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Studies on Quality of Coconut Oil Blends after Frying Potato Chips

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Abstract The quality (chemical and sensory) of oil blends prepared by blending equal proportions of coconut oil with sesame oil (blend 1), coconut olein with sesame oil (blend 2) and coconut olein with palmolein (blend 3) was evaluated after deep-fat frying of potato chips. After frying, the free fatty acid content did not change, however, the anisidine value increased. Blend 2 had the highest anisidine value (44.0). A marginal decrease in the iodine value and an increase in the diene values were observed in blends 1 and 2. The β-carotene content in blend 3 and tocols in all the three blends were found to decrease after frying. Sensory odor profiles of oil blends after frying showed a decrease in the characteristic coconut oil aroma. The earthy and seedy aroma associated with sesame oil was found to decrease on frying. The sensory profile of potato chips showed a slight bitter taste in the samples fried in blends 1 and 2. However, the intensity of bitterness decreased and the earthy note increased on storage. Blend 3 had the highest overall quality.

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

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Introduction

During frying, the degradation of oil may be attributed to thermal, physical and chemical reactions resulting in numerous decomposition products that affect the functional, sensory and nutritional quality of the oil [1]. Components of the food (proteins, sugars, food lipids and moisture) being fried also contribute to the heterogeneity of the degradation products found in used frying oils [2].

Peroxides, free fatty acids (FFA), oxidized fatty acids, polymeric compounds, polar compounds (alcohols, aldehydes, ketones, partial glycerides, dimers) are among degradation products in deep-fat frying. The degradation compounds may be broadly classified into volatiles and non-volatiles. Generally those degradation products of molecular mass greater than 1.8 kDa are non-volatiles and those of molecular mass less than 1.8 kDa are volatiles [2]. The volatile products escape the system via volatilization. Non-volatiles remain in the oil and affect the physical properties of the frying fat. Analysis of non-volatiles, since they remain in the oil, could be a better way of following degradation of a frying fat. However, they are also absorbed by the food.

Fatty acid composition of a frying oil/fat has a significant effect on the flavor of fried food [3]. The more unsaturated the oil, the greater the tendency to form polymeric degradation compounds [4]. Polymeric degradation products give rise to off-flavor. Higher oleic acid (42–63%) and lower linoleic acid (23–37%) have been reported to provide the best flavor stability [3]. In contrast, higher level of linoleic acid makes the oil more susceptible to oxidation during storage which produces increased levels of volatiles that may be undesirable [5]. Oleic acid forms volatile 2-alkenals, heptanal, nonanal and t-2-decenal [6, 7]. Linoleic acid forms t, t-2, 4-decadienal, hexanal [6, 8], t-2-nonenal [9].

t, t-2, 4-Decadienal imparts desirable flavor to fried foods [10]. Linolenic acid forms benzaldehyde, and t, t-2, 4- heptadienal during frying [6, 10].

Natural antioxidants reduce the rate of oxidation during deep-fat frying. In palm olein, carotenes are major compounds that react with free radicals in the oil [11]. The tocotrienols and carotenes in palm olein act synergistically to decrease the oxidation of oil during frying of potato chips at 163 °C [11]. Tocols in oils have been reported to protect the oxidation of polyunsaturated fatty acids (PUFA) at room temperature through antioxidant activity [3]. During frying, tocols are lost in the order $\alpha > \beta > \gamma > \delta$. Polymeric and polar compound formation during heating is prevented to some extent by tocols depending upon the type of tocopherol present and degree of unsaturation in the oil [4]. Lignan compounds in sesame oil are stable during frying/heating and have been shown to protect tocols from degradation [12]. Lignans are among potent natural antioxidants that protect oils from oxidation [12].

Coconut oil (CNO) has about 90% saturated fatty acid (SFA), including 14–15% medium chain fatty acid (MCFA). Due to the presence of MCFA, which are more soluble in water than long chain fatty acid (LCFA) [13], CNO is prone to hydrolytic oxidation. Sesame oil (SESO) has 45–49% mono-unsaturated fatty acid (MUFA) and 37–41% poly-unsaturated fatty acid (PUFA), which are prone to autoxidation as well as hydrolytic reaction during frying, but the thermally stable lignans present in the oil offer protection against oxidation. Palmolein (POL) is accepted as a frying oil because of its tocols and carotenoids composition, and its relative proportion of unsaturated & saturated fatty acid content. Susceptibility of CNO to hydrolytic oxidation and the high SFA level can be minimized by blending with SESO and POL. The objective of the study was to assess the acceptance of using CNO as deep-fat frying oil by blending it with SESO and POL and to determine the stability and sensory quality of the blended oils during frying.

Materials and Methods

Food Materials and Chemicals

Potato and crude coconut oil were procured from a local market. Crude palm oil was a gift from Palm Tech India Ltd. (Mysore, India) and the sesame oil was obtained from N. S. Karthikeyan & Co. (Kangayam, Tamilnadu, India).

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, India). All other chemicals and reagents used were of analytical grade.

Fractionation of Palm and Coconut oils

Palm oil was fractionated (35–40% hard fraction) by crystallizing at 25 ± 1 °C for about 4 h to get POL which was liquid at ambient temperature (25–30 °C). CNO was crystallized at 14 ± 1 °C for 70–80 min. Around 40% solid fraction was removed by filtration of crystallized CNO. The liquid part (coconut olein) was used for blending.

Blending of Oils

Blend 1 consisted of CNO and SESO, blend 2 had COL and SESO and blend 3 contained POL and COL in 1:1 ratios.

Frying of Chips and Collection of Leftover (heated) Oil

About 2 kg of potato were washed, peeled and immersed in 2 l of water containing 0.15% potassium metabisulphate (KMS) in a stainless steel container. About 200 g of peeled potato was sliced (1 mm thickness) using a stainless steel slicer into 1 l water containing 0.1% KMS in another steel vessel. About 1.5 l of blended oil (blend 1, 2 and 3) was taken in a stainless steel pan and heated to 180 °C. Each batch of sliced potato was fried for 5–6 min, and a total of 15 batches of chips were fried. The total duration of frying was approximately 100 min including the initial heating time and the time lag between two consecutive batches. Fried chips were cooled to room temperature and salted. Fried chips (40 g) were then packed in polypropylene pouches, sealed and stored under ambient conditions. The leftover oil was collected and was used for analysis of physico-chemical characteristics to assess the frying stability of the oil blends.

Analysis of Chemical Properties of Fresh and Heated Oil

Free fatty acid (FFA), iodine value (IV), and p-anisidine value (AV) were analyzed by the AOCS official methods Ca 5a-40, Cd 1–25, Cd 18–90, respectively [14]. Total tocopherols (tocols), β-carotene (carotenes) and conjugated dienes were determined by using a double beam spectrophotometer, model UV-160 A (Shimadzu Corporation, Kyoto, Japan) according to Wong et al. [15], A0AC official method 941.15 [16], and AOCS official method Ti 1a-64 [14], respectively.

Fatty Acid Methyl Esters (FAME) Analysis

Fatty acid methyl esters was prepared by using the procedure of Brokerhoff [17] and analyzed using a Shimadzu gas liquid chromatograph (Model GC-9A, Shimadzu Corporation, Kyoto, Japan) equipped with a data processor (Model CR-6A, Shimadzu Corporation, Kyoto, Japan) and a flame ionization detector (FID). The column used was 3 m length × 3.3 mm i.d., coated with 15% diethylene glycol succinate (DEGS) on Chromosorb WAW 60–80 mesh. The operation conditions of the equipment were: nitrogen flow, 40 ml/min; hydrogen flow, 40 ml/min; air flow, 300 ml/min; column temperature 180 °C, injector temperature 220 °C and detector temperature 230 °C. The fatty acids were identified by using standard FAME.

Sesamol Analysis by HPLC

Sesamol analysis was done as reported by Yoshida et al. [18] using LC-10 AVP (M/s Shimadzu Corp., Tokyo, Japan) fitted with C18 (ODS) column of 25 cm length × 4.6 mm i.d. (SGE, Melbourne, Australia) and UV detector. CLASS-VP integrator software was used for data processing. The mobile phase consisted of methanol/water (70/30, 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.

Color Measurement of Oil

Color was measured in the ultraviolet–visible range (380–800 nm) using barium sulfate as a standard following the CIE system. The lab values, using the color measuring instrument model MPC-3100 (M/s Shimadzu Corporation, Kyoto, Japan) were determined [19]. 'L' indicates lightness, 'a' (+ to −) and 'b' (+ to −) indicate the change in hue from 'red' to 'green' and 'yellow' to 'blue', respectively. The values were recorded using illuminant 'C' as standard with 2° observer angle and 5 mm slit width.

Odor Profiling of Oil

Oil samples were dispersed in citrate–phosphate buffer medium (pH 4.6) at 10% (w/v) at room temperature. Quantitative descriptive analysis (QDA) [20] was used for profiling the odor of oil samples by a trained panel of 10 members. The score card consisted of a 15 cm line scale anchored as "Low" and "High" at 1.25 cm on either end representing "identification threshold" and "saturation threshold", respectively. Panelists were asked to mark the perceived intensity of each attribute listed on the score card by drawing a vertical line on the scale and writing the code number (on the flask) on top of the line. The scores for each attribute of a given sample were tabulated and mean value was taken. The values are presented graphically as odor profiles.

Sensory Profiling of Chips

A trained panel of 10 members carried out sensory profiling of potato chips using QDA [20] method described above. Samples were presented in coded containers and panelists were asked to taste the samples. Warm water was provided along with the samples for palate cleansing. The mean values of individual attributes were calculated for generating sensory profiles of chips.

Extraction of Oil from Fried Potato Chips

AOCS official method Ba 3-38 [14] was used for extracting oil from fried potato chips.

Data Analysis

All chemical analyses were carried out in triplicate for the three blended oils. Mean ± SD values were taken for final computation. The statistical computation of the sensory analyses was carried out using Duncan's multiple range test (DMRT) [21] using Statistica '99 (statistical software).

Results and Discussion

Free Fatty Acid Content

The FFA level in parent, blended and leftover oils is listed in Table 1. Changes in FFA level during frying were found to be inconsistent. Breakdown of triacylglycerols by hydrolytic or autoxidation reaction contribute to FFA level. It has been reported that hydrolysis occurs more in oil with short chain fatty acids than oil with long chain saturated fatty acids. Short chain fatty acids and unsaturated fatty acids (USFA) are more soluble in water than long chain saturated fatty acids. Water from foods is easily accessible to short chain fatty acids for hydrolysis [13]. The variations in FFA level could be due to loss of FFA through vaporization and neutralization of the FFA by the food being fried [22]. FFA level, therefore, does not represent the actual acidity of the frying oil.

Iodine Value

Table 1 shows the decrease in the iodine value of USFA-rich parent oils on blending with SFA rich oil. Iodine value of the blended oils decreased in blends 1 and 2 after frying (Table 1). The IV in blend 3 did not change, which may be

Table 1 Changes in chemical parameters of blends during frying

Sample	FFA[a] (%)	IV[a] (Wijs)	AV[a]	Diene[a] (%)
CNO	0.3 ± 0.03	8.8 ± 0.4	tr	0.07 ± 0.006
COL	0.3 ± 0.02	12.5 ± 0.3	tr	0.08 ± 0.006
SESO	1.3 ± 0.03	107.2 ± 1.2	3.7 ± 0.03	0.27 ± 0.025
POL	0.4 ± 0.03	60.9 ± 0.34	3.4 ± 0.17	0.08 ± 0.003
Blend 1				
Initial	1.6 ± 0.09	57.9 ± 0.11	3.1 ± 0.04	0.20 ± 0.06
After frying	1.3 ± 0.07	54.7 ± 0.05	30.5 ± 0.14	0.28 ± 0.02
Blend 2				
Initial	0.9 ± 0.06	59.2 ± 0.3	5.5 ± 0.25	0.20 ± 0.06
After frying	1.6 ± 0.03	55.4 ± 0.04	44.0 ± 1.0	0.49 ± 0.06
Blend 3				
Initial	0.5 ± 0.04	35.6 ± 0.03	5.0 ± 0.05	0.12 ± 0.06
After frying	0.5 ± 0.03	34.5 ± 0.2	13.2 ± 0.17	0.13 ± 0.03

tr trace amounts

[a] Values are means ± SD, $n = 3$

attributed to the lower USFA content. It has been reported that IV decreases during heating of oils and the extent of decrease varies directly with the USFA content [24]. The double bonds in USFA are vulnerable to attack by atmospheric oxygen and break down to give oxidized fatty acids and/or peroxides.

Anisidine Value

Anisidine values increased (Table 1) drastically in blends 1 (3.1–30.5) and 2 (5.5–44.0) whereas in blend 3 the increase was less dramatic (4.2–13.2). AV indicates formation of volatile breakdown products such as aldehydes, ketones and anhydrides of USFA, which contribute to the flavor of food being fried. AV measures the level of carbonyl breakdown products. Oxygen content is one major factor and unsaturation level is another that affects AV level [25]. Carbonyl compounds formed during deep-fat frying can react with amino acids, amines and proteins to produce desirable and nutty pyrazines. Some of the carbonyl breakdown products provide off odor in deep-fat frying [26]. The high unsaturation level in SESO, blends 1 and 2, probably contributed to the high AV, while blend 3 had lower unsaturation and AV.

Conjugated Diene Content

The conjugated diene content increased on frying (Table 1). Blends 1 and 2 had greater increases in conjugated diene compared to blend 3. The conjugated diene value depends upon unsaturation, frying temperature and duration [24]. Choe et al. [25] stated that oxidized polymer compounds accelerated the oxidation in oil. Polymeric compounds further accelerate degradation of the oil, increase oil viscosity, reduce heat transfer, produce foam during deep-fat frying and develop undesirable color in the food, after being absorbed [27]. Polymers also cause high oil absorption to foods. Highly conjugated diene polymers produce a brown-like residue along the sides of the fryer, where the oil and metals come in contact with oxygen from the air. A resin-like residue is often produced when the oil traps moisture and air [28]. Highly unsaturated fatty acids such as linoleic and linolenic acids present in oils have non-conjugated double bonds and tend to isomerize to more stable conjugated double bonds after reacting with oxygen [25].

Table 2 Fatty acid composition of frying oils

Sample	Fatty acid (relative %)[a]								USFA/SFA ratio
	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	
CNO	8.5	6.0	47.3	17.9	9.6	0.7	6.8	2.4	0.1
COL	7.5	6.4	51.7	17.6	6.9	2.4	4.8	1.4	0.1
SESO	ND	ND	ND	ND	11.3	tr	44.1	42.0	7.6
POL	ND	ND	tr	1.4	37.5	5.4	41.0	11.8	1.2
Blend 1									
Initial	1.5	2.2	21.6	9.7	10.9	4.7	26.3	21.7	0.9
After frying	1.9	2.8	22.9	10.6	10.9	5.9	24.9	19.9	0.8
Blend 2									
Initial	2.9	2.6	20.7	8.2	9.4	7.7	27.1	19.0	0.9
After frying	1.8	2.7	20.4	10.0	14.3	6.3	26.8	17.8	0.8
Blend 3									
Initial	4.4	3.5	26.3	9.5	22.2	3.9	22.9	6.6	0.4
After frying	2.4	2.5	21.8	9.4	24.0	5.9	26.8	7.0	0.5

ND not detected; *tr* trace amounts

[a] Values are the relative area (%) of GLC chromatograms

Fatty Acid Composition

The fatty acid composition (Table 2) shows that on blending with CNO/COL the USFA was less than SESO and POL. Blends also had less SFA content than CNO, which contains about 91% SFA. Overall fatty acid composition of the blends after frying showed no significant change. But individual fatty acids showed inconsistent changes. SESO had about 86% USFA including about 42% PUFA. On the other hand POL had about 52% USFA including about 11% PUFA. It has been reported that USFA level decrease during deep-fat frying [22]. However in the present experiment significant changes were not observed (evident from USFA/SFA ratio) which may be due to short duration of frying and antioxidant effect of lignans and tocols in blends 1 and 2 [12, 23] and tocols and carotenes in blend 3 [4, 11]. From this observation it was clear that the blends had higher heat stability. The reason for the stability may be due to the relative proportion of SFA and USFA contents of the blends. The USFA content of blends was lower and the SFA was higher than that of SESO and POL. This resulted in higher stability at frying temperatures.

Natural Antioxidant Content

Table 3 shows the natural antioxidant content in parent oils, blended oils and heated oils. The blends had lower sesamol (blends 1 and 2), β-carotene and tocols (blend 3) concentration than the parent oils. Tocols decreased on frying in all the blends. The level of β-carotene decreased sharply on frying in the POL-containing blend. Tocols [4] and carotenes are known to be heat and light sensitive [25] and form polymerized degradation products after heating.

Table 3 Natural antioxidant content of frying oil and their blends

Sample	Sesamol (mg%)	β-Carotene (mg%)	Tocols (mg%)
POL	ND	55.0 ± 1.6	31.9 ± 1.07
SESO	0.25 ± 0.03	ND	24.3 ± 0.47
CNO	ND	ND	tr
COL	ND	ND	tr
Blend 1			
Initial	0.1 ± 0.04	ND	12.7 ± 0.24
After frying	9.2 ± 0.53	ND	9.1 ± 0.54
Blend 2			
Initial	0.1 ± 0.04	ND	14.4 ± 0.78
After frying	9.6 ± 0.26	ND	10.5 ± 0.3
Blend 3			
Initial	ND	26.7 ± 1.12	17.4 ± 0.6
After frying	ND	6.6 ± 0.25	7.7 ± 0.26

tr trace amounts; *ND* not detected

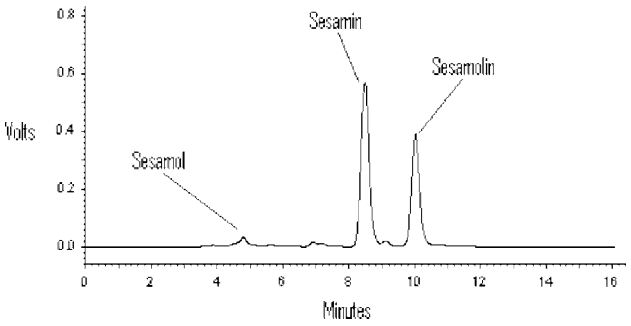

Fig. 1 HPLC chromatogram of sesame oil

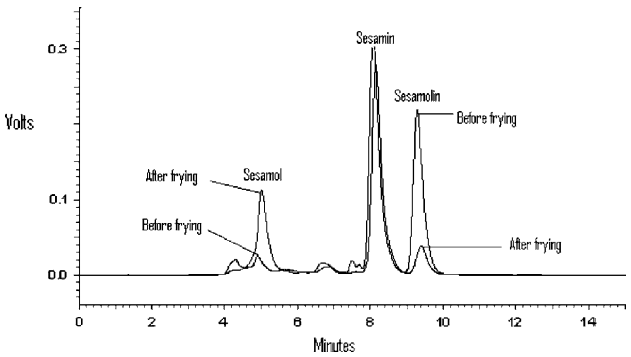

Fig. 2 Overlay chromatograms of initial and chips fried blend 1. The sesamol peak at 5.0 min increased after frying chips. The samolin peak was eluted after 9.0 min which reduced after frying chips. The sesamin peak was eluted after 8 min. There was no significant change in sesamin concentration

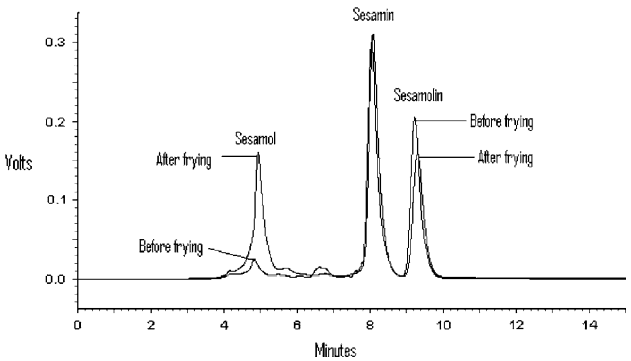

Fig. 3 Overlay chromatograms of initial and chips fried blend 2. The observations were the same as in blend 1 (Fig. 2)

Sesamol content increased in the frying oil after chips frying in blends 1 and 2. The increase of sesamol after heating may be due to the breakdown of sesamolin (Figs. 1, 2, 3) at high temperature as reported in literature [23].

Chemical Changes During Storage

Storage studies (Table 4) showed no changes in the levels of FFA which may be due to loss via volatilization of the

Table 4 Quality of oil extracted from stored potato chips

Sample	Storage (day)	FFA[a] (%)
Blend 1	0	1.6 ± 0.03
	21	1.4 ± 0.02
	42	1.4 ± 0.03
	63	1.6 ± 0.03
	84	2.0 ± 0.1
Blend 2	0	1.3 ± 0.02
	21	1.7 ± 0.08
	42	1.3 ± 0.25
	63	1.7 ± 0.03
	84	1.7 ± 0.03
Blend 3	0	0.5 ± 0.03
	21	0.6 ± 0.03
	42	0.5 ± 0.03
	63	0.6 ± 0.02
	84	0.6 ± 0.03

[a] Values are means ± SD, $n = 3$

Table 5 Color values of oil blends

Standard white		Blend 1		Blend 2		Blend 3	
		Fresh	After frying	Fresh	After frying	Fresh	After frying
L	99.8	12.1[a]	13.6[a]	11.0[a]	12.0[a]	18.6[a]	22.1[b]
a	0.3	0.5[a]	2.3[b]	0.6[a]	2.5[b]	5.4[b]	1.3[a]
b	0.3	6.1[b]	4.1[a]	6.4[b]	5.3[a]	1.8[a]	5.1[b]

Different letters in the same row for individual blend indicate significant difference ($p \leq 0.05$) in the values

Table 6 Sensory odor quality of oil blends

Oil blends	Fresh oil	Sweet	Copra	Earthy	Seedy	Heated
Blend 1						
Fresh	9.8[b]	4.9[b]	7.1	3.9[a]	4.3[b]	0
After frying	5.1[a]	3.1[a]	3.7	3.5[a]	2.1[a]	8.1
Blend 2						
Fresh	10.2[b]	5.1[b]	7.3[b]	4.7[b]	5.1[b]	0
After frying	5.9[a]	2.9[a]	3.2[a]	3.8[a]	1.9[a]	7.9
Blend 3						
Fresh	10.6[b]	6.5[b]	6.8	0	0	0
After frying	6.1[a]	4.3[a]	2.8	0	0	7.3

Different letters in the same column for individual blend indicate significant difference ($p \leq 0.05$) in the values

free fatty acids formed during heating [3]. It is possible that antioxidants absorbed from oil blends during frying prevented further deterioration of chip lipids. The results agree with the findings of Pangloli et al. [10] who reported that POL blends did not affect FFA values during 6 weeks of storage in the dark.

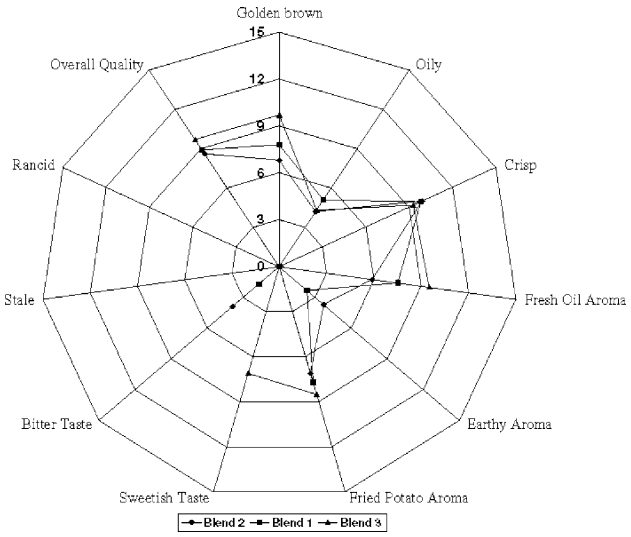

Fig. 4 Sensory profile of potato chips (fresh) fried in oil blends

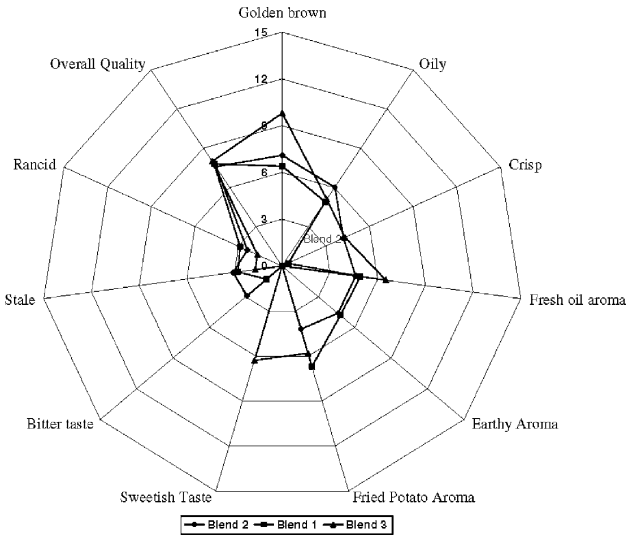

Fig. 5 Sensory profile of potato chips fried in oil blends after 6 weeks of storage

Color Value

Table 5 shows that on subsequent frying, the L values of blends 1 and 2 remained unchanged while that of blend 3 increased. Blends 1 and 2 (containing SESO) had increased 'a' values resulting in a brownish color. The change in 'b' values was insignificant in blends 1 and 2 whereas it increased in blend 3, which indicates an increase in yellowness. The reason for this is not clear; probably the formation of breakdown products or lowering of redness value (a) could have increased the relative intensity of yellowness.

Odor Profile of Fresh and Heated oil

Sensory odor analysis of the blends is presented in Table 6. The odor attributes described by Ravi et al. [29] for sensory odor profiling of oil blends after frying were chosen for this study. During frying, coconut oil aroma decreased while heated oil aroma increased in all blends. Fresh oil aroma decreased and sweet aroma in the oil increased on frying. In blends 1 and 2 there was a decrease in earthy aroma after frying. A seedy odor was perceived to be significantly ($p \leq 0.05$) low in these two blends after frying. This may be due to the loss of some volatile compounds such as 2, 3-dimethyl pyrazine or 2-ethyl pyrazine [30] responsible for this particular odor. Blend 3 did not have earthy and seedy aromas either in fresh oil or after frying.

Sensory Profile of Fresh and Stored Potato Chips

Figure 4 shows the sensory profile of fresh potato chips fried in blends 1, 2 and 3. Samples were golden brown in color with high crispness and intense fresh oil aroma, which was highest in samples fried in blend 3. A bitter taste was noticeable in chips fried in blends 1 and 2, which was completely absent in chips from blend 3. No off-odor was perceived in the chips. Samples fried in blends 1, 2 and 3 had good overall quality (OQ) with scores of 8.9, 8.6 and 9.7, respectively, and were highly acceptable.

Figure 5 shows the sensory profile of potato chips at the end of 6 weeks of storage under ambient conditions. There was no significant change in the color of the samples. A significant ($p \leq 0.05$) decrease in crispness of the chips was observed. A similar trend was seen in fresh oil and fried potato aroma notes. A slight increase in earthy aroma was perceived in chips fried in blends 1 and 2. There was a mild decrease in bitter taste of these samples compared to their initial (before storage) counterparts. On the 15-cm line scale used for representing the perceived intensity of attributes, 7.5 indicates "Fair", regarding OQ. When a product is rated at 7.5 or above on this scale, it is normally considered acceptable. Compared to freshly fried samples, stored products had lower OQ scores but the scores were above 7.5. The difference in OQ scores between fresh and stored products was not statistically significant ($p \leq 0.05$). This indicated that the stored products were acceptable.

Conclusion

This study demonstrated that blend 3 was more suitable for frying potato chips. The deterioration of the oil was less in blend 3. Sensory analysis showed that the chips were acceptable for up to 6 weeks of storage. Hence the use of CNO in frying oil blends can increase in potato frying applications.

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