2. REVIEW OF LITERATURE

Rice bran oil (RBO) is popular in several countries such as Japan, India, Korea, China and Indonesia as a cooking oil. It has been shown that RBO is an excellent cooking and salad oil due to its high smoke point and delicate flavour. The nutritional qualities and health effects of rice bran oil are also established and is considered rich in unsaponifiable fraction (unsap), which contains the micronutrients like vitamin E complexes, gamma oryzanol, phytosterols, polyphenols and squalene.

Kato et al., (1981) studied the esterified tocopherols and tocotrienols in rice bran oil, soybean oil, and sesame oil were separated from free tocopherols and tocotrienols by TLC. After saponification of the esters, free tocopherols and tocotrienols were determined by HPLC. Refined rice bran oil contained 40 μg/g alpha-tocopherol, 3 μg/g beta-tocopherol, 3 μg/g gamma-tocopherol and 5 μg/g gamma-tocotrienol. Refined soybean oil contained 3 μg/g gamma-tocopherol and 3 μg/g delta-tocopherol. Tocopherol (7 μg/g) occurred as an esterified form in commercial sesame oil.

The fractions of neutral lipids of rice bran oil were studied by Shimasaki and Ueta, (1983). A centrifugal liquid chromatography was used to isolate neutral lipids of rice-bran oil and corresponding model compounds. Rapid, clear-cut separation of the neutral lipids was obtained. Oryzanol, a bioactive molecule reported as the key element responsible for that function is naturally present in crude rice bran oil and ranges from 1.1 to 2.6 % (Seetharamaiah et al., 1986).
Crick et al., (1988) studied the blended oils, which offer some advantages like nutritionally better status compared to individual oil constitutes. Fatty acids absorption of sunflower and canola oil blend at 7:3, 5:5 was found to be superior to that of unblended oil.

It has been shown that RBO is an excellent cooking and salad oil due to its nutritional qualities, health effects, high smoke point and delicate flavour. RBO is rich in unsaponifiable fraction (unsap 4.2%) which includes antioxidants and micronutrients, like vitamin E complexes, gamma oryzanol, phytosterols, polyphenols and squalene. Presence of antioxidants imparts a very good shelf life to RBO as compared to other cooking oils. Its low viscosity allows less oil to be absorbed during cooking, reducing overall calories (Chakrabarty, 1989).

Effect of moisture on rice bran oil expression was studied by Sivala et al., (1991). During oil expression, water is sprinkled as a pre-treatment to increase the moisture content for better extractability. The experiments were designed, based on response surface methodology, to determine the best treatment combinations of applied pressure, pressing time and moisture content for maximum oil recovery. Prediction equations were generated for oil recovery and found to be non-linear within the range of factors studied, namely 7-30 MPa applied pressure, 8-42 min pressing time and 8.3-11.7% (w.b.) moisture content.

A fat simulating butter was prepared from a fat base containing 70% partially hydrogenated rice bran oil and 30% refined rice bran oil; the margarine thus obtained had a smooth texture. Fat base comprising rice bran oil yielded good quality margarines/spreads, due to formation of stable 'beta' type crystals by partially hydrogenated rice bran oil (Joshi et al., 1993). Orthoefer, (1996) reported that the rice bran oil is a healthy lipid source. Reduction in serum cholesterol levels in hamsters fed diets containing rice bran oil (active constituent oryzanol) has also been noticed.
There are varieties of oils which are refined worldwide and some of the oils are being blended as per the current trends in globalization and demand of nutritional enrichment. Blended oils are gaining popularity worldwide due to advantages they offer such as improved thermal stability, oxidative stability, nutritional benefits (Sharma et al., 1996 b) and an ability to tailor the desired properties. Indian food regulations do not permit addition to vegetable oils of health-promoting components (e.g. oryzanol, tocotrienols and lignan antioxidants) in the form of concentrates and isolates.

RBO contains unique component oryzanol which is linked with increase in good cholesterol and lowering down of bad cholesterol and triglycerides and also possesses high levels of phytosterols, gamma-oryzanol, tocotrienols as well as tocopherols (Taylor et al., 1996). Numerous studies show that RBO reduces harmful cholesterol (LDL) without reducing the good cholesterol (HDL) (Sugano, 1997, Nicolosi et al., 1991, Sharma & Rukmini, 1987).

Various samples, including soybean oil, lard, rice bran oil, peanut oil and squid visceral oil, were quantitatively analysed for total and free fatty acids, and their relative compositions were determined using split less direct injection GC with a mega bore polar column (DB-wax, 30 m x 0.53 mm). The total fatty acids contents of these oils and fats were 567-766 mg/g. The contents of free fatty acids in the fats and oils were 6-178 mg/g as per the study of Wang et al., (1997).

Takahashi and Wasa, (1998) reported the excellence of rice bran oil as a glazing agent for food coating. A very workable glossy glazing preparation for confectionery, including chocolate, is made by dissolving a lipid in a film-forming component (e.g. zein or shellac) in ethanol and/or isopropanol, at predetermined proportions. The lipid fraction is a
liquid (at room temperature) fatty acid or fatty acid ester of polyglycerol, e.g. oleic acid, myristic acid, lauric acid and/or a mixed fatty acid derived from vegetable oil/fat.

A simple, cost-effective enrichment process for enhancing antioxidant content of rice bran oil (RBO) from crude RBO was reported by Cherukuri et al., (1999). The process includes alcohol extraction of crude RBO at 25-77°C, followed by purification of enriched RBO from the extracts. Enriched RBO contains 74-300% more antioxidants than crude RBO.

RBO does not produce any allergic reactions when ingested, unlike several vegetable oils (Crevel et al., 2000).

Gopala Krishna et al., (2001) studied the effect of different processing steps of refining on retention or the availability of oryzanol in refined oil and the oryzanol composition of Indian paddy cultivars and commercial products of the rice bran oil (RBO) industry. Degumming and dewaxing of crude RBO removed only 1.1 and 5.9% of oryzanol while the alkali treatment removed 93.0 to 94.6% of oryzanol from the original crude oil. Irrespective of the strength of alkali (12 to 20° Be studied), retention of oryzanol in the refined RBO was only 5.4–17.2% for crude oil, 5.9–15.0% for degummed oil, and 7.0 to 9.7% for degummed and dewaxed oil. The oryzanol content of oil extracted from the bran of 18 Indian paddy cultivars ranged from 1.63 to 2.72%. The oryzanol content ranged from 1.1 to 1.74% for physically refined RBO while for alkali-refined oil it was 0.19–0.20%. The oil subjected to physical refining (commercial sample) retained the original amount of oryzanol after refining (1.60 and 1.74%), whereas the chemically refined oil showed a considerably lower amount (0.19%). Thus, the oryzanol, which is lost during the chemical refining process, has been carried into the soapstock. The content of oryzanol of the commercial RBO, soapstock, acid oil, and deodorizer distillate were in the range: 1.7–2.1, 6.3–6.9, 3.3–7.4, and 0.79%, respectively. These results showed that the processing steps—viz., degumming (1.1%), dewaxing (5.9%), physical refining (0%), bleaching and deodorization of
the oil—did not affect the content of oryzanol appreciably, while 83–95% of it was lost during alkali refining. The oryzanol composition of crude oil and soapstock as determined by high-performance liquid chromatography indicated 24-methylene cycloartanyl ferulate (30–38%) and campesteryl ferulate (24.4–26.9%) as the major ferulates.

Prakash et al., (2001) studied the effects of blending on sensory odour profile and physico-chemical properties of selected vegetable oils. Three types of vegetable oils commonly consumed in India (groundnut, sunflower and mustard oils) were used as base oils and were blended with 20% sesame, rice bran or refined palm oil, and analysed for changes in sensory profile, colour and viscosity. With regard to the 3 base oils, mustard oil had a strong sulphury and pungent flavour note which did not decrease significantly in the blends, whereas the characteristic aroma of groundnut and sunflower oils decreased in intensity upon blending. Blends containing refined palm oil were positively correlated with a+ (redness) value, while sesame oil blends were positively correlated with b+ (yellowness) values; rice bran blends were greener in colour. Sensory colour perception values and CIE colour values for L*, a* and b* were negatively correlated for lightness (L*) and sensory redness, while a positive correlation existed between a* and sensory redness values. Apparent viscosity of the oil blends indicated a pseudo plastic shear thinning behaviour. Apparent viscosity of the base oil increased slightly with addition of sesame or rice bran oil, whereas it decreased upon blending with refined palm oil.

Rice bran, rice bran oil and honey were investigated as ingredients of biscuits. Effects on quality of biscuits were studied and an orthogonal experiment was designed to obtain the optimal formula. Amount of rice bran was the main factor affecting biscuit quality. Use of 5% rice bran, 5% rice bran oil and 10% honey produced good biscuits with even yellow colour, a fragrant flavour and fluffy texture studied by Chen et al., (2003). Sensory and physicochemical properties of 4 samples of rice bran oil (2 purchased in a supermarket and 2 in a pharmacy) were determined by Marco, (2003).
Rice bran oil is unique among edible oils due to its rich source of commercially and nutritionally important phytoceuticals such as oryzanol, lecithin, tocopherols and tocotrienols. However, most of these phytoceuticals are removed from the rice bran oil as waste by-products during the refining process. The γ- oryzanol is one of such component having the potential to be used in nutraceutical, pharmaceutical and cosmeceutical preparations. It is a mixture of ferulic acid esters of sterol and triterpene alcohols. It occurs in rice bran oil at a level of 1-2 % where it serves as natural antioxidant. Patel and Naik, (2004) describes the production of rice bran oil from rice bran and different methods of extraction of γ- oryzanol from rice bran oil and also reviews the health care properties of γ- oryzanol.

Danielski et al., (2005) studied that rice bran as a by-product of rice processing, obtained through the polishing of the rice grain. It presents considerable high oil content (between 20 and 25%) and it is considered an excellent source of nutritionally beneficial compounds, such as tocotrienols, tocopherols and sterols. Batch supercritical fluid extraction (SFE) of rice bran with CO₂ was performed at different operational conditions (from 100 to 400 bar, 50 and 60 °C) and the extract yields were in the range of 20%. The next step corresponded to the deacidification of the obtained oil in a countercurrent (CC) column, where the experiments were carried out at 250 bar and 67 °C. The results have shown that the free fatty acids (FFA) removal from the crude rice bran oil (RBO) was successfully achieved. Deacidified RBO with <1% FFA could be obtained by applying the described process. To conclude this work, an industrial process has been proposed which couples batch SFE of rice bran with CC-SFE of the extracted oil obtained, in order to isolate the undesired FFA fraction from the raffinatted oil, composed mainly by triglycerides (TG).

The compositions of rice bran oils (RBO) and three commercial vegetable oils were investigated by Gopala Krishna et al., (2006). For refined groundnut oil, refined sunflower
oil, and refined safflower oil, color values were 1.5–2.0 Lovibond units, unsaponifiable matter contents were 0.15–1.40%, tocopherol contents were 30–60 mg%, and FFA levels were 0.05–0.10%, whereas refined RBO samples showed higher values of 7.6–15.5 Lovibond units for color, 2.5–3.2% for unsaponifiable matter, 48–70 mg% for tocopherols content, and 0.14–0.55% for FFA levels. Of the four oils, only RBO contained oryzanol, ranging from 0.14 to 1.39%. High oryzanol RBO also showed higher FFA values compared with the other vegetable oils studied. The analyses of FA and glyceride compositions showed higher palmitic, oleic, and linoleic acid contents than reported values in some cases and higher partial glycerides content in RBO than the commonly used vegetable oils. Consequently, the TG level was 79.9–92% in RBO whereas it was >95% in the other oils studied. Thus, refined RBO showed higher FFA values, variable oryzanol contents, and higher partial acylglycerol contents than commercial vegetable oils having lower FFA values and higher TG levels. The higher oryzanol levels in RBO may contribute to the higher FFA values in this oil.

**Hoed et al., (2006)** investigated the effects of each individual step of the chemical refining process on major and minor components of rice bran oil. In comparison with common vegetable oils, rice bran oil contains a significantly higher level of several bioactive minor components such as γ-oryzanol, tocotrienols, and phytosterols. Alkali treatment or neutralization results in a significant loss of oryzanol. In addition, it gives rise to a change in the individual phytosterol composition. After bleaching, some isomers of 24-methylene cycloartenol were detected. Because of their relatively high volatility, phytosterols and tocotrienols are stripped from the rice bran oil during deodorization and concentrated in the deodorizer distillate. At the same time, oryzanol is not volatile enough to be stripped during deodorization; hence, the oryzanol concentration does not change after deodorization. Complete refining removed 99.5% of the FFA content. Depending on the applied deodorization conditions, trans FA can be formed, but the total trans content generally remains below 1%.
Oryzanol is an important value-added co-product of the rice and rice bran-refining processes. The beneficial effects of oryzanol on human health have generated global interest in developing facile methods for its separation from rice bran oil soap stock, a by-product of the chemical refining of rice bran oil. Isolation of oryzanol and the effect of impurities on its extraction and purification were discussed by Narayan et al., (2006). Engineering inputs required for solving problems such as saponification, increasing mass transfer area, and drying methods were emphasized. Based on an analysis of existing processes, those having potential to work in large-scale extraction processes were presented. Ghosh, (2007) reported detailed study of several RBO processing techniques with special emphasis on membrane-based techniques from the production and quality point of view.

Tahira et al., (2007) studied the characterization of rice bran oil, which was taken from the Pattoki Rice Mills, Jaranwala and was stabilized to inactivate lipase activity. The oil was extracted through solvent extraction. The extracted oil was subjected to refining process. Different physico-chemical parameters were characterized. The refractive index, peroxide value, iodine value, and free fatty acid value were recorded as 1.4792, 0.92 meq/kg, 105, and 0.07% (as oleic acid), respectively. The fatty acid profile showed palmitic acid (16.74%), stearic acid (1.9%), oleic acid (42.79%), linoleic acid (34.65%) and linolenic acid (0.19%) as major fatty acids.

According to the study of Chopra et al., (2009) lipase-catalyzed enrichment of rice bran oil with ω-3 fatty acid in order to obtain a structured lipid containing essential fatty acids has been optimized by response surface methodology. In this process, α-linolenic acid was used as an acyl donor using lipase-catalyzed acidolysis in hexane in presence of immobilized lipase from Rhizomucor miehei. The effect of incubation time and temperature, enzyme concentration and substrates mole ratio and their complex interaction on percentage
incorporation of \( \omega-3 \) fatty acid, ratios of saturated fatty acid to polyunsaturated fatty acids, monounsaturated fatty acids to polyunsaturated fatty acids and \( \omega-6 \) to \( \omega-3 \) (18:2 to 18:3) fatty acids have been studied using a central composite rotatable design of experiments. The results showed that at the optimum conditions such as reaction time 4.5 h and reaction temperature 37.5°C, substrate ratio ranging from 1.0 to 1.9, enzyme concentration varying from 1.0% to 2.0% are needed to fulfill the conditions such as percentage incorporation of \( \omega-3 \) fatty acid \( \leq 18\% \), ratio of saturated fatty acid to poly unsaturated fatty acid \( \geq 0.42 \), ratio of mono unsaturated fatty acid to poly unsaturated fatty acid \( \geq 0.8 \), and ratio of \( \omega-6 \) to \( \omega-3 \) \( \geq 1.30 \).

Zullaikah et al., (2009) studied the isolation of oryzanol from crude rice bran oil (RBO), which was achieved by a two-step crystallization process. In the first crystallization, oryzanol was concentrated in the liquid phase along with free fatty acid (FFA), monoacylglycerol (MG), squalene, tocols, and phytosterols, whereas the solid phase contained mainly triacylglycerol (TG) and steryl esters. Oryzanol-rich product obtained from the first crystallization was subjected to the second crystallization where the oryzanol-rich product was kept at room temperature (20.5 ± 1.5 °C) for 24 h. Hexane was added as anti-solvent to the oryzanol-rich product and kept at 5 ± 1 °C for another 48 h. Parameters that affect the isolation of oryzanol from crude RBO were systematically investigated. Under optimal operation conditions, oryzanol with purity and recovery of 93-95% and 59%, respectively, was obtained from RBO with an initial FFA content of approximately 5%.

Rahman and Adeyanju, (2010) studied the effects of roasting temperature and duration on yield and quality (free fatty acid, peroxide value, color) of oil extracted from ofada rice bran studied using response surface methodology. Roasting temperature and duration were 160, 170, 180, 190, and 200 °C and 5, 10, 15, 25, and 35 min respectively. Data were analyzed by ANOVA and regression analysis. The oil yield ranged between 11.31% and 14.4%, free fatty acid (7.10–12.75%), peroxide values (8.25–13.25 meq/kg) and
The treatments have significant effects on oil yield, free fatty acid, peroxide values, and color (P<0.05). Coefficient of determination, R² of oil yield, free fatty acid, color, and peroxide value models were 0.79, 0.91, 0.99, and 0.99 respectively. Optimum temperature and duration of roasting were 190 °C and 10.75 min, respectively. This combination gave 14.45% oil yield, 5.80% free fatty acid, 8.25 meq/kg peroxide values and 1.51 abs oil color. Desirability of optimization was 0.99.

As per the study of Sereewatthanawut et al., (2010) crude rice bran is a natural source of γ-oryzanol, a nutritionally valuable phytochemical with antioxidant properties. In the present paper the refining and γ-oryzanol enrichment of rice bran oil was investigated through solvent extraction optimization and nanofiltration processing. Several solvent resistant nanofiltration membranes were screened and successfully applied in a two step membrane cascade with fluxes between 39 and 53 L m⁻² h⁻¹. A first membrane stage operation provided the separation between glycerides and γ-oryzanol, promoting the oil enrichment in this phytochemical. In the second membrane stage, the oil could be refined to acceptable consumption levels (FFA < 0.20 wt.%) and its γ-oryzanol content was further enhanced. Overall, the integrated process provided a RBO γ-oryzanol enrichment from 0.95 to 4.1 wt% in oil, which corresponded to more than a two fold increase in the oil’s antioxidant capacity. These results demonstrate the potential of organic solvent nanofiltration as a technology to enrich and refine oil based products.

According to Jesus et al., (2010), the residue of fatty acids distillation from rice bran oil soapstock (RFAD-RBOS) is a byproduct from rice bran oil industry. It contains a large amount of γ-oryzanol, which is a valuable antioxidant. The main objective of this work was to investigate the recovery of γ-oryzanol from the RFAD-RBOS using supercritical fluid extraction (SFE). The Soxhlet technique was conducted in order to compare results with SFE. The influence of process parameters over SFE was evaluated in terms of global yield, γ-oryzanol content, γ-oryzanol recovery rate, and fatty acids composition. The mathematical
modeling of SFE overall extraction curve (OEC) was also investigated. The condition of 30 MPa/303 K presented the maximum global yield (39 ± 1%, w/w), maximum γ-oryzanol recovery rate (31.3%, w/w), relatively high γ-oryzanol content (3.2%, w/w), and significant presence of monounsaturated and polyunsaturated fatty acids. The logistic model presented the best fit to experimental OEC.

Noor et al., (2011) developed a eco-friendly technology for producing high quality edible oil. Development of health and environmental issues specifically related to the use of chemical ingredients in foods both in producing processes and as a preservative agent has encouraged the emergence of non-chemically processed products on the market. This condition is predicted to continue increasing with high market response. Enzymatic and ultrasound assisted/pre-treatment in aqueous, cold pressing and supercritical fluid extraction will be highlighted, as well as adsorptive refining and other processes as an alternative for purification technology.
2.1. Degumming of rice bran oil

Degumming is the simplest method for removing phospholipids (lecithin) from vegetable oils. However, only hydratable phospholipids can be removed during water degumming leaving 80 to 200 ppm of phosphorus in the oil, depending upon the type and the quality of the crude oil due to the presence of non-hydratable phospholipids (Andersen, 1962).

Crude oils of vegetable origin contain impurities of varying types. These impurities are affected by storage and handling as well as extraction processes. In comparison to other vegetable oils, crude RBO tends to contain higher levels of non-TAGs, most of which are to be removed during refining processes. The FFA, MAG and DAG in RBO are associated with enzymatic hydrolysis. The phospholipids are predominantly hydratable phosphatidylcholine (PC), phosphatidyl-inositol (PI) and non-hydratable phospholipids that are calcium and magnesium salts of phosphatidic acid (PA) and phosphatidylethanolamine (PE) (Hvolby, 1971).

Hydratable phospholipids can be removed in most part by water-degumming process. Non-hydratable phospholipids can be removed only during acid degumming or enzymatic degumming processes. Technically, degumming is referred as an operation of purification of seed oils, which normally contain impurities in the colloidal state or dissolved in them (Bernardini, 1985).

To evaluate the process of refining for edible purpose, Munshi et al., (1990) studied physico-chemical characteristics of raw, industrially refined and laboratory refined rice bran oil, along with the effect of different degumming agents [phosphoric acid (0.04% for dry degumming, 0.05% for wet degumming with 7% water), citric acid (0.5% with 5% water), and oxalic acid (0.5% with 5% water)] on various chemical parameters of oil. Laboratory refined rice bran oil showed lower hydroxyl, acetyl and peroxide values and higher
saponification and iodine values than industrial refined and unrefined oils. Citric acid was most effective in facilitating degumming and dewaxing. Decreases in hydroxyl and acetyl values were significant ($P < 0.05$) with phosphoric, citric and oxalic acids by wet degumming in comparison to phosphoric acid by dry degumming. Peroxide value also decreased with citric acid and phosphoric acid as degumming agents. Free fatty acid contents decreased significantly during neutralization and most of the phospholipids were removed at the stage of degumming. Refined oil contained lower amounts of phosphatidyl ethanolamine and phosphatidic acid.

A comparative nutritive study was made by Sarkar and Bhattacharyya, (1991) to show that the extent of purification markedly influences the nutritive characteristics of rice bran oil. The coefficient of digestibility was found 93.8% when rice bran oil purified by degumming, deacidifying, bleaching and deodorizing. Whereas it was found 94.8% for RBO, when an additional dewaxing step, was used. Rice bran oil without deodorization, but purified by other treatments, showed a 96.2% coefficient of digestibility, this is somewhat lower than that of groundnut oil. However, after a feeding experiment over 3 months, the highly purified rice bran oil showed better results than the other 2 purified samples of rice bran oil, and was sometimes better than groundnut oil in terms of total lipid, triglyceride and especially in cholesterol content in serum, liver and heart tissues.

Acetone insolubles from rice bran oil (a lecithin preparation) may be affected by the choice of solvents used in their production. Six reagents (water, citric acid, phosphoric acid, oxalic acid, acetic anhydride and maleic anhydride) were evaluated by Lee et al., (1991) for their effectiveness in degumming rice bran oil. All chemical reagents tested were found to be significantly more effective than water in removing phosphatides from crude rice bran oil. Acetic anhydride and phosphoric acid were especially effective in reducing phosphorous levels (92.5 and 93.3% removal, resp.). Nonhydratable phospholipids and lysophosphatidyl choline, were removed more effectively by the chemical reagents than by water degumming.
The major phospholipid (PL) component was phosphatidyl choline. Oleic, linoleic and palmitic acids were the major fatty acids of PL in rice bran acetone insolubles (AI). The AI recovered by acetic anhydride degumming produced the most stable emulsions. The AI obtained from phosphoric acid or oxalic acid treatments had very poor emulsifying properties.

Crude rice bran oil has a high acid value. Physical or steam refining is a process used for high acid value oils which reduces loss of neutral oil, minimizes pollution from soap water and enables recovery of high quality fatty acids. Rice was pre-treated by winterization, degumming and bleaching. The oil was then subjected to physical refining using a high temperature and high vacuum steam distillation process; this reduced the free fatty acid content and removed unpleasant flavours. Details of the various treatments are given by Wong et al., (1992).

Physical refining of rice bran oil (RBO) with acidity between 4.0 and 12.4% has been investigated by De and Bhattacharyya, (1998) in relation to degumming and dewaxing pretreatments. It appears that physical refining after combined low-temperature (10°C) degumming-dewaxing produces good-quality RBO with respect to color, free fatty acid, oryzanol, and tocopherol content.

The effects of enzyme pre-treatment and ordinary cooking pre-treatment on yield and quality of oil extracted from rice bran were investigated. Yield of extracted oil was higher after enzyme pre-treatment than after ordinary cooking pre-treatment. In addition, total sterol and oryzanol contents were also higher following enzyme pre-treatment. Takahashi et al., (1999) suggested that enzyme pre-treatment altered the rice bran so that unsaponifiable matter was extracted more easily.

Indira et al., (2000) studied commercially extracted crude rice bran oil (1.8% phospholipids) degumming under a range of experimental conditions of water concentration,
temperature, time and speed of agitation. Efficiency of degumming was evaluated based on the yield of dry gums, phospholipids and acetone insoluble’s in the gum. An orthogonal experimental design, with four variables (at five levels each) and three response functions, was employed to study the effect of the individual variables on the response functions. The response functions correlated with these variables ($r \geq 0.925$, $P \leq 0.01$) by second order polynomials consisting of linear, quadratic and interaction terms. The effect of water added and temperature dominated over the other two variables. The optimum level of these variables for obtaining maximum magnitude of the response functions is reported.

A standardized degumming method for both RBO and soybean oil was developed by Nasirullah and Ramanatham (2000), which involved addition of 2% water to the oil and heating at 75°C for 30 min. Gum yields using this method were in the range 2.5-3 and 1-2% for soybean and rice bran oils, respectively, phospholipid content of degummed oils fell to within the range 0.12-0.25%. These values compared very well with those obtained by phosphoric acid treatment. Up to 80% removal of non-hydratable gums was also achieved, using 1% aqueous solution of potassium chloride. Three bleaching earths were selected for bleaching studies. De-sludged and degummed rice bran oil was mixed with 5% of bleaching earth, heated at 95°C (60 mm pressure on Hg) for 30 min and centrifuged to recover oil. The colour index decreased from 45 to 10 units, indicating the efficacy of the bleaching system. Deacidification of rice bran oil was also carried out using a set of adsorbents. The oils were mixed with 5% of absorbent, heated at 90°C (6 mm pressure on Hg) for 30 min. This treatment was capable of reducing free fatty acid content in oils from 8 to 5.5%. Kieselguhr G was found to be highly effective compared with other adsorbents studied. It was found that the major advantage of using water instead of phosphoric acid in degumming was the elimination of a washing step and reduced oil loss; the adsorbent entrapment technique eliminated use of alkali.
Clausen (2001) reported that phospholipase-A mediated oil degumming is an established stage in the physical refining of vegetable oils. A screening programme of type A microbial phospholipases was undertaken to develop a stable and robust phospholipase with optimal oil-degumming at pH 4-5 and at 30-70°C. A novel phospholipase A1 from Fusarium oxysporum (Lecitase(R) Novo) was selected and characterized in detail. On application of the lipase to the degumming of rapeseed oil, Lecitase Novo demonstrated optimal degumming performance at pH 5 and 40-45°C. In addition, the lipase was superior to porcine pancreatic Lecitase 10L and other phospholipases and was suited to degumming a range of oil qualities from water degummed to crude oil. The new lipase acts at a very low water content thus eliminating the need for the problematic sludge recycling which is usually characteristic of the phospholipase-mediated degumming process.

Pagliero et al., (2001) studied the ability of two ultrafiltration polymeric membranes to perform the degumming of a crude soybean oil/hexane mixture. The performance of both membranes is defined in terms of their permeation flux; permeate colour, and rejection of phospholipids. One of the membranes was synthesized in laboratories from polyvinylidenefluoride (PVDF); the other one was a commercially available membrane made of polyimide. The degumming experiments were done in a stirred dead-end ultrafiltration cell pressurized with N₂. Results showed that tested membranes are suitable for removing phospholipids from the crude oil/hexane miscella in the range of temperature and trans-membrane pressure utilized in this work. Both membranes have high selectivity regarding phospholipids and produce a moderate reduction in permeate colour. The PVDF membrane gives permeate fluxes up to threefold larger than those obtained with polyimide membrane at the same operational conditions, making the former more suitable for use at industrial scale.
Crude oil extracted from oil seeds and is generally refined to remove impurities that can impact the oil’s stability, colour, and flavour. Gums in vegetable oils need to be removed to ensure a stable and good oil quality. Phospholipids are natural components of oil and oilseeds. They are not desirable because they settle out of the oil during shipping and storage. Phospholipids have adverse effects on the colour and flavour of oil. The presence of phospholipids creates problems during oil processing and some food applications, i.e. frying. Phospholipids should be removed because of their strong emulsifying action and if they are not removed, the oil will go through undue darkening during deodorization at high temperature (Kim et al., 2002).

Roy et al., (2002) discussed the use of enzyme degumming in physical refining of rice bran oil with the aim of increasing production of this nutritionally valuable product. Degumming removes P-containing components which cause colour problems with the oil. Treatment with water or other degumming agents removes some, but not all, of the phospholipids from the oil. Use of porcine pancreatic phospholipase A2 (the Enzymax process, Lurgi AG, Frankfurt, Germany) and other phospholipases has been reported for degumming of some vegetable oils other than rice bran oil. Enzyme degumming of rice bran oil was investigated using fungal phospholipase A1 (Lecitase Novo, Novozymes A/S, Denmark). Crude rice bran oil was incubated with phospholipase A1 for 2 h, or alternatively for 4 h followed by bleaching. Phospholipase treatment of water-degummed rice bran oil was also studied. Enzyme degumming caused a slight increase in free fatty acid content of the oil. P levels in crude and water-degummed oils (403 and 60 ppm, respectively) were decreased to 15-18 ppm by enzymatic treatment; bleaching caused a further decrease to <5 ppm. It is concluded that degumming with phospholipase A1 followed by bleaching is a suitable method for P removal from rice bran oil prior to physical refining.
A simple and economical process for the pretreatment of vegetable oils prior to physical refining is described by (Chakrabarti & Rao, 2004). It involves: enzymic degumming with commercially-available phospholipase A1 from sources such as Aspergillus oryzae; bleaching of the enzymically-degummed oil using bleaching earth and activated C; and dewaxing (in the case of rice bran oil) of degummed and bleached oil at lower temperature, to obtain oil with <5 ppm residual P, which is amenable for physical refining.

Muench, (2005) discussed enzymic degumming of vegetable oils. Aspects considered include: the purpose of oil degumming; enzymic activity of phospholipases and enzymic degumming using Lecitase Ultra (Novozymes); the enzymic degumming process for rapeseed and soybean oils in an industrial-scale plant with a capacity of 450 tonnes/day; and a novel industrial process for degumming and pre-dewaxing of sunflower oil.

The simultaneous degumming and dewaxing of the crude oil with a solution of water and CaCl₂, followed by crystallization at a low temperature (20°C), facilitated precipitation of the hydratable and nonhydratable phosphatides along with the wax, which enabled its separation and reduction to a greater extent. Bleaching and subsequent winterization (20°C) of this oil further reduced the phosphorus content to less than 5 ppm. Thus, these pretreatment steps enabled the physically refined rice bran oil to meet commercially acceptable levels for colour, FFA content, and cloud point values (10–12 Lovibond units in a 1-in. cell, <0.25%, and 4–5°C, respectively) with very low neutral oil loss (Rajam et al., 2005).

A method for degumming vegetable oils and reducing fouling of processing equipment was described by Dayton et al., (2007). An anti-fouling agent including an organic or mineral acid was added to vegetable oils between the reactor and post-reactor equipment such as heat exchangers. The anti-fouling agent was added at a concentration of >100 ppm, and the pH of the oil was between 3.5 and 4.2.
Response surface methodology was used to determine the optimum processing conditions for enzymatic degumming of rice bran oil. Reaction time, enzyme dosage, level of water added and temperature were the factors investigated with respect to phosphorus and free fatty acids contents. Applying desirability function method, optimum operating conditions were found to be reaction time of 4.07 h, enzyme dosage of 50 mg/kg, added water of 1.5 ml/100 g and temperature of 49.2°C. At this optimum point, phosphorous and free fatty acids contents of degummed oil were found to be 8.86 mg/kg and 2.01 g/100 g as oleic acid, respectively (Jahani et al., 2008).

Yang et al., (2008) studied insight into the enzymatic degumming process of soybean oil. An enzymic degumming trial of soybean oil was carried out at a capacity of 400 tons/day by applying microbial phospholipase A1 from Thermomyces lanuginosus/Fusarium oxysporum. When pH was maintained in the range 4.8-5.1, <10 mg/kg of the P content of the oil was obtained. The gum and oil were easily separated after centrifugation, and oil loss was minimal under the process conditions. Analysis of phospholipid compounds in the gum by electrospray ionization MS and determination of P content revealed that both glycerophospholipids and lysophospholipids were present at concentration of 45.7 and 54.3%, respectively. The effectiveness of enzymic degumming was found to be related to the production of glycerophospholipids.
2.2. Storage Stability of rice bran oil and its blends

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). 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).

Health aspects of rice bran oil are described together with its properties in extending the shelf-life of fried snacks such as potato, corn and tortilla chips. High grade rice bran oil contains high levels of phytosterol, tocopherols and gamma-oryzanol. These naturally occurring components impart a high resistance to thermal oxidation and deterioration. Rice bran oil's with high oxidative stability makes it preferred oil for frying and baking applications as per the study of Anonymous, (1991).

Nasirullah et al., (1991) prepared edible oil blends by mixing groundnut oil with rice bran oil (GR) and mustard oil with rice bran oil (MR) in the proportions 10:90, 30:70 and 40:60 (v/v) and stored in coloured glass bottles at room temperature for 3 year, for determining the physical and chemical characteristics at regular intervals. In the GR blend, the iodine value decreased from 95 to 92.9, and saponification value from 189 to 187.9; increases were noted in butyro refractometer reading from 56.8 to 59.3, free fatty acid % from 0.6 to 2.1, peroxide value from 0.4 to 54.8 and Kries colour value from 2 to 40. In the MR blend, the changes in these values were: iodine value 99.7 to 94.6; saponification value 182.7 to 181.6; butyrorefractometer reading 58.5 to 60.5; free fatty acid % 0.46 to 1.3; peroxide value 1.0 to 9.5; and Kries colour value 2 to 15. Silver nitrate precipitation and
dinitrophenylhydrazine colour increased with storage time. The MR blend was stable up to 2 year, but strong rancidity developed in the GR blend in 9 months. The cloud point and Bellier turbidity temperature tests gave inconclusive results.

The storage studies have shown a small but steady rise in peroxide value, free fatty acids and fall in iodine value and decrease in colour in pure groundnut oil and pure cottonseed oil. The similar trend was observed in case of oil blends. The shelf life of 50:50 blend of cottonseed oil: groundnut oil was comparable to pure groundnut oil. The oil blends were thermally stable than pure cottonseed oil. The ratio of oleic to linoleic acid increased as the percentage of groundnut oil in the oil blends increased. This also depicts greater resistance of oil blends towards onto oxidation as compared to pure cottonseed oil. Frying experiments with all the oils were also conducted by Handoo et al., (1992) regularly at one month intervals and the fried products were evaluated organoleptically by taste panelists. At room temperature, refined sunflower oil remains stable in high-density polyethylene (HDPE) bottles and sealed tin for two years (Semwal and Arya, 1992).

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.

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). Current trends in globalization and nutritional enrichment have led to increased interest in the use of blended oils. Blended oils are gaining popularity worldwide due to advantages they offer such as improved thermal stability, oxidative stability, nutritional benefits (Sharma et al., 1996a) and an ability to tailor the desired properties.
High content of natural antioxidants present in rice bran oil, impart higher oxidative stability and a longer shelf life as compared to other edible oils. The oxidative stability of natural antioxidant enriched RBO has been found to be five times more than the groundnut oil. Rice bran oil (RBO) extends the shelf life of snack foods. The oil contains high levels of phytosterols, gamma-oryzanol, tocotrienols as well as tocopherols (Taylor et al., 1996).

Dong and Jong, (1998) evaluated the oxidative stabilities of rice germ oil, dried rice germ oil, and crude and refined rice bran oils, by measuring acid value, peroxide value (POV) and fatty acid composition during 0-31 days of storage at 40 and 60°C. Acid values of all lipids were slightly altered during storage, while POV were greatly dependent on storage temperature. POV of the dried rice germ oil and the refined rice bran oil were 146.2 and 15.1 meq/kg oil, respectively, after 31 days of storage at 40°C; however, after 24 days of storage at 60°C, POV of the dried germ oil and the refined rice bran oil were 151.7 and 219.6 meq/kg oil, respectively. Major fatty acids of rice germ oil were linoleic (39.8%) and oleic acids (34.7%) while oleic (40.1%) and linoleic acids (38.1%) were predominant in rice bran oil. Major fatty acid compositions were not greatly influenced by drying and storage temperature, although linolenic acid decreased by approx. half during storage.

Thermal and storage stabilities of refined cottonseed oil- mustard seed oil blends (80:20) were investigated by Premavalli et al., (1998). The blends were packaged in cans and stored under ambient condition for up to 15 months. Storage changes in the blends were followed by measuring peroxide and carbonyl formation. To test thermal stability, blended oils were heated to 190°C, and poories were fried in the heated oil continuously for 6 hr at a rate of 75-80 poories/h. The frying experiments were continued for up to 18 hr at the rate of 6 hr/day; fresh blended oil was added daily to the fried oil before poori frying commenced and oil was sampled every three hour for analysis. Mustard seed oil only was used in the frying experiments as a control. Storage result showed that the oil blends remained stable for up to
12 months under ambient conditions. Thermal stability results showed that the oil blends remained in good condition for up to 12 hr of frying. Overall thermal stability of the oil blends was lower than that of the mustard seed oil.

The quality of palm oil, in different film packaging material indicate, that the quality deterioration of palm oil was more pronounced when stored under 30-40% relative humidity and 45°C (Narasimhan et al., 2001). Storage stability of 2 edible oil blends (refined rice bran oil: unrefined groundnut oil and refined soybean oil: unrefined groundnut oil; 80:20 proportion for both blends) in sealed tin containers at room temperature (15-34°C) was studied by Semwal and Arya, (2001). Both oil blends remained stable for 15 months without development of perceptible off-flavour or odour. Peroxide, TBA, total carbonyls and anisidine values increased during storage; these changes correlated linearly with storage period. Increase in free fatty acids content during storage was more pronounced in unrefined oils than in refined oils. In general, the oil blends showed good stability. However, pooris fried in the blend containing soybean oil showed lower sensory scores than those fried in the blend containing rice bran oil.

Sundararaj et al., (2002) reported an increase in color, refractive index, free fatty acid peroxide value, anisidine value, totox value and decrease in iodine value after 3, 6, 9 months of storage of rice bran oil at 7°C and 38°C in transparent PET bottles. Fatty acid composition of oil was not affected by storage conditions, while α-tocopherol had been totally destroyed after storage for 9 months, minimal decreases were observed in γ-Oryzanol content. The frying stability of rice bran oil was assessed by measuring the oxidative deterioration undergone by the oil and was compared with groundnut oil (GNO). There was an increase in color, %free fatty acid, peroxide value, anisidine value and totox value of both oils following deep fat frying procedure. Rice bran oil showed less oxidative deterioration as compared to groundnut oil.
Rice bran oil (RBO) was applied into baked products such as cookies at various levels i.e. 0, 25, 50, 75 and 100% by gradually replacing normal shortening to check its effectiveness in extending the shelf life of product due to its natural antioxidants by using thiobarbituric acid number (TBA number) test with the help of spectrophotometer. Five treatments of RBO and normal shortening (NS) (T1=100 NS+0% RBO, T2=75% NS+25% RBO, T3=50% NS+50% RBO, T4=25% NS+75% RBO, and T5=0% NS+100% RBO) were used to prepare cookies and 45 days storage study was conducted. TBA number was calculated after each storage interval. There was an increase in TBA number during storage of 45 days. Treatment T5 (100% RBO) showed the minimum increase (0.05) followed by T4 (0.06) and T3 (0.08). It was evident from the results that by increasing the percentage of rice bran oil (RBO), the TBA number decreases and the onset of rancidity are delayed according to the study of Sharif et al., (2003).

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). Indian food regulations do not permit addition to vegetable oils of health-promoting components (e.g. oryzanol, tocotrienols and lignan antioxidants) in the form of concentrates and isolates. However, vegetable oils containing such components can be blended with those that do not.

Shiela et al., (2004) investigated the storage stability of blends of groundnut oil, sunflower oil and mustard seed oil with plam olein, rice bran oil and sesame oil. Physicochemical properties and levels of minor and potentially health-promoting components of the blended oils packaged in pouches were studied during storage for 6 months at 27°C and 65% RH (relative humidity) or 40°C and 30-40% RH. Colour, peroxide value (PV; 0.6-20.7 meq O₂/kg), and contents of free fatty acids (0.08-2.1%), tocopherol (360-1700 ppm), oryzanol (460-2000 mg%) and sesame antioxidants (400-2000 mg%) did not change in either unblended or blended oils. Oils and oil blends containing a higher initial
PV (18.9-20.7 meq O₂/kg) showed a slight reduction in PV at 40°C, whereas oils having lower PV (5-10 meq O₂/kg) showed slight increase during storage. The β-carotene contents decreased by 8.9-60.2% at 27°C and 48-71% at 40°C. Results suggest that the packaged oil blends tested were stable under the conditions used.

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). Extra-virgin olive oil has 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).

Blends of sunflower oil (SFO) and rice bran oil (RBO) were evaluated by Mezouari and Eichner (2007) for their stability. Additionally, known amounts of natural antioxidants extracted from RBO were added to SFO, and their protective effect was compared to that of the blends.
2.3. Quantification of rice bran oil

A simple TLC method was reported to detect the presence of watermelon seed oil in groundnut and sesame oils. Datta, (1981) has detected some admixtures such as rapeseed in mustard oil by using critical solution temperature. Seetharamaiah and Prabhakar, (1986) also detected the rice bran oil content in other edible vegetable oils by isolation of oryzanol in rice through TLC.

The percentage of erucic, eicosenoic and linolenic acids can be used to detect semi-quantitatively the proportion of Indian rape-mustard oil present in rice bran oil. Fatty acid compositions of 22 samples of Indian rape-mustard oil extracted from different seed variety and of market samples were studied. At 10% level of rape-mustard oil admixture or adulteration of rice bran oil, contents would be 5.0% for erucic acid (22:1), 0.7% for eicosenoic acid (20:1) and 1.7% for linolenic acid (18:3). At 20% admixture or adulteration, corresponding values would be 10.0, 1.4 and 2.7%, respectively according to the study of Adhikari and Adhikari (1991).

Techniques for detection of specific vegetable oils in mixtures were described by Adhikari and Adhikari (1992). Palmolein adulteration of groundnut oil was detected using silver nitrate TLC, ambadi oil (Hibiscus cannabinus) was detected in other vegetable oils using colorimetry and spectrophotometry, and mustard oil was detected in rice bran oil-mustard oil blends using spectrophotometry. All methods were considered suitable for routine application.

Nasirullah et al., (1992) described the method for detection of rice bran oil, mustard oil and karanja oil in other vegetable oils and detection of rice bran cake in other oilseed cakes. Rice bran oil is detected by TLC analysis for oryzanol. Mustard oil is detected by a
colorimetric test for isothiocyanates. Karanja oil is detected by TLC analysis for karanjin, karanjone, pongaglabrone and pongamol. Rice bran cake may be detected by IR spectrometric analysis for acyl sterol glycosides, or TLC analysis for oryzanol.

To understand the chemical nature of the dark colouring constituents responsible for colour fixation in rice bran oil, crude and dewaxed rice bran oils of 6.8% free fatty acids were fractionated on a silica gel column, producing a dark-coloured material (0.57% of the oil). TLC analysis of the material showed a spot corresponding to monoglycerides; no spots corresponding to other glycerides. The extract contained traces of phosphorus (<0.1 p.p.m., which is equivalent to 2.5 p.p.m. phospholipids) and iron (1.3 p.p.m.) that could not be attributed to phospholipids or to any iron-complex. Upon saponification it yielded 12% nonsaponifiable matter. GLC analysis of saponifiable matter (after acidification and methylation of fatty acids) showed the presence of palmitic, oleic and linoleic acids. Comparison with spectroscopic data of synthetic monoglycerides showed the constituent to be a mixture of monoglycerides with side chains of oxidized unsaturated fatty acids (Gopala-Krishna, 1993).

Krishnamurthy (1993) updated the methods for detection of adulterants and contaminants in edible oils and fats. Current methods for detection of adulteration and contamination in edible oils and fats are reviewed, with respect to their mechanisms, sensitivities and limitations. Aspects considered include: sampling; moisture and impurity; detection of groundnut oil; detection of sesame oil; detection of cottonseed oil; detection of palmolein in groundnut oil; detection of rice bran oil in other edible vegetable oils; detection of linseed oil; detection of animal fat in vegetable fat (microscopic examination of fat crystals, separation of cholesterol by reversed phase TLC, detection of animal fat in vegetable fat based on the presence of unusual fatty acids in animal fats by GLC); detection of mineral oil in edible oils; detection of castor oil in edible oils (TLC method for detection of castor oil and its differentiation from rancid oils); detection of argemone oil in edible oils; detection of
karanja (Pongamia glabra) oil in edible oils; detection of hydrocyanic acid in edible oils; detection of kusum (Schleichera trijuga) oils; detection of teaseed (Camellia sinensis) oil; detection of tricresyl phosphates and tri-o-cresyl phosphate in edible oils; and detection of coal tar soluble colors in edible oils.

**Rogers et al., (1993)** developed a reverse-phase HPLC method for simultaneous separation and quantitation of tocopherols, tocotrienols and oryzanols in rice bran oil. Tocopherols and tocotrienols were quantitated by fluorescence detection and oryzanols (ferulic acid esters of sterols and triterpene alcohols) by photodiode array detection. Chemical ionization MS was used to identify cycloartenyl ferulate, 24-methylene cycloartanyl ferulate, campesteryl ferulate, beta-sitosteryl ferulate and cycloartanyl ferulate as the major oryzanols separated by this procedure. Levels of these nutritionally significant components were found to vary in fully processed, edible rice bran oils from different manufacturers.

Detection of rice bran oil or rapeseed oil in adulterated sesame oils was discussed by **Yamazaki et al., (1994)**. Six rice bran oils and 14 rapeseed oils were mixed with 10 sesame oils at ratios of 0, 5, 10, 15, 20, 30, and 100% (wt/wt) and analyzed by GLC with FID. Adulterant rice bran oil estimation was based on detection of 2 unsaponifiable components with relative retention times (RRT) of 1.19 and 1.15. Rapeseed oil was identified by determination of the percent linolenic acid and an unsaponifiable component (brassicasterol) with RRT 0.69. Crude rice bran has been successfully identified and isolated using reverse-phase HPLC by **Xu & Godber, (1999)**.

**Sharma et al., (1999)** developed a simple method of quantification of oil blends based on the Bellier test, cloud point and fatty acid analysis of pure and blended oils. **De and Bhattacharya (2000)** developed a rapid spectroscopic method for detection of rice bran oil in other oils. The method is based on the characteristic UV absorption at 315 nm by oryzanol, present in rice bran oil. Rice bran oil as such, or when present in other edible oils at the level
of 1.0-1.5% by wt., could be detected. The method is entirely dependent on the oryzanol content of rice bran. Rice bran oil might not be quantified if present at a very low level or if the oryzanol content in rice bran oil is very low. *Sharma and Prasad (2001)* reported a rapid and reliable method for detection of oil by infrared spectroscopy.

*Shukla et al., (2004)* identified a simple, rapid, reliable and economical qualitative technique for the identification of refined rice bran oil in other oils (including mustard seed oils). A suspected oil sample was treated with a small quantity of benzenediazonium chloride solution at 0-5°C followed by shaking of the mixture. Adulteration by rice bran oil was detected within 1 min. A small quantity of alkaline solution of the suspected oil sample developed the brilliant orange-red colour of 5-phenylazo-gamma-oryzanol or 5-phenylazofeuralic acid (which are dye materials) within a few seconds, indicating the presence of rice bran oil adulteration in the test sample. Results indicated that less than or equal to 2.5% rice bran oil adulteration could be detected with this technique.

*Kang (2004)* developed a UV adsorption method to detect adulteration of sesame oil with rice bran oil. Sesame oil was characterized by a peak in the UV adsorption spectrum at 290 nm, whereas the spectrum of rice bran oil had a peak at 320 nm. Therefore, measurement of absorbance at 290 and 320 nm could be used to differentiate between pure sesame oil and sesame oil adulterated by rice bran.

Edible oils such as coconut, groundnut, hydrogenated vegetable, linseed, mustard, olive, palm, refined vegetable, rice bran, safflower, sesame, soybean, and sunflower were analysed by *Pandey et al., (2004)* for the presence of light and heavy polycyclic aromatic hydrocarbon (PAH) residues using liquid-liquid extraction, cleanup on a silica gel column, and resolution and determination by HPLC using a fluorescence detector. Ten PAH were monitored. Analysis of 296 oil samples showed that 88.5% (262) samples were contaminated with different PAH of 262 contaminated edible oil samples, 66.4% of the samples showed
PAH content of more than the 25 micro g/kg recommended by the German Society for Fat Science. The total PAH content was highest in virgin olive oil (624 micro g/kg) and lowest in refined vegetable oils (40.2 micro g/kg). The maximum content (265 micro g/kg) of heavy PAH was found in olive oil and the minimum (4.6 micro g/kg) in rice bran oil. The intake of PAH was highest through olive oil (20.8 micro g/day) followed by soybean oil (5.0 micro g/day) and lowest through refined vegetable oil (1.3 micro g/day). Based on these monitoring studies, international and national guidelines for permissible levels of PAH can be prepared so as to restrict the intake of these toxic contaminants.
2.4. Thermal oxidation of rice bran oil during oven test and microwave heating

Various studies have been conducted on microwave heating of fats and oils. Peanut oil was heated in a microwave oven and the fatty acid composition was determined (Mai et al., 1980). Linseed, soybean, corn, olive and palm oil were heated by microwave and after 10 min of exposure the amount of tocopherols decreased and the occurrence of oxidation were determined by the increase in peroxide, p-anisidine, TBA and carbonyl values (Yoshida et al., 1990).

A good correlation between peroxide value (PV) and absorptivity at 232 nm during oven test (65°C, 17 days) was observed with canola oil that had BHA, BHT, TBHQ or a canola extract added (Wanasundara & Shahidi, 1994). Antioxidants either in combination or singly are commonly added to oils and fats to retard oxidation changes (Omura, 1995). Ruiz-Lopez et al., (1995) observed a small increase in PV of extra virgin olive oil after 8 min of microwave heating. Results of PV and absorptivity at 232 nm during oven test (62.8°C) and ambient storage for Brazil nut crude oil suggested a linear correlation coefficient over than 0.9 (Regitano-d’Arce & Vieira, 1996).

Albi et al., (1997) studied the effects of microwave energy and conventional heating on physical and chemical parameters of five edible oils and fats (virgin olive oil, olive oil, sunflower oil, high oleic sunflower oil, and lard). These fats and oils were subjected to three well-controlled treatments: heating in conventional electric oven, heating by microwave energy, and exposure to microwave energy, respectively. The effect of microwave heating on the visible spectrum, $K_{232}$ and $K_{270}$, density, viscosity, and squalene and trans-isomer contents of fats and oils was worse than that produced by heating the same fats in a conventional oven at the same temperature, time, surface/volume ratio, and light conditions. Subjecting fats and
oils to microwave energy under the same conditions, but below 40 °C, did not produce considerable variations in the same parameters when compared to the original ones. The results obtained for PV of olive, sunflower (Albi et al., 1997) and soybean oils (Vieira et al., 1998) heated in microwave oven did not increase in a clear way, due to the instability of hydroperoxides at high temperatures. Storage tests, like the oven test can be used to indicate the effect of an antioxidant, but it requires time to give the result. The oxidative stability of refined, bleached and deodorized canola oil was evaluated under oven test (Vieira and Regitano-D’Arce, 2001).

The effects of microwave heating on the quality characteristics and thermal properties of RBD palm olein was studied by Tan et al., (2002). The influence of microwave power slow-, medium- and high-power settings and heating time on lipid deterioration produced during the microwave heating of RBD palm olein was evaluated. The changes in thermal profiles by differential scanning calorimetry were studied in comparison to the changes in chemical parameters. The chemical evaluation of the oils was based on free fatty acid content, C18:2/C16:0 ratio, peroxide, iodine, and anisidine values. A good correlation was indicated between the DSC and chemical methods. Based on the results obtained, the DSC appeared to be a useful instrumental method in monitoring the oxidation of microwave heated oils, and it may have the potential to replace the time- and chemical-consuming standard chemical methods.

A simple HPLC technique, using a Hypersil silica resin column, spectroscopic detector and acetonitrile:methanol:isopropanol (50:45:5) mobile phase, was developed to analyse the quality and thermostability of commercial rice bran oils, which were heated at temperature of 100 and 180°C for 15 min and 2 hr. The technique revealed the presence of 5 peaks for gamma-oryzanol (an indicator of ferulic esters of triterpenic alcohols), and showed a clear effect of the higher heating temperature on three of the peaks. It was suggested that the technique can also be used as an aid to establishing the genuineness of commercial rice
bran oils and for comparison with other vegetable oils, such as corn and wheat germ. (Adinolfi, 2003).

Minar et al., (2003) studied the effect of microwave heating on three vegetable oils having different lipid compositions. Sunflower, soybean and peanut oils in comparison with oil admixture of soybean and peanut oil (1:1, w/w), were selected for this study. Each oil was heated for 2, 4, 6, 8, 10, 12, 15 and 18 minutes in microwave oven. Peroxide value, free acidity and colour absorbance (at 420 nm) were proportionally increasing with the increase of heating period. Colour absorption threw light on the formation of browning products arising from phospholipids during microwave heating. Total tocopherol contents were determined by preparative thin layer chromatography, whereas the fatty acid compositions and formed epoxy acid were analyzed by capillary gas liquid chromatography. The formed conjugated dienes and trienes were determined by UV spectrophotometry. It was found that the total tocopherols of the microwave heated oils, decreased depending on the type of the predominating tocopherols. Polyunsaturated fatty acids generally decreased by increasing the heating period.

Ohmic heating was used by Lakkakula et al., (2004) to stabilize rice bran and to improve rice bran oil extraction yield as compared to microwave heating and a control (no heating). Results showed that ohmic heating is an effective method for rice bran stabilization with moisture addition. Free fatty acid concentration increased more slowly than the control for raw bran samples subjected to ohmic heating with no corresponding temperature rise, indicating that electricity has a non-thermal effect on lipase activity. Ohmic heating increased the total percent of lipids extracted from rice bran to a maximum of 92%, while 53% of total lipids were extracted from the control samples. Lowering the frequency of alternating current significantly increased the amount of oil extracted, probably due to electrorotation. Ohmic heating was successfully applied to rice bran despite its high oil content. This could have important implications for the enhanced extraction of non-polar constituents.
Dostalova et al., (2005) reported the oxidative changes of vegetable oils during microwave heating. The oxidative stabilities of pork lard, sunflower, zero-erucic rapeseed, peanut and high-oleic peanut oils were tested under microwave heating conditions. Vegetable oils and lard were heated in a microwave oven for up to 40 min between 25°C and 200°C. The peroxide value, the contents of conjugated dienoic and trienoic acids, and polymers were used as markers of lipid degradation. Sunflower oil was found the least stable oil because of a high polyenoic acid content and a low content of γ-tocopherol. Rapeseed oil was more stable because of a lower polyenoic acid content and a high γ-tocopherol level. Conventional peanut oil was relatively stable, but substantially less stable than high-oleic peanut oil. Pork lard and high-oleic peanut oil formed only low levels of polymers due to a low polyenoic acid content.

Thermal behaviour of pure rice bran oil, sunflower oil and their model blends during deep fat frying shall be deleted offer some advantages like better nutritional quality, lower cost and greater storage stability than pure oils. Model blends prepared from pure rice bran oil (RBO) and sunflower oil (SFO) were examined for change in their physico-chemical parameters (acid value, iodine value, colour value, peroxide value and fatty acids). Repeated deep fat frying processes were carried out using dried potato chips in pure rice bran oil, sunflower oil and their model blends, in order to study the thermal behaviour of pure rice bran oil, sunflower oil and their model blends. Pure rice bran oil and sunflower oil showed good thermal stability during the repeated deep fat frying cycles. Although all the blended oils used in the study showed good thermal stability during repeated deep fat frying cycles, model blends consisting of 60%RBO + 40% SFO showed better suitability during repeated deep fat frying than the remaining blended oils (Sharma et al., 2006). Natural antioxidants extracted from olive oil mill waste water are highly effective for oxidative stabilization of lard (Leonardis et al., 2007).
Singh et al., (2007) studied on the thermal behaviour of pure RBO, safflower oil and their model blends during deep fat frying. Model blends prepared from pure rice bran oil (RBO) and safflower oil (SFO) were explored for changes in the physico-chemical parameters (acid value, iodine value, specific gravity, refractive index, colour value, peroxide value and fatty acids of triglycerides). Repeated deep-fat frying process was carried out by using dried potato chips in pure RBO, SFO and their model blends, to study the thermal behaviour of pure RBO, SFO and their model blends. Pure RBO and SFO had shown good thermal stability during the repeated deep-fat frying cycles. Although, all the blended oils, used in the study showed good thermal stability during repeated deep-fat frying cycles yet model blends constituting 20% RBO + 80% SFO showed better suitability during repeated deep fat frying than other blended oils, studied.

Zigoneanu et al., (2007) studied that rice bran oil, extracted by microwave-assisted extraction with isopropanol and hexane using a solvent-to-rice bran ratio of 3:1 (w/w). The experiments were done in triplicate at 40, 60, 80, 100, and 120 °C with a total extraction time of 15 min/sample. The oil components were separated by normal-phase HPLC and quantified with a fluorescence detector. The radical scavenging capability of the oil was tested with DPPH and was expressed as μmol Trolox Equivalent Antioxidant Activity. The increase in total vitamin E with temperature from 40 to 120 °C was 59.63% for isopropanol and 342.01% for hexane. Isopropanol was the best solvent for the extraction of γ-tocopherol and γ-tocotrienol as compared with hexane for both microwave-assisted and conventional solvent extraction. Isopropanol was better for oil yield extraction at high temperatures. Samples extracted with isopropanol at 120 °C had higher antioxidant activity. No differences in oil yield, total vitamin E, and antioxidant activity of oil was noticed between the two methods (microwave-assisted and solvent extractions), at 40 °C. No degradation of α-tocopherol was noticed during the process.
Khuwijitjaru et al., (2011) reported the effects of ferric chloride on thermal degradation of $\gamma$-oryzanol and oxidation of rice bran oil. The kinetics of $\gamma$-oryzanol degradation in antioxidant-stripped rice bran oil were investigated at 180°C for 50 h. Ferric chloride was added to the oil at different concentrations (0, 2.5, 5.0, and 7.5 mg/kg-oil) to determine the degradation reaction rate of $\gamma$-oryzanol and the extent of lipid oxidation (peroxide value and $p$-anisidine value). It was found that the losses of $\gamma$-oryzanol and its four components (cycloartenyl ferulate, 24-methylene cycloartanyl ferulate, campesterol ferulate, and $\beta$-sitosteryl ferulate) could be described by a first-order kinetics model. The degradation rate constant, $k$, linearly increased ($P<0.05$) with the ferric chloride concentration, and increased about 1.5 times when 7.5 mg/kg-oil ferric chloride was added. Ferric chloride addition also accelerated the lipid oxidation of rice bran oil significantly ($P<0.05$).
2.5. Frying properties of rice bran oil

Yen and Lai, (1989) studied on the oxidative stability of instant noodles fried with sesame oil-vegetable oil blends. They blend seven different oils, i.e. soybean oil (SBO), rice bran oil (RBO), unroasted sesame oil (USO), lard, USO-SBO blend (1:4, w/w), USO-RBO blend (1:4, w/w) and SBO with 200 ppm TBHQ, were used for frying instant noodles. The oil quality of instant noodles fried at 180°C for 1, 8, 16, 24, 32 and 48 h in each kind of oil was evaluated by chemical and sensory methods after storage at 37°C for 2 months. Sensory evaluation showed that rancid flavour of stored instant noodles was very low at 1 h frying time in all treatments, but when frying time was >8 h only samples fried with USO and USO-RBO blend had a low rancid flavour. Analysis of changes in peroxide value, dielectric constant and total volatiles of oil extracted from stored instant noodles showed that the noodles fried with USO and USO-RBO blend had the best oxidative stability.

Sharma et al., (1996 b) studied the pattern of oil, uptake of oil constituents during frying while taking dehydrated potato chips. Investigations on the analysis of the oil and fatty acid composition in the fried product and the oil remaining in the frying pan suggested a preferential uptake of saturated lipid constituents by the potato chips, while the oil remaining in the frying pan was rich in unsaturated constituents. The effect was accentuated in blended oils, although it was also observed in pure oils.

The effect of type of frying oil and temperature on the oxidative stability of potato chips during storage was studied by Lolos et al., (1999). Cottonseed oil, soybean oil, olive kernel oil and palmolein were used as frying media. The chips were packaged in metallised cellophane bags and incubated at 63°C. At definite time intervals the absorbed oil was extracted and analyzed for peroxide value, Totox number and conjugated diene content. Olive kernel oil and palmolein absorbed into the chips showed better stability, whereas soybean oil
presented the higher oxidation rate. Frying temperature (170, 180 or 190°C) did not affect the oxidation rate during storage, with the exception of conjugated diene formation which was greater for chips fried at 190°C. Ground oregano or oregano extract, obtained by petroleum ether extraction, were added to the chips as antioxidants. Both retarded significantly the oxidation rate of the oil absorbed into the chips, with results comparable to tertiary butylhydroquinone (TBHQ) during storage at 63°C for 7 days; however TBHQ proved significantly more effective after that time.

The physical properties of 6 commonly used oils and 3 blends consisting of 3 oils in each blend were studied after three successive frying of ‘poories’. The change in viscosity, CIE trans-reflectance colour and related parameter, UV-Visible spectra and UV-spectra of oil samples in solvent system (chloroform: methanol; 2:1, v/v) were studied by Susheelamma et al., (2002). The result showed that viscosity and colour of the oils changed to a much higher extent after the first frying than subsequent frying. The hue angle followed a similar trend. Changes in the UV-spectra in the solvent system indicated an increase in the formation of conjugated compounds and PV (peroxide value) after successive frying. Principal Component Analysis plots of the data indicated that among oils examined, ground nut oil and soybean oil in combination with other oils were preferred for frying.

High-oryzanol rice bran oil (HORBO), rice bran oil (RBO), and partially hydrogenated soyabean oil (PHSBO) were used to prepare french fries. Polar fractions of the three oils were analysed for nonvolatile components by high-performance size-exclusion chromatography (HPSEC) with ELSD. In all frying experiments, both HORBO and RBO yielded predominantly dimeric and monomeric materials. The concentrations of polymeric species in HORBO and RBO were greater than in PHSBO. The major degradation products from HORBO, RBO, and PHSBO were dimers (8.93 mg/100 mg oil), monomers (10.5 mg/100 mg oil), and DG (22.4 mg/100 mg oil), respectively. Thermal degradation via hydrolysis was much greater in PHSBO than in HORBO or RBO. Distribution data indicated
that the extent of polymer formation from frying was in the order RBO > HORBO > PHSBO, consistent with the degree of lipid unsaturation and the oryzanol content in these oils. HPSEC-ELSD results from the two RBO showed that the amounts of various polymeric species, including trimers and higher polymers, were lower in HORBO than in RBO. The percentage of polar materials and the percentage of polymerized TG, which were used as indicators of oil quality and stability, decreased with increasing tocopherol and oryzanol contents in the order PHSBO > HORBO > RBO (Abidi and Rennick, 2003).

Effects of frying were investigated on the viscosity and sensory properties of oil blends containing 80 parts sunflower oil (SNO), groundnut oil (GNO) or mustard oil (MO), and 20 parts rice bran oil (RBO), red palm oil (RPO) or sesame oil (SO). The different oil blends were used to deep-fat fry poori, a common Indian food prepared from wheat flour dough. Seven 50 g portions of poori were fried successively, and oil samples were withdrawn for analysis following frying of the 1st, 4th and 7th portions. Aroma and colour were evaluated by 10-12 trained panellists, and colour was also evaluated instrumentally using the CIE system. Apparent viscosity was calculated using a Haake RT10 rheometer. Frying was found to decrease the intensity of the typical aroma notes of the oil blends. Instrumental colour measurement indicated that the dominant parameters were a* (red) in RPO blends, b* (yellow) in blends containing MO or SO, and negative a* (green) in RBO blends. During frying, changes to colour parameters occurred to a lesser extent in blends containing RBO and SO than in those containing RPO. Deep-fat frying caused an increase in apparent viscosity for all blends. Principal component analysis segregated the oils into distinct groups and traced the pathway of changes occurring during frying. It is concluded that the aroma profiles of blended oils are distinguishable even after 7 frying cycles in the study of Ravi et al., (2005).
**Gopala Krishna et al., (2005)** studied the frying performance of processed rice bran oils (refined chemically and physically) compared to sunflower oil. Their physicochemical differences showed in appearance, color and oryzanol content, partial acylglycerols and unsaponifiable matter. Bhujia was prepared in sunflower and RBO and their frying performance measured in the oil from the bhujia. Oils after frying had deeper color (23.9–137.5% increase) and higher peroxide (101.4–274.3% increase) and free fatty acid values (−4.7 to +27.3% change) compared to the starting oils, but the RBO studied showed lesser changes compared to the control. Oil in the bhujia was slightly lower (−7.9%) for a low-oryzanol chemically refined RBO while it was slightly higher (+7.0%) for a high-oryzanol physically refined RBO. Both showed mild foaming compared to the control sunflower oil while retaining oryzanol in the oil and bhujia during frying (when partial acylglycerols caused some foaming). The bhujia retained the RBO's healthy oryzanol.

Rice bran oil (RBO) is popular in several countries such as Japan, India, Korea, China and Indonesia as a cooking oil. It has been shown that RBO is an excellent cooking and salad oil due to its high smoke point and delicate flavor. The nutritional qualities and health effects of rice bran oil are also established. RBO is rich in unsaponifiable fraction (unsap), which contains the micronutrients like vitamin E complexes, gamma oryzanol, phytosterols, polyphenols and squalene. However, the high FFA and acetone-insoluble content of RBO made it difficult for processing. Therefore, in recent years, research interest has been growing in RBO processing to obtain good quality oil with low refining loss. **Ghosh, (2007)** deals with detailed reports on RBO processing including membrane-based techniques from the production and quality point of view.

Repeated deep-fat frying was done by using dried potato chips in pure RBO (rice bran oil), SFO (safflower oil) and their model blends to study their thermal behaviour. Pure RBO and SFO showed good thermal stability during the repeated deep-fat frying cycles. Although,
all the blended oils, showed good thermal stability during repeated deep-fat frying cycles yet model blends constituting 20% RBO + 80% SFO showed better suitability during repeated deep-fat frying than other blended oil samples (Singh et al., 2007).

Chotimarkorn and Silalai, (2008) studied the effect of proportion of soybean oil to rice bran oil on lipid peroxidation inhibition in fried dough with rice flour during storage was investigated. Rice flour dough was fried in 100% soybean oil and mixtures with 25, 50 and 75% of rice bran oil at 160 °C for 1 min, then stored in the dark at 60 °C for 10 days. During 10-day storage, polyunsaturated fatty acid decreased rapidly in fried dough frying in 100% soybean oil and mixtures with 25% rice bran oil, while saturated fatty acid increased. Furthermore, total tocopherol content (p<0.05) and headspace oxygen concentration in vial eadspace (p<0.05) were significantly rapidly decreased in fried dough frying in 100% soybean oil and mixtures with 25% rice bran oil, while peroxide and p-anisidine values were significantly lower in fried dough with using oil mixtures (50%, 75% and 100% rice bran oil) during storage (p<0.05). However, an increase of FFA was significantly higher in fried dough with frying in 100%, 75% and 50% of rice bran oil during storage (p<0.05). There was no significant difference in decreasing gamma-oryzanol contents of fried dough during storage (p >0.05). These results demonstrated the effect of soybean oil mixtures with 50% and 75% rice bran oil on retardation of oxidative rancidity and hydrolytic rancidity in fried dough during storage.

The effect of sesame oil (SEO) and rice bran oil (RBO) on the rancidity of canola oil (CAO) during the process of frying potato pieces at 180°C was investigated by Farhoosh and Kenari, (2009). The SEO and RBO were added to the CAO at levels of 3 and 6%. Frying stability of the oil samples during the frying process was measured on the basis of total polar compounds (TPC) content, conjugated diene value (CDV), acid value (AV), and carbonyl value (CV). In general, frying stability of the CAO significantly (P <0.05) improved in the presence of the SEO and RBO. The positive effect of the SEO on the stability of the
CAO was more than that of the RBO. Increasing the amounts of SEO and RBO from 3 to 6% led to decreases in the TPC and AV, and increases in the CDV and CV of the CAO during the frying process. The best frying performance for the CAO was obtained by use of 3% of both SEO and RBO together.

Fats and oils are recognized as essential nutrients in human diets. Nutritionally, they are concentrated source of energy (9 cal/gram); provide essential fatty acids which are the building blocks for the hormones needed to regulate bodily systems; and are a carrier for the oil soluble vitamins A, D, E and K. Kinematic Viscosity of unheated and heated (270°C) rice bran oil is measured 30º to 90ºC. Valantina et al., (2010) reported the antioxidant stability in palm oil and rice bran oil at different times of heating is investigated using the parameters like density, viscosity, adiabatic compressibility and acoustic impedance of the oils at different times of heating. The antioxidant stability is resolute at every time of heating. Hence, it can be recommended that rice bran oil can be used for frying without adverse effect preventing the incidence of malignancy and coronary heart diseases.

The work of Debnath et al., (2011) deals with the effect of frying cycles on physical, chemical and heat transfer quality of rice bran oil (RBO) during the preparation of poori (an Indian traditional fried food) by deep-fat frying. The frying was carried out in intermittent mode (5 batches each for 3 min in a day without any time lag) and repeated for 6 frying cycles. Result indicated that in first two cycles, free fatty acid content, peroxide value and total polar materials increased, while radical scavenging activity decreased. Further increase in frying cycles did not result in any significant changes in these parameters \((p > 0.05)\). Similar trends were observed for these parameters in case of heating. Relative amounts of total saturated fatty acids increased due to marginal decrease in total unsaturated fatty acids content during frying cycles, however, no significant change was observed during heating. The convective heat transfer coefficient was found to decrease with an increase in frying cycle due to increase in kinematic viscosity of RBO for every frying or cycles. Despite the
marginal changes in physical and chemical properties, there was no significant difference \((p > 0.05)\) in the sensory characteristics of poori prepared in oil subjected to different cycles of frying.

**Rangaswamy and Nasirullah, (2011)** studies the physico-chemical changes in rice bran oil during heating at frying temperature. Rice bran oil was subjected to static heating at 180\(^{\circ}\)C in a domestic fryer for 8 h in this process 150 ml of the heated oil samples were drawn, at intervals of every 2 h, to study the changes in the physico-chemical characteristics. Results indicated that the peroxide value and free fatty acid content increased gradually from 0.2 to 2.9 meq. O2/kg of oil and 0.25 to 0.63\% respectively. The oil became darker as given by the colour value (5R + Y) 63 Lovibond units. Tocopherol content was found to decrease from 48 mg/100gram to 5 mg/100gram at the end of 8 h of heating whereas, oryzanol was fairly stable (1.59 to 1.40\%). The p-anisidine value and Total polar compound (TPC) increased from 5.04 to 18.30 and 1.0 to1.8\% respectively, showing the formation of secondary oxidation products. Rice bran oil is a non-Newtonian fluids having shear thinning behavior. Heating was found to cause an increase in the flow behavior index. Fatty acid composition did not show significant changes except for the linoleic acid content which decreased from 29.4 to 27.1\%.

**Jana et al., (2011)** reported that frying is one of the popular food preparation technique which helps in imparting desired properties to fried foods such as colour, flavour and texture. Several vegetable oils, modified or otherwise, are used as medium of heat transfer. The inherent composition of the vegetable oils dictates some of its properties viz., melting point, smoke point, fire point over and above having an impact on health of individuals consuming such fried foods. Vegetable oils with higher level of monounsaturated fatty acid and potent source of natural antioxidants are desirable for frying purpose, which can be developed through hybridization, genetic modification, fat modification (fractionation, interesterification) etc. The desirable frying oil must be low in free fatty acids and polar
compounds and have a high breakdown resistance during continuous use. Frying oil should not be too fresh for producing high quality fried foods. Increasing consumption of fried foods contributes to a high intake of fats and oil and thus calories. There are vegetable oils which when used to fry would absorb to the fried food to lesser extent than other oils favoring lower calorie intake. The success of any deep-fried product is associated with the progress in the frozen food distribution of par-fried products.