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RESEARCH ARTICLE

Effect of Deep-Fat Frying on Fatty Acid Composition and Iodine Value of Rice Bran Oil Blends

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Abstract Rice bran oil is nutritionally superior oil as compared to other common vegetable oils. In the present study, six rice bran oil blends were prepared in two ratios i.e., 80:20 and 70:30 and the effect of deep-fat frying was studied by assessing changes in iodine value and fatty acid composition. Results showed that the minimum iodine value was found in the blend of rice bran oil and palm-olein oil as 107.3 g (70:30) and 107.0 g (80:20) at fresh conditions which decreased by 1.6 and 1.3 % after second frying and by 2.7 and 4.5 % after third frying respectively. The saturated: mono-unsaturated: poly-unsaturated fatty acids in the deep fried products prepared using the blend of rice bran oil and palm-olein oil was close to the recommendations as 1:1.9:1.4 and 1:1.2:1.7 in the ratio of 80:20 and 70:30 respectively. The present study concluded that the blend of rice bran oil and palm-olein oil in both ratios was the most stable frying medium among all rice bran oil blends based on changes in iodine value and fatty acid ratio under frying conditions.

Keywords Rice bran oil · Blending · Iodine value · Fatty acid composition

Introduction

Deep-fat frying is one of the most common processes in the preparation and manufacture of food [1]. During deep-fat frying, the fat is continuously being exposed to elevated temperatures (150–180 °C) in the presence of the substrates, air and water. Normally, frying oils are used repeatedly to fry food to save cost which results in the formation of volatile and non-volatile compounds affecting the sensory, functional, and nutritional qualities of the frying oil [2].

In general, deep-fat frying decreases the content of unsaturated fatty acids in frying fat and oil. Researchers [1, 3] have found a relative loss of the C18:2 fatty acid and a decrease in the iodine value of oil after heating due to more intensive thermo-oxidative transformations that occur as compared to heated oil containing food. The decrease in the iodine value can be attributed to the destruction of double bonds by oxidation, scission, and polymerization. According to previous studies, the heat treatment causes the oxidative rancidity resulting in an increase in the free fatty acids. This is why heated and unheated fats and oils should be monitored by means of analysis of the fatty acid composition and iodine value indicating the degradation of the fatty acids [4–6].

Vegetable oil used for frying must have good flavor and oxidative stability in order to achieve good shelf life for the product fried. To meet today's consumer demands the frying oil must be low in saturated fat, linolenic acid, and have good flavor, high oxidative stability and should be trans fat free [7]. Rice bran oil (RBO), a non-traditional vegetable oil meets these requirements due to its unique nutritional characteristics. A number of scientific studies conducted in India and abroad have well documented the better cholesterol lowering properties of RBO as compared to other traditional vegetable oils [8–12]. RBO is the world's healthiest edible oil, containing vitamins, antioxidants and nutrients. India has substantial reserves of non-traditional oil seeds and oil–bearing materials. At present, merely half of this potential is realized; yet India is the second largest producer of crude RBO in the world [13]. RBO has high level of phytosterols,

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gamma-oryzanol, tocotrienols as well as tocopherols and it extends the shelf-life of the snack food. The high oxidative stability of RBO makes it preferred oil for frying and baking applications [14]. The quality of fried food products depends on the nature of oil used, food fried, and temperature during frying [7]. By blending traditional vegetable oils with RBO, the consumer can be offered a better quality product with respect to flavor, frying quality and nutritive value [15]. Moreover, as India imports considerable quantity of edible oil, use of domestic RBO for blending will help in import substitution, thus saving valuable foreign exchange [16].

Despite of large production and health benefits, RBO is less popular in Indian households due to lack of awareness about this vegetable oil. Hence, the present work was conducted to study the changes in the iodine value and fatty acid composition of RBO blends under the frying conditions.

Material and Methods

Materials

The raw ingredients for deep frying, refined RBO and other refined vegetable oils viz., Olive oil (OO), groundnut oil (GO), soybean oil (SOO), sunflower oil (SO), mustard oil (MO) and palm-olein oil (PO) were purchased from local markets. All the analytical and GC grade chemicals and solvents used were supplied by Himedia (Mumbai, India).

Preparation of Blends

A 100 ml mixture of RBO and other vegetable oils were placed in duplicate in 250-ml beakers for each blend and were mixed by using a mechanical stirrer at 180 rpm for 15 min. Blends of RBO viz. RBO+OO, RBO+GO, RBO+SOO, RBO+SO, RBO+MO and RBO+PO were prepared in two ratios i.e., 80:20 and 70:30 [17].

The selection of two ratios i.e. 80:20 and 70:30 was based on recommendations given by Prevention of Food Adulteration Act (PFA) [18]. According to PFA 4th Amendment Rules 1992, blending of any two vegetable oils (wherein the component oil used in the admixture is not <20 %) has been permitted.

Chemical Analysis

Iodine Value and Peroxide Value

Vegetable pakoda: It is a traditional fried snack in India was prepared using RBO blends to assess changes in iodine value after deep frying.

Selection criteria for vegetable pakoda: Vegetable Pakoda is a popular street food and sold at various food shops in India. Despite the warnings issued by nutritionists, vegetable oil is used repeatedly for frying of vegetable pakoda by the sellers.

Vegetable pakoda was prepared using 100 g raw wet materials in 500 g of oil. The stainless steel pan used for frying had an area of 121 cm^2 and a depth of 12.5 cm. Deep frying was done for three times and the time period used for each frying was 4.5 min and Iodine value and peroxide value of the blended oils were determined according to the AOAC [19] methods after each frying i.e., First, second and third respectively.

Fatty Acid Composition by Gas Chromatography (GC)

Poori (an unleavened deep fried bread): It was prepared using different RBO blends to assess changes in fatty acid composition of food product.

Selection criteria for poori: Poori, an Indian traditional fried food, is commonly prepared at home. It is eaten for breakfast or as a snack.

Poori was prepared using standard method. After that, deep fried samples of *poori* were dried and were ground to make a uniform powder. Fatty acid composition was determined by first conversion of the oil present in samples to fatty acid methyl esters (FAMEs) using the method of Appleqvist [20]. FAMEs were analysed on a gas chromatograph (Varian CP 3800, USA), equipped with a flame ionization detector (FID) and a fused silica capillary column (50 m × 0.25 mm i.d.), coated with CP-SIL 88 as the stationary phase. The oven temperature was programmed at 200 °C for 13 min. The injector and FID were at 250 °C. A reference standard FAME mix (Supelco Inc.) was analyzed under the same operating conditions to determine the peak identity. The FAMEs were expressed as relative area percentage.

Statistical Analysis

All the determinations were carried out in triplicate and the results were given in mean ± standard error. The data obtained from the experimental measurements were subjected to a one-way analysis of variance (ANOVA) to determine the significant differences using Statistical Package for the Social Sciences (SPSS) version 16.0. The statistical significance was expressed at $p < 0.05$. The significant differences ($p < 0.05$) between the means were further determined by Tukey's HSD test.

Results and Discussion

Changes in Iodine Value

Iodine value is an index of the unsaturation, which is the most important analytical characteristic of oil [21]. The

Table 1 Changes in iodine value (g) of RBO blends during deep-fat frying

Blend	Fresh	Frying			Percent decrease in iodine value after frying		
		I	II	III	I	II	III
Ratio 80:20							
RBO+OO	115.2±0.08 [b, A]	108.4±0.08 [e, B]	105.7±0.25 [c, C]	104.2±0.16 [d, D]	5.9	8.2	9.5
RBO+GO	113.2±0.16 [d, A]	111.3±0.00 [d, B]	109.6±0.08 [b, C]	106.5±0.08 [c, D]	1.7	3.2	5.9
RBO+SOO	115.7±0.08 [b, A]	112.4±0.09 [c, B]	110.2±0.16 [a, b, C]	108.8±0.08 [a, D]	2.9	4.8	6.0
RBO+SO	118.9±0.16 [a, A]	115.8±0.08 [a, B]	110.2±0.00 [a, b, C]	106.5±0.05 [c, D]	2.6	7.3	10.4
RBO+MO	114.7±0.08 [c, A]	114.2±0.08 [b, B]	110.9±0.16 [a, C]	107.8±0.08 [b, D]	0.4	3.3	6.0
RBO+PO	107.0±0.08 [e, A]	105.6±0.09 [f, B]	100.7±0.34 [d, C]	102.2±0.09 [e, D]	1.3	5.9	4.5
Ratio 70:30							
RBO+OO	114.6±0.08 [c, A]	113.7±0.31 [a, B]	112.1±0.16 [a, C]	110.2±0.09 [a, D]	0.8	2.2	3.8
RBO+GO	113.4±0.08 [d, A]	109.6±0.08 [c, B]	108.4±0.09 [c, C]	106.1±0.34 [c, D]	3.4	4.4	6.4
RBO+SOO	112.5±0.00 [e, A]	111.3±0.08 [b, B]	109.6±0.16 [b, C]	108.4±0.09 [c, D]	1.1	2.6	3.6
RBO+SO	117.0±0.08 [a, A]	110.1±0.08 [c, B]	107.0±0.09 [d, C]	104.5±0.09 [b, D]	5.9	8.5	10.7
RBO+MO	115.1±0.08 [b, A]	111.6±0.09 [b, B]	109.4±0.16 [b, c, C]	107.0±0.09 [d, D]	3.0	5.0	7.0
RBO+PO	107.3±0.09 [f, A]	105.6±0.09 [d, B]	104.3±0.09 [e, C]	104.4±0.29 [d, C]	1.6	2.8	2.7

Values are expressed as mean ± SE

RBO rice bran oil, *OO* olive oil, *GO* groundnut oil, *SOO* soybean oil, *SO* sunflower oil, *MO* mustard oil, *PO* palm-olein

[a–f] Means within each column with different superscripts are significantly ($p < 0.05$) different

[A–D] Means within each row with different superscripts are significantly ($p < 0.05$) different

data on changes in the iodine value of the RBO blends during deep frying are presented in Table 1. It was observed that iodine value decreased significantly ($p < 0.05$) during deep frying in the experimental RBO blends. At fresh conditions, the maximum iodine value was observed in RBO+SO i.e., 117.0 g (70:30) and 118.9 g (80:20) whereas the minimum iodine value was found in RBO+PO i.e., 107.3 g (70:30) and 107.0 g (80:20). In comparison, the initial iodine values of the different oils viz. RBO, OO, GO, SOO SO, MO and PO were 93.5, 83.1, 103.4, 124.3, 113.4, 110.6 and 57.2 g respectively [2, 22–25]. The greater the degree of unsaturation (or high IV), the more rapid the oil tends to be oxidized, particularly during deep-fat frying [2]. By comparing both ratios, it was found that RBO+OO in the ratio of 80:20 showed the highest significant ($p < 0.05$) percent decrease (5.9 %) in the iodine value whereas the lowest percent decrease was recorded in RBO+MO (0.4 %) and RBO+PO (1.1 %) after first frying. In the ratio of 70:30, the highest and the lowest significant ($p < 0.05$) percent decrease was observed in RBO+SO (5.9 %) and RBO+OO (0.8 %) respectively. Besides, the significant ($p < 0.05$) percent decrease in iodine value was also at lower side in RBO+SOO (1.1 %) and RBO+PO (1.6 %) in the ratio of 70:30 after first frying. Rastogi et al. [26] also reported a significant decrease in iodine value of cooking oils after deep –frying. As compared to blended oils, the iodine values of RBO, OO, SO, SOO and PO significantly ($p < 0.05$) decreased by 2.0, 6.1, 4.3, 6.3 and 2.1 % respectively [2, 22, 25]. After second frying, again RBO+OO (80:20) and RBO+SO (70:30) showed the highest significant ($p < 0.05$) percent decrease in the iodine value i.e. 8.2 and 8.5 % respectively whereas the lowest significant ($p < 0.05$) percent decrease in iodine value was observed in RBO+GO (80:20) and RBO+OO (70:30) as 3.2 and 2.2 % respectively. Comparatively, the iodine values of RBO, OO, SO and GO significantly ($p < 0.05$) decreased by 4.1, 29.0, 9.5 and 6.7 % respectively after second frying [22, 23, 25]. RBO+MO (80:20) and RBO+SOO (70:30) also showed less significant ($p < 0.05$) percent decrease (i.e. 3.2 and 2.6 %) in the iodine value after second frying. Studies have reported that the changes taking place in oil due to repeated frying are often deteriorative and make the fried food an unsuitable product in terms of nutritional facts [27].

After third frying, the highest significant ($p < 0.05$) percent decrease in the iodine value was recorded in RBO+SO (10.4 %) followed by RBO+OO (9.5 %) in the ratio of 80:20 whereas the lowest significant ($p < 0.05$) percent decrease was observed in RBO+PO (4.5 %). The percent decrease in RBO+SO and RBO+OO could be due to the predominance of mono- and poly-unsaturated fatty acids (PUFAs) in these blended oils [28]. It is well known that during frying some of the non-conjugated double bonds are converted to conjugated ones. The conjugated system, in general, precludes the complete addition of iodine [29]. This fact indicates the decrease of iodine value for the oils under study during frying [30]. Similar trends

Table 2 Changes in peroxide value (meq/kg) of RBO blends during deep-fat frying

Blend	Fresh	Frying			Percent increase in peroxide value after frying		
		I	II	III	I	II	III
Ratio 80:20							
RBO+OO	0.33±0.07 $^{d, A}$	0.93±0.07 $^{c, B}$	1.80±0.00 $^{c, C}$	2.53±0.07 $^{e, D}$	64.5	81.7	87.0
RBO+GO	1.13±0.07 $^{b, A}$	1.73±0.02 $^{a, B}$	2.53±0.06 $^{b, C}$	3.13±0.07 $^{d, D}$	34.7	55.3	63.9
RBO+SOO	1.38±0.06 $^{a, A}$	1.53±0.04 $^{a, b, B}$	2.73±0.07 $^{b, C}$	4.87±0.13 $^{a, b, D}$	9.8	49.5	71.7
RBO+SO	0.73±0.03 $^{c, A}$	1.33±0.05 $^{b, B}$	2.73±0.07 $^{b, C}$	4.73±0.09 $^{b, c, D}$	45.1	73.3	84.6
RBO+MO	1.33±0.06 $^{a, A}$	1.73±0.08 $^{a, B}$	3.93±0.07 $^{a, C}$	5.13±0.06 $^{a, D}$	23.1	66.2	74.1
RBO+PO	1.10±0.08 $^{b, A}$	1.33±0.07 $^{b, B}$	1.73±0.07 $^{c, C}$	4.40±0.00 $^{c, D}$	17.3	36.4	75.0
Ratio 70:30							
RBO+OO	0.53±0.07 $^{d, A}$	1.13±0.05 $^{d, B}$	2.33±0.06 $^{d, C}$	2.93±0.07 $^{d, D}$	53.1	77.3	81.9
RBO+GO	1.53±0.07 $^{b, A}$	2.40±0.00 $^{a, B}$	2.93±0.07 $^{c, C}$	3.47±0.13 $^{c, D}$	36.3	47.8	55.9
RBO+SOO	1.40±0.00 $^{c, A}$	1.73±0.07 $^{c, B}$	3.53±0.07 $^{b, C}$	6.13±0.07 $^{a, b, D}$	19.1	60.3	77.2
RBO+SO	0.93±0.07 $^{d, A}$	1.60±0.00 $^{c, B}$	3.13±0.07 $^{c, C}$	6.47±0.13 $^{a, D}$	41.9	70.3	85.6
RBO+MO	1.73±0.07 $^{a, A}$	2.13±0.07 $^{b, B}$	4.53±0.07 $^{a, C}$	5.80±0.00 $^{b, D}$	18.8	61.8	70.2
RBO+PO	1.47±0.07 $^{c, A}$	1.80±0.00 $^{c, B}$	2.13±0.07 $^{d, C}$	5.73±0.07 $^{b, D}$	18.3	31.0	74.3

Values are expressed as mean ± SE

RBO rice bran oil, *OO* olive oil, *GO* groundnut oil, *SOO* soybean oil, *SO* sunflower oil, *MO* mustard oil, *PO* palm-olein

$^{a–e}$ Means within each column with different superscripts are significantly ($p < 0.05$) different

$^{A–D}$ Means within each row with different superscripts are significantly ($p < 0.05$) different

were observed in the ratio of 70:30, the significant ($p < 0.05$) highest and the lowest percent decrease was found in RBO+SO (10.7 %) and RBO+PO (2.7 %) respectively. The iodine values of RBO, SO, OO and PO decreased by 6.6, 14.1, 51.8 and 7.7 % respectively after third frying [22, 23, 25]. Previous studies have reported that the over-use of deep-frying oil causes adverse effects on flavor, stability, color and texture of fried product and may be harmful to human health. It is, therefore, necessary to use vegetable oil up to first frying [6]. Interestingly, it was also found that the percent decrease in the iodine value of RBO+PO after third frying was lower than the percent decrease after second frying in both ratios. During frying, a progressive decrease in unsaturation was observed in all blends by measurement of iodine value. This decrease can be attributed to the destruction of double bonds by oxidation, scission, and polymerization [5, 31]. By comparing all the RBO blends in terms of repeated frying process and changes in iodine value, RBO+PO in both ratios was found to be the most stable frying medium up to third frying. Further, blending with RBO improved the stability of all RBO blends when compared to single oils in terms of changes in iodine value after frying.

Changes in Peroxide Value

Peroxide value is a measure of oxidation during storage and the freshness of lipid matrix. In addition, it is a useful indicator of the early stage of rancidity occurring under mild condition and it is a measure of the primary lipid oxidation products. So, greater the peroxide value, the more will be the rate of oxidation of the oil [32]. The changes in the peroxide values of selected oil blends during deep-frying are given in Table 2. It was observed that peroxide value increased significantly ($p \leq 0.05$) during deep frying in the experimental RBO blends. At fresh conditions, the minimum peroxide value was observed in RBO+OO as 0.53 meq/Kg (70:30) and 0.33 meq/Kg (80:20) and the maximum peroxide value was found in RBO+MO as 1.73 meq/Kg (70:30) and RBO+SOO as 1.38 meq/Kg (80:20). The initial peroxide values of single oils viz. RBO, OO, MO and SOO were 0.38, 9, 5.86, and 1.86 meq/Kg respectively. By comparing both ratios, it was found that RBO+OO in the ratio of 70:30 showed the highest percent increase (53.1 %) in the peroxide value whereas the lowest percent increase was recorded in RBO+PO (18.3 %) and RBO+MO (18.8 %) after first frying. In the ratio of 80:20, the highest and the lowest percent increase was observed in RBO+SOO (9.8 %) and RBO+PO (17.3 %) respectively. The increase in the peroxide values of RBO+OO and RBO+SOO could be due to the presence of high concentrations of unsaturated fatty acids as unsaturated fatty acids are prone to oxidation due to the presence of double bonds [17]. As compared to blended oils, the peroxide values of RBO, OO, MO, SOO and PO significantly ($p < 0.05$) increased by 32.1, 15.9, 14.3, 30.9 and 27.8 % respectively.

Table 3 Fatty acid composition of RBO blends

Fatty acid (%)	RBO+OO	RBO+GO	RBO+SOO	RBO+SO	RBO+MO	RBO+PO	CD[a]
Ratio 80:20							
Palmitic acid (C16:0)	20.6±0.04	16.8±0.03	16.7±0.08	20.5±0.07	16.4±0.06	21.8±1.00	1.64
Stearic acid (C18:0)	0.5±0.01	0.2±0.01	0.3±0.01	0.4±0.01	0.5±0.02	0.7±0.02	NS
Oleic acid (C18:1)	42±0.09	36.9±1.00	30.4±0.06	29.4±0.07	32.3±0.06	33.4±0.05	1.44
Linoleic acid (C18:2)	36.9±0.07	46.1±0.09	51.7±0.09	49.7±0.04	39.1±0.20	44.1±1.00	2.52
Linolenic acid (C18:3)	ND	ND	0.9±0.4	ND	8.6±0.04	ND	1.74
Arachidic acid (C20:0)	ND	ND	ND	ND	3.1±0.03	ND	0.70
SFA %	21.1±0.03	17±0.03	17±0.09	20.9±0.06	16.9±0.04	22.5±0.08	1.49
MUFA %	42±0.09	36.9±1.00	30.4±0.06	29.4±0.07	32.3±0.06	33.4±0.05	1.44
PUFA %	36.9±0.07	46.1±0.09	52.6±0.05	49.7±0.04	50.8±0.08	44.1±1.00	2.02
SFA:MUFA:PUFA	1:2:1.7	1:2.2:2.7	1:1.8:3.1	1:1.4:2.4	1:1.9:1	1:1.5:2	–
Ratio 70:30							
Palmitic acid (C16:0)	18.7±0.04	14.8±0.03	14.4±0.06	13.8±0.06	14.9±0.09	23.9±0.06	2.28
Stearic acid (C18:0)	0.3±0.02	0.1±0.00	0.5±0.02	0.6±0.02	0.3±0.01	0.6±0.02	NS
Oleic acid (C18:1)	47.6±0.04	30.7±0.04	23.5±0.06	27.1±0.02	25.6±0.08	30.3±0.01	2.34
Linoleic acid (C18:2)	33.4±0.01	54.4±0.06	60.5±0.06	58.5±0.09	45.2±0.03	45.2±0.02	1.71
Linolenic acid (C18:3)	ND	ND	1.1±0.02	ND	9.8±0.09	ND	1.39
Arachidic acid (C20:0)	ND	ND	ND	ND	4.2±0.09	ND	1.83
SFA %	19±0.06	14.9±0.03	14.9±0.04	14.4±0.08	15.2±0.08	24.5±0.04	2.33
MUFA %	47.6±0.04	30.7±0.04	23.5±0.06	27.1±0.02	25.6±0.08	30.3±0.01	2.34
PUFA %	33.4±0.01	54.4±0.06	61.6±0.04	58.5±0.09	59.2±0.03	45.2±0.02	1.68
SFA:MUFA:PUFA	1:2.5:1.8	1:2.1:3.7	1:1.6:4.1	1:1.9:4.1	1:1.7:3.9	1:1.2:1.8	–

Values are expressed as mean ± SE

NS non significant, *RBO* rice bran oil, *OO* olive oil, *GO* groundnut oil, *SOO* soybean oil, *SO* sunflower oil, *MO* mustard oil, *PO* palm-olein, *SFA* saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids

[a] Significant at 5 %

After second frying, again RBO+OO showed the highest percent increase in the peroxide value as 77.3 and 81.7 % whereas the lowest percent increase in peroxide value was observed in RBO+PO as 31.0 and 36.4 % respectively in the ratio of 70:30 and 80:20. Comparatively, the peroxide values of RBO, OO and PO significantly ($p < 0.05$) increased by 49.5, 30.8 and 37.3 % respectively after second frying [2, 22, 23]. In contrast, after third frying, RBO+GO showed the least percent increase in the peroxide value as 55.9 and 63.9 % in the ratio of 70:30 and 80:20 respectively. With regard to single oils, the peroxide values of RBO, GO and PO significantly ($p < 0.05$) increased by 64.9, 57.1 and 48.1 % respectively after third frying [2, 22, 24]. In the ratio of 80:20, the trend in the highest percent increase in the peroxide value of RBO blend (RBO+OO) was consistent after frying, whereas, an inconsistent trend was observed in the lowest percent increase in the peroxide value of RBO blends, for instance, RBO+SOO, RBO+PO and RBO+GO showed the lowest percent increase in the peroxide value after first, second and third frying respectively. Comparatively, a consistent trend was observed in the highest and lowest percent increase (RBO+OO and RBO+PO, respectively) in the peroxide value of the RBO blends up to second frying in the ratio of 70:30. So, RBO+PO (70:30) was the most stable blend up to second frying. In addition, the percent increase in peroxide value of RBO+PO (70:30) was less as compared to single oils (RBO and PO) up to second frying.

Fatty Acid Composition

The fatty acid composition of the blends of RBO is given in Table 3. RBO+OO (70:30) and RBO+GO (80:20) contained highest amount of mono-unsaturated fatty acids (MUFAs) (oleic acid) as 47.6 and 36.9 % respectively. Several studies reported the beneficial effect of MUFA on cardiovascular and diabetic risk factors [33]. Oleic acid had been described to reduce the cardiovascular risk by reducing blood lipids, mainly cholesterol [34–36]. RBO+SOO contained highest percentage of PUFA as 61.6 % followed by RBO+MO (59.2 %) and RBO+SO (58.5 %) in the ratio 70:30. Similar trend was also observed in the ratio of 80:20 for PUFA content in RBO+SOO (52.6 %), RBO+MO

Table 4 Fatty acid composition of food product (*Poori*) prepared in RBO blends using deep-fat frying

Fatty acid (%)	Control (wheat flour)	RBO+OO	RBO+GO	RBO+SOO	RBO+SO	RBO+MO	RBO+PO	CD[a]
Ratio 80:20								
Palmitic acid (C16:0)	23.6±0.02	16.3±0.01	17.0±0.01	17.0±0.06	15.4±0.08	16.1±0.03	20.7±0.02	NS
Stearic acid (C18:0)	1.0±0.03	0.7±0.01	1.6±0.04	2.0±0.03	1.8±1.00	1.6±0.02	1.8±0.02	NS
Oleic acid (C18:1)	9.9±0.06	31.7±0.09	37.8±0.06	31.6±0.02	27.0±0.08	33.3±0.09	41.8±0.01	3.12
Linoleic acid (C18:2)	61.8±0.02	44.9±0.05	43.1±0.06	49.2±0.02	55.7±0.07	45.3±0.02	31.4±0.01	3.41
Linolenic acid (C18:3)	3.6±0.04	0	0	0	0	3.2±0.01	0	2.33
Arachidic acid (C20:0)	0	0	0	0	0	0	0	–
SFA %	24.6±0.01	17.0±0.02	18.6±0.04	19.0±0.09	17.2±0.08	17.7±0.05	22.5±0.01	NS
MUFA %	9.9±0.06	31.7±0.09	37.8±0.06	31.6±0.02	27.0±0.08	33.3±0.09	41.8±0.01	3.12
PUFA %	65.4±0.03	44.9±0.05	43.1±0.06	49.2±0.02	55.7±0.07	48.5±0.03	31.4±0.01	3.85
SFA:MUFA:PUFA	1:0.4:2.7	1:1.9:2.6	1:2:2.3	1:1.7:2.6	1:1.6:3.2	1:1.9:2.7	1:1.9:1.4	–
Ratio 70:30								
Palmitic acid (C16:0)	23.6±0.02	15.5±0.01	16.0±0.05	16.0±0.01	14.7±0.09	15.6±0.09	23.0±0.04	2.58
Stearic acid (C18:0)	1.0±0.03	1.3±0.02	1.7±0.03	1.9±0.03	1.4±0.03	0.7±0.02	2.1±0.03	2.04
Oleic acid (C18:1)	9.9±0.06	47.3±0.01	38.1±0.03	28.5±0.08	27.8±0.09	29.5±0.01	31.0±0.05	2.37
Linoleic acid (C18:2)	61.8±0.02	33.9±0.04	43.8±0.02	52.4±0.02	55.8±0.09	49.2±0.06	43.6±0.03	2.69
Linolenic acid (C18:3)	3.6±0.04	0	0	0	0	4.4±0.01	0	1.89
Arachidic acid (C20:0)	0	0	0	0	0	0	0	–
SFA %	24.6±0.01	16.8±0.03	17.7±0.07	17.9±0.03	16.1±0.08	16.3±0.09	25.1±0.01	2.85
MUFA %	9.9±0.06	47.3±0.01	38.1±0.03	28.5±0.08	27.8±0.09	29.5±0.01	31.0±0.05	2.37
PUFA %	65.4±0.03	33.9±0.04	43.8±0.02	52.4±0.02	55.8±0.09	53.6±0.05	43.6±0.03	3.14
SFA:MUFA:PUFA	1:0.4:2.7	1:2.8:2	1:2.2:2.5	1:1.6:2.9	1:1.7:3.5	1:1.8:3.3	1:1.2:1.7	–

Values are expressed as mean ± SE

NS non significant, *RBO* rice bran oil, *OO* olive oil, *GO* groundnut oil, *SOO* soybean oil, *SO* sunflower oil, *MO* mustard oil, *PO* palm-olein, *SFA* saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids

[a] Significant at 5 %

(50.8 %) and RBO+SO (49.7 %). Scientific studies demonstrated the potential beneficial effects of PUFA for chronic diseases including cancer, insulin resistance and cardiovascular disease [37–40]. Saturated fatty acids (SFA) were found be highest in RBO+PO as 24.5 % in the ratio of 70:30. Similar findings were also reported by Fan et al. [41]. A significant ($p \leq 0.05$) difference was found in fatty acid composition of RBO blends. To maintain a good health, the fatty acid ratio (SFA:MUFA:PUFA) of vegetable oil should be 1:1.5:1 as per the recommendations given by the World Health Organization (WHO) [42]. The results showed that the fatty acid ratio of RBO+PO in the ratio of 80:20 (1:1.5:2) and 70:30 (1:1.2:1.8) was near to the recommendations.

Changes in Fatty Acid Composition

The fatty acid composition of deep fried product (Poori) prepared using RBO blends is given in Table 4. Deep fried product (Poori) prepared using RBO+PO had highest amount of SFA and MUFA in the ratio of 80:20 as 22.5 and 41.8 % respectively whereas in the ratio of 70:30, highest amount of MUFA was present in the product prepared using RBO+OO as 47.3 %. The highest amount of PUFA was present in the product prepared using RBO+SO as 55.7 and 55.8 % in the ratio of 80:20 and 70:30 respectively. Results showed that linolenic acid was absent in RBO+SOO in both ratios whereas RBO+MO contained linolenic acid as 3.2 and 4.4 % in the ratio of 80:20 and 70:30 respectively. Recent studies reported that linolenic acid present in soybean oil was less stable at high temperature [43]. Significant ($p \leq 0.05$) difference was found in SFA, MUFA and PUFA content of product prepared using RBO blends in both ratios but a non significant difference was found in SFA content in the ratio of 80:20. Ratio of SFA:MUFA:PUFA in the product prepared using RBO+PO was close to the recommended ratio (1:1.5:1) by WHO as 1:1.9:1.4 and 1:1.2:1.7 in the ratio of 80:20 and 70:30 respectively.

Conclusion

The present study revealed that RBO+PO in both ratios was the most stable frying blended oil among all RBO blends based on changes in iodine value and fatty acid ratio under frying conditions. In conclusion, blending of traditional oil (PO) with non-traditional oil (RBO) in deep fat frying brought about the fatty acid composition of oil near to the recommendations. But more research studies should be carried out on stability issues against lipid oxidation as the present research work has considered only the primary measure of oxidation. Further, blending of oil with RBO may serve to reduce the burden on India's oilseed economy by decreasing the demand and cost of traditional oils.

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