REVIEW OF LITERATURE
2.0 Review of Literature

2.1. Virgin coconut oil (VCO)

Virgin coconut oil (VCO) is one of the emerging products in Indian oil market and is gaining lot of importance among consumers due to its medicinal and other valuable properties which is only next to virgin olive oil. The term VCO refers to an oil, which is obtained from fresh, mature kernel of the coconut by mechanical or natural means, with or without the use of heat and devoid of chemical refining process (refined, bleached, deodorized) (Villarino et al. 2007). Due to increase in public awareness of health, it is expected in near future that VCO will gain significant importance and consumption growth in the market. The demand for this oil continues to rise, which can be attributed to its superior flavor, and potential health benefits. Among the coconut oil producing countries, India is placed 3rd after Philippines and Indonesia (FAO 2010). USA, Canada, Europe, Asia, Australia and South Africa are importing VCO from south pacific countries (Muralidharan and Jayashree 2011).

2.2. Biological activity of VCO

Physico-chemical and sensory properties are the distinguishing features for differentiating the coconut oil from the VCO is well documented. Normal coconut oil has distinct yellow color, perceptible aroma while VCO is almost colorless and had an acid flavor (Villarino et al. 2007; Dayrit et al. 2007). As per Codex Alimentarius (2006) and Asian Pacific Coconut Community (APCC) (2006), it can be concluded that VCO has same physico-chemical properties like iodine value, saponification value, moisture and other parameters almost similar to normal coconut oil. The fatty acid compositions of both the types of oil are almost similar (Marina et al. 2009a). In contrast to this, some researchers reported higher lauric acid in VCO than normal coconut oil but this difference is not considerable because it may vary with location, variety of crop (Laureles et al. 2000), age of nuts (Balleza and Sierra 1976) and time of harvesting (Carandang 2008). To differentiate the VCO from refined coconut oil (RCO) many methods have been used, among them P$^{31}$ NMR was found to be more reliable and also it has been found that, 1-monoglycerides was higher in VCO (0.027%) than RCO (0.019%) and total sterols were more in VCO (0.096%) compared to RCO (0.032%) while diglyceride was lower in VCO (1.55%) than RCO (4.10%) (Dayrit 2008). Due to high biological significance of VCO now-a-days, it is prone for adulteration with oils of less value. Methods for monitoring adulteration in VCO using Fourier Transform Infrared
Spectroscopy (FTIR), Differential Scanning Colorimeter (DSC), and Surface Acoustic Wave (SAW) sensor electronic nose have been developed to generate a pattern of volatile compounds present in samples (Marina et al. 2010). The lack of rapid method availability and simplicity, still there is needed to develop some efficient methods for detection of adulteration in VCO.

There is a remarkable difference between coconuts and other seed oils as it contains skin of kernel known as testa which plays an important role in final phenol content of coconut oil. VCO contains phenolic compounds like caffeic acid, p-coumaric acid and ferulic acid (Seneviratne and Disssanayake 2008). These compounds play a major role in biological antioxidant property of VCO. The relationship between the phenolic content and the antioxidant capacity of plants also had been reviewed (Cowan 1999; Robards et al. 1999). Phenolic compounds or phytochemicals are secondary metabolite of plant origin and forms an important component of both human and animal diet. Its intake is associated with reduction of cancer, cardiovascular diseases (CVD) and mortality rates (Zern and Fernandez 2005). Fruits and vegetables are good source of polyphenolic phytochemicals. In general, the biological properties of polyphenols (PPs) depend on their bioavailability. The bioavailability of most polyphenols depends upon gut absorption which undergoes several biological changes like, sulphatation, acylation, ester formation and conjugation. After further conjugation and deconjugation PPs finally reaches to the blood and then circulates to different tissues. From liver, some of the PPs may be transported to colon via bile for microbial hydrolysis. Colonic microflora catalyse the breakdown of the PPs to more simple phenolic compounds and absorbed again through liver and transported into tissues. The metabolized PPs may be transported to tissues and kidney for excretion from liver (Felginés et al. 2003; Mohsen et al. 2002; Crespy et al. 2002; Nardini et al. 2002). The concentration of PPs reaches maximum more after 1-2 hrs of feeding. The maintenance of high concentration of PPs in plasma thus requires a repeated ingestion of PPs (Vanhet et al. 1999). It is well established that PPs ingestion results in an increase in the concentration of plasma antioxidant activity and reduces plasma concentration of malonaldehyde (MDA) (Young et al. 1999). The rate and extent of intestinal absorption and the metabolites found in plasma and urine are largely determined by the chemical structure of the compound (Scalbert and Williamson 2000; Aziz et al. 1998; Unno et al. 1996; Manach et al. 2004; Scalbert et al. 2005). Till date, more than 8000 different phenolic compounds have been identified. They vary structurally from being simple molecules to complex molecules (Beecher 2003; Cheynier 2005). These phenolic compounds are synthesized in plants to protect them from fungal or bacterial infection or high energy radiation exposure. These PPs compounds inhibit
CVD by inhibiting LDL, preventing platelet aggregation, reducing blood pressure and improving endothelial dysfunction (Cheynier 2005; Fortes 2005; Joseph 2005).

Food PPs

\[ \text{Stomach} \]
\[ \text{Small Intestine} \]

\[ \text{Bile} \quad \rightarrow \quad \text{Liver} \]
\[ \text{Colon} \quad \rightarrow \quad \text{Tissue} \quad \rightarrow \quad \text{Kidney} \]
\[ \text{Faeces} \quad \rightarrow \quad \text{Urine} \]

**Fig. 1.** Possible route for absorption of polyphenol in biological system

PP effectively prevents Cu induced LDL oxidation as well as oxidation of phosphatidyl choline (the main lipid found in LDL) (Fuhrman *et al.* 1995; Rijke *et al.* 1996). Earlier, antibacterial, antiulcer, antiviral, antithrombotic, anti-inflammatory and antifungal properties of the different phenolic extracts have been reported (Yun *et al.* 2008; Hii *et al.* 2009; Jae Min Song *et al.* 2005; Gaetano *et al.* 2002). Numbers of studies have demonstrated that the consumption of PPs reduced LDL uptake by macrophage which was due to decreased oxidation. Similar, results were obtained through supplementation of virgin olive oil which is rich in polyphenols (Vauzour *et al.* 2010).

Antioxidants may function as free radical scavengers, reducing agents, complexes’ of pro-oxidant metals and quenchers of the formation of singlet oxygen (Ramadan *et al.* 2003). One of the possible explanations of antioxidant activity (AO) present in food could be due to reducing properties. These antioxidants by donating an electron can stabilize the free radicals. The excessive formation of the reactive oxygen species (ROS) has to be controlled to inhibit the pathogenicity by supplementation of antioxidants through diet. The consumption of natural dietary antioxidants from natural sources has been shown to enhance the function of antioxidant defence response mediated by antioxidant enzymes such as glutathione (GSH), Superoxide dismutase (SOD), catalase (CAT) and glutathione S-transferase (GST) interface (Block *et al.* 1992; Serdula *et al.* 1996; Tapiero *et al.* 2002; Duthie *et al.* 2003). Glutathione peroxidase (GSH-Px), glutathione reductase, catalase, superoxide dismutase (SOD) and glutathione (GSH) are among the most important natural antioxidant enzymes which synthesized in the body and provide an important defense against free radicals. These enzymes permit and promote a series of chemical process which allow the free radicals to be inactivated harmlessly. GSH act as a redox compound is the most abundant intracellular reductant in
cell and protects the cell against ROS and thus inhibit cellular injury. The glutathione induces glutathione peroxidase to reduce soluble peroxides and membrane bound peroxides to alcohols. In the process GSH is oxidized to glutathione disulphide (GSSG) (Mates and Sanchez 1999a; Mates et al. 1999b; Lusini et al. 2001). SOD is a very efficient enzyme system in removing superoxide radicals from biological systems which is coupled to another enzyme CAT that is involved in removing H₂O₂ molecules which are byproducts of the reactions catalysed by SOD. Thus, these two enzymes which are abundantly present in body and join themselves for a protective response in all the cellular systems. Removal of superoxide and H₂O₂ to H₂O by these two integrated enzymes is the most effective system of free radical control (Mates and Sanchez 1999a; Mates et al. 1999b). This operates efficiently in an oxidant environment due to enhanced oxidative stress. CAT is found in peroxisomes in eukaryotic cells. It degrades hydrogen peroxide to water and oxygen, and hence finishes the detoxification reaction started by SOD. GSH-Px is a group of enzymes, the most abundant of which contain selenium. They also reduce organic peroxides to alcohols, providing another route for eliminating toxic oxidants. VCO itself contains beneficial natural antioxidants namely tocopherols which can protect the oil against atmospheric oxidation and rancidity (Enig 2000). The contents of antioxidants in VCO vary on the basis of method adopted for extraction. Phenolic dependent antioxidant capacities are expected more for hot extraction VCO than cold extraction VCO because solubility of polar phenolic substances in non polar coconut oil is certainly improved at high temperature (Kapila et al. 2009). Marina et al. (2009b) reported contrast results from the above that VCO obtained from fermentation had highest phenolic content than VCO obtained from chilling technique. Consequently, VCO obtained from fermentation and chilling technique has higher scavenging activities than normal coconut oils.

2.3. Biological significance of VCO

Earlier Anitha and Lokesh (2008) and Eqbal et al. (2011) have reported in vivo studies for positive health effects of coconut oil. Lipid-heart theory (i.e. high saturated fats cause hypercholesterimia and coronary heart disease) is universally accepted for the effects of lipids on heart function (Cecille et al. 2010). Hypercholesterolemia is one of the most common diagnosed diseases that lead to coronary heart disease (CHD) and atherosclerosis. CHD has been defined as impairment of heart function due to inadequate blood flow caused by obstructive changes in the coronary blood circulation to the heart. Recently, it has been proved that hypercholesterolemia and CHD have direct relationship. It is a modern epidemic and complex degenerative disease which is the single largest killer of both men and women. Serum cholesterol at level 220mg/dl or
more is an important risk factor for CHD (Keys 1980). In CHD, plasma concentration of LDL cholesterol increases and reduction of low density lipoprotein (LDL) levels has become a major focus of medical research (Oluba et al. 2011). Many theories have been proposed to explain the genesis of CHD. The well accepted one is Fuster and colleagues theory based on hyperglycemia which increases LDL cholesterol overwhelm the antioxidant properties of the healthy endothelium (Vasudevan 2009). The dietary cholesterol during its metabolism is delivered to the hepatic cells where substantial amounts of reactive oxygen species are generated. This process is believed to generate highly toxic products, including lipid peroxides as aldehydes, epoxides, carbonyls, and cause rapid consumption of antioxidants such as vitamin E or vitamin C. Further, high cholesterol diet increases serum LDL levels and due to oxidative medicine and cellular longevity to oxidative stress, the LDL is oxidized increasingly thereby facilitating atherosclerotic plaque formation (Erdincler et al. 1997; Warnholtz et al. 2001).

Earlier Nevin and Rajamohan (2004) investigated the effect of consumption of virgin coconut oil (VCO) on various lipid parameters in comparison with copra oil (CO). They concluded that VCO obtained by wet process has a beneficial effect in lowering lipid components compared to CO by reducing total cholesterol (TC), triglycerides (TG), phospholipids, LDL, and very low density lipoprotein (VLDL) levels and increase the high density lipoprotein (HDL) in serum and tissues. In another study, Chandrashekar et al. (2010) studied the effect of coconut oil blends in conjunction with sunflower oil/soybean oil on the hypocholesterimic property in rats. These studies indicated that, the atherogenic potentials of a saturated fatty acid rich CNO can be significantly decreased by blending with an oil rich in unsaturated lipids in appropriate amounts.

Anitha and Lokesh (2008) studied the effect of blended oils consisting of coconut oil (CO) with groundnut oil (GNO) or coconut oil (CO) with olive oil (OLO) (i.e. balanced amounts of saturated to unsaturated fatty acids) and concluded that serum cholesterol levels were lowered in rats given blended oils containing CO/GNO and CO/OLO in comparison with rats fed with CO. Similarly, the liver cholesterol levels were decreased when rats were given CO/GNO blends and interesterified oils compared with those given CO. Cholesterol levels in liver of rats given blend and interesterified oils of CO/OLO were reduced as compared with that in rats given CO alone. Eqbal et al. (2011) evaluated the effects of different vegetable oils [red palm olein (RPO), palm olein (PO), corn oil and coconut oil (CO)] on lipid profile in rat. The results concluded that after 4 weeks showed a decline in LDL values at RPO and PO groups whereas in CO and COC groups the LDL were increased compared to the control group. The HDL values increased in RPO and PO groups whereas it was declined in CO and COC groups compared to the control group. At 8 weeks, there was no significant difference (p≤0.05)
in HDL of rats treated with vegetable oils compared to the control group. However, the LDL in RPO and PO was significantly decreased ($p \leq 0.05$) in the LDL and there was no significant difference ($p \leq 0.05$) for CO and COC groups compared to the control groups. There was a significant decrease ($p \leq 0.05$) in the total cholesterol (TC) in RPO group for 4 weeks compared to the control group while the TC in PO, CO and COC were within the normal range.

Sabitha et al. (2009) compared the lipid profile and antioxidant enzymes of normal and diabetic subjects consuming two different types of oil as cooking medium (coconut oil and sunflower oil). The results showed that triacylglycerols, LDL and VLDL cholesterol levels were high in the diabetic subjects compared to the controls. Total GSH and GSH-Px values showed significant decrease in diabetic subjects as compared to the controls, while SOD values showed significant difference between coconut oil consuming groups. Though lipid profile parameters and oxidative stress were high in Type 2 diabetic subjects compared to controls, no pronounced changes for these parameters were observed between the subgroups (coconut oil vs. sunflower oil).

After Second World War, the negative publicity of vegetable oil industry created a myth among common people that it contributes to heart disease and because of its illusion, the knowledge about coconut oil has been kept buried for decades (Hegde 2009). Coconut oil is rich in saturated medium chain fatty acids, which seems to be cholesterogenic but animal studies showed that these were flawed as they were used as hydrogenated coconut oil. Hydrogenation process saturates the small amount of the essential fatty acid linoleic acid that makes hydrogenated coconut oil to cholesterogenic, hence animal suffered from essential fatty acid deficiency (Cecille et al. 2010). Recently one truth has come in the picture that, chemically all the saturated fatty acid are not alike in their dietary properties. The length and number of carbons in fatty acid is extremely important for metabolic response. Medium chain fatty acids (MCFA) do not participate in biosynthesis and transport of cholesterol. It is absorbed directly through the portal vein into the liver. It does not require carnitine transport for their entry into the cells and subsequent metabolism for energy release in comparison to long chain fatty acid. Moreover, MCFA is easy to digest, absorb and oxidize in comparison to long chain fatty acid. Short and MCFA are easily solubilized in the aqueous phase of the intestinal contents, absorbed readily and is carried to the liver where it release energy. MCFA affect the physiology of a body by less deposition in adipose tissue (less obesity), decrease protein catabolism in hypercatabolic states, raise thyroid function and not forming esters with cholesterol while animal fats (having long chain fatty acids) do not mix easily with biologic fluids, need lipase for digestion, bypass the liver and deposit cholesterol in tissues before going to liver for oxidation (energy release) (Ghosh et al. 2010).
Due to this peculiar property of MCFA, it is favorable for sports nutrition, sliming diet product (Kaunitz and Dayrit 1992), infant formulation and preparation of hospital intravenous solutions. Medium chain triglyceride provides wellness for individual suffering from short bowel syndromes, childhood epilepsy, and aseptic fibrosis, those that have undergone by-pass surgery, for premature babies (Babayan and John 1991).

VCO contains more vitamin E and polyphenol contents than copra oil. Animal experiments suggested that, rats fed with diets containing these coconut oils for 45 days exhibits increased levels of antioxidant enzymes (Nevin and Rajamohan 2006). It is not only able to reduce the level of TC, TG, phospholipids, LDL and VLDL but also capable to increase the concentration of HDL, which is good cholesterol (Nevin and Rajamohan 2004). LDL cholesterol in its native state is not atherogenic. However, the chemical modification, i.e. oxidative modification, of LDL may lead to be atherogenic. In addition to this, the oxidized LDL is considered to be atherogenic by blocking the resident macrophages from leaving the intima, increasing the recruitment of circulating monocytes into the intima, and being cytotoxic for endothelium resulting in endothelial dysfunction (Stocker and Keaney 2004). Some comparative clinical trials were conducted to check the hypocholesterimic effect of coconut oil versus sunflower oil and safflower oil. It has been concluded that coconut oil feeding leads to lower production of LDL and higher production of HDL in comparison to sunflower oil and safflower oil. The total tissue cholesterol accumulation for animals on the safflower oil diet was six times greater than for animals fed the coconut oil was observed (Hostmark et al. 1980; Awad 1981).

Cancer is one of the five leading causes of death worldwide. Several studies were carried out to determine the role of coconut oil in cancer treatment (Cohen et al. 1984). The type and quantity of fat affects the growth of the ubiquitous rogue cell in the human body (Hegde 2009). Coconut oil has ability to protect breast cancer (Cohen et al. 1984). Several invivo studies were conducted to check the anticancer properties of vegetable oils using chemical induced mammary cancer cell models. It has been concluded that all animals were developed tumors except those fed with coconut oil (Cohen et al. 1984). In another study animals were subjected to chemical induced skin cancer within a week and showed that by the application of coconut oil along with cancer causing chemical, there was a complete depletion of tumour development (Nolasco et al. 1994). These studies make a clear forecast about coconut oil that, it may be helpful in curing the colon cancer and other types of cancer. Coconut oil contained MCFA which not only has ability to inhibit tumour growth but also stimulate the production of white blood cells, especially T-cells, which plays a major role in protection mechanisms of immune system. So,
coconut oil is helping the immune system to fight against the foreign particles (Ling et al. 1991; Wanten 2006; Witcher et al. 1996).

Diabetes mellitus, chronic metabolic disorder a silent killer, characterized by not only by hyperglycemia but also hyperphagia, polydipsia, decreased body weight and polyurea (Vats et al. 2005). It is mainly due to lack of insulin secretion of β-cells in pancreas and desensitization of insulin receptors for insulin. It is the most prevalent disease in the world affecting 25% of population and is set to rise to 300 million by 2025 (Vats et al. 2005). It is an important risk factor for hyperlipidemia and atherosclerosis. It is assumed that good control of diabetes may also reduce the risk of complications of CAD (Vasudevan 2009). Studies have also shown that coconut oil helps in regulating blood sugar because MCFA improve insulin production and insulin sensitivity (Garfinkel et al. 1992; Han et al. 2003). In other words, coconut oil helps the body to produce insulin and reverses insulin resistance, thus relieving many of the symptoms associated with diabetes. The major cause of diabetes is considered to be imbalanced food habits, change in life style, obesity, lack of physical activity, uncontrolled oxidative stress and genetic defects (Siddalingaswamy et al. 2011). A number of complications like retinopathy, neuropathy, and peripheral vascular insufficiencies have been raised from diabetes (Chehade and Mooradian 2005). Generally, for invivo studies injection of streptozotocin (STZ) [antibiotic from Streptomyces achromogenes] used to mediate the pancreatic β-cell destruction which can lead to oxidative stress (Reed et al. 2000). The mechanism involved is, STZ enters inside the cell and spontaneously decomposed to form an isocyanate and methylidiazohydroxide. Isocyanate compound and methylidiazohydroxide undergoes intra molecular carboxylation and alkylation of cellular components respectively. This process leads to the formation of carbonium ion which can damage the DNA of β-cells of pancreas (Wright et al. 1999; Junaid et al. 2004; Loven et al. 1986; Varva et al. 1960). Destruction of β-cells leads to the insulin deficiency which directly corresponds to hyperglycemia which is known to cause oxidative stress i.e. enhanced production of mitochondrial reactive oxygen species (ROS) through glucose autoxidation. It is well known that ROS which cause cellular damage by the oxidation ability is one of the major determinants of diabetic complications (Jiang et al. 1992). ROS are constantly formed in the human body and are removed by an antioxidant defense system. In healthy individuals, a perfect homeostasis exists in the biological system to regulate the excessive production of ROS. Under stimulated condition an imbalance between ROS and antioxidant defenses has been described as oxidative stress. Oxidative stress, which is associated with the formation of lipid peroxides, is suggested to contribute to pathological processes in aging and many diseases such as diabetes, atherosclerosis and cataract. Increased oxidative stress as a
result of increased free radical formation has also been suggested as a contributor to vascular damage in diabetes (Halliwell 1993; Gutteridge 1995; Bae et al. 1997; Jiang et al. 1992).

VCO contain lauric and capric acid which is recognized for its unique antimicrobial property. Lauric acid converted into monolaurin in body (i.e. present only in mother’s milk) has antiviral, antibacterial and antiprotozoal monoglyceride to destroy lipid coated viruses such as HIV, herpes, cytomegalovirus, influenza (Enig 1999). Monolaurin is generally recognized as safe and can be tolerated in relatively high dose (Lazo and Dayrit 1998). Monolaurine (moderate chain fatty acid) is very effective to recognize the fatty layer at outer membrane of microbe (Kabara 1984). It can kill pathogenic bacteria i.e. Listeria monocytogenes, Staphilococcus aureus, Staphilococcus agalactiae and Helicobacter phylory (Sibuea 2005). An initial study conducted in the Philippines using coconut oil to treat HIV/AIDS patients demonstrated a 60% success rate in reducing viral load dramatically and immune system enhanced as reflected in the CD4/CD8 count (Dayrit et al. 2000).

In animal experiments conducted using coconut oil or its derivatives monolaurin, monolaurin removed the bacterial drug resistance of Staphilococcus aureus to Penicillin G. (Ontengco et al. 1998; Gamboa and Carandang 1998). Some clinical trials reported that formation of some pro mutagenic DNA adducts is lower in rats fed with a coconut oil supplemented diet, compared to rats fed with the diets rich in linoleic acid (Eder et al. 2006). Health effects of coconut oil mainly attributed by lipid portion. Coconut oil prevented sepsis caused by E. coli enterotoxin shock (Lim-sylianco et al. 1992). Another powerful medium chain fatty acid i.e. capric acid (6-7%) is same as laurin for killing the germs (Hegde 2009). In coastal regions there is a very less chance of dandruff and fungus infection because they are using coconut oil which is having capric and lauric acid. It has reported that in clinical trials replacement of coconut oil found to be good in dandruff control (Anuradha and Sugumar 2009).

Coconut oil is in one form or another is used in hospital as intravenous (IV) solutions and in baby formulations and is recommended for those with cystic fibrosis and digestive problems. Coconut oil is used for wide variety of health problems, ranging from the treatment of burns and constipation to gonorrhea and influenza (Duke and Wain 1981).

2.4. Standards of VCO

Codex Alimentarius (2006) and Asian Pacific Coconut Community (APCC) (2006) have defined ‘Virgin oils’ as vegetable oils which should be suitable for human consumption in its natural state and may be purified by washing with water, settling,
filtering and centrifuging only. The current codex standard for coconut oil, which is based on commercial refined, bleached and deodorized coconut oil (RBD CNO), states that edible vegetable oils may be refined by alkali extraction and washing, bleaching, deodorization to remove undesirable constituents and prolong shelf life (Codex Alimentarius 2006). Due to specific needs of coconut producer, the APCC (2006) forwarded a standard for VCO. In 2004, an intergovernmental technical panel drafted the interim Philippine National Standard for VCO (PNS/BAFPS 22:2004). Marina et al. (2009a) described that iodine value (IV), peroxide value (PV), saponification value (SV) and free fatty acid (FFA) in VCO and refined bleached deodorized (RBD) coconut oil in commercial samples of Malaysia and Indonesia were almost same. The study revealed that, medium chain fatty acids ranged from 60 to 63% and VCO from Malaysia had relatively higher contents of lauric acid than Indonesian samples. Currently there are two standards for VCO i.e. Phillipines National Standard designated as PNS/BAFPS 22:2004 and APCC (Table 1). However, in India there are no such standards available to PFA regarding VCO.

2.5. Methods for the extraction of VCO

Several reports are available for the extraction of VCO (Villarino et al. 2007; Che Man et al. 1997). Normal coconut oil has been extracted from copra and undergoes refining process while VCO is produced through coconut milk without involvement of any refining process. Several researchers reveled that; refining process may lead to the decrease of nutritional benefits (Grimwood 1975). The general extraction procedures for VCO are as follows-

2.5.1. Wet extraction

This method excludes the use of solvent which reportedly may lower the cost and energy requirements (Villarino et al. 2007). The principle behind this method is to break cream emulsion and liberate oil. In wet method, coconut milk is used under mild temperature resulting in the production of VCO which retains more biologically active components (Grimwood 1975). In this process, coconut milk is subjected to three steps creaming, flocculation or clustering, coalescence process by which VCO has been obtained. It is the most commercially attractive and eco friendly method than solvent extraction.

2.5.2. Fermentation

In fermentation process, separation of coconut milk emulsion is carried out by using pure culture of L. plantarum, L. delbruekii and L. plantarum strains inoculation which result a rapid breaking of the coconut milk emulsion and the liberation of the oil compared to L. delbrueckii (Che Man et al. 1997). It is reported that L. plantarum strain
could multiply faster in coconut milk at 40-50°C under microaerophilic conditions which increased the fermentation process. Coconut milk emulsion can also be separated by adjusting pH in between 3.0 to 5.6 with bacterial cultures (Chen and Diosadey 2003). Che Man et al. (1996) reported improvement in the oil recovery up to 60% with the use of 25% acetic acid at different level for 10 to 14hrs at room temperature. Some other treatments are also employed to break the coconut milk emulsion like heat, brine solution, refrigeration, enzymes and acidification of short waves (Seow and Gwee 1997).

2.5.3. Enzymatic

Plant cell wall consists of complex carbohydrate molecules such as cellulose, hemicellulose, mannans etc. (Christensen 1991). For the destruction of cell wall and liberation of oil, some degradation enzyme like cellulase, α-amylase, polygalacturonase and protease at 1% level was applied to extract 74% of coconut oil (Che Man et al. 1996). Cell wall degrading enzymes can be used to extract oil by solublizing the structural cell wall components (mannan, galactomannan, arabinoxylogalactan and cellulose) of the oil seeds.

Table 1. Existing standards for virgin coconut oil (VCO) (APCC, PNS/BAFPS 22:2004)

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Parameters</th>
<th>APCC</th>
<th>PNS/BAFPS 22:2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>% Fatty Acid Composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Caproic (C₆:0)</td>
<td>0.4-0.6</td>
<td>ND-0.7</td>
</tr>
<tr>
<td></td>
<td>Caprylic (C₈:0)</td>
<td>5.0-10.0</td>
<td>4.6-10.0</td>
</tr>
<tr>
<td></td>
<td>Capric (C₁₀:0)</td>
<td>4.5-8.0</td>
<td>5.0-8.0</td>
</tr>
<tr>
<td></td>
<td>Lauric (C₁₂:0)</td>
<td>43.0-53.0</td>
<td>45.1-53.2</td>
</tr>
<tr>
<td></td>
<td>Myristic (C₁₄:0)</td>
<td>16.0-21.0</td>
<td>16.8-21.0</td>
</tr>
<tr>
<td></td>
<td>Palmitic (C₁₆:0)</td>
<td>7.5-10.0</td>
<td>7.5-10.2</td>
</tr>
<tr>
<td></td>
<td>Stearic (C₁₈:0)</td>
<td>2.0-4.0</td>
<td>2.0-4.0</td>
</tr>
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<td></td>
<td>Oleic (C₁₈:1)</td>
<td>5.0-10.0</td>
<td>5.0-10.0</td>
</tr>
<tr>
<td></td>
<td>Linoleic (C₁₈:2)</td>
<td>1.0-2.5</td>
<td>1.0-2.5</td>
</tr>
<tr>
<td></td>
<td>Linolenic (C₁₈:3)</td>
<td>-</td>
<td>ND-0.2</td>
</tr>
<tr>
<td></td>
<td>Arachidonic (C₂₀:0)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Iodine Value</td>
<td>4.1-11.0</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Free Fatty Acid</td>
<td>&lt;0.4%</td>
<td>0.2%</td>
</tr>
<tr>
<td>4.</td>
<td>Moisture % weight max</td>
<td>0.1-0.5</td>
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</tr>
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<td>5.</td>
<td>Matter volatile at 105C, m/m</td>
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<td>0.2%</td>
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<tr>
<td>6.</td>
<td>Peroxide value</td>
<td>&lt;3meq/kg</td>
<td>3</td>
</tr>
<tr>
<td>7.</td>
<td>Microbiological contamination</td>
<td>&lt;10cfu</td>
<td>-</td>
</tr>
</tbody>
</table>
2.5.4. Low temperature/centrifuge/super critical carbon dioxide extraction technique

Refrigeration is a common method to prepare VCO by cooling the coconut milk in order to separate it in two phases’ viz., upper cream phase and lower watery phase. The cream was further subjected to mild heating in a thermostat oven for several hrs to separate VCO (Songkro et al. 2010). Marina (2008) has reported two methods i.e. Robledano-Luzuriage and Krauss-Maffei known to apply freeze and thaw operation in the extraction of coconut oil. In the previous one, fresh coconut kernel was comminuted and pressed to obtain approximately equal amounts of emulsion and residue. The residue was pressed again to obtain more emulsion and residue. The emulsion was centrifuged to obtain cream, skim milk and some solids or protein. Songkro et al. (2010) had applied same cooling technique but after cooling, sample was centrifuged at 9000rpm at 10°C for 5min resulting two layers separated. Further oily layer obtained was subjected to mild heating (50°C) for 15min and again centrifuged for 5min at 25°C at similar rpm. Norulaini et al. (2009) reported the method based on super critical carbon dioxide extraction technique for VCO extraction. In this method, yield of VCO is directly proportional to the pressure. This method gave the better yield than the methods proposed by other researchers.

2.6. Applications of VCO

VCO (lauric oil) is rich in antioxidants and medium chain fatty acids. This property of VCO has a potential to be food preservative related with bacterial contamination (Frazier and Westhoff 1994). Salam et al. (2009) was reported that the submersion of the meat in VCO has ability to decrease moisture content, bacterial colony count it leads to the increased shelf life of meat.

Global warming leads to increase of immune suppression, photo ageing and skin carcinogenesis are the common problems associated with UV radiation (Matsumura and Ananthaswamy 2002). These problems cannot solved by sunscreen lotions as they are helpful to cure this problem but their protection are not ideal, may be due to inadequate use, incomplete spectral protection and toxicity (Pinnell and Durham 2003). Now, media attention has focused on utilizing natural ingredients such as vitamins, minerals and botanical extracts to protect the skin diseases. VCO was claimed having several beneficial effects for skin on its topical or systemic usage. Some trial study was conducted to check the VCO protection against UVB induced erythema and pigmentation. It has been proved that VCO’s protective property was better if it is used orally (Merlin et al. 2008).
VCO is mainly utilized for cosmetic and aromatherapy (considered as a complimentary therapy). The oil utilized for aromatherapy *i.e.* massage oil made by carrier oil. Among commercially available carrier oil, VCO has been found to be the best carrier oil (Lis 2006). VCO blended with lemon, eucalyptus and lavender oil; produce effective and economical massage oil. VCO can form nano emulsion with water which is the key constituent of the cosmetic cream. Nano emulsions (fines disperse emulsions or submicron emulsions) are attractive system for many industrial applications due to their purity and simplicity (Songkro *et al.* 2010).

Generally, medium chain fatty acids are utilized in flavor industries, because they are more polar, hydrophilic and can dissolve a variety of polar substances that are insoluble in conventional fats and oils. VCO is considered as good frying oil as it has relatively high oxidative stability than Virgin olive oil (VOO) (Henna and Tan 2009). In recent years, the rise in world petroleum prices devalued the national currencies. Some researches proved that coconut oil is a natural biofuel. It can substitute diesel and act as a blend substitute for kerosene. The relatively low cost of nuts and labour could make production of coconut oil for fuel on economic proposition (Herkules *et al.* 2010).

### 2.7. Stability of vegetable oils

The quality and shelf life of the packaged food are mainly determined by the barrier properties of the package against moisture, oxygen and interaction of food constituents with the packaging material (Sharma *et al.* 1996). The major function of packaging is to minimize reactions that affect the stability of the contained products (Karel *et al.* 1975).

Storage stability of sunflower oil in glass and Polyethyleneterephthalate (PET) bottles were determined both light and dark with and without headspace to check the effects of light, air, packaging materials. Glass bottles recorded lower oxidation values than oils packed in PET. The oxidation proceeded faster in packages stored in light than darkness and in those with headspace. The best quality oil was found stored in the dark, free of air and packed in glass and then in PET (Kucuk and Caner 2005).

The effects of different plastic films [PET, polyvinylchloride (PV), polypropylene (PP) and polystyrene (PS)] on the stability of olive, sunflower and palm oils were studied at 24°C and 37°C during 60 days of storage. They found out that changes in peroxide value (PV) and thiobarbituric acid value (TBA) were significantly higher ($p \leq 0.05$) in the plastic glass. They showed that the ranking of stability of oil samples was PVC$>$PET$>$PP$>$PS (Tawfik and Huyghebaert 1999).

Kiritsakis (1984) studied the oxidative stability of olive oil stored in glass and polyethylene (PE) plastic bottles and concluded that glass bottles provide better
protection from oxidation than polyethylene plastic bottles. Sharma et al. (1990) studied the effect of plastic film contact (including PE, PP and BHA and BHT incorporated in polyethylene) on the storage stability of refined sunflower oil and groundnut oil at 37°C and concluded that changes in peroxide value and thiobarbituric acid were significantly (p≤0.05) less in the presence of antioxidant heated plastic films than control samples. Both BHA and BHT were found to leach out from plastic films into vegetable oils during storage. Nkpa et al. (1992) had studied on the quality of crude palm oil, packaged in clear plastic bottles, sealed polyethylene film and clear glass bottles and reported higher total oxidation values than oils packed in either lacquered metal or amber and green glass bottle. Lacquered metal cans gave the greatest protection against oxidation.

Kaya et al. (1993) studied the effect of permeability and transparency of the packages (PET and glass bottles) on the shelf life of sunflower and olive oils. The determinations were based on the oxidative stability of oils by measuring their peroxide values. The storage stability of oils increased in the following order with respect to packaging materials: PET<clear glass< colored glass. Mathews et al. (1988) had worked out the storage quality of groundnut oil packed in tin-free steel and tin plate containers which indicated that there was no significant (p≤0.05) difference in the peroxide value, free fatty acid and the quality of oil between the two types of containers.

Suitability of different packaging materials for packaging of refined groundnut oil has been studied by Srinivasa et al. (1977). The results indicated that the oils packed in galvanized iron drum and high density polyethylene jerry cans were acceptable upto 9 months storage.

Mendez and Falque (2007) had analyzed four commercial samples of extra-virgin olive oil in clear PET bottle, PET bottle covered with Al foil, glass bottle, tin and tetra brik. The results showed that after 6 months of storage there was 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. Padmashree et al. (2009) had reported packaging system for refined vegetable oils for Indian army to overcome transit damage and consequent loss through leakage of contents. They found that Low density polyethylene (LD, 50µ) / Nylon /LD) co-extruded flexible film bags housed in 5-ply card board boxes were found most suited for keeping quality and transport worthiness of oils.

Anwar et al. (2007) had carried out study in order to prove the extent of oxidative alterations in soybean oil, subjected to ambient and sunlight storage, over a period of 180 days. They found that, magnitude of oxidative deterioration of the soybean oil samples exposed to sunlight significantly (p<0.05) pronounced as compared to ambient temperature stored samples. Maloba et al. (1996) had studied oxidative stability of sunflower oil at 23-37°C in presence of a novel oxygen scavenging film that contained
polyfuryloxirane (PFO). During storage of virgin grape seed oil, the pleasant sensory attributes change and more and more degradation products like ethyl acetate, acetic acid or ethanol are detectable (Bertrand 2008). Azeredo et al. (2003) maximized the sensory stability of soybean oil packaged in pet bottles. Nobile et al. (2003) reported that, it is possible to obtain quality decay kinetic slower than that obtained for olive oil bottled in glass containers by either using an oxygen scavenger or reducing the concentration of oxygen dissolved in the oil prior to bottling.

Studies on shelf stability of VCO in different packaging material/container at ambient temperature and accelerated temperature are scanty and need systematic study.

2.8. Blending of vegetable oils

Blending of edible vegetable oil means an admixture of any two edible vegetable oils where the proportion by weight of any edible vegetable oils used in admixture should be not less than 20%. The spectral bands of VCO: olive oil and VCO:palm oil were scanned and found out the spectral VCO frequency as 1120-1105 cm\(^{-1}\) and 965-960 cm\(^{-1}\) (Rohman and Che Man 2010).

Murthy et al. (1996) reported that edible oil blends of mustard oil and rapeseed oil (1:3), sesame oil and refined cotton seed oil (1:3), groundnut oil and refined cotton seed oil (1:3), and coconut oil and refined palm oil (1:3) kept for storage at 37˚C in an incubator and found out that acceptability of refined oils was poor after 90 days while their blends were remained stable after 120 days.

The blending of Moringa (Moringa oleifera) oil (MO) with sunflower oil (SFO) and soybean oil (SBO) in proportions of 0-80% resulted in the reduction of linoleic acid content of SFO and SBO from 67% to 17% and 56.2% to 14.6% and increase in the contents of oleic acid from 26.2% to 68.3% and 21.4% to 65.9% factors of 0.72, 0.72 and 1.27, 1.33 respectively. A storage stability test (180 days) showed an appreciable improvement in the oxidative stability of substrate oils with increase of MO concentration, as depicted by the least oxidative alterations in PV, IV and highest increase in induction period of the MO: SBO (80:20) blend (Anwar et al. 2007).

Mariod et al. (2005) improved the oxidative stability of sunflower oil by blending with Sclerocarya birrea oil and Aspongopus viduatus oils. Mezouari and Elchner (2007) evaluated the stability of blends of sunflower oil and rice bran oil. Frankel and Huang (1994) reported that, mixtures of soybean and high oleic sunflower oil (HOSO) containing 2.0% and 4.5% linolenate were equivalent or better in oxidative stability than the hydrogenated soybean oil.

Blends of palm olein (PO) (90, 80, 70 and 60%) with peanut oil (PnO) (10, 20, 30 and 40%) were made which showed that with increasing amounts of PnO coupled with
decreasing amounts of PO in the blends, the degree of unsaturation increased and pleasant nutty flavor was imparted. The FFA content increased from 0.36% to 0.9%. Fatty acid compositions with major changes observed in the percentage of palmitic and linoleic acid (Myat et al. 2009).

Literatures based on studies on shelf stability of VCO blends with refined soybean oil and safflower oil in different packaging material/container at ambient temperature are scanty and need a proper focus on this aspect.

2.9. Frying of vegetable oil

Frying is defined as the process in which food is submerged in fat and it is heated in the presence of air. Therefore, the fat/oil is exposed to the action of moisture from the foodstuff, oxygen from the atmosphere, and high temperature at which the operation takes place or it is defined as the process of simultaneous transfer of heat and mass i.e. heat transfer from frying media to food (hot oil to cold food), which leads to evaporation of water from food and absorption of oil by the product (Krishnamurthy and Chang 1967).

Frying temperature are high between 130˚C and 200˚C or more, but only surface layers of the fried substance are heated to a temperature above 100˚C because of the short frying time. Inner layers of food are heated only to 70˚C-98˚C. Reported alterations of chemical composition are generally much higher at the surface and nearly negligible in deeper layers. Frying oil interacts with food components almost exclusively in the surface layer. Therefore, reactive compounds may be consumed very rapidly on the surface. Their diffusion from inner layers onto the surface of fried food is usually too slow to substantially influence the composition during the relatively short frying time. Crust formation may prevent reactants from coming into contact with the interior. Frying oils and their degradation products interact with fried food producing various artifacts, which remain mainly on the surface (Pokorny 1999).

The moisture from the foodstuff causes hydrolytic reaction giving rise to free fatty acid, monoglycerides, diglycerides and glycerol. The atmospheric oxygen causes oxidative reactions giving rise to oxidized monomers, dimers and polymers. Non polar dimers and polymers as well as volatile compounds are also produced. The thermal reactions caused by high temperature produce cyclic monomers, dimers and polymers (Chang et al. 1978). The oxidative and thermal degradation take place in the unsaturated fatty acid constituents of the triacylglycerols. Thus, the principal components altered are triacylglycerols with at least one of their acyl radicals altered. In addition, the three types of reactions are not only superimposed but interrelated. The existence of high temperature plays a large role in the oxidation products, favoring the formation of
oxidative and non-oxidative dimers and polymers. The free fatty acids produced during hydrolysis are more susceptible to oxidative and thermal changes than when esterified to the glycerol (Gutierrez et al. 1988).

As the fat is heated, the quality decreases as evidenced by a decrease in heat capacity, surface and interfacial tension, and increases in specific gravity, viscosity, acid values, anisidine values and polymer content. Surface tension and interfacial tension are reduced by low polarity and high polarity oxidative polymers causing excessive oil pick up by the food (Blumenthal and Stier 1991). Fat oxidation to form hydroperoxides takes place by loss of a hydrogen radical in the presence of trace metals, light or heat. This reaction is described in terms of initiation, propagation, branching and termination process. The formation of a lipid radical (R°) from an unsaturated fatty acid (RH) is the key event in the initiation step. This can occur by thermal hemolytic cleavage of an RH double bond or by hydrogen atom abstraction from RH by a free radical initiator. Propagation normally begins with the addition of molecular oxygen to R° but the rate limiting reaction consists of abstraction of a hydrogen atom from RH by a peroxyl radical (ROO°) to form hydroperoxides (ROOH) and another radical R°. In the termination step, the peroxidation chain reaction ends when peroxy radicals combine with a radical scavenger (antioxidants) such as vitamin E (Fig. 2.) (Porter et al. 1995).

The hydroperoxide decomposition products depend on temperature, pressure and the concentration of oxygen. Due to thermal oxidation and polymerization of unsaturated fatty acids in fat, formation of volatile, nonvolatile decomposition products occur. Nonvolatile products causes’ physical changes to fat such as darkening in color increase in viscosity and decrease in smoke point while a volatile decomposition product changes the flavor. The hydroperoxide formed as primary products of autooxidation are very unstable and breakdown to alkoxy free radicals which decompose mainly by cleavage on either side of the carbon atom bearing the oxygen atom to form numerous secondary degradation products (Kubow 1992).

Frying stability of genetically modified corn oils containing 65% oleic acid and high oleic corn oil after 20hrs of heating at 190°C leads significantly lower total polar compound levels in high oleic corn oil than normal corn oil, hydrogenated corn oil and high oleic (80% and 90%) sunflower oils (Warner and Knowlton 1997). The storage stability in virgin coconut oil and extra virgin olive oil upon thermal treatment and found that VCO was considered as good frying oil as it has relatively high oxidative stability as compared to extra virgin olive oil (Henna and Tan 2009). Chen Man and Wan Hussin (2007) compared the frying quality of refined, bleached and deodorized coconut oil and refined, bleached and deodorized palm olein (RBDPO) and concluded that RBDPO has
excellent frying quality after intermittent frying of potato chips at 180˚C for 5hrs/day for 5 consecutive days.

The comparative analysis of mustard, groundnut, soybean and sunflower oil for stability against longer storage and heat deterioration during frying revealed that composition of mustard and groundnut oils have not been disturbed either during longer storage or during thermal abuse (Sharma et al. 2007). Irwandi et al. (2000) optimized the amounts of rosemary and sage extracts together with citric acid as synergist antioxidants in stabilizing refined, bleached, and deodorized palm olein during repeated deep fat frying of potato chips.

They suggested that an optimal mixture of phytochemical antioxidants derived from rosemary and sage together with citric acid could be produced using RSM for stabilizing thermally processed oil. Quiles et al. (2002) checked the effect of lipid profile, vitamin E and total phenolic content in relation to the antioxidant capacity (measured by ESR) of three edible oils (virgin olive, sunflower and olive oils), using short time deep fat frying as a model and concluded that sunflower oil underwent more chemical changes by frying than olive and virgin olive oil. Radwan et al. (2008) found that mixing of sunflower oil with jojoba oil or paraffin oil increased the stability and hence improved the quality of sunflower oil during frying process.

Marco et al. (2007) had selected blend (sunflower/palm oil 65:35 v/v) which has been monitored during prolonged frying process (8hrs discontinuous frying without oil replenishment) in comparison to pure palm oil. Choo et al. (2007) studied physiochemical and stability characteristics of flaxseed oils during pan frying.

![Fig. 2. The mechanism of early stages of oxidation involves a free radical chain process](image-url)
The behavior of two non-conventional oil i.e crude *Sclerocarya birrea* kernel oil (SCO) and sorghum bug (*Agonoscelis pubescens*) oil (SBO) studied during frying. Potatoes fried in SCO had been used for 24hrs of deep frying at 175˚C were suitable for human consumption than potatoes fried in SBO that had been used for 6-12hrs on sensory basis. In contrast to SBO, SCO did not exceed the limits for the content of polar compounds and oligomer triglycerides during the frying experiment (Mariod *et al.* 2006).

Ravi *et al.* (2005) studied odour analysis in edible oil blends containing 80 parts of mustard oil (MO) or groundnut oil (GNO) or sunflower oil (SNO) and 20 parts of sesame oil (SO) or refined red palm oil (RPO) or rice bran oil (RBO) during deep fat frying and found that intensity of sulphur, pungent and vinegar notes of MO, nutty and sweet notes of GNO, sweet and seedy notes of SNO, seedy and earthy notes of SO, husk like note of RPO and beany and branny notes of RBO decreased significantly by the end of the 7th frying. Apparent viscosity of the oil blends increased on successive frying. Colour measured in CIE system indicated that the dominant parameters were a+ (redness) in RPO blends, b+ (yellowness) in blend containing SO or MO and a- (greenness) in RBO blends. The redness component decreased and yellowness increased with successive frying in SNO + RPO blend and GNO and RBO blend, respectively.

The effect of proportion of soybean oil, rice bran 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 mixture with 25%, 50% and 75% of rice bran oil 160˚C for 1min, then stored in the dark at 60˚C for 10 days. During 10 days storage polyunsaturated fatty acid decreased rapidly dough fried in 100% soybean oil and mixtures with 25% rice bran oil, while saturated fatty acid increased (Chotimarkorn and Silalai 2008).

The stability of argan oil (*Argania spinosa*) (55.4% oleic acid and 24.4% linoleic acid) and comparison with high oleic olive oil (78.2% oleic acid and 7.9% linoleic acid) and cottonseed oil (19.8% oleic acid and 52.0% linoleic acid) at high temperatures in heating and deep-fat frying conditions were studied. After frying no change in the contact angle of argan, olive and cottonseed oils was observed, while in other tests (colour index, viscosity, peroxide value, induction period, conjugated dienes content, total polar compounds) the stability of argan and olive oil was better than that of cottonseed oil (Yaghmur *et al.* 2001).

Frying performance of palm olein, sesame oil, canola oil and their blends were significantly (p<0.05) influenced by the type and concentration of the component oil. Among all six frying oils canola oil generally exhibited the least chemical stability during the frying process and RBD palm olein being highest (Yaakob *et al.* 2010).
2.10. Oil cakes (meals)

Various oil cakes have been in use for feed application to poultry, fish and swine industry. Being rich in protein, some of these have also been considered ideal for food supplementation. However, with increasing emphasis on cost reduction of industrial process and value addition to agro-industrial residues, oil cakes could be ideal source of proteinaceous nutrients and as support matrix for various biotechnological processes. Several oil cakes, in particular edible oil cakes offer potential benefits when utilized as substrate for bioprocesses. These have been utilized for fermentative production of enzymes, antibiotics, mushrooms etc. Biotechnological applications of oil cakes also include their usages for vitamins and antioxidants production (Ramachandran et al. 2007).

By using deoiled coconut oil cake (a waste produced during oil extraction) extra cellular lipase was produced from Candida rugosa by solid-state fermentation (Benjamin and Pandey 1997). Mohanta et al. (2007) prepared six iso-nitrogenous (30% crude protein) and iso-energetic (15kjg⁻¹) diets by using different oil cake sources viz. Groundnut, soybean, sunflower, sesame, mustard and mixed oil cakes. Ankrah (1998) reported that the copra generally contain 10.2% moisture, 20.6% protein, 12.6% fat, 6.0% ash per 100 gm and calcium and phosphorus also gave mean values of 90 and 513mg/100 gm sample. Moorthy and Viswanathan (2006) studied the effect of extracted coconut meal on egg production performance, egg quality, carcass characteristics and biochemical parameters from 21 to 52 weeks in 180 single comb white leghorn layers. Dairo and Fasuyi (2008) conducted an experiment for evaluation of fermented palm kernel meal and fermented copra meal proteins as a substitute for soybean meal protein in laying hens diets. Samson (2006) studied the heat treatment on coconut meats and coconut meal and reported that there was a marked loss of lysine availability upon heating coconut meats with hot air at 120°C while coconut meal can tolerate 105°C air for at least 60min without significant loss of protein solubility. Chy et al. (1983) had prepared protein isolate from defatted coconut and soybean meals.

A number of value added products from coconut are available internationally but only few got consumer preference in India (Singh et al. 2007). Industries are commercially producing desiccated coconut, coconut milk powder and packed tender coconut water are being marketed at present in India. Coconut chips, tender coconut as snow ball type or minimally processed and virgin coconut oil are produced at community level and marketed. Standards for packed and preserved tender coconut water are reported by Sabapathy and Bawa (2007). The byproduct obtained during VCO production is currently not effectively utilized for any value addition. Some value added
products such as coconut chips and snow ball tender nut were developed by Central Plantation Crops Research Institute (Bosco et al. 2002).

2.11 Food products prepared from various oil meals

2.11.1. Traditional Indian sweets (*burfi* and *ladoo*)

The top three countries that are in leading position in production of coconut are Indonesia, Philippines and India. In India coconut is cultivated in an area of about 1.78 million hectares. According to FAO (2004) production data, the world annual coconut production was 53.00 million tonnes which yielded about 1.80 million tonnes of coconut meal. India’s coconut meal production was 0.28 million tonnes which was about 15.4% of world production (Moorthy and Viswanathan 2009). In India from long time people always prefer traditional sweets not only on festival season but also during common days. The unity in diversity is also comes out in our sweet-meat products so it is difficult to predict the origin of any sweet items. Coconut based *ladoo* is a highly popular Indian sweet and is a rich source of fibre and protein. It is prepared from desiccated coconut powder, sugar or jaggery, wheat flour and hydrogenated fat after adding dry fruits such as cashew nuts, almonds and flavoring substances like cardamom. Because of its moisture content (12-15%) and its non acidic nature, spoilage in *ladoo* is mostly caused by growth of surface yeast and molds, often accompanied by fermentive and acidic odours. Due to their high susceptibility to microbial spoilage, coconut *ladoo* have very short shelf life. At present, coconut *ladoo* are generally prepared by small scale confectioners and sold loose without any protective packaging. Some workers have tried to extend the shelf life of desiccated coconut powder based traditional Indian sweet products viz. *holige, modaka, burfi* (Satyanarayan Rao 1992 a, b; Gupta et al. 2010).

The consumption of sweets is an integral part of the Indian dietary system. The term *burfi* is generally coined for traditional sweets prepared by using *khoa* (Sawhney et al. 1997). Several varieties of *burfi* are available in the market such as plain *khoa burfi*, fruit and nut, cashew *burfi* (Satyanarayan Rao et al. 1993), chocolate, groundnut *burfi* (Khan et al. 2008), saffron and rawa *burfi* (Sarkar et al. 2002). Due to accelerated microbial activity, chemical deterioration and textural changes in product ultimately results in poor keeping quality with unpredictable shelf life (Suresh and Jha 1994). As sweet items are highly relished by children, products like *burfi* will go a long way to provide nutritious, calorie dense and highly palatable products to the consumers. Satyanarayan Rao et al. (1993) standardized the processing conditions for cashewnut *burfi* and evaluated the requirement of packaging materials for a long shelf life of the product.
Sharma et al. (1992, 2003) have reported that the preparation and storage behavior of besan and moong dhal *burfi* in various packaging materials. Vijayalakshami et al. (2005) extended the shelf life of *burfi* through packaging in metalized film/foil laminate under different atmospheric conditions. Although, most of the traditional Indian sweet dishes have attained familiarity in all parts of the country, yet their manufacture is still best done in their place of origin. Coconut *burfi* is a popular traditional Indian sweet of south India. Variations in ingredients, their proportions and processing conditions affect the quality of *burfi* and lack of knowledge in these aspects is a serious limitation for the process standardization and quality control (Chetana et al. 2010). Satyanarayan Rao et al. (1990a) described the process for the preparation of coconut *burfi* using dehydrated coconut powder, jaggery, whole milk powder, vanaspati (hydrogenated fat) and cardamom powder.

As the data on the preparation of traditional sweet like *ladoo* and *burfi* with the incorporation of VCM are scanty and attempts was made to standardize the recipe, processing methods as well as shelf stability.

### 2.11.2. Bakery products (Biscuit and Cake)

The term biscuit is used in Britain to describe a flat crisp baked product. Biscuits are chemically leavened, ready to eat, quick snacks with good eating quality and long shelf life (Singh et al. 1993). The basic constituent of biscuit is flour, water, sugar and fat. The variation in these constituents causes the changes in textural properties of biscuits (Zoulikha et al. 1998). Biscuits are highly popular among the large segment of population in urban and rural places and its demand and consumption are increasing by leaps and bounds. Children also like the biscuits as these are available in different attractive shape and size as well as taste and palatability.

The bakery industry are one of the largest organized food industries all over the world and particularly biscuits are one of the most popular products because it is economically cheaper as well as considered to be luxurious gifts for infants and school going children who are under weight (Sindhuja et al. 2005). Bakery products are generally used as a source for incorporation of different nutritionally rich ingredients for their diversification (Sudha et al. 2007).

Various types of nutritious biscuits have been prepared by fortifying the wheat flour with various types of oil seed meals like soy flour (Tsen et al. 1983), peanut (Subrahmanyan 1958), corn germ flour (Blessin et al. 1972), cotton seed flour (Fogg and Tinklin 1972), sunflower kernel (Bajaj et al. 1991), safflower protein isolate (Ordorica and Pareds 1991) and coconut residue (Khan et al. 1976) and received popularity being nutritionally rich in protein and vitamins. Biscuits prepared from flour blends containing varying proportions of sorghum flour (0, 10, 20, 30, 40, 50 and 60%) and fortified with
5% defatted soy flour leads to decrease in spread ratio as increased proportion of sorghum flour similar trend found out in dough strength while hardness, toughness, breaking force and breaking energy of biscuits increased (Mridula et al. 2007).

Tyagi et al. (2007) replaced the wheat flour by defatted mustard flour at 5, 10, 15 and 20% incorporation levels in biscuit preparation. The protein content of mustard flour biscuit increased nearly 2.5 times as a result of mustard flour incorporation, coupled with reduction in fat and an increase in fibre content. Sensory evaluation results revealed that the sample containing 15% defatted mustard flour scored highest in most of the attributes including overall acceptability. Textural characteristics of all dough and biscuit upto 15% supplement of defatted mustard flour were similar while at 20% level, the values were significantly different. The study reveals that incorporation of 15% defatted mustard flour gave desirable results in terms of nutritional, sensory and textural attributes of mustard fortified biscuits.

Sudha et al. (2007) studied the incorporation of fibre from wheat, rice, oat and barley to study their influence on rheological characteristics of wheat flour dough and biscuit making quality. Farinograph characteristics of the wheat flour-bran blends showed increase in water absorption from 60.3% to 76.3% with increase in the level of bran from 0 to 40%. The resistance to extension values as well as extensibility of the dough decreased with increase in the bran level. The spread ratio of the biscuits prepared from wheat, rice and oat bran blends decreased from 8.38 to 7.52, whereas the same increased to 9.3 for biscuits prepared from barley bran blends. The breaking strength values of biscuits ranged between 1.34 and 3.83 kg. Highly acceptable biscuits could be obtained by incorporating 30% of oat bran or 20% of barley bran in the formulation.

Singh et al. (2003) used the composite flours from wheat, green gram and black gram for the preparation of biscuits. Protein content of biscuits increased as the level of the pulse flours increased. Wheat flour containing bengal gram and black gram flours adversely affected the top grain texture and color of biscuits. Biscuits made with higher levels of bengal gram (more than 15%) were tough and difficult to break and required higher compression force. Addition of green gram flour did not significantly affect top grain, texture and color of biscuits. The biscuits made from 15% green gram supplemented wheat flour scored the highest for flavor characteristics. Thickness, diameter and spread ratio of biscuits containing different levels of pulse flours were significantly different from control sample. Sensory evaluation scores showed that acceptable biscuits can be prepared from wheat flour supplemented with these pulse flours at a level of 15%.

Incorporation of soy protein into a fried cookie could give health benefits and therefore may result in an increased consumption of the product. Soy protein provides
several functionalities such as water holding, binding and emulsifying properties (Arrese et al. 1991). Watters (1978) reported that 20% or 30% soy flour substitution adversely affected the baking performance of a cookie type product.

Gomez et al. (2010) checked the effect of wheat bran, oat bran with different particle size and percentage on batter and layer cake characteristics, and found that batter density, rheological properties and sensory characteristics were significantly affected with increased percentage of fibre content. Shafer and Mary (1978) studied the effect of flour substitution with two varieties each of hard red, soft red and soft white wheat bran, commercial wheat bran, corn bran, soy bran and oat bran on quality characteristics of layer cakes and that batter viscosity was higher for cakes with non wheat brans, but cakes were less tender and received lower total sensory scores. However, the cake with the corn bran had the highest volume. Cakes with corn and all types of wheat bran were acceptable; however, oat and soy bran substitution produced cakes with poor flavor.

Though a lot of research and development work has been carried out on the development of nutritious bakery products like biscuits and cake, but information on the utilization of VCM and their effect on the overall quality of biscuit and cake were scanty, hence, studies were undertaken to develop nutritious bakery products with better sensory attributes as well as nutrition value.