SUMMARY & CONCLUSION
5.0 Summary and Conclusion

5.1. The quality attributes of virgin coconut oil (VCO) produced by hot and cold processes

Both hot and cold extracted VCO have been subjected to the various quality parameters. There was a marginal difference in iodine value, saponification value, refractive index, fatty acid profile, specific gravity and moisture content of HEVCO, CEVCO and CCO samples.

The phenolic component of the HEVCO, CEVCO and CCO were found to be 650.35±25.11µg/gm, 401.23±20.11µg/gm and 182.82±15.24µg/gm respectively. The antioxidant activity ranged from 80-87% in HEVCO, 65-70% in CEVCO and 35-45% in CCO. It has been concluded that VCO obtained from hot extraction process was found to be better in comparison to CEVCO samples in terms of bioactive components i.e. total polyphenol, antioxidant activity, tocopherol, phytosterol, monoglycerides and diglyceride content in both type of VCO samples than CCO samples.

5.2. Evaluation of the shelf life of virgin coconut oil (VCO) in different packaging materials

The physicochemical parameters analyzed in different packaging systems containing CEVCO and HEVCO. At the beginning of the study all the physicochemical parameters were within the limits established by the legislation, but vary during the 12 months of storage. The acidification and oxidative rancidity of the CEVCO and HEVCO increased after 12 months of storage. The degree of unsaturation tends to decrease as the expiry date becomes closer and although the percentages of fatty acid remain constant until 12 months of storage.

From the present study, it is evident that both the oils viz. CEVCO and HEVCO remained in stable and acceptable condition for 12 months in RT (15-35°C) and 37°C. The rate of lipid peroxidation was found to slightly higher in CEVCO as compared HEVCO. Among the packaging material studied, MP and HDPE provided the best protection towards oxidation and dhal fried in these oil samples were rated higher sensory acceptable score.
The refractive index, iodine value and moisture content of both CEVCO and HEVCO were not increased during the entire storage period both in flexible and rigid packaging system. There was decrease in OAA of bengal gram dhal fried in stored CEVCO and HEVCO samples in flexible as well as rigid packaging systems.

5.3. Studies on the stability of blended VCO with non-conventional oil in different packaging system.

Blending of oil would be highly beneficial not only from nutrition point of view but also for maintaining good health. The blending of VCO-RSOY and VCO-RSAFF has been encouraged to modify the fatty acid composition of the oil because RSOY and RSAFF rich in PUFA while VCO is rich in SFA. All the blends of VCO-RSOY and VCO-RSAFF had SFA: MUFA: PUFA ratio nearby to ideal fatty acid composition.

RSOY and RSAFF were characterized by its high PUFA while VCO for SFA and this difference was reflected in IV. Blending has strong influence on IV which can be improved with the increase percentage on VCO. From the present study it is clear that iodine value of VCO-RSOY and VCO-RSAFF blends had decreased with the increase percentage of IV in comparison to RSOY and RSAFF.

DSC provides useful information regarding the nature of thermodynamic changes that are associated with vegetable oils transforming from one physical state to another. These physical properties includes melting and crystallization event which require the intake and release of energy. These thermodynamic changes are affected by the chemical composition of the oils mainly fatty acid profile.

The specific spectral regions prove to be very useful for the determination of adulteration as well as for the study of oxidation process. A band shift observed at 3008cm⁻¹, 1652cm⁻¹, 1397cm⁻¹, 1097cm⁻¹, 912cm⁻¹ and 845cm⁻¹ have been used to differentiate RSAFF from VCO as VCO spectrum do not have these chemical shifts. Further the spectrum of RSOY showed same band shifts as RSAFF except 1652cm⁻¹, 1397cm⁻¹, 869.6cm⁻¹ and 845cm⁻¹.

The sensory evaluation of VCO-RSOY and VCO-RSAFF blends in different proportions (20:80, 40:60, 60:40, 80:20) with bengal gram dhal frying gave an idea that blends with
20:80 VCO-RSOY and VCO-RSAFF found to higher score by panelist than the other blends.

The data obtained from storage study of 20:80(v/v) VCO-safflower oil blend and VCO-soybean oil showed 12 months storage stability in different packaging system in terms of PV, FFA, TBA, AV, TC and OAA.

5.4. Evaluation of the thermal stability of virgin coconut oil (VCO)
In the present investigation initially specific absorbtivity CD$_{232}$ and CT$_{270}$ of VCO sample was 0.04 and 0.03 which was continuously increased upto 0.79 and 0.31, respectively, after 8hrs of continuous frying. It was found from the present study that the levels of conjugated dienes are higher than trienes, this is indicated by the higher values of specific absorbitivity at 232 nm.

The results of the present study showed that VCO was stable and acceptable after 8 hrs of soaked Bengal gram dhal frying. The VCO was stable as indicated by peroxide value, FFA, TBA, TC and anisidine value. The PV initially increased with the frying time but after 8 hrs of frying it got decreased due to hydroperoxides decomposition.

The L* value decreased from 5.12 to 2.02 with repeated frying cycle of the oil, which contradicted with the increase in a* from -1.42 to 5.39 and b* value from 0.52 to 5.12. The rate of darkening of oil during frying was found to be directly proportional to the frying time.

Viscosity of VCO was strongly affected by its degradation products. In the present study the viscosity was increased from 50.87 to 91.05cp as a result of formation of dimmers, trimers, polymers, epoxides, alcohols and hydrocarbons.

High frying temperature and time leads to polyphenol oxidation due to radical scavenging activity leading to decrease in antioxidant activity. As such, after 8hrs of frying VCO was found to be acceptable and stable.

5.5. Development of value added traditional Indian sweets and evaluation of their storage stability
5.5.1. VCM ladoo
The present study suggested that earlier oil meal (i.e. left over material after oil extraction) which was utilized in the cattle feed purpose can be incorporated in traditional sweet products to give more earning to small scale industry people. The different ingredients were optimized following response surface methodology with three independent variables i.e. sugar (27%-37%), water (7%-17%) and VCM (20%-28%) and sensory attributes as responses. The recipe for optimized VCM ladoo was VCM (23%), desiccated coconut powder (12%), whole wheat flour (8%), sugar (32%), hydrogenated fat (10%), fried cashew nut (2%) and water (13%).

The optimized VCM ladoo had 12.26% moisture, 30.34% fat, 5.23% protein, 33.1% total sugar, and 5.26% crude fibre, 0.69% total ash providing 481.62 Kcal 100 g⁻¹ of energy. Lauric acid (35.08%) was the major fatty acid present followed by palmitic (21.76%), oleic acid (19.45%). The concentration of potassium (467.68mg 100 g⁻¹) in VCM ladoo was high and this may be attributed to a high level of potassium in coconut meal.

The changes in the quality of VCM ladoo packed in polypropylene (PP, 75 µ) and laminates of metalized poly-ester (MP, 75 µ) were monitored during storage to establish the shelf life under ambient temperature conditions (15°C-35°C). Samples without added potassium sorbate spoiled within three weeks of storage due to mold growth and fermented odour. VCM ladoo containing sorbic acid did not support any microbial growth during storage up to 4 months, however, during storage samples packed in PP lost moisture and became hard and brittle, while those packed in MP remained soft. Peroxide and thiobarbituric acid values were higher in PP packed samples as compared to those packed in MP. Sorbic acid degraded during storage of ladoo and the rate of degradation was higher in PP packed ladoos than that in MP packed ones.

5.5.2. VCM burfi
Response Surface Methodology (RSM) was successfully utilized for optimization of the levels of various ingredients for burfi (an Indian traditional milk based sweet). The optimized recipe for VCM ladoo is 30gm for VCM, 15gm for skim milk powder, 45ml for water and 36gm sugar.

The nutritional benefits of VCM ladoo showed 13.35% moisture, 15.12% fat, 8.56% protein, 5.81% fibre, 1.45% ash, 55.71 % carbohydrate (by difference), 30.18mg/100gm Iron, 5.32mg/100gm calcium, 33.86mg/100gm sodium, 941.05mg/100gm potassium and 0.98mg/100gm zinc.
The changes in quality of VCM burfi packed in polypropylene (PP) and metallised polyester (MP) were monitored during storage in order to assess the shelf life. The samples without sorbic acid spoiled within 15 days of storage due to mold growth and rancid flavour. VCM burfi containing sorbic acid did not support any microbial growth during the entire storage period. Peroxide and thiobarbituric acid values were higher for the product packed in PP than for the one packed in MP pouches. Sorbic acid degraded during storage of VCM burfi and the rate of degradation was higher for samples packed in PP than those packed in MP pouches. As per the chemical changes, autoxidation of lipids was not the main determining factor but the texture and sensory quality of burfi during storage. Apart from microbiological spoilage, texture hardening was the most limiting factor for shelf life.

5.6. To study the effect of virgin coconut meal on different quality attributes of selected bakery products

5.6.1. VCM biscuit

From the above investigation it can be concluded that though biscuits containing 20-25% VCM were nutritionally rich in terms of protein (5.82, 5.97%), fibre (2.91, 3.55%) and minerals but scored lower sensory attributes than the ones prepared from 15% VCM.

Textural property of dough clearly showed that hardness (from 6.14 to 8.55N) and toughness (from 26.42 to 46.05Nmm) were increased while stickiness (from 3.58 to 2.19N) and adhesiveness (from 1.56 to 0.57Nmm) decreased which affected the texture properties of biscuits.

Color characteristics of biscuits such as L*, a*, b* values varied significantly (p≤0.05) with addition of VCM (5-25%) than the control. The L* value decreased from 55.06 to 50.94 with the addition of VCM while a* and b* value increased from 5.55 to 8.91, 21.41 to 25.15, respectively.

The data obtained from thermal property showed that onset (Tₒ), endset (Tₑ) temperatures and enthalpy of gelatinization (ΔH) got affected by VCM. The present study revealed that Tₒ decreased from 60.78 to 59.04°C while Tₑ and ΔH showed decrement from 86.74 to 98.75°C and 14.87 to 90.53 Joule/gm.

The study established that the incorporation of 15% VCM results in not only nutritious product but also more acceptable in comparison to other VCM biscuits on the basis of...
sensory and textural characteristics by panelists. The commercialization of this product, *i.e.* transfer of technology has been done during the work tenure to M/S Subicsha, Nochad (via) Naduvanoor, Calicut, India.

### 5.6.2. VCM cake

Virgin coconut meal (VCM) based cakes were prepared by replacing refined wheat flour (maida) from 5 to 20% level as it is a good source of fibre, protein and mineral content which has beneficial health and nutritional effect and its effect were evaluated on chemical, textural and rheological attributes of cake and its batter.

From the data shown in this study revealed that volume and symmetry index got decreased with the higher percentage of VCM from 11.71 to 9.72 and 1.01 to 0.41, respectively. However, uniformity index, specific gravity and weight loss increased from 0.21 to 0.71, 1.01 to 1.25 and 19.85 to 39.55 respectively which lead to the increase in hardness from 24.22 to 32.79 N and decrease in gumminess from 25.20 to 17.47 and chewiness from 20.51 to 13.37.

Color characteristics of cake such as L*, a*, b* values showed that with addition of VCM decreased L* value while a* and b* values were increased in comparison to control. The study has shown a potential use for VCM in the preparation of bakery products such as cake. The effect of flour replacement with VCM increased the viscosity of batter.

The cake contained higher protein, ash and fibre than the control samples. The data obtained from thermal property showed that onset ($T_o$), endset ($T_e$) temperatures and enthalpy of gelatinization ($\Delta H$) got affected by VCM.

### 5.7. To study the effect of virgin coconut oil (VCO) on lipid profiles in hypercholesterolemic rats

The present epidemiologic study was aimed and designed to elucidate the hypolipidimic effect of cold Virgin Coconut Oil (CEVCO) and hot extracted (HEVCO) in comparison to commercially available coconut oil (CCO). In order to this a total of 42 male Wistar rats were divided into 7 dietary groups of 6 rats each. The groups were designated as control, hypercholesterimic control (HC), HC+10%CEVCO, HC+15%CEVCO, HC+10%HEVCO, HC+15%HEVCO and HC+15%CCO.
The rats in the control group were fed a basal diet (BD) (which included wheat starch, casein, coconut oil, vitamin, and mineral mixture) and rest of the groups were initially made hypercholesterimic by feeding hypercholesterimic diet (cholesterol 2% and bile salts 0.25% in basal diet) for 15 days and further fed with CEVCO, HEVCO (at 10% and 15% levels) and commercial coconut oil (15%) for 30 days along with control animals fed with commercial coconut oil.

After 30 days of feeding the total cholesterol, low density lipoprotein (LDL) was significantly (p ≤ 0.05) decreased ~25% and ~40% respectively in blood plasma while HDL increased significantly (p ≤ 0.05) ~21% in rats fed with HEVCO. The reduction in TC, LDL level and increase in HDL was high in HEVCO fed rats than CEVCO and CCO fed ones. Tissue cholesterol Triglycerides content in both liver and heart decreased significantly (p ≤ 0.05) high in animals fed with CEVCO and HEVCO than CCO fed rats.

In conclusion we have clearly established the hypolipidemic/cholesterimic effects of both CEVCO and HEVCO in hypercholesterimic rats. These oils may be helpful in reducing obesity due to their properties of not depositing in tissues due to faster metabolism of fatty acids present in them besides increasing the antioxidant status.

5.8. Study the effect of virgin coconut oil (VCO) on modulation of diabetes in experimental animals.

Virgin coconut oil (VCO) extracted from hot process contained better antioxidant properties than cold extracted VCO. Diabetes was induced in rats using streptozocin (55 mg/kg intraperitoneal injection). The treatment schedule was set for feeding of CEVCO, HEVCO and CCO at different concentration for 21 days. In order to this a total of 56 male Wistar rats were chosen and divided into 7 dietary groups of 8 rats each; the groups were designated as Control, diabetic control, D+10%CEVCO, D+15%CEVCO, D+10%HEVCO, D+15%HEVCO and D+15%CCO.

Blood glucose (once in 5 days), body weight gain, food intake (once in week) and water intake, urine output (daily) were monitored. Total cholesterol, triglycerides (TG), serum creatinine, urea, glutamate-pyruvate Transferase (SGPT), glutamate-oxalate Transferase (SGOT) activities were measured. Based on the data obtained from this study, it is concluded that the HEVCO was better than CEVCO in enhancing the antioxidant status and reducing the blood glucose. The better results of HEVCO may be attributed to its higher polyphenols content.
Our results on streptozotocin induced diabetic rats, CEVCO, HEVCO possess significant anti-diabetic activity on chronic treatment, indicating its possible applications in diabetics. More prominent and significant results were obtained with HEVCO then compared to CEVCO and CCO.

The histopathological study has shown anti-inflammatory, cellular infiltration, cytoprotective, and pancreatic enlargement. Anti-lipidemic properties in liver indicating not only its efficacy in overcoming from diabetes but also autoimmune disorders. HEVCO and CEVCO possess anti-diabetic, nephroprotective and cytoprotective activities probably due to the presence of anti-oxidant active constituents (polyphenols, phytosterols) present in high numbers than compared to CCO.

Based on improvement in enzyme levels, physical parameters and histological studies, it is concluded that both the oils possesses antidiabetic effect and thus support the traditional application of the same under the light of modern science.