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Full Length Research Paper

Effect of packaging materials on the storage stability of physically refined rice bran oil and its blends

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Physically refined rice bran oil (PRBO) was blended with refined sunflower (SFO) and Safflower oil (SAF) in different ratios. The PRBO and blended oils were packed in PET, laminates and glass bottles and were stored for 11 months to study the effect of storage on physico-chemical properties at regular interval of two months. The individual and blended oils were evaluated for their physico-chemical properties and fatty acid composition. Storage study had shown a steady rise in Peroxide value, FFA, Color, p-anisidine value and fall in Iodine value. No significant changes were observed in refractive index, specific gravity and oryzanol content. The gradual increase in saturated fatty acids and decrease in unsaturated fatty acids was observed during storage at room temperature in all the packaging materials. A similar trend was observed in case of oil blends. Blended oil (rice bran oil with safflower oil) showed minimum changes. When packaging materials were evaluated better quality was observed in samples stored in laminate pouches followed by glass bottles and PET.

Key words: Rice bran oil, storage stability, packaging material, blended oils, fatty acid.

INTRODUCTION

One of the most important factors in oil processing is packaging which affect the shelf life of oil in such a manner that carefully processed oil can be damaged by improper selection of packaging material. Packaging protects the product from the point of manufacture to its usage by consumers. Environmental factors such as light, gaseous atmosphere, temperature and moisture can affect the stability of oil (Leo, 1985).

The quality characteristics and oxidative stability of date seed oil during storage revealed that the oil could be easily stored for 40 days (Besbes et al., 2004). The quality of palm oil, in different film packaging material indicate, that the quality deterioration of palm oil was more pronounced when stored under 30 to 40% relative humidity and 45°C (Narasimhan et al., 2001). During long-term storage of soybean oil in plastic bottles and glass bottles, it was concluded that the oil in plastic containers could serve as an alternative to clear glass bottles (Warner and Mounts, 1984). The storage quality of sunflower oil in different packaging materials indicated that the oil in glass and steel containers had better qualities than the others (Jaimand and Rezaee, 1995). At room temperature, refined sunflower oil remains stable in high-density polyethylene (HDPE) bottles and sealed tin for two years (Semwal and Arya, 1992). Extra-virgin olive oil have been analysed in order to evaluate the influence of storage time on quality. Olive oil stored, in clear PET bottle, PET bottle (covered with Al foil), glass bottle, tin, and Tetra-brik, at room temperature showed a gradual loss of quality during storage, especially in plastic or glass bottles. The best containers for commercial packing of extra-olive oil were tin and Tetra-brik (Mendez and Falcon, 2007).

The high-quality rice bran oil has a very neutral, delicate flavour and high smoke point therefore is considered good cooking oil. Beside this, the oil is known for its significant nutritional attributes due to the naturally occurring antioxidants (Sharma et al., 2006). The light viscosity of the oil allows less oil to be absorbed during cooking therefore provides economic viability to the

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industry. The deterioration by auto-oxidation in Rice bran oil (RBO) and other edible oils is the cause of concern with respect to the shelf life of the product (Mishra et al., 2010).

Current trends in globalization and nutritional enrichment have led to increased interest in the use of blended oils. Blended oils are gaining popularity world-wide due to advantages they offer such as improved thermal stability, oxidative stability and nutritional benefits (Sharma et al., 1996a) and an ability to tailor the desired properties. Frankel and Huang (1994) reported that mixing different proportions of high-oleic sunflower oil (HOSO) with polyunsaturated vegetable oils provides a simple method to prepare more stable edible oils with a wide range of desired fatty acid composition. Investigations pertaining to the blended oils, especially from the non conventional sources, are scarce. Therefore, the study dealing with quality characteristics and shelf life of pure rice bran oil (physically refined) and blended oils thereof while using different packaging material was undertaken.

MATERIALS AND METHODS

Physically refined rice bran oil, sunflower oil and safflower oil were obtained from A. P. Organics Pvt. Ltd. Dhuri, Punjab. Packaging materials, used for storage of oil samples were PET, laminates consisted of typical three layer co-extruded film consists of LD+LLD-HM HDPE- Primacor and glass bottles. The packaging materials used under study were also supplied by A. P. Organics Pvt. Ltd., Dhuri, Punjab. All the chemicals used in the study were of AR grade.

Preparation of samples and their storage

PRBO: Safflower, PRBO: Sunflower, oil blends were prepared in the proportions of 20:80 and 60:40, respectively (Sharma et al., 1996 b and Sharma et al., 2006) and were filled in PET bottles, glass bottles and laminated pouches (typical three layer co-extruded film consists of LD+LLD-HM HDPE- Primacor). The samples were stored for a period of 11 months at a temperature of 25±5ºC and relative humidity of 60 to 70%, respectively. The samples were opened after every two months for the evaluation of various physico-chemical parameters.

Analysis of the samples

Free fatty acids (FFA) [Ca 5a-40], Peroxide value (PV) [Cd 8 to 53], Iodine value (IV) [Cd 1 to 25], Saponificataion value (SV) [Cd 3-25], Refractive index (RI) [Cc 7-25], p-content [Ca 12-55] and p-anisidine value [Cd 18 to 90] and specific gravity [Cc 10a-25] were determined by using standard methods (AOCS, 2004). Colour of the oil was measured by using Lovibond tintometer (Model F, Effem Technologies Pvt. Ltd., New Delhi, India). Oryzanol value (IICT, 2008) was measured by using Spectrophotometer (UV-1700, SHIMAZDU). Fatty acids of triglycerides were analyzed by preparing methyl esters according to a conventional procedure consisting of saponification followed by acidification and finally methylation using diazomethane as per the reported method (Sharma et al., 2006). Gas chromatographic (GC) analysis of fatty acid methyl esters was carried out using a NUCON SERIES 5700 of data station 0 to 2.5 mV range and < 1.5 s response rate. A 2m x 2 mm stainless steel 10% Silar 7C column packed with 60-120 mesh Gas Chrom Q was used. The injector and detector temperatures were maintained at 240°C. The column temperature was set at 160°C for 5 min and then ramped at a rate of 5°C per min to a final temperature of 220°C and kept there for 20 min. The total time for analysis was 37 min. Fatty acids were tentatively identified by comparison with retention times of authentic reference samples. The data was tabulated and subjected to two ways ANOVA, test of significance, means and standard deviation using Sigma Stat 3.5 version and excel windows version.

RESULT AND DISCUSSION

Effect of packaging material on the physico-chemical characteristics during storage

The initial quality of physically refined rice bran oil (RBO) and its blends with sunflower and safflower oil sample is shown in Table 1. The oil sample of PRBO and its blends with sunflower oil and safflower oil had colour 13.0, 11.5 and 6.0 units, oryzanol value 14,690, 8926 and 2381 ppm and p- anisidine value in the proportion of 30.56, 29.02 and 20.79, respectively while the moisture, free fatty acids (ffa), peroxide value (PV), saponification value (SV), p-content and iodine value (IV) were found in the range as per the regulatory standards. The refractive index was 1.4692, 1.4635 and 1.4651 and specific gravity was 0.9170, 0.9159 and 0.9188 in PRBO and its blends with sunflower oil and safflower oil, respectively.

The effect of storage on the different quality parameters of physically refined rice bran oil (PRBO) and its blend is given in Tables 2 to 4. No significant changes were observed ($P<0.01$) in the oryzanol content, specific gravity and refractive index of all the samples during the storage. Free fatty acids of PRBO and its blends increased during the storage period. The highest level of free fatty acids formation was found in PRBO, 0.30% when stored in PET bottles whereas the lowest was 0.24% when packed in laminated film pouches after 11 months of storage. However, the blended oil, consisting of PRBO and SAF (safflower oil) showed least amount of free fatty acids formation after 11 months of storage as compared to the PRBO and blended oil (PRBO+SNF). Initially, free fatty acids were 0.08, 0.06 and 0.06 in PRBO and its blends with sunflower oil and safflower oil. After 11 month of storage, free fatty acid in PRBO and its blends with sunflower oil and safflower oil were 0.30, 0.25 and 0.24 in PET bottles, 0.24, 0.21 and 0.19 in laminate pouches and 0.29, 0.23 and 0.22 in glass bottles. The packaging material, laminated films showed better storage stability of all the oils samples as compared to

Table 1. Initial quality of physically refined rice bran oil and its blends with safflower oil and sunflower oil.

Parameters	PRBO	PRBO +SAF	PRBO+SnFO
MIV (%)	0.05±0.005	0.045±0.005	0.047±0.005
FFA (%)	0.08±0.005	0.06±0.005	0.06±0.005
Colour (y+5r unit)	13.0±0.28	6.0±0.28	11.5±0.28
PV (meq/kg)	0.63±0.02	1.88±0.04	1.92±0.03
IV	105.74±0.14	143.82±0.03	142.75±0.05
SV	190.89±0.08	192.38±0.08	189.45±0.06
p-anisidine value	30.56±0.03	20.79±0.02	29.02±0.02
P-content (ppm)	Nil	Nil	Nil
Ory.V (ppm)	14,690±71.50	2381±41.50	8926±23
RI	1.4692±0.0001	1.4651±0.0001	1.4635±0.0001
Specific gravity	0.9170±0.0006	0.9188±0.0003	0.9159±0.0008

*MIV – moisture, FFA- free fatty acid, Colour, IV- iodine value, PV- peroxides value, SV – saponification value, Ory.V - oryzanol value, RI - refractive index, Specific Gravity, PAV- p-anisidine value. PRBO-physically refined rice bran oil, SNF-sunflower oil, SAF- safflower oil. PRBO+SAF- 80:20, PRBO+SnFO- 60:40.

Table 2. Physico-chemical parameters of rice bran oil and its blends with sunflower oil and safflower oil during storage in PET (polyethylene terephthalate) bottles.

Time	Sample name	FFA*	Colour*	PV*	IV*	PAV*
0	PRBO	0.08±0.005	13.0±0.28	0.63±0.01	105.75±0.02	30.56±0.05
0	PRBO+SNF	0.06±0.005	11.5±0.28	1.92±0.01	142.75±0.03	29.02±0.03
0	PRBO+SAF	0.06±0.005	6.0±0.28	1.88±0.01	143.82±0.02	20.79±0.03
1	PRBO	0.09±0.005	13.5±0.28	1.57±0.01	103.29±0.02	32.03±0.03
1	PRBO+SNF	0.07±0.01	12.0±0.28	2.71±0.01	140.75±0.03	31.26±0.04
1	PRBO+SAF	0.08±0.005	7.0±0.28	2.70±0.01	141.82±0.02	23.40±0.02
3	PRBO	0.11±0.01	14.5±0.28	2.76±0.01	101.05±0.03	35.15±0.03
3	PRBO+SNF	0.09±0.01	13.0±0.28	3.52±0.02	136.11±0.03	34.47±0.05
3	PRBO+SAF	0.08±0.005	8.5±0.28	3.26±0.005	135.25±0.03	25.77±0.04
5	PRBO	0.15±0.005	16.0±0.28	3.91±0.01	99.02±0.02	37.98±0.02
5	PRBO+SNF	0.14±0.01	15.5±0.28	4.42±0.01	130.34±0.03	36.71±0.03
5	PRBO+SAF	0.10±0.005	10.5±0.28	4.59±0.01	129.84±0.03	28.59±0.03
7	PRBO	0.19±0.005	17.5±0.28	5.47±0.01	91.46±0.02	41.11±0.04
7	PRBO+SNF	0.16±0.01	16.5±0.28	6.08±0.005	121.21±0.02	39.85±0.03
7	PRBO+SAF	0.16±0.01	13.5±0.28	5.94±0.01	125.38±0.01	31.63±0.04
9	PRBO	0.25±0.005	19.0±0.28	6.54±0.01	87.60±0.02	45.31±0.02
9	PRBO+SNF	0.20±0.01	18.5±0.28	7.22±0.005	117.14±0.03	42.66±0.05
9	PRBO+SAF	0.19±0.01	15.5±0.28	7.02±0.01	119.21±0.03	34.25±0.04
11	PRBO	0.30±0.005	22.5±0.28	8.96±0.01	83.17±0.02	49.32±0.03
11	PRBO+SNF	0.25±0.005	20.0±0.28	9.01±0.01	110.76±0.02	46.17±0.03
11	PRBO+SAF	0.24±0.01	18.5±0.28	8.19±0.01	109.09±0.03	36.68±0.05

*FFA- free fatty acid, Colour, IV- iodine value, PV- peroxides value, PAV- p-anisidine value. PRBO-physically refined rice bran oil, SNF-sunflower oil, SAF- safflower oil, PET- polyethylene terephthalate. Values are expressed by Mean±SD, *Significant at 1% level.

the glass and PET which may be due to the better resistance of the package towards the water vapour and gas transmission rate. In practice, because of the susceptibility of the oil to hydrolysis, the FFA content may vary with age and storage history (Semwal and Arya, 2001). The initial amount of the free fatty acids in all the

Table 3. Physico-chemical parameters of rice bran oil and its blends with sunflower oil and safflower oil during storage in laminated films.

Time	Sample name	FFA*	Colour*	PV*	IV*	PAV*
0	PRBO	0.08±0.005	13.0±0.28	0.63±0.02	105.75±0.04	30.56±0.03
0	PRBO+SNF	0.06±0.005	11.5±0.28	1.92±0.02	142.75±0.04	29.02±0.02
0	PRBO+SAF	0.06±0.005	6.0±0.28	1.88±0.03	143.82±0.02	20.79±0.04
1	PRBO	0.09±0.005	13.0±0.28	1.29±0.02	104.68±0.03	32.26±0.03
1	PRBO+SNF	0.06±0.005	11.5±0.28	2.41±0.04	141.51±0.02	31.51±0.03
1	PRBO+SAF	0.07±0.01	6.0±0.28	2.50±0.02	142.12±0.02	22.63±0.03
3	PRBO	0.11±0.01	14.0±0.28	2.18±0.02	103.83±0.03	34.40±0.04
3	PRBO+SNF	0.08±0.005	12.5±0.28	3.39±0.04	140.10±0.04	33.99±0.02
3	PRBO+SAF	0.08±0.005	7.5±0.28	3.21±0.04	141.08±0.03	24.71±0.03
5	PRBO	0.15±0.01	15.0±0.28	3.06±0.04	101.99±0.02	36.71±0.03
5	PRBO+SNF	0.10±0.005	14.0±0.28	4.26±0.03	136.88±0.03	35.63±0.03
5	PRBO+SAF	0.09±0.005	9.0±0.28	4.37±0.03	135.48±0.03	26.45±0.04
7	PRBO	0.18±0.01	16.5±0.28	4.87±0.01	98.56±0.01	39.17±0.02
7	PRBO+SNF	0.14±0.01	15.5±0.28	5.91±0.02	130.74±0.03	37.59±0.02
7	PRBO+SAF	0.13±0.005	10.5±0.28	5.62±0.02	133.48±0.01	29.76±0.005
9	PRBO	0.21±0.005	18.0±0.28	5.91±0.02	92.71±0.02	43.81±0.02
9	PRBO+SNF	0.17±0.005	17.5±0.28	6.83±0.03	122.11±0.04	40.29±0.03
9	PRBO+SAF	0.16±0.01	13.0±0.28	6.75±0.03	128.53±0.02	31.55±0.03
11	PRBO	0.24±0.01	20.5±0.28	7.26±0.02	90.04±0.03	46.72±0.02
11	PRBO+SNF	0.21±0.005	19.0±0.28	8.15±0.03	119.15±0.03	44.56±0.03
11	PRBO+SAF	0.19±0.01	16.0±0.28	7.90±0.02	125.66±0.04	34.87±0.01

*FFA- free fatty acid, Colour, IV- iodine value, PV- peroxides value, PAV- p-anisidine value. PRBO-physically refined rice bran oil, SNF-sunflower oil, SAF- safflower oil, laminated film- typical three layer co-extruded film consists of LD+LLD-HM HDPE- Primacor. Values are expressed by Mean±SD, *Significant at 1% level.

samples was low because of the removal of FFA during the refining process. However, all the oil samples, packaged under different packaging material remained acceptable and within the limits, less than 0.5% as stipulated by PFA (1954).

All the oil blends showed an increase in colour as the storage period increased. PRBO showed an increase in colour, ranging from 13.0 and 22.5 units in PET bottles, 13.0 and 20.5 units in laminated film pouches, 13.0 and 21.5 in glass bottles. Pure fats and fatty acids are colourless and devoid of spectral properties in the visible range. However, all natural fats and oils contain pigments, which have more or less characteristic absorption patterns (Gupta, 2005). Intensity of the colour was seen to be higher in samples which were stored in PET bottle than that of laminated film pouches and glass bottles.

After 11 months storage, highest colour value was observed 22.5 units for the pure physically refined rice bran oil sample stored in PET bottle and lowest colour value of 16.0 was observed for blend of PRBO with safflower oil stored in laminated film. Darkening of the colour may be attributed to several factors such as storage conditions and oxidative effects during storage. Gulla et al., (2010) reported increase in the Lovibond colour units during the storage of soybean-palmolein blends. However, the lovibond colour units of red palm oil blends with refined sunflower and groundnut oil had no change in colour during the storage of 6 months (Sarojini and Bhavani, 1997; Sundararaj et al., 2002).

The PV of PRBO and blends stored for 11 months in PET, laminated pouches and glass bottles was increased with the storage period (Tables 2 to 4). However, all the oil samples, packaged under PET, glass and laminates remained acceptable and within the limits, less than 10 meq/kg stipulated by PFA (1954). An increase in all the blends was observed possibly in accordance to the extent of oxidation possibly caused by the formation of hydro peroxides during oxidation. The initial PV was seen to be lowest in PRBO as compared to the blends during the storage. The highest PV of 9.01 was observed in the PRBO blend with sunflower oil stored in PET bottle after the storage of 11 months, but not exceeded the limit specified by the PFA (1954). However, all the samples remained acceptable and within the limits till the storage of 11 months under controlled conditions. Initially,

Table 4. Physicochemical parameters of rice bran oil and its blends with sunflower oil and safflower oil during storage in glass bottles.

Time	Sample name	FFA*	Colour*	PV*	IV*	PAV*
0	PRBO	0.08±0.01	13.0±0.28	0.63±0.04	105.74±0.04	30.56±0.01
0	PRBO+SNF	0.06±0.005	11.5±0.0	1.92±0.02	142.75±0.03	29.02±0.02
0	PRBO+SAF	0.06±0.01	6.0±0.28	1.88±0.04	143.82±0.04	20.79±0.03
1	PRBO	0.09±0.01	13.0±0.28	1.41±0.03	103.77±0.02	32.11±0.02
1	PRBO+SNF	0.06±0.01	11.5±0.28	2.59±0.03	141.79±0.03	31.39±0.01
1	PRBO+SAF	0.06±0.005	6.5±0.28	2.61±0.02	143.03±0.02	23.25±0.02
3	PRBO	0.10±0.005	14.0±0.28	3.39±0.04	103.26±0.04	35.22±0.02
3	PRBO+SNF	0.08±0.01	12.5±0.0	3.44±0.02	139.90±0.05	34.36±0.02
3	PRBO+SAF	0.07±0.01	8.0±0.28	3.25±0.03	138.25±0.04	25.53±0.01
5	PRBO	0.14±0.005	15.5±0.28	3.57±0.02	100.01±0.04	37.62±0.03
5	PRBO+SNF	0.11±0.005	14.5±0.0	4.36±0.01	135.67±0.02	36.79±0.02
5	PRBO+SAF	0.10±0.005	9.5±0.28	4.50±0.04	134.55±0.04	28.11±0.01
7	PRBO	0.19±0.01	17.0±0.28	5.14±0.03	97.46±0.04	40.76±0.01
7	PRBO+SNF	0.15±0.01	16.0±0.28	5.98±0.03	127.16±0.05	38.99±0.02
7	PRBO+SAF	0.14±0.01	11.5±0.28	5.89±0.03	130.95±0.03	31.51±0.01
9	PRBO	0.23±0.01	18.5±0.28	6.32±0.02	91.75±0.05	44.88±0.02
9	PRBO+SNF	0.19±0.01	18.0±0.0	7.15±0.01	121.01±0.03	42.49±0.03
9	PRBO+SAF	0.19±0.005	14.5±0.0	6.95±0.02	126.94±0.04	33.97±0.03
11	PRBO	0.29±0.01	21.5±0.28	8.56±0.02	89.84±0.03	48.73±0.01
11	PRBO+SNF	0.23±0.01	19.5±0.0	8.89±0.03	117.22±0.02	45.86±0.02
11	PRBO+SAF	0.22±0.005	17.5±0.28	8.10±0.03	121.00±0.05	36.21±0.01

*FFA- free fatty acid, Colour, IV- iodine value, PV- peroxides value, PAV- p-anisidine value. PRBO-physically refined rice bran oil, SNF- sunflower oil, SAF- safflower oil, Glass bottles. Values are expressed by Mean±SD, *Significant at 1% level.

peroxide values were 0.63, 1.92 and 1.88 in PRBO and its blends with sunflower oil and safflower oil, respectively. The peroxide value in PRBO and its blends with sunflower oil and safflower oil were 8.96, 9.01 and 8.19 in PET bottles, 7.26, 8.15 and 7.90 in laminates and 8.56, 8.89 and 8.10 in glass bottles after 11 month of storage. Among the packaging materials, the increase in PV was seen to be the highest in samples stored in PET bottles. The results are in the similar lines as reported by Gulla et al. (2010) in the storage study of soybean-palmolein blends. However, the changes in peroxide values of the edible oils stored at room temperature were not regular which was proved by a few other workers (Murthy et al., 1996; Schnepf et al., 1991). In most raw edible oils, there was a steady increase to a peak value and slight decline thereafter, refined oils showed irregular behaviour. The PV in the sesame-soyabean (80:20) increased from 4.63 to 17.55 meq/kg and for sesame-soyabean (20:80) it increased from 5.14 to 20.97 meq/kg. The rate of degradation of hydro peroxides is seen to be higher than control in case of blended oils. Oxidative stabilities of rice germ oil, dried germ oil and crude and refined rice bran oils were evaluated by measuring acid value, PV and fatty acid composition during storage and observed that PV increases during storage. PV was greatly dependent on storage temperature (Dong and Jong, 1998).

The changes in the iodine value (IV) of PRBO and its blend stored in different packaging materials during storage are shown in Table 2 and 4. It was observed that IV decreased gradually during the storage and was lowest for the samples stored in glass bottles. Maximum IV was 143.82 units initially in PRBO with safflower oil blend, closer to 142.75 units in PRBO with sunflower oil blend which decreased to 109.09 and 110.76 units by the end of the storage period in PET bottles whereas IV decreased to 121.0 and 117.22 units in glass and 125.66 and 119.15 units in laminated films. Minimum IV 105.75 units was observed in PRBO initially which decreased to 83.17 for the sample stored in PET bottle, 89.84 for the sample stored in glass bottle and 90.04 for the sample stored in laminated films.

The IV of PRBO was lower as compared to the blends, which suggests that the oils selected for making the blends had more unsaturated fats and higher degree of unsaturation. Changes in IV of oil blends may be attributed to propagation of auto oxidation process where hydro peroxides are formed from free radicals in fatty

Table 5. Fatty acid profile for PET (polyethylene terephthalate) bottles.

Time month	Sample name	C14:0*	C16:0*	C18:0*	C18:1*	C18:2*	C18:3*
0	PRBO	0.19±0.005	18.15±0.03	3.35±0.01	40.90±0.03	35.46±0.01	0.97±0.02
0	PRBO+SNF	0.15±0.005	13.46±0.04	3.56±0.03	46.59±0.02	35.53±0.01	0.63±0.01
0	PRBO+SAF	0.17±0.005	14.28±0.04	4.28±0.02	28.48±0.01	51.88±0.03	0.78±0.02
1	PRBO	0.20±0.01	18.23±0.02	3.38±0.01	40.80±0.01	35.43±0.02	0.95±0.03
1	PRBO+SNF	0.17±0.005	13.50±0.03	3.59±0.02	46.43±0.02	35.51±0.01	0.61±0.01
1	PRBO+SAF	0.18±0.01	14.35±0.02	4.32±0.02	28.43±0.04	51.85±0.04	0.77±0.02
3	PRBO	0.19±0.01	18.38±0.01	3.42±0.02	40.73±0.01	35.41±0.01	0.91±0.04
3	PRBO+SNF	0.17±0.005	13.62±0.03	3.61±0.03	46.40±0.03	35.50±0.02	0.60±0.03
3	PRBO+SAF	0.18±0.01	14.39±0.03	4.35±0.03	28.37±0.03	51.83±0.02	0.75±0.04
5	PRBO	0.20±0.005	18.49±0.01	3.45±0.03	40.69±0.02	35.37±0.03	0.88±0.04
5	PRBO+SNF	0.19±0.005	13.65±0.01	3.65±0.02	46.38±0.04	35.45±0.01	0.55±0.03
5	PRBO+SAF	0.19±0.01	14.47±0.02	4.38±0.03	28.30±0.03	51.82±0.04	0.73±0.02
7	PRBO	0.22±0.005	18.54±0.03	3.47±0.02	40.65±0.02	35.33±0.01	0.86±0.01
7	PRBO+SNF	0.20±0.005	13.70±0.02	3.67±0.02	46.33±0.01	35.41±0.02	0.54±0.01
7	PRBO+SAF	0.19±0.01	14.51±0.03	4.39±0.04	28.27±0.01	51.80±0.03	0.70±0.03
9	PRBO	0.23±0.005	18.60±0.02	3.50±0.02	40.61±0.01	35.30±0.03	0.83±0.02
9	PRBO+SNF	0.22±0.01	13.73±0.04	3.70±0.03	46.30±0.02	35.37±0.01	0.52±0.02
9	PRBO+SAF	0.20±0.005	14.54±0.02	4.43±0.02	28.26±0.03	51.78±0.04	0.67±0.01
11	PRBO	0.23±0.005	18.66±0.03	3.56±0.02	40.57±0.01	35.26±0.01	0.80±0.02
11	PRBO+SNF	0.22±0.005	13.79±0.01	3.72±0.01	46.24±0.02	35.34±0.02	0.50±0.04
11	PRBO+SAF	0.21±0.01	14.60±0.03	4.47±0.01	28.20±0.04	51.71±0.02	0.64±0.04

* PRBO-physically refined rice bran oil, SNF- sunflower oil, SAF- safflower oil. PET- polyethylene terephthalate, C14:0- myristic acid, C16:0- palmitic acid, C18:0- stearic acid, C18:1- oleic acid, C18:2- linoliec acid, C18:3- linolenic acid. Values are expressed by Mean±SD, *Significant at 1% level.

acids generated in initiation stage or auto oxidation reaction. The results are in agreement with the various researchers (Semwal and Arya, 2001; Nasirullah et al., 1991).

The formation of secondary oxidation products in the PRBO and blends, packaged under different packaging materials during the storage was determined by p-anisidine value (PAV) and is shown in Tables 2 to 4. The initial PAV in PRBO and its blends with sunflower and safflower oil was 30.56, 29.02 and 20.79, respectively. The highest PAV was observed for the PRBO, stored in PET bottles 49.32 and lowest PAV, 34.87 units was observed in the PRBO sample with safflower oil stored in laminated film after 11 months storage. PAV for all the samples increased with storage period. Gulla et al. (2010) reported increase in PAV during storage of sesame and sesame and soybean blends. PAV in PRBO and its blend with sunflower oil and safflower oil were 49.32, 46.17 and 36.68 in PET bottles, 46.72, 44.56 & 34.87 in laminates and 48.73, 45.86 & 36.21 in glass bottles after 11 month of storage. Semwal and Arya. (2001) reported that PV, PAV and TBA increased during storage, these changes correlated linearly with storage period.

Effect of packaging materials on the fatty acids composition during storage

Tables 5 to 7 illustrate the behaviour of rice bran oil and its blends, based on the different fatty acids composition during storage conditions in different packaging materials. The chromatograms of PRBO and its blended oils with SnFO and SAF are given in Figures 1 to 3. High reactivity of unsaturated fatty acid is associated with oxidation (rancidity), loss of nutritional value and quality (Labuza, 1971). The gradual increase in saturated fatty acids was observed in PRBO and its blends during storage. Composition of myristic, palmitic and stearic acid in pure rice bran oil and sunflower oil has been reported to be 1.0 and 0.5%, 18 to 20 and 3 to 10%, and 2.5 to 3.5 and 1 to 10%, respectively (Orthoefer and Smith, 1996). Initially pure rice bran oil contained myristic, palmitic and stearic acid in the proportion of 0.19, 18.15 and 3.35, respectively and its blend with safflower and sunflower oil contained 0.17, 14.28 and 4.28 and 0.15, 13.46 and 3.56, respectively. The myristic, palmitic and stearic acids in PRBO were 0.23, 18.66 & 3.56 in PET bottles, 0.22, 18.63 & 3.42 in laminated film pouches and 0.41, 18.36 and 3.53 in glass bottles after 11 months of the storage of

Table 6. Fatty acid profile for laminated films.

Time month	Sample name	C14:0*	C16:0*	C18:0*	C18:1*	C18:2*	C18:3*
0	PRBO	0.19±0.005	18.15±0.01	3.35±0.03	40.90±0.01	35.46±0.01	0.97±0.02
0	PRBO+SNF	0.15±0.01	13.46±0.01	3.56±0.01	46.59±0.01	35.53±0.02	0.63±0.01
0	PRBO+SAF	0.17±0.005	14.28±0.02	4.28±0.04	28.48±0.04	51.88±0.01	0.78±0.03
1	PRBO	0.19±0.01	18.26±0.01	3.36±0.03	40.78±0.02	35.45±0.03	0.97±0.01
1	PRBO+SNF	0.15±0.01	13.49±0.04	3.56±0.02	46.46±0.01	35.52±0.01	0.62±0.01
1	PRBO+SAF	0.18±0.005	14.32±0.02	4.29±0.02	28.51±0.03	51.88±0.02	0.78±0.02
3	PRBO	0.19±0.005	18.40±0.01	3.38±0.01	40.76±0.02	35.43±0.02	0.96±0.02
3	PRBO+SNF	0.16±0.005	13.57±0.01	3.58±0.04	46.44±0.02	35.51±0.01	0.60±0.01
3	PRBO+SAF	0.18±0.01	14.34±0.03	4.31±0.04	28.50±0.01	51.86±0.04	0.77±0.04
5	PRBO	0.20±0.01	18.47±0.02	3.39±0.01	40.75±0.03	35.42±0.02	0.95±0.01
5	PRBO+SNF	0.16±0.005	13.60±0.03	3.59±0.03	46.43±0.01	35.49±0.04	0.57±0.02
5	PRBO+SAF	0.18±0.005	14.41±0.03	4.33±0.01	28.48±0.03	51.85±0.01	0.75±0.03
7	PRBO	0.21±0.01	18.51±0.01	3.40±0.01	40.71±0.03	35.40±0.02	0.93±0.01
7	PRBO+SNF	0.16±0.005	13.64±0.01	3.61±0.02	46.41±0.03	35.47±0.01	0.56±0.02
7	PRBO+SAF	0.19±0.01	14.46±0.04	4.33±0.02	28.45±0.01	51.82±0.01	0.72±0.03
9	PRBO	0.21±0.005	18.58±0.02	3.40±0.01	40.69±0.02	35.37±0.03	0.92±0.03
9	PRBO+SNF	0.18±0.005	13.66±0.02	3.61±0.04	46.38±0.01	35.44±0.02	0.56±0.02
9	PRBO+SAF	0.19±0.005	14.50±0.02	4.35±0.03	28.41±0.02	51.80±0.01	0.70±0.04
11	PRBO	0.22±0.005	18.63±0.03	3.42±0.03	40.68±0.02	35.35±0.04	0.90±0.01
11	PRBO+SNF	0.20±0.01	13.71±0.01	3.62±0.02	46.36±0.04	35.41±0.01	0.54±0.01
11	PRBO+SAF	0.19±0.005	14.54±0.04	4.36±0.01	28.40±0.03	51.79±0.03	0.70±0.02

* PRBO-physically refined rice bran oil, SNF- sunflower oil, SAF- safflower oil. Laminated films, C14:0- myristic acid, C16:0- palmitic acid, C18:0- stearic acid, C18:1- oleic acid, C18:2- linoliec acid, C18:3- linolenic acid. Values are expressed by Mean±SD, *Significant at 1% level.

the samples. The results showed hardly any difference in the fatty acids composition when packaged in the different packaging materials.

Initially, PRBO and its blends with sunflower and safflower oil had oleic, linoleic and linolenic acid in the proportion of 40.90, 35.46 and 0.97% and 46.59, 35.53 and 0.63% and 28.48, 51.88 and 0.78%, respectively. The initial compositions of oleic, linoleic and linolenic acid in pure rice bran and sunflower oil have been reported to be 40 to 42% and 14 to 65%, 32-35 and 20 to 75% and 1 to 1.5 and 0.7%, respectively (Orthoefer and Smith, 1996). The oleic, linoleic and linolenic acid in PRBO were 40.57, 35.26 and 0.80% in PET bottles, 40.68, 35.35 and 0.90% in laminate pouches and 40.62, 35.30 and 0.86% in glass bottles after 11 months of the storage of the samples.

The data showed that the amount of unsaturated fatty acids decreased gradually during storage at room temperature whereas the amount of saturated fatty acids increased in all the packaging materials. The fatty acid, mainly C18:0 in PRBO was increased 6.27% while the unsaturated fatty acid, mainly C18:3 was decreased, 17.52% when packaged in PET bottles. However, the increase in saturated fatty acids mainly C18:0 was 4.49 and 4.44% and decrease in C18:3 were 20.63 and 17.95% in sunflower and safflower oil blends, respectively when packaged under PET bottles. The increase and decrease spectrum of fatty acids was found randomly which may be due the random degradation and formation of fatty acids. The changes in C18:0 and C18:3 of PRBO were 2.09 and 7.22% when packaged under the laminates after the storage of 11 months while the changes were 5.37 and 11.34% when packaged under glass after the storage of 11 months. The changes in fatty acids may probably be due to the oxidative changes during storage. The results are in agreement with the findings of Murthy et al. (1996) and Nasirullah et al. (1982). These researchers reported increase in total saturated fatty acids and a decrease in total unsaturated fatty acids during storage of palm oil and groundnut oil. The changes in fatty acids were not significantly different with respect to the packaging materials. However, in most of the samples, the maximum changes in saturated and unsaturated fatty acids were observed in the samples when packaged under PET after the storage period of 11 months as compared to the glass and laminates. The changes in the quality of the oils were lesser when packaged under glass and laminates as compared to PET. Though, all the samples packaged under different packaging materials were acceptable in

Table 7. Fatty acid profile for glass bottles.

Time	Sample name	C14:0*	C16:0*	C18:0*	C18:1*	C18:2*	C18:3*
0	PRBO	0.19±0.01	18.15±0.01	3.35±0.01	40.90±0.02	35.46±0.03	0.97±0.01
0	PRBO+SNF	0.15±0.005	13.46±0.02	3.56±0.03	46.59±0.02	35.53±0.01	0.63±0.01
0	PRBO+SAF	0.17±0.01	14.28±0.01	4.28±0.02	28.48±0.01	51.88±0.01	0.78±0.01
1	PRBO	0.22±0.005	18.17±0.01	3.38±0.01	40.76±0.03	35.43±0.02	0.95±0.01
1	PRBO+SNF	0.17±0.005	13.49±0.02	3.58±0.01	46.43±0.01	35.51±0.01	0.62±0.03
1	PRBO+SAF	0.20±0.01	14.32±0.03	4.31±0.04	28.50±0.04	51.86±0.01	0.76±0.01
3	PRBO	0.25±0.005	18.20±0.01	3.40±0.01	40.72±0.01	35.42±0.02	0.92±0.02
3	PRBO+SNF	0.20±0.005	13.51±0.02	3.61±0.01	46.40±0.02	35.48±0.02	0.60±0.02
3	PRBO+SAF	0.32±0.005	14.35±0.04	4.34±0.02	28.47±0.01	51.82±0.03	0.73±0.01
5	PRBO	0.28±0.01	18.24±0.01	3.42±0.02	40.70±0.01	35.40±0.01	0.90±0.03
5	PRBO+SNF	0.24±0.01	13.54±0.01	3.64±0.01	46.38±0.03	35.43±0.01	0.58±0.03
5	PRBO+SAF	0.36±0.005	14.37±0.01	4.36±0.02	28.44±0.03	51.79±0.04	0.70±0.04
7	PRBO	0.31±0.01	18.29±0.03	3.46±0.01	40.69±0.01	35.37±0.04	0.89±0.01
7	PRBO+SNF	0.29±0.005	13.56±0.03	3.67±0.03	46.36±0.02	35.40±0.01	0.55±0.02
7	PRBO+SAF	0.38±0.01	14.40±0.01	4.39±0.03	28.41±0.01	51.75±0.02	0.68±0.02
9	PRBO	0.35±0.005	18.32±0.02	3.50±0.03	40.65±0.01	35.32±0.03	0.87±0.01
9	PRBO+SNF	0.35±0.005	13.58±0.03	3.70±0.01	46.33±0.04	35.34±0.04	0.52±0.03
9	PRBO+SAF	0.40±0.01	14.43±0.04	4.40±0.02	28.39±0.04	51.71±0.02	0.65±0.01
11	PRBO	0.41±0.01	18.36±0.01	3.53±0.04	40.62±0.01	35.30±0.01	0.86±0.02
11	PRBO+SNF	0.40±0.01	13.61±0.01	3.74±0.01	46.30±0.03	35.31±0.03	0.50±0.01
11	PRBO+SAF	0.40±0.005	14.47±0.02	4.43±0.04	28.40±0.02	51.68±0.01	0.62±0.02

* PRBO-physically refined rice bran oil, SNF- sunflower oil, SAF- safflower oil. Glass bottles, C14:0- myristic acid, C16:0- palmitic acid, C18:0- stearic acid, C18:1- oleic acid, C18:2- linoliec acid, C18:3- linolenic acid. Values are expressed by Mean±SD, *Significant at 1% level.

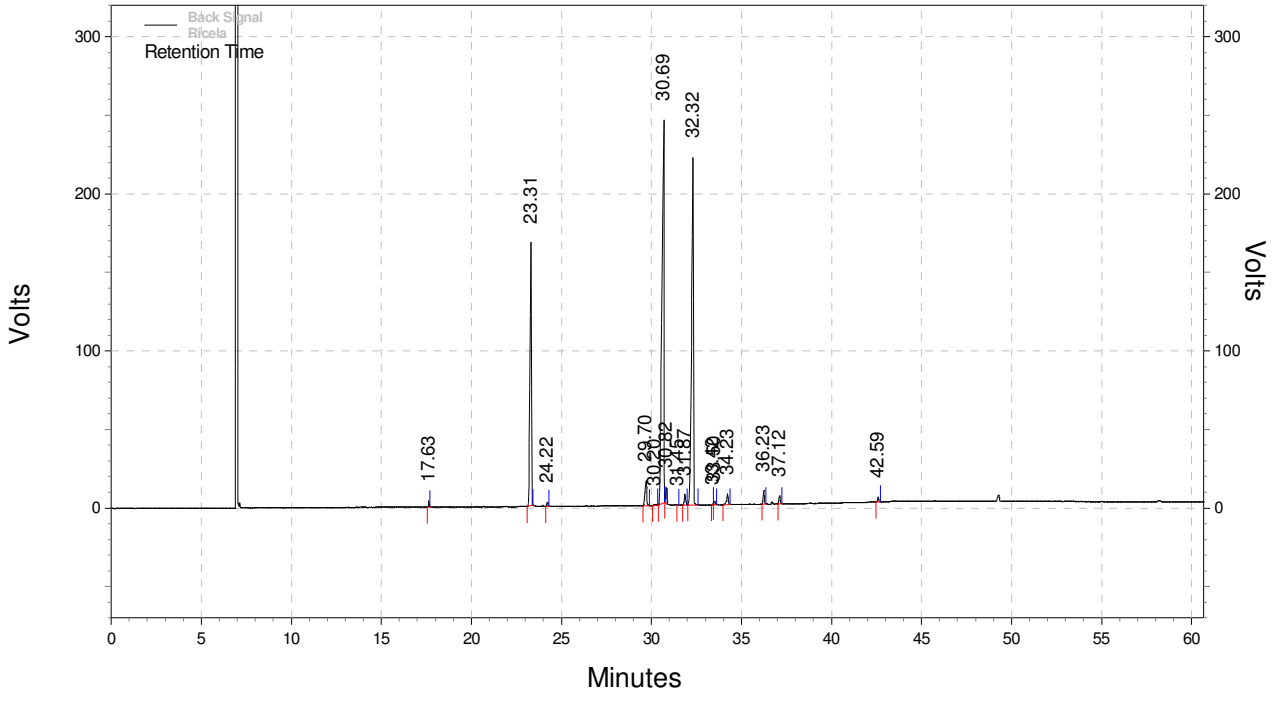

Figure 1. Fatty acid profile for pure rice bran oil.

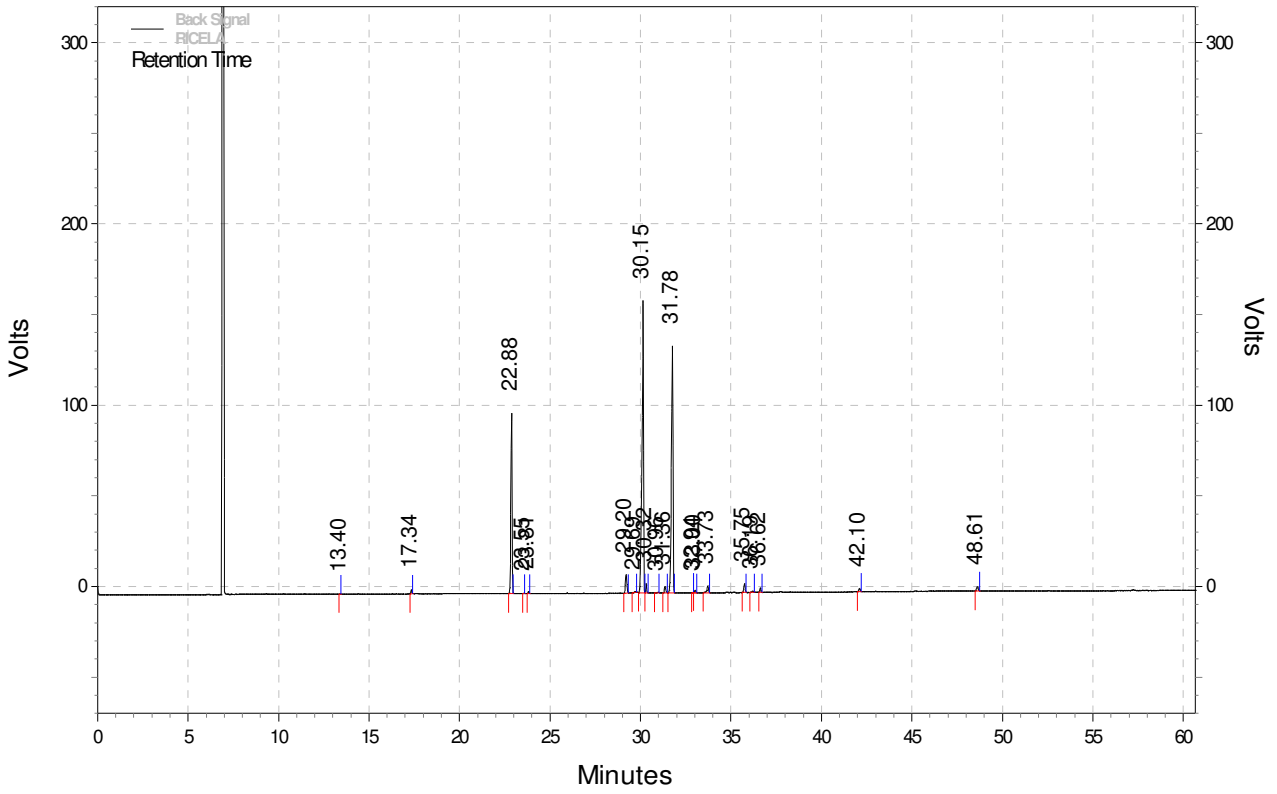

Figure 2. Fatty acid profile for blended oil (RBO:Safflower Oil- 80:20).

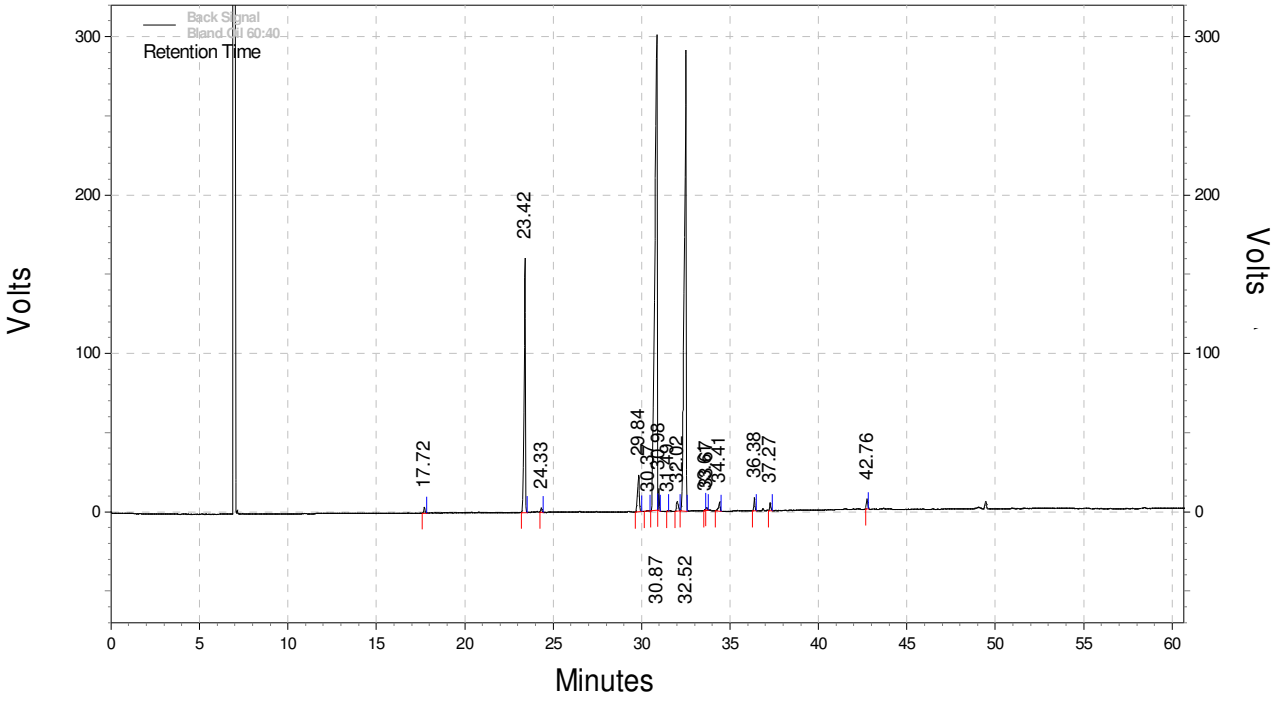

Figure 3. Fatty acid profile for blended oil (RBO:Sunflower Oil- 60:40).

terms of quality after 11 months. The best quality sunflower oil was found when packed in glass and then in PET (Kucuk and Caner, 2005). The study reported that glass offered the best protection against oxidation; PET materials also offered adequate protection especially in dark. The protection offered by the packaging materials may depend upon the physical characteristics of the packaging material (permeability and light transmittance) and hence can directly affect the quality of oil.

Conclusion

Increasing the storage time had an adverse effect on different physico-chemical parameters of all the samples. An increase in free fatty acids, colour, PV and PAV was observed in all samples, whereas the blended oil, consisting of PRBO and SAF (safflower oil) showed least changes after 11 months of storage as compared to the PRBO and blended oil (PRBO+SNF). All the samples were acceptable even after 11 months of storage as changes were within limits. The data observed for all the physico-chemical parameters concluded the superiority of laminate pouches over glass and PET bottles. Laminated pouches and glass bottles are most useful for long term storage as physio-chemical characteristics of all oil samples were not changed or minutely changed, thus making it most appropriate for storage in comparison to PET bottles. The results obtained showed that the amount of unsaturated fatty acids decreased gradually during storage at room temperature in all the packaging materials.

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