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ORIGINAL ARTICLE

Studies on chemical and sensory parameters of coconut oil and its olein blends with sesame oil and palmolein during wheat flour-based product frying

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Abstract Blends of coconut oil—coconut oil with sesame oil (blend 1); coconut olein with sesame oil (blend 2); coconut olein with palmolein (blend 3) in 1:1 (v/v) ratio—were used in this study for frying *Poori*, a traditional Indian fast food prepared from wheat flour. Changes in oil quality were determined by chemical and sensory methods. Free fatty acid content did not change whereas peroxide value increased. Anisidine value increased from 5.5, 0.9 and 4.2 to 34.3, 42.8 and 23.6 for blends 1, 2 and 3, respectively. Iodine value showed marginal decrease in blends 1 and 2. Diene value showed no change in all three blends. Sesamol content in blends 1 and 2, total tocopherols in all the three blends, and β-carotene content in blend 3 decreased after frying. The blends showed a significant decrease ($P \leq 0.05$) in the characteristic coconut oil odour after frying. Blend 3 showed comparatively better frying stability and also overall sensory quality of poori fried in this blend was the highest.

Keywords Deep-fat frying · Coconut olein · Sesamol · β-Carotene · Tocols

Deep-fat frying may lead to formation of numerous decomposition products that affect the functional, sensory and nutritional quality of the oil and the product being fried (Stevenson et al. 1984). Peroxides, free fatty acids, oxidized fatty acids, polymeric compounds, polar compounds (alcohols, aldehydes, ketones, partial glycerides, dimers) are the degradation products formed in the frying oil. The types of compounds formed depend upon the food being fried, how the fryers are operated and maintained, and the frying medium oil. Generally, oil degradation products of molecular mass less than 1.8 kDa are volatile and the rest are non-volatile (Melton et al. 1994). The volatile products escape from the system via volatilization or absorption by the material being fried, and they impart deep-fried flavour. Non-volatiles formed during frying get either absorbed by the food being fried or deposited on frying kettle parts (Melton et al. 1994). Presence of non-volatiles affects the physical properties of the frying oil.

Flavour is one of the important quality factors of fried food to assess the suitability of frying oil. Fatty acid composition of frying oil has a significant effect on the flavour of fried food (Barrera-Arrelano et al. 2002; Warner et al. 1997). The more unsaturated the oil, the greater is the tendency to form polymeric degradation products (Melton et al. 1994) which give rise to off-flavour. Higher oleic acid (42–63%) along with lower linoleic acid (23–37%) has been reported to provide the best flavour stability (Warner et al. 1997). Oleic acid forms volatile 2-alkenals, heptanal, nonanal and t-2-decenal (deMan 1999; May et al. 1983); linoleic acid forms t, t-2, 4-decadienal, hexanal (deMan 1999; Thompson et al. 1978), t-2-nonenal (Mookerji et al. 1965); linolenic acid forms benzaldehyde, t, t-2, 4- heptadienal (Pokorny 1989; deMan 1999). t, t-2, 4-Decadienal imparts desirable flavour to fried foods (Pokorny 1989). Higher level of linoleic acid, on the contrary, makes the oil more susceptible to oxidation during storage of the fried food resulting in increased levels of volatiles and peroxides that may be undesirable (Pangloli et al. 2002).

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Sensory evaluation of flavour and odour of frying oil and/or fried food has been accepted as a method of testing the oil quality (Melton et al. 1994). Measurements such as the concentration of total polar contents, polymeric content, or physical test such as smoke point are also used often in combination with the sensory evaluation (Melton et al. 1994).

Coconut oil (CNO) contains about 90% saturated fatty acid (SFA), that do not get oxidized, including medium chain fatty acids (60–66%) which are nutritionally important (Mensink and Katan 1990). Although CNO is used as a frying medium in some parts of the world, it is not well accepted by consumers for reasons of its characteristic aroma and SFA content. Sesame oil (SESO) has thermally stable lignan compounds, but 45–49% mono-unsaturated fatty acid (MUFA), and 37–41% poly-unsaturated fatty acid (PUFA) which are prone to auto-oxidation as well as hydrolytic oxidation. Palmolein (POL) is generally used as frying oil because it has natural antioxidants like tocopherols and β-carotene and balanced unsaturated and saturated fatty acid contents which are good for health. CNO fractions have been blended with palm stearin to achieve specific end use (Jeyarani et al. 2009). In this study, medium chain fatty acids rich CNO was blended in 1:1 (v/v) ratio with other oils containing nutraceuticals and polyunsaturated fatty acids. Blending of CNO with other oils reduced the perception of the copra note which has regional preference. Coconut oil was fractionated and fractions were used for blending with sesame oil in 1:1 ratio to get medium chain triglycerides. In addition, the blends also contained sesamol and tocopherols from sesame oil. Coconut olein fraction was blended with palmolein in 1:1 (v/v) ratio to get medium chain triglycerides (34.4%) and nutraceuticals like β-carotene and tocopherols.

In continuation of our earlier study (Khan et al. 2008) the objective of this research was to investigate the changes in the quality of coconut oil blends during frying of wheat flour based snack food, *Poori*.

Materials and methods

Food materials Wheat flour and refined coconut oil (CNO) were purchased from the local market. Crude palm oil was procured from Palm Tech India Ltd (Mysore, India) and sesame oil (SESO) was obtained from N. S. Karthikeyan & Co (Kangayam, Tamilnadu, India).

Chemicals HPLC-grade iso-octane, methanol, chloroform, hexane were purchased from Ranbaxy Fine Chemicals (New Delhi, India). Sesamol was obtained from Spectrochem (Mumbai, India). α-Tocopherol and β-carotene were obtained from Sigma-Aldrich Co. (St. Louis, Mo., USA). Wijs solution was procured from Nice Chemicals Pvt Ltd (Cochin, India). Citric acid and disodium phosphate were obtained form S.D. Fine Chemicals (Boisar, Mumbai, India). All other chemicals and reagents used were of analytical grade.

Fractionation of palm and coconut oils Fractionation of palm and coconut oil (100 g each) were carried out after holding the oil at 25±1 and 14±1 °C for 4 and 1 h to get a yield of solid fractions (40% each), respectively (Khan et al. 2008). The liquid fractions (60% each) palmolein (POL) and coconut olein (COL) were used for blending.

Blending of oils Blends prepared were homogenous mixtures containing oils as given below:

Blend 1 (1:1, w/w) coconut oil (CNO) and sesame oil (SESO)
Blend 2 (1:1, w/w) coconut olein (COL) and sesame oil (SESO)
Blend 3 (1:1, w/w) coconut olein (COL) and palmolein (POL)

Blending of oils was carried out under vacuum by continuous stirring the oil mixture for 10 min at 50 °C.

Preparation of poori Poori was prepared as described earlier (Raj et al. 2006). Briefly, 375 g of wheat flour mixed with 0.4% common salt, and then 225 ml of water was added and kneaded to form the dough (~ 37% moisture). Dough balls of 12.0–12.5 g were made and rolled to circular sheets (diameter 7.3–7.7 cm; thickness 1.8–2.2 mm) with rolling pin. About 300 g of oil blend was taken in a stainless steel pan (diameter 17.3 cm) and heated to 175 °C. *Poori* was prepared by frying the rolled dough till it puffs and turns light brown. Three *pooris* were fried in one batch and 15 such fryings were carried out continuously at the same temperature without adding fresh oil. The total frying time was approximately 60 min. About 50 ml of fried oil samples were withdrawn after 5, 10 and 15 fryings for sensory odour profiling and chemical analysis. *Pooris* from first five fryings were subjected to sensory analysis.

Analysis of free fatty acids, peroxide value, iodine value, and anisidine value Free fatty acid (FFA), peroxide value (PV), iodine value (IV), *p*-anisidine value (AV) were analysed following AOCS official method Ca 5a-40, Cd 1-25, Cd 18-90, respectively (AOCS 1990).

Analysis of total tocopherols,β-carotene, and dienes content Total tocopherols (Tocols) were analysed following the method described by Wong et al. (1988) by oxidizing tocols in the presence of ferric chloride and α,α-bipyridyl. A pink coloured-complex was formed in the presence of 95% alcohol. The colour was quantified at λ_{max} 520 nm

using a double beam spectrophotometer model UV-160 A (Shimadzu Corporation, Kyoto, Japan). β-carotene was analysed by taking the oil in acetone and reading the absorbance at λ_{max} 446 nm using a spectrophotometer, as described in AOAC official method 941.15 (AOAC 2000). Dienes were determined according to AOCS official method Ti 1a-64 (AOCS 1990) after dissolving oil in iso-octance. Ultraviolet absorbance of the solution was recorded at λ_{max} 268 nm employing a spectrophotometer.

Fatty acid methyl esters (FAME) analysis FAME were prepared (Brokerhoff 1965) and analysed using a gas liquid chromatograph (GLC) (Model GC-9A, Shimadzu Corporation, Kyoto, Japan) equipped with a data processor (Model CR-6A, Shimadzu Corporation, Kyoto, Japan) and provided with a flame ionization detector (FID). The column was 3 m×3.3 mm i.d. coated with 15% diethylene glycol succinate (DEGS) on Chromosorb WAW (60–80 mesh). Samples were analysed under the following conditions: nitrogen flow, 40 ml/min; hydrogen flow, 40 ml/min; air flow, 300 ml/min; column temperature, 180 °C; injector temperature, 220 °C; detector temperature, 230 °C. The fatty acids were identified by using standard FAME.

Sesamol analysis Sesamol content in the oils was estimated by incorporating a slight modification to a reported method (Yoshida et al. 2007). LC-10 AVP (M/s Shimadzu Corp., Kyoto, Japan) fitted with C18 (ODS) column of 25 cm long and 4.6 mm i.d. (SGE, Melbourne, Australia) was used along with UV detector. The mobile phase consisted of methanol/water (80/20, v/v) and flow rate was maintained at 0.4 ml/min. The sample run time was 20 min and absorption was recorded at 300 nm.

Colour measurement of oil Colour was measured in the ultraviolet–visible range (380–800 nm) using barium sulfate as a standard by following the *CIE* system. The *Lab* values, using colour measuring instrument MPC-3100 (M/s Shimadzu Corp., Kyoto, Japan), were determined (Ranganna 1986). Illuminant 'C' was taken as the standard, with 2° observer angle and 5 mm slit width. '*L*' indicates lightness, '*a*' (+ or −) and '*b*' (+ or −) indicate the change in hue from 'red' to 'green' and 'yellow' to 'blue', respectively.

Odour profiling of oil Quantitative descriptive analysis method (Stone and Sidel 1998) was used for profiling the odour of oil samples by a trained panel of 10 members. A 15 cm line scale was used, anchored as "low" and "high" at 1.25 cm on either end, representing "identification threshold" and "saturation threshold", respectively.

Oil samples were dispersed (10% w/v) in citrate-phosphate buffer medium (pH 4.6) at room temperature. The samples were presented in 250 ml stoppered conical flasks coded with 3-digit random numbers. Panelists were asked to remove the stopper and sniff the volatiles in the head space for 2–3 s and indicate intensity of perceived odour on the 15 cm scale. Between two sniffings, an interval of 10 min was given for build up of volatiles in the headspace. For each sample, intensity of each attribute listed on the score card was marked by drawing a vertical line on the scale. Code number of flask containing oil sample was written on the top of the line.

The scores for each attribute of a given sample were tabulated and mean value was calculated. These are presented in tabular form as "odour profile".

Sensory profiling of poori Similar procedure (Quantitative descriptive analysis) was followed by a trained panel of 10 members for sensory profiling of *pooris* from first five fryings. Containers coded differently were used for presenting the samples to the panelists and they were asked to taste the samples. Warm water was provided along with the samples for palate cleansing. The mean values of individual attributes are presented as "sensory profile".

Statistical analysis All the chemical analyses were carried out in triplicate for all the samples. Two-way ANOVA without replication was carried out for data in Tables 1, 2, and 3. Data in Tables 1 and 3 are least significantly different means of the analyses whereas statistical analysis of sensory data was carried out using Duncan's Multiple Range Test (DMRT) (Duncan 1955) using Statistica '99. Significance was set at $P \leq 0.05$.

Results and discussion

Changes in free fatty acids, peroxide value, iodine value, anisidine value, and dienes value Though there was significant ($P \leq 0.05$) difference in FFA content among the blends, frying did not significantly increase the FFA content within the blends (Table 1). Breakdown of triglycerides during frying occurs via hydrolytic or auto-oxidation reactions which results in increased FFA level and formation of secondary oxidation products such as carbonyls and polymerized or oxidized fatty acids (Tyagi and Vasishtha 1996). It has also been reported that hydrolysis occurs to a greater extent in oils containing short chain fatty acids because they are more soluble in water than long chain saturated fatty acids. Also, water from foods is easily accessible to short chain and unsaturated fatty acids for hydrolysis (Choe and Min 2007). Part of the fatty acids formed during frying is lost due to vaporization and also neutralised by the components of the food being fried (Che

Table 1 Changes in chemical parameters of the oil blends during frying

Sample	No. of fryings	FFA (%)	PV (meqO_2/Kg)	IV (Wijs)	AV	Diene (%)
Blend 1	0	0.9 b	0 d	59.2 a	5.5 c	0.2 c
	5	0.9 b	1.8 d	57.8 a	19.2 c	0.2 c
	10	1.0 b	3.2 d	57.8 a	23.7 c	0.2 c
	15	1.0 b	6.2 c	55.4 a	34.3 b	0.3 a
Blend 2	0	1.6 a	1.6 d	57.9 a	0.9 d	0.2 c
	5	1.6 a	3.7 d	56.7 a	18.5 c	0.2 c
	10	1.5 a	4.3 c	56.0 a	32.3 b	0.2 c
	15	1.6 a	5.4 c	55.8 a	42.8 a	0.3 a
Blend 3	0	0.5 c	6.3 c	35.0 c	4.2 d	0.2 c
	5	0.6 c	5.2 c	36.1 c	21.4 c	0.1 e
	10	0.6 c	8.3 b	36.2 c	22.6 c	0.2 c
	15	0.6 c	11.2 a	36.5 c	23.6 c	0.2 c

Different alphabets in the same column represent significant difference

$P \leq 0.05$ (df=11)

Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

Man et al. 1999). Therefore, the level of FFA may not truly reflect the acidic products formed during frying.

Peroxide value of oil samples withdrawn after 5th, 10th and 15th frying showed significant ($P \leq 0.05$) difference within the blends and also among the blends. At the end of 15th fryings the PVs were 6.2, 5.4 and 11.2 for blends 1, 2 and 3, respectively (Table 1). The initial PV of blend 3 was high as it was held in room temperature for longer time before the frying experiment. During experiment the increase (i.e., 2-fold) in peroxide level in the blend 3 was comparatively less which may be because of low unsaturated fatty acids (USFA) content (29%). The atmospheric oxygen reacts with oil during deep-fat frying resulting in formation of peroxides and the presence of USFA increases the oxidation rate (Choe and Min 2007). Tocotrienols have been reported to work synergistically with carotenes to decrease oil oxidation during frying (Schroeder et al. 2006). Though SESO had lignan compounds which are among the potent natural antioxidants (Fukuda et al. 1986), the USFA content of SESO blends were about two times of POL containing blend which may be the reason lignan antioxidant effect on peroxide formation was less pronounced as

Table 2 Changes in fatty acid composition of oil blends during frying

Sample	No. of fryings	Fatty acid composition (relative%)[a]								USFA	SFA
		$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$		
Blend 1	0	1.5 c	2.2 c	21.6 c	9.7 b	10.9 c	4.7 c	26.3 d	21.7 a	48 a	50.6 d
	5	2.2 cd	2.7 b	25.1 a	10.0 b	9.9 c	4.7 c	25.1 d	20.2 a	45.3 a	54.6 cd
	10	2.1 d	2.6 bc	23.5 b	10.0 b	10.1 c	4.8 c	25.7 d	21.2 a	46.9 a	53.1 d
	15	1.7 d	2.4 c	22.1 c	9.7 b	11.1 c	6.2 b	26.6 c	20.1 a	46.7 a	53.2 d
Blend 2	0	2.9 c	2.6 bc	20.7 c	8.2 e	9.4 c	7.7 a	27.1 c	19.0 a	46.1 a	51.5 d
	5	2.7 c	2.6 bc	22.1 c	8.7 d	9.2 c	7.4 a	27.4 c	19.9 a	47.3 a	52.7 d
	10	2.1 d	3.0 b	22.0 c	10.6 a	12.0 c	6.4 b	25.0 d	18.8 a	43.8 b	56.1 c
	15	1.9 d	3.0 b	23.0 b	10.3 a	12.3 c	6.3 b	24.6 d	18.4 a	43.0 b	56.8 c
Blend 3	0	4.6 a	3.5 a	26.3 a	9.5 c	22.2 a	3.9	22.9 e	6.6 c	29.5 c	70 a
	5	1.9 d	2.3 c	22.0 c	9.9 b	24.9 a	4.4 c	26.7 c	7.5 c	34.2 c	65.4 b
	10	0.6 e	1.3 e	16.0 e	8.9 c	24.7 a	7.8 a	32.1 a	7.8 c	39.9 b	59.3 c
	15	2.0 d	2.4 c	22.1 c	10.0 b	24.8 a	4.3 c	26.7 c	7.5 c	34.2 c	65.6 b

[a] Values are mean relative area (%) of GLC chromatograms for three consecutive analyses. Fatty acids with concentration less than 0.5% have not been represented in the table

$C_{8:0}$-caprylic, $C_{10:0}$-capric, $C_{12:0}$-lauric, $C_{14:0}$-myristic, $C_{16:0}$-palmitic, $C_{18:0}$-stearic, $C_{18:1}$-oleic, $C_{18:2}$-linoleic, USFA-unsaturated fatty acids, SFA-saturated fatty acids

Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

Different alphabets in the same column represent significant difference between the means

$P \leq 0.05$ (df=11)

Table 3 Changes in natural antioxidant content of oil blends during frying

Sample	No. of fryings	Sesamol	β-carotene	Tocols
Blend 1	0	0.10 b	ND	12.7 c
	5	0.09 b	ND	9.9 b
	10	0.05 a	ND	9.6 b
	15	0.03 a	ND	5.2 a
Blend 2	0	0.14 b	ND	14.4 d
	5	0.08 a,b	ND	8.9 c
	10	0.06 a,b	ND	6.6 b
	15	0.03 a	ND	3.3 a
Blend 3	0	ND	26.7 d	17.4 d
	5	ND	10.6 c	9.6 c
	10	ND	5.4 b	6.5 b
	15	ND	3.5 a	4.6 a

Different alphabets in the same column for the same nutraceutical indicate significant difference ($P \leq 0.05$). ND-not detected. Values are mg/100 g of oil

Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

observed in PV of SESO blends. The level of lignan compounds (Table 3) was also found to decrease on frying, probably due to absorption by the food material. However, PV alone is not sufficient to assess the deterioration of frying oil or antioxidant potential because peroxides are unstable at frying temperatures and undergo volatilization and decomposition (Che Man et al. 1999).

Iodine value (Table 1) of the blends did not change significantly within the blends whereas among the blends there was significant ($P \leq 0.05$) difference after frying. Blend 3 showed no reduction which may be attributed to the lower content of USFA in it. In blends 1 and 2, USFA was contributed by SESO whereas POL contributed USFA in blend 3. The IV reduces depending upon the USFA in the oil (Che Man et al. 1999; Tyagi and Vasishtha 1996; Khatoon and Gopalakrishna 2005).

Anisidine value is a measure of volatile breakdown products like aldehydes, ketones and anhydrides of USFA which contribute to the flavour of food being fried. In all the blends there was significant ($P \leq 0.05$) increase in AV of the samples withdrawn at frying numbers 5th, 10th, and 15th (Table 1). However, the increase in AV of blend 1 (0.9 to 42.8) and blend 2 (5.5 to 34.3) were more in percentage and magnitude than that of blend 3 (4.2 to 23.6). After 5th fryings the AV of blend 3 showed little difference. Contact with air (oxygen) during frying, and unsaturation level in fatty acids are the factors that affect the AV level. As unsaturation level was higher in SESO blends, it had high AV while POL blend had lower AV.

Diene values of blends did not show significant ($P \leq 0.05$) increase (Table 1). Diene value depends upon the USFA content and frying temperature (Tyagi and Vasishtha 1996). Non-conjugated double bonds of linoleic and linolenic acids isomerize to more stable conjugated double bonds after reacting with oxygen (Choe and Min 2007). Dienes are among the polymeric and non-polymeric compounds formed during deep-fat frying and after being absorbed by the food, they accelerate degradation of the oil, increase oil viscosity, reduce heat transfer, produce foam during deep-fat frying and develop undesirable colour in the food (Gertz 2000).

Fatty acid composition Fatty acid composition of blends 1, and 2 (Table 2) showed inconsistent change in individual fatty acid content. Blends 1, and 2 had SESO which contained about 85% USFA whereas blend 3 contained POL with about 50% USFA and about 38% palmitic acid. Due to this compositional difference, blend 3 showed reduction in some of short chain SFA and corresponding increase in long chain SFA. In blend 3 (Table 2), caprylic, capric, and lauric acid decreased significantly till 10th fryings and then increased after 15th fryings while palmitic and stearic acid increased significantly till 10th fryings and then decreased after 15th fryings. USFA contents in blends 1 and 2 were significantly ($P \leq 0.05$) higher than that of blend 3. In blends 1 and 2, USFA were contributed by SESO whereas POL contributed USFA in blend 3. SFA content of blend 1 did not change significantly ($P \leq 0.05$) whereas there was increase in SFA content of blend 2. In contrast, blend 3 showed significant decrease in SFA content. Reduction in the USFA content during deep-fat frying has been reported (Tyagi and Vasishtha 1996; Che Man et al. 1999; Khatoon and Gopalakrishna 2005). In this study the overall fatty acid composition of the blends during frying did not change significantly ($P \leq 0.05$). The reason for little changes in the overall fatty acid composition could be the short duration of frying and balanced SFA and USFA content (Khan et al. 2008).

Natural antioxidant content Table 3 shows the natural antioxidant content in frying oils. In blends 1 and 2, the sesamol content decreased significantly ($p \leq 0.05$) after 15 fryings. The reduction in sesamol content could be attributed to the absorption by the product being fried. It has been reported that sesamol content reduced in leftover oil after frying flour dough (Chung and Choe 2004). Moisture content, duration of frying and chemical nature of the material being fried affect the breakdown of sesamolin to sesamol (Fukuda et al. 1986). Although sesamolin breaks down to sesamol, the sesamolin content was not quantified in this study. β-Carotene, detected only in POL containing blend, showed a significant ($P \leq 0.05$) drop (26.7 to 3.5) as number of frying increased, indicating the detrimental effect of heat on β-carotene. Tocols (Barrera-Arrelano et al. 2002)

Table 4 Changes in colour value of oil blends during frying

Sample	No. of fryings	*L*	*a*	*b*
Standard white	NA	99.8	0.33 a	0.34 a
Blend 1	0	11.3 a	0.54 a	6.0 b
	5	12.3 b	1.3 b	5.1 a,b
	10	12.9 b,c	1.9 b,c	5.0 a
	15	13.0 c	2.0 c	4.6 a
Blend 2	0	10.8 a	0.62 a	6.4 c
	5	11.4 a	1.3 b	5.3 b
	10	11.0 a	1.9 b	5.0 b
	15	11.9 a	2.4 c	4.8 a
Blend 3	0	18.6 a	5.4 d	1.8 a
	5	20.1 b	3.7 c	3.4 b
	10	20.6 b	2.7 b	4.0 b,c
	15	21.1 b	1.3 a	5.1 c

Different alphabets in the same column for the same sample indicate significant difference ($P \leq 0.05$). NA-not applicable

Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

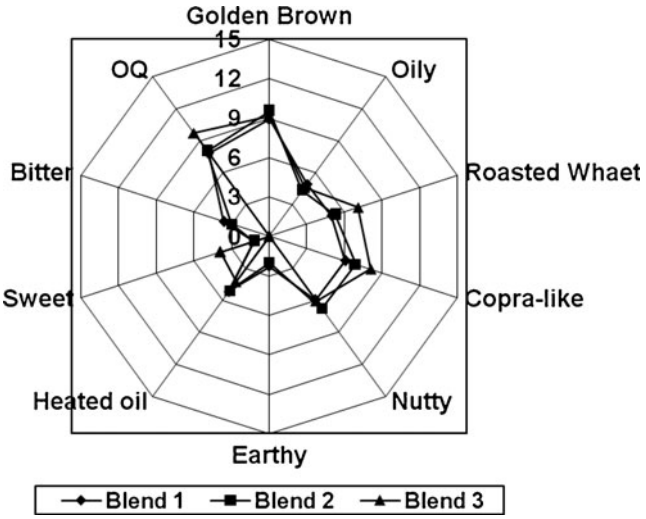

Fig. 1 Sensory profile of *poori* fried in oil blends 1, 2 and 3. Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

and β-carotene are known to be heat and light sensitive (Choe and Min 2007). In all the blends, considerable loss in tocols content was observed after 15th fryings. The values decreased from 12.7 to 5.2, 14.4 to 3.3 and 17.4 to 4.6 in blends 1, 2 and 3, respectively. Among the three blends, retention was better in blends 1 and 2 due to protection by lignans (Chung et al. 2006). These observations were in accordance with earlier report (Khan et al. 2008).

Changes in colour of oil blends on frying Table 4 shows the colour values of blends 1, 2 and 3. In blends 1 and 2, marginal increase in lightness ('*L*' value) but significant increase ($P \leq 0.05$) in '*a*' value and also slight decrease in '*b*' value was observed indicating a shift towards redness. This may be due to accumulation of degradation products in the frying oil. Data on blend 3 showed marginal increase in '*L*' value and decreased '*a*' value indicating loss of most of the original red colour and increased '*b*' value indicating predominant yellow colour. Diminished red colour of blend 3 during frying may be attributed to the loss of natural antioxidants which impart colour to POL. It was confirmed from these observations that blends containing SESO (Ravi et al. 2005) were brownish red after 15th fryings but POL containing blend, originally red in colour (Ravi et al. 2005), lost its characteristic redness and became lighter in colour.

Odour profile of oil blends In all the three blends (Table 5), significant decrease ($P \leq 0.5$) in fresh oil odour note, seedy note and sweet odour note was perceived between samples from successive fryings. Blend 3 showed maximum decrease in copra-like odour among the blends. Earthy

Table 5 Changes in sensory odour quality of oil blends during frying

Sample	No. of fryings	Fresh oil	Seedy	Sweet	Copra	Earthy	Heated oil
Blend 1	0	10.3 c	6.3 d	9.0 d	2.2 b	2.8 b	0.0 a
	5	7.4 b	2.8 c	7.9 c	1.9 a,b	1.8 a,b	1.7 a
	10	6.5 a	1.8 b	6.3 b	1.7 a b	1.3 a	2.3 a,b
	15	6.1 a	0.6 a	5.2 a	1.2 a	1.2 a	2.8 b
Blend 2	0	9.3 c	8.3 b	3.4 b	2.0 b	1.9 b	0.0 a
	5	6.4 b	3.4 a	2.0 a	0.8 a	1.2 a	3.0 a
	10	4.1 a	3.0 a	2.0 a	0.6 a	1.1 a	4.6 b
	15	4.0 a	2.8 a	1.2 a	0.6 a	1.0 a	4.3 b
Blend 3	0	10.8 c	8.6 c	6.8 b	6.7 c	ND	0.0 a
	5	9.7 b	8.0 c	6.1 b	6.1 c	ND	2.1 a
	10	8.1 a	3.6 b	1.3 a	1.2 b	ND	4.8 b
	15	7.5 a	2.1 a	1.2 a	0.4 a	ND	7.5 c

Different alphabets in the same column indicate significant difference ($P \leq 0.05$). ND-not detected

Blend 1—CNO+SESO, blend 2—COL+SESO, and blend 3—COL+POL

odour in blend 1 and 2 decreased to some extent whereas it was not perceived in blend 3. Heated oil aroma increased in all the blends which indicate release of volatile compounds-formed from USFA- that give odour to the oil. Blend 3 showed the highest heated oil aroma. Chemical odour and rancid odour were not perceived in any of the blends during frying. The findings were supported by our earlier report (Khan et al. 2008).

Sensory profile of poori Sensory profile of *poori* fried in oil blends 1, 2 and 3 are shown in Fig. 1. The samples were golden brown in colour and were moderately oily. Samples from blends 1 and 2 had perceptible earthy aroma, due to presence of SESO, which was completely absent in samples from blend 3 because of absence of SESO in it (Khan et al. 2008). Desirable aroma of roasted wheat was perceived at significantly high ($P \leq 0.05$) level in *poori* from blend 3. Heated oil aroma note was perceived to lesser extent in *poori* fried in blend 3. Copra aroma of *pooris* fried in blend 3 was higher than that of *pooris* fried in blends 1, and 2. However, this observation was in contrast to the copra note in odour profile of blend 3 which showed a reduction after frying *pooris* (Table 5). Odour quality was evaluated in oil samples from 0 to 15 fryings while sensory profile of *poori* was assessed only up to 5th frying. There was loss of copra aroma in the oil samples collected after 15th frying which explains decrease in copra aroma in the oil samples. However, in the *poori* samples, collected only upto 5th frying, copra aroma was considerably intense, compared to the samples fried in other blends. In addition, blend 1 and 2 contain SESO which has dominant earthy and seedy aroma notes which possibly affected the intensity of copra note whereas in blend 3, POL which has milder aroma notes, did not interfere with sensory perception of copra notes. This probably resulted in higher perception of copra note in the product. Frying in blends 1 and 2 imparted perceptible bitterness to *poori* whereas *poori* made in blend 3 had distinct sweetish taste, probably due to compositional difference of the oil blends. This resulted in higher overall quality score, 9.7 for samples fried in blend 3 compared to 8.0 and 7.8 for samples fried in blends 1 and 2, respectively. Bright yellow colour of *poori* fried in blend 3 was found to gradually fade on subsequent fryings which may be due to absorption of degradation products from the frying oil. The loss of coloured compounds (like carotenes and tocols) from the oil during frying also may be a reason for the faded colour of *poori* after subsequent fryings.

Conclusion

From this study, it was concluded that blend 3 (COL+POL) was more suitable for frying *poori*. The deterioration of the oil was less because of the lower USFA and higher SFA contents. *Poori* fried in this blend had distinct sweetish taste, roasted wheat aroma and also reduced copra aroma. The overall quality was higher (Fig. 1) for the *poori* fried (5th fryings) in this blend. In view of this finding, it can be inferred that use of coconut oil blends as frying oil is a promising possibility.

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