After taste	Overall acceptability
CPO	1h	1.54 ± 0.51	1.75 ± 0.74	1.83 ± 0.96	1.54 ± 0.51	1.67 ± 0.64	1.75 ± 0.68	1.58 ±0.50[a]
	4h	1.65 ± 0.49	2.33 ± 0.48	2.29 ± 0.46	2.33 ± 0.48	2.29 ± 0.46	2.29 ± 0.46	2.29 ± 0.46
	8h	2.75 ± 0.90	2.38 ± 0.65	2.63 ± 0.49	2.62 ± 0.49	2.67 ± 0.48	2.62 ± 0.49	2.66 ± 0.48
CPO:SFO	1h	1.96 ± 0.73	3.12 ± 0.60	2.20 ± 1.50	1.88 ± 0.78	1.76 ± 0.66	1.52 ± 0.51	1.48 ± 0.51[b]
	4h	3.33 ± 0.76	3.50 ± 0.66	3.70 ± 0.55	3.42 ± 0.78	2.75 ± 0.61	2.38 ± 0.49	2.70 ± 0.69
	8h	3.38 ± 0.87	2.70 ± 0.46	3.17 ± 0.76	3.04 ± 0.81	3.29 ± 0.95	2.04 ± 0.69	3.04 ± 0.95
CPO:GNO	1h	2.75 ± 1.07	2.88 ± 0.68	3.08 ± 0.78	2.54 ± 0.51	2.62 ± 0.49	2.58 ± 0.50	2.50 ± 0.50[c]
	4h	2.95 ± 0.75	2.45 ± 0.51	3.54 ± 0.51	2.79 ± 0.72	2.83 ± 0.70	3.00 ± 0.78	2.70 ± 0.66
	8h	3.00 ± 0.78	2.88 ± 0.74	3.75 ± 0.68	3.46 ± 0.51	2.83 ± 0.70	2.58 ± 0.50	3.38 ± 0.49

* (Mean ± SD) for two frying trials (n = 12 panelists). ANOVA ($p<0.05$) for overall acceptability.

[a] CPO - 8h > 4h > 1h, [b] CPO:SFO - 8h > 4h > 1h, [c] CPO:GNO - 8h > 4h > 1h.

Table 2 : Fatty acid composition (%)[a] of CPO, CPO:SFO and CPO:GNO before and after 8h frying[b]

Fatty Acid	% composition								
	CPO			CPO:SFO			CPO:GNO		
	Initial	After 8 hours		Initial	After 8 hours		Initial	After 8 hours	
		Observed	Corrected		Observed	Corrected		Observed	Corrected
14:0	1.2	1.2	1.2	0.7	0.7	0.7	0.5	0.6	0.5
16:0	46.5	46.3	46.5	30.6	31.3	30.6	29.8	31.0	29.8
18:0	3.3	3.4	3.3	3.0	3.2	3.0	3.2	3.3	3.2
18:1	38.4	38.8	39.0	38.9	39.3	38.4	41.5	41.8	40.2
18.2	10.6	10.3	10.3	26.4	25.2	24.6	23.5	21.4	20.6
SFA%	51.0	50.9	51.0	34.3	35.2	34.3	33.5	34.9	33.5
MUFA%	38.4	38.8	39.0	38.9	39.3	38.4	41.5	41.8	40.2
PUFA%	10.6	10.3	10.3	26.4	25.2	24.6	23.5	21.4	20.6
P/S ratio (0.8-1.0)[c]	0.2			0.8			0.7		
SFA:MUFA:PUFA ratio (1:1:1)[c]	1:0.8:0.2			1:1.1:0.8			1:1.2:0.7		
Loss(%weight) of unsaturated fatty acids after 8 h			+ 0.3%			- 2.3%			- 4.2%

[a] % of totals may not be 100 due to non detection of minor compounds. ; [b] Mean of 2 frying trials. ; [c] indicates the desirable values

a score of good (4) for any sensory attribute. Our previous study on unblended GNO and SFO gave higher scores of 4.2 and 4.0 respectively for overall acceptability of fried rice flakes (1h batch) but by a different panel (Joshi *et al.*, 2000). Hence CPO did not emerge to be a promising frying medium and blending with conventional oils only marginally improves acceptability of CPO as a deep frying medium.

The percentage fatty acid (FA) composition of the oils before and after the 8 h frying trials is given in Table 2. Initial analysis shows that CPO had high SFA (51.0%) content with a P/S ratio of 0.2 and SFA:MUFA:PUFA ratio of 1:0.8:0.2. Both the blends, CPO:SFO (60:40) and CPO:GNO (50:50) had high unsaturated fatty acids (USFA) (MUFA+PUFA) of 65.3% and 65.0% respectively resulting in a more desirable P/S ratio of 0.8 and 0.7 respectively and a better SFA:MUFA:PUFA ratio of 1:1.1:0.8 and 1:1.2:0.7 respectively. Thus blending resulted in an improvement in the fatty acid profile of the blend. Further, blending of SFO or GNO with CPO has resulted in a less unsaturated blend. This approach reduces the need to hydrogenate unsaturated oils thereby eliminating the chances of introduction of harmful *trans* fatty acids.

Table 2 also depicts the observed and calculated FA composition of the oils at the end of 8h frying regimen. There was an apparent marginal decrease of SFA in CPO and an apparent increase of SFA in CPO:SFO and CPO:GNO. There was also an apparent increase of oleic acid (18:1) and a decrease in polyenoic acid (18:2) in all the three oils. The actual values were calculated keeping palmitic acid constant. Such a calculation gives an indication of the degree of modification, oxidative polymerization, scission and other side reactions taking place during DFF (Tyagi *et al.*, 1998). Table 2 shows that there was a small loss of 2.3% and 4.2% of USFA in CPO:SFO and CPO:GNO respectively. However no such change in FA composition was seen in CPO indicating that oxidatively it was more thermostable.

Joshi *et al.* (2000) in a similar heating and frying regimen reported loss in USFA of 2.1%, 3.5% and 1.4% in Malaysian deacidified, deodorized red palmolein (Carotino), GNO and SFO respectively. Clearly GNO is more susceptible to losses than SFO.

Table 3 : Physico-chemical characteristics of CPO, CPO:SFO and CPO:GNO

Characteristic	CPO		CPO:SFO (60:40)		CPO:GNO (50:50)	
	Present study	ISI values	Present study	ISI values	Present study	ISI values
Physical						
Colour (1" cell) Lovibond units	109.3	-	99.8	-	92.1	-
Moisture (%)	0.50	0.25 (max)	0.40	0.20 (max)	0.39	0.20 (max)
Refractive index (at 40°C)	1.4582	-	1.4612	-	1.4612	-
Specific gravity (30°C/30°C)	0.893	-	0.899	-	0.899	-
Chemical						
FFA %(Palmitic/ Oleic acid)	4.5[a]	5.0[a] (max)	2.9	2.5 (max)	2.75	2.5 (max)
PV (meqO_2/Kg oil)	2.4	5.0 (max)	2.1	-	1.9	-
Anisidine value	4.2	-	4.0	-	3.9	-
Totox value	9.1	-	8.1	-	7.6	-
β-carotene (mcg/g)	390.1	-	230.3	-	190.5	-
α-tocopherol (ppm)	197.3	-	351.0	-	201.3	-

[a] FFA % as palmitic acid ; other oils FFA % is expressed as oleic acid

The physico-chemical characteristics of CPO and its two blends are given in Table 3. The Lovibond colour units for all the three oils was very high since CPO is orange red in colour when solid and deep wine red in colour when liquid. The initial moisture content of all the three oils was greater than the respective ISI specifications. Higher moisture content of CPO might be due to non removal of excess moisture as CPCRI, Palode factory does not have a vacuum dryer where as the lower moisture content of the blended oils may be attributed to the presence of refined oils, SFO and GNO, as refining removes excess moisture. Refractive index in case of CPO was higher as compared to the two blends since it is a more saturated oil. This also resulted in CPO having a lower specific gravity.

Table 3 shows that FFA was highest in case of CPO (4.5%) followed by CPO:SFO (2.9%) and CPO:GNO (2.75%). The high FFA in case of CPO might be due to delay in processing fresh fruit bunches (FFB) as lipase activity increases after harvesting of FFB. The enzyme is inactivated only after sterilisation during processing. The PV, AV and totox value in CPO were again on the higher side as compared to the two blends.

Table 3 shows that the β-carotene content (mcg/g of oil) of CPO, CPO:SFO and CPO:GNO was 390.1, 230.3 and 190.5 respectively. The β-carotene content of the two blends obtained is in accordance with the ratio of CPO present in each blend since only CPO contains this carotenoid pigment.

Alpha-tocopherol content (ppm) in CPO, CPO:SFO and CPO:GNO was 197.3, 351.0 and 210.3 respectively (Table 3). The α-tocopherol content in case of the blends was higher as compared to CPO since SFO and GNO also contain good amounts of this vitamin (Ghafoorunissa, 1995). CPO:SFO had the highest content as SFO is richest in a-tocopherol among the three individual oils. Presence of good amounts of α-tocopherol adds to the nutritional value of the blends.

During the 8 h frying regimen the colour of CPO changed from orange to yellow and that of the two blends changed from light orange to brownish yellow. Thus all the three oils recorded decreased colour units on the Lovibond scale (Table 4). The colour of CPO at 8h decreased by 58.6 Lovibond units as compared to the initial value. In case of CPO:SFO and CPO:GNO the colour decreased by 78.8 and 75.1 Lovibond units respectively. This loss of

Table 4 : Changes in Color (Lovibond Units)[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	Lovibond colour units[b]					
	CPO		CPO:SFO		CPO:GNO	
	(Y+10R)	Δ[c]	(Y+5R)	Δ[c]	(Y+5R)	Δ[c]
0	109.3	-	99.8	-	92.1	-
1	90.8	-18.5	69.0	-30.8	80.0	-12.1
2	90.8	-18.5	64.0	-35.8	70.0	-22.1
3	80.9	-28.4	48.9	-50.9	57.9	-34.2
4	80.8	-28.5	38.9	-60.9	52.0	-40.1
5	65.9	-43.4	28.9	-70.9	32.0	-60.1
6	60.9	-48.4	23.9	-75.9	20.0	-72.1
7	60.9	-48.4	21.0	-78.8	18.0	-74.1
8	50.7	-58.6	21.0	78.8	17.0	-75.1
Net change (0h-8h)		-58.6		-78.8		-75.1

[a] Mean of 2 frying trials ; [b] According to ISI specifications color is expressed as
Y + 10R - for moderately dark colored oils
Y + 5R - for other oils ; Δ[c] Change with respect to initial values

colour could partly be attributed to destruction of β-carotene in CPO and its blends on prolonged heating.

Changes in moisture content of the three oils were determined. Increase in moisture of the 4 h and 8 h batches was observed and the net increase (0 h-8 h) was 0.48%, 0.80% and 0.91% in CPO, CPO:SFO and CPO:GNO respectively. Further, CPO had the least increase as compared to the blends, with CPO:GNO having almost twice the value of moisture in CPO.

On 8 h heating of the three oils there were only marginal changes in RI values of CPO and CPO:SFO. No change in RI values of CPO:GNO was observed throughout 8 h heating. This suggests that no major change has occurred in fatty acid composition of the three oils even after they

Table 5 : Changes in free fatty acid[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	CPO[b]		CPO:SFO[c]		CPO:GNO[c]	
	FFA%	Δ[d]	FFA%	Δ[d]	FFA%	Δ[d]
0	4.50	-	2.90	-	2.75	-
1	5.48	0.98	2.98	0.08	3.29	0.54
2	5.65	1.15	3.12	0.22	3.85	1.10
3	5.65	1.15	3.18	0.28	3.85	1.10
4	5.78	1.28	3.26	0.36	3.91	1.16
5	5.79	1.29	3.38	0.48	3.98	1.23
6	5.84	1.34	3.40	0.50	4.02	1.27
7	5.91	1.41	3.59	0.69	4.02	1.27
8	6.02	1.52	5.38	2.48	6.08	3.93
Net change (0h-8h)		1.52		2.48		3.93

[a] Mean of 2 frying trials ; [b] FFA% as palmitic acid ; [c] FFA% as oleic acid

Δ[d] Change with respect to initial values

had been subjected to 8 h heating.

Changes in specific gravity of the 4 h and 8 h batches of the three oils were also studied. In the case of CPO the net change (0 h-8 h) was an increase of 0.014 while in the case of the two blends it decreased (0.013 and 0.019) from its initial values.

Table 6 : Changes in peroxide value (meqO_2/Kg oil)[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	CPO		CPO:SFO		CPO:GNO	
	PV	Δ[b]	PV	Δ[b]	PV	Δ[b]
0	2.4	-	2.1	-	1.9	-
1	3.7	1.3	8.9	6.8	7.9	6.0
2	4.5	2.1	9.1	7.0	8.1	6.2
3	4.6	2.2	9.2	7.1	9.7	7.8
4	5.0	2.6	10.1	8.0	12.3	10.4
5	5.2	2.8	11.4	9.3	15.7	13.8
6	9.0	6.6	12.1	10.0	18.2	16.3
7	9.6	7.2	14.4	12.3	24.1	22.2
8	10.3	7.9	20.8	18.7	24.3	22.4
Net change (0h-8h)		7.9		18.7		22.4

[a] Mean of 2 frying trials ; Δ[b] Change with respect to initial values

Changes in FFA in the three oils on 8 h continuous heating and hourly frying are presented in Table 5. A steady increase in FFA of all the oils was observed between 1h and 8 h. A sharp increase was seen between 7 h- 8 h sample for both the blends (especially GNO containing) but not for unblended CPO.

Table 6 depicts the changes in PV in the three oils subjected to the heating and frying regimen. There was a marked increase in PV of all the 3 oils from 0 h-8 h. The trend of increase was similar to FFA. CPO showed the least net increase (7.9meqO_2/Kg oil) followed by CPO:SFO (18.7 meqO_2/kg oil) and CPO:GNO (22.4meqO_2/kg oil).

The AV also increased considerably over the 8 h heating period (Table 7), the trends paralleling those of FFA and PV. The net increase (0 h-8 h) in AV was least in CPO (23.5) followed by CPO:SFO (49.2) and CPO:GNO (62.3).

Table 7 : Changes in anisidine value[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	CPO		CPO:SFO		CPO:GNO	
	AV	Δ[b]	AV	Δ[b]	AV	Δ[b]
0	4.2	-	4.0	-	3.9	-
1	5.8	1.6	7.4	3.4	17.0	13.1
2	7.2	3.0	12.1	8.1	19.6	15.7
3	11.6	7.4	17.5	13.5	29.8	25.9
4	12.9	8.7	26.1	22.1	37.4	33.5
5	14.8	10.6	37.2	33.2	37.8	33.9
6	17.1	12.9	39.1	35.1	46.5	42.6
7	27.5	23.3	50.0	46.0	53.0	49.1
8	27.7	23.5	53.2	49.2	66.2	62.3
Net change (0h-8h)		23.5		49.2		62.3

[a] Mean of 2 frying trials ; Δ[b] Change with respect to initial values

Thus the deterioration of the oils was in order of CPO:GNO>CPO:SFO>CPO while peroxides are primary degradation products formed on thermal oxidation. Anisidine value is a measure of oxidation products which have been formed from the degradation of peroxides. Thus it assess the secondary oxidation products like unsaturated carbonyl compounds derived from fatty acids containing two or more double bonds (Arumughan *et al.*, 1984). The anisidine value is a much more meaningful test than PV for oils during frying because it measures aldehydes which are less easily destroyed under frying conditions (Pantzaris, 1999). CPO with 51.0% SFA was more thermostable. Even though both the blends had almost identical USFA (65.3% and 65.0%), CPO:GNO had a greater increase in AV, presumably due to a lower proportion of CPO in the blend.

Totox value is the combined effect of PV and AV and hence gave the same trend of oxidative deterioration (Table 8) as seen in constituent counterparts. Thus net increase (0 h-8 h) in totox value was least in CPO (39.2) followed by CPO:SFO (86.7) and CPO:GNO (107.3). Further it is seen that PV, AV and totox value in CPO:SFO (60:40) were twice compared to those in CPO and they were almost three times in CPO:GNO (50:50) as compared to CPO.

Table 8 : Changes in totox value[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	CPO		CPO:SFO		CPO:GNO	
	Totox value	Δ^b	Totox value	Δ^b	Totox value	Δ^b
0	9.1	-	8.1	-	7.6	-
1	13.2	4.1	25.2	17.1	32.8	25.2
2	16.2	7.1	30.4	22.3	35.8	28.2
3	20.7	11.6	35.8	27.7	49.2	41.6
4	23.0	13.9	46.3	38.2	62.1	54.5
5	25.1	16.0	60.0	51.9	69.2	61.6
6	35.0	25.9	63.3	55.2	82.8	75.2
7	46.7	37.6	78.7	70.6	101.1	93.5
8	48.3	39.2	94.8	86.7	114.9	107.3
Net change (0h-8h)		39.2		86.7		107.3

[a] Mean of 2 frying trials ; Δ^b Change with respect to initial values

Beta-carotene decreased in CPO on heating and was totally destroyed by 4 h (Table 9). It fell by 36.6% at 1 h, 73.2% at 2 h and 89.6% at 3h. CPO:SFO showed a total loss by 2 h of heating regimen. Most (93.7%) of the ß-carotene in CPO:GNO was lost in 1h sample. This is inkeeping with the values obtained for other oxidative parameters in the case of this blend which was observed to be the least oxidatively stable among the three oils studied. CPO was found to be the most stable oil. The fact that in blends, ß-carotene degrades faster than in CPO alone also suggests an additional dimension that ß-carotene acts as an antioxidant and oils with larger proportion of USFA accelerate the damage of ß-carotene.

The loss of ß-carotene in the oil during frying could occur due to it being heat-labile and also due to incorporation into the fried food. Our data showed that rice flakes absorbed only 25.06% to 26.82% of oil in 1h of frying. Hence major proportion of the pigment has been destroyed by heat. The loss of ß-carotene in the oil samples was reflected in lower Lovibond colour units obtained for 0 h-8 h batches (Tab. 4). Further, acceptance of rice flakes of the later batches improved due to decrease in the yellow colour which however is not nutritionally desirable.

Jideani (1992) observed that there was progressive loss of ß-carotene in Nigerian palm oil when heated to160°, 180° and 200°C and held at these temperatures for 20, 40 and 60 min. Manorama and Rukmini (1992) observed a loss of 16%, 72% and 94% in the ß-carotene content of palm oil after 1st, 2nd and 3rd frying regimen respectively.

A total loss of α-tocopherol was observed within 1h of heating in case of all the three oils. The rapid destruction of this vitamin is due to its role as an antioxidant. Accordingly it protects the oil from peroxidation and in turn itself gets oxidized. Alpha-tocopherol acts as the first line of defense against oxidation and hence it has a sparing effect on ß-carotene.

Lakshmi and Sarojini (1996) reported that there was 89% loss of a-tocopherol in red palm oil subjected to frying condition of 130°C for 15 min. and a loss of 93% of the vitamin in red palm oil blend with GNO (50:50) when used for frying at 140°C for 18 min.

CONCLUSION

The present study reveals the oxidative stability of CPO and its blends, CPO:SFO (60:40) and CPO:GNO

Table 9 : Changes in β-carotene (mcg/g)[a] of CPO, CPO:SFO and CPO:GNO during 8h frying regimen

Time point of sampling of oil (h)	CPO			CPO:SFO			CPO:GNO		
	β-carotene	Δ^b	% loss from initial	β-carotene	Δ^b	% loss from initial	β-carotene	Δ^b	% loss from initial
0	390.1	-	-	230.3	-	-	190.5	-	-
1	247.2	142.9	36.6	95.0	135.3	58.7	12.0	178.5	93.7
2	104.5	285.6	73.2	0.0	230.3	100.0	0.0	190.5	100.0
3	40.4	349.7	89.6	0.0	-	-	0.0	-	-
4	0.0	390.1	100.0	0.0	-	-	0.0	-	-

[a] Mean of 2 frying trials ; Δ^b Change with respect to initial values

(50:50) to be in the order of CPO>CPO:SFO>CPO:GNO. Organoleptic scores of the rice flakes fried in the two blends were only marginally higher than those obtained for rice flakes fried in unblended CPO. The heating and frying regimen resulted in substantial loss of ß-carotene and α-tocopherol thus defeating the purpose of advocating palm oil for its nutritionally superior minor components. Indian cookery largely relies on deep frying procedure and subjecting to high heat upto 15-20 minutes in most of the dishes. Hence CPO or its blends cannot be recommended for use as deep frying medium. However, use of these oils for the preparation of dishes requiring minimum heat treatment can be promoted.

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