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From Editors Desk

Dear Readers,

It is my great pleasure and honor to bring forth the first issue of the Journal of Lipid Science & Technology (JLST) for the year 2021 to you.

The Journal intends to be the mainstream representation of Oil Technology. A meticulous attempt has been made to include the articles of 'classic' as well as 'modern' Technology. However, I must admit that there can be honest and healthy differences over what to count as a classic and as modern.

This issue of the Journal of Lipid Science and Technology of Oil Technologist Association of India (OTAI) comprises papers collected and reviewed by eminent scholars & researchers. The work reflects the research work of the scientists who have not only come up with innovative and groundbreaking ideas, but have also articulated them in an uncomplicated fashion.

The consumption pattern of fats and oils, both in terms of quantity and quality has changed over the years. However, there continues to be a lack of awareness amongst consumers about the health effects of both. Therefore, the need of the hour is to plan and implement public health awareness programmes to promote moderate consumption of fats & oils where the intake of omega 3 PUFA and MUFA is favored. Simultaneously, awareness needs to be fostered that the intake and usage of Saturated Fatty Acids (SFA) is lowered and Trans fatty Acids (TFA) is negligible.

Fats which are worse for health are the industrially-produced trans-fats. They are present in partially hydrogenated fats used extensively in bakery products and fried foods. Globally, the target to eliminate these fats from the food supply chain is by 2023. The Indian food regulator Food Safety and Standards Authority of India (FSSAI) has set out an aggressive target to achieve less than 2% industrially-produced trans-fat content by 2022.

The Editor-in-Chief wishes to thank all the contributors. I am also thankful to reviewers who have taken great pains to meticulously review the contributions. Hope this volume will serve the purpose of research & development for students and the members of OTAI.

I would be happy to receive any feedback regarding the JLST. Please feel free to email me your inputs and comments.

Prof. Rakesh Kumar Trivedi
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Comparative effect of hypolipidemic and anti-platelet aggregative role of different medium chain fatty acid rich rice bran oils against hypercholesterolemic rats

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ABSTRACT

Medium chain fatty acids (MCFAs) containing structured lipids are known to potray different beneficial effects. Rice bran oil (RBO) is very good upcoming cooking oil used in many households nowadays due to its high oryzonal content which is a potent antioxidant present only in RBO. The modification of RBO with MCFAs leads to the production of new kinds of nutraceutical or structured lipids. The purpose of the present study was to assess the nutraceutical effects of prepared structured lipid in normal and hypercholesterolemic cases.

In the present study three kinds of MCFA rich RBOs, caprylic acid rich RBO, capric acid rich RBO and lauric acid rich RBO are prepared by using packed bed bioreactor. Sixty six male albino rats divided into ten groups were investigated to know the role of MCFA rich RBOs on normal and hypercholesterolemic cases in comparison to native RBO. The MCFA rich RBOs were given to the rats daily for 4 weeks. The plasma, liver and brain lipid profiles were elevated in hypercholesterolemic group, but were significantly lowered by both RBO and MCFA rich RBOs. Platelet count and aggregation were increased in hypercholesterolemia, but effect was reversed by feeding the rats with MCFA rich RBOs. Microscopic study of liver cells highlighted the abnormal fatty change in the liver due to hypercholesterolemia which was altered by administration of RBO and MCFA rich RBOs. Osmotic fragility data suggested that the erythrocyte membrane of hypercholesterolemia was relatively more fragile than that of the normal rat's membrane which could be reversed with the addition of MCFA rich RBOs. In all the cases the effect of MCFA rich RBOs was much better than native RBO. Among the MCFA rich RBOs caprylic acid rich RBO portrayed the best result.

Key words: Rice bran oil; Medium chain fatty acids; Hypercholesterolemia; Plasma and tissue lipid profile; Platelet aggregation; Osmotic fragility

1. INTRODUCTION

The development of atherosclerosis is positively correlated with increasing levels of cholesterol and low density lipoprotein (LDL) and decreasing levels of high density lipoprotein (HDL) in blood. Atherosclerosis is an established major risk factor for coronary heart disease.

The beneficial effects of rice bran oil (RBO) have already been established. Nutritional studies in animals and humans have shown a cholesterol-lowering potential of RBO. Crude RBO contains an unusually high content of unsaponifiables (upto 4.4%) like phytosterols, squalene, oryzanol and

tocotrienols at a level which is much higher than other vegetable oils. The hypolipidemic effect of RBO is explained by the presence of essential fatty acids and also due to the greater content of unsaponifiables. It has also been reported that RBO improve lipid abnormalities, reduce the atherogenic index.

Medium chain fatty acids are saturated fatty acids with a chain length between 8 and 12 carbon atoms. They are found in medium chain triglycerides (MCT). They require less bile salts for solubilization, are not re-esterified in the enterocyte and are transported as free fatty acid, bound to albumin, through the portal system. Because the portal blood flow rate is about 250 times faster than lymph flow, MCT are digested quickly and are not likely to be affected by intestinal factors that inhibit fat absorption. Medium chain fatty acids are stored in adipose tissues but are oxidized to acetic acid. Furthermore, MCTs have been shown to enhance thermogenesis (i.e., fat burning). MCTs have been shown to suppress appetite, an ability of obvious benefit for those attempting to lower their intake of total calories. MCTs have a number of properties that may be beneficial in preventing atherosclerosis. Among these are that MCTs have anti-coagulation effects, and have been shown to lower serum cholesterol. In addition, MCTs reduce levels of cholesterol in the liver and other tissues. MCTs have also been reported to act as antioxidants and reduce tissue requirements for Vitamin E. MCTs have a slight hypoglycemic (blood glucose-lowering) effect, and thus may be useful for diabetics. Thus MCT can be used for a patient suffering both from atherosclerosis and diabetes in conjugation. MCTs have proven useful in treating a number of medical disorders that involve impaired or damaged lipid metabolism. These include: obstructive jaundice, biliary cirrhosis, pancreatitis, cystic fibrosis, celiac disease, Whipple's disease, Crohn's disease, regional enteritis, and malabsorption in neonates. Natural MCT occur in milk fat, coconut oil and palm kernel oil. Clinically, MCT oil is used for patients with fat malabsorption or in catabolic states such as acquired immune deficiency syndrome and cancer.

MCTs is however attributed by a major adverse effect namely nausea and gastric discomfort. This can be minimized or eliminated by starting with very small doses initially and increasing the dose as tolerated. Due to the ever increasing scope of structured lipids or modified lipids RBO can be esterified by biocatalyst with medium chain fatty acids (MCFA) to obtain the beneficial effects of both RBO and MCFAs. Thus the aim of this study was to evaluate the hypolipidemic effect of MCFA rich RBOs.

2. MATERIALS AND METHODS

2.1 Materials

Rice bran oil was physically refined and bleached in the laboratory. Caprylic acid (C8:0), capric acid (C10:0) and lauric acid (C12:0) was obtained from Sigma Chemical Company. Lipase RMIM was a gift from Novozyme India Pvt. Ltd. All other reagents used were of analytical grade and procured from Merck India Ltd. Mumbai, India.

2.2 Preparation of Oils

The reaction between caprylic acid, capric acid and lauric acid with rice bran oil was carried out in a packed-bed bioreactor. The reactor consisted of a tubular glass column of 10 mm ID and was 50 cm long. It was also provided with a water jacket for temperature control. The immobilised enzyme (*Rhizomucor mehei*) packed into the reactor was retained in place by means of a sintered plate. The substrates were fed from the top and the products were collected at the bottom. The substrates were previously blended and well mixed at the reaction temperature before conducting the packed-bed reaction and were poured into the enzyme bed, maintaining a fixed sample head. Water from a constant temperature bath was circulated through the jacket by a peristaltic pump. A partial suction was given to maintain the constant flow rate (0.4 mL/min; optimized in the previous study); 20 g of enzyme was closely packed into the column by repeated tapping to avoid any air gaps. Transesterification reactions were then carried out

by passing the substrate through the column. The temperature was maintained at the desired value of 60ºC by passing water through the column jacket. The product mixture was collected at the outlet, steam stripped for removal of excess fatty acids and the fatty acid composition of the oils was determined by gas chromatography (GC).

2.3 Chromatographic analysis of oils

Fatty acid compositions of native and MCFA rich rice bran oil were analysed by GC. The oils were saponified with 0·5 M KOH and methylated with boron trifluoride in methanol. The gas chromatograph (Agilent 6890 N; J&W Scientific, Wilmington, DE, USA) was fitted with a DB-Wax capillary column (30m x 0·32mm x 0·25 mm) and a flame ionization detector. N2, H2 and airflow rate were maintained at 1, 30 and 300 ml/min, respectively. Inlet and detector temperatures were kept at 250ºC and the oven temperature was programmed to increase from 150 to 190°C at a rate of 15°C/min, then to hold for 5 min, and then to increase to 230°C at a rate of 48°C/min, and then again to hold for 10 min.

2.4 Animals

Male Charles Foster rats weighing 80-100gms were grouped into ten groups (six rats in each group) by random distribution and housed in individual cages, under a 12h light/dark cycle. Animals were given a fresh diet daily, and the leftover food was weighed and discarded. The gain in body weight of animals was monitored at regular intervals. The animals had free access to food and water throughout the study. The animals were divided into ten groups with six rats in each: Group I: vehicle treated control animals, Group II: rats fed with rice bran oil instead of control oil, Group III: rats fed with caprylic acid rich rice bran oil, Group IV: rats fed with capric acid rich rice bran oil, Group V: rats fed with lauric acid rich rice bran oil, Group VI: rats were fed with cholesterol (1%) for 32 days, Group VII: rats received rice bran oil along with cholesterol (1%) for 28 days, Group VIII: rats received caprylic acid rich rice bran oil along with cholesterol (1%) for 28 days, Group IX: rats received capric acid rich rice bran oil along with cholesterol (1%) for 28 days, Group X: rats received lauric acid rich rice bran oil along with cholesterol (1%) for 28 days; Groundnut oil was used as the vehicle and given to all the groups. At the end of the experiment the feeding of rats was stopped and after 12h fasting, the rats were anesthetized by chloroform and 5ml of blood was taken from the heart. The plasma was obtained by centrifugation of the blood. The liver, brain and mesentery was removed, rinsed with ice-cold saline, blotted, weighed and stored at -20°C until analyzed. The experimental protocol was approved by the Animal Ethical Committee of Dept. of Chemical Technology, University of Calcutta.

2.5 Apparent fat digestibility

The samples of freeze dried diet and faecal matter were taken for analysis. The total crude lipid content of both the diet and the faecal matters were measured with the help of soxhlet apparatus. Apparent fat digestibility was calculated from the difference between intake and excretion expressed as a fraction of total lipid ingested during the balance study.

2.6 Apparent protein digestibility

The total crude protein content of both the diet and the faecal matters were measured with the help of Kjeldahl method (Archibald, 1958). Apparent protein digestibility was calculated from the difference between intake and excretion expressed as a fraction of total protein ingested during the balance study.

2.7 Analysis of Plasma Lipids

According to the standard methods, the lipid components such as total cholesterol, HDL cholesterol and triglyceride were analyzed using enzyme kits supplied by Merck India Ltd., Mumbai, India.

2.8 Analysis of Tissue Lipids

Tissue (liver, brain and mesentery) lipid was extracted by the method of Folch et al (Folch *et al*., 1951). One gram of tissue was homogenized with 1ml of 0.74% potassium chloride and 2ml of

different proportions of chloroform and methanol for 2min and then centrifuged. The mixture was left overnight and the chloroform layer was filtered through a Whatman filter paper (no.1). The chloroform layer was dried, the tissue lipid contents were measured and the lipid was used for lipid analysis. The liver and brain lipids were used for the estimation of total cholesterol, triglyceride and phospholipid estimation by using standard kits.

2.9 Analysis of different components of brain phospholipids

The brain phospholipids were separated by TLC (Hexane:diethyl ether-8:2) and extracted with diethyl ether. The extracted phospholipids were separated by reversed-phase HPLC (Nakagawa and Horrocks, 1983).

2.10 Collection of Blood Samples and Measurement of Haematological Parameters

Blood Samples taken from the abdominal aorta were collected in sample bottles containing heparin as anticoagulant. Total white blood counts (WBC), number of platelets, haemoglobin concentration, mean cell haemoglobin concentration (MCHC), mean corpuscular volume (MCV) and haematocrit value were analyzed.

2.11 Platelet preparation

Blood, 4.5ml, was collected from the abdominal aorta of urethane-anaesthetized animals into 0.5ml trisodium citrate (3.8% w/v) and centrifuged (250g, 15min, room temperature) to obtain platelet-rich plasma (PRP).

2.12 Platelet aggregation study

PRP was taken and washed platelets were prepared as described by Paul et al (Paul *et al*., 2007) and suspended in tyrode buffer. Platelets were incubated for 15min at 37°C prior to use. Platelet aggregation measurements were performed using a Chronolog dual channel aggregometer. The aggregometer was calibrated using the light transmission of PRP/platelet suspension and PPP/Tyrode buffer to represent 0 and 100% aggregation, respectively. Platelet suspension 450 µl was stirred at 1000rpm at 37°C and 10 µl of ADP (25m) was added and aggregation followed for at least 5min. The reading was recorded until a plateau was reached.

2.13 Histopathological studies

Permanent preparations were made using routine method (Edem, 2009). The livers were fixed in 10% buffered formalin. The tissues were subsequently dehydrated in upgraded concentrations of alcohol, cleansed in xylene, impregnated and embedded in paraffin wax. Several sections of 3–6 lm were cut using a microtome. The sections were stained with haematoxylin and eosin.

2.14 Marker enzyme assay in liver tissue

Aspartate transaminase (AST), alanine transaminase (ALT) were determined and expressed in terms of U/L. Alkaline phosphatase activity was assayed and expressed as U/L.

2.15 Brain amino acid assay

About 0.1 g of brain tissue was taken and digested for 6 h with 6 N HCl. The digested product was filtered and converted to N-[2,2-bis (ethoxycarbonyl) vinyl] derivatives by for easy spectrophotometric detection at 280 nm. Amino acid profile was determined by HPLC (Waters 2487 with UV detector, column; Nova-pak C_{18}, 3.9 × 150 mm) analysis after hydrolysis of protein and derivatizing the amino acids with diethyl-ethoxy-methylenemalonate (Alaiz *et al*., 1992).

2.16 Changes in erythrocyte membrane

2.16.1. Osmotic fragility determination

The method described by Dacie and Lewis (Dacie and Lewis, 1975) employed here provided different concentrations of sodium chloride 0.1-0.9% in a series of tubes made from appropriate dilutions of 1% sodium-chloride-phosphate buffer, pH 7.4 to a final volume of 5ml. Freshly heparinized blood (20µl) was pipetted into these tubes containing varying sodium chloride concentration. The contents were gently mixed and allowed to stand for 30mins at room temperature. At the end, the contents of the tubes were mixed

again and centrifuged at 500xg for 10mins. Absorbance of the supernatant was measured at 540nm against water blank. The degree of haemolysis was expressed in percentage, where 100% represents full haemolysis.

2.16.2. Preparation of erythrocyte membranes

All procedures were done at 0-5°C (typically on ice) and all centrifugations were performed in a Sorvall SS-34 rotor at 15,000 rpm unless specified. Rat red cells and haemoglobin free ghosts were prepared as described in the literature (Fairbanks *et al*., 1971), except that the haemolysis buffer was 5 m~ NaPi (pH 8), 0.01 mM MgSO4 and the membranes were suspended for 10 min in this buffer before each centrifugation to allow haemoglobin to exit fully.

2.16.3. Extraction of lipids from erythrocytes

The erythrocyte membranes were homogenized with 1 mL of 0.74% potassium chloride and 2 mL of different proportions of chloroform and methanol (1:1 and 2:1 v/v) for 2 min and then centrifuged. The mixture was left overnight and the chloroform layer was filtered through a Whatman filter paper (No. 1). The chloroform layer was dried, the lipid contents of the erythrocyte membrane were measured and the lipid was used for lipid analysis (Folch *et al*., 1951) .

2.16.4. Erythrocyte Membrane Lipid Analysis

The lipid components such as total cholesterol and phospholipid were analyzed using enzyme kits supplied by Merck India Ltd. following the standard methods. After obtaining the total cholesterol and phospholipid values their ratios were also calculated.

2.17. Statistical Analysis

All the data were presented as mean±S.D. Significance was calculated using one way ANOVA by Tukey's Test. Differences were considered significant at $p<0.05$.

3. RESULTS

3.1 Changes in fatty acid composition

Analysis of the medium chain fatty acid rich RBO showed that caprylic acid rich RBO contained 14.00% caprylic acid (C8), capric acid rich RBO contained 13.73% capric acid (C10) and lauric acid rich RBO contained 13.11% lauric acid (C12). The fatty acid compositions of the MCFA rich RBOs, are given in Table- 1.

3.2 Effect of Dietary Lipids on Growth Parameters

The fat level was kept constant at 20% in all the dietary groups. The amount of diet consumed in the different groups was comparable. The effect of feeding dietary lipids on body weight gain of both normal and hypercholesterolemic rats is shown in Table- 2. Animals of all the groups had similar food intake. However there was significant difference between the body weight gain of normal and hypercholesterolemic group ($p<0.01$). There was no significant difference between the body weight gain of the group fed with RBO and the group fed with MCFA rich RBOs in the normal case. On the other hand the body weight gain decreased on feeding the rats with MCFA rich RBOs in hypercholesterolemic condition. The food efficiency ratios of the normal rats fed with four different oils were almost equal. There was no significant difference between the food efficiency ratios of the hypercholesterolemic rats fed with the four oils but they were slightly greater than that of normal rats.

The effect of dietary lipids on organ weights in normal and hypercholesterolemic cases is illustrated in Table- 3. In normal case there was a slight significant change ($p<0.05$) in the weight of the liver and brain on treating the rats with experimental oils in comparison with the control diet. In hypercholesterolemic condition similarly there was significant change in the weight of the liver and brain.

3.3 Changes in Apparent Fat and Protein Digestibility

Table- 4 depicts the changes in apparent fat and protein digestibility. The results show that there was no change in the apparent protein digestibility both in normal and hypercholesterolemic

condition. The fat digestibility however was reduced in rats fed with high cholesterol diet and in rats fed with native RBO diets than in rats fed with MCFA rich RBO.

3.4 Effect of the Different Dietary Lipids on Lipid Parameters in Plasma

The plasma lipid profile of normal rats fed with dietary lipids is shown in Table- 5. The type of fat consumed altered the cholesterol concentration in plasma. Rats fed with RBO had plasma total cholesterol of 130.30mg/dL which was significantly decreased to 65.33mg/dL, 73.33mg/dL and 106.67mg/dL by feeding them with caprylic acid, capric acid and lauric acid rich RBO respectively. Thus the decrease in total cholesterol was maximum in case of caprylic acid rich RBO. The similar results were found in case of estimation of non-HDL cholesterol levels and triacylglycerol levels. Thus the experimental oils lowered the levels of non-HDL cholesterol and triacylglycerol significantly ($p<0.05$). The level of HDL cholesterol, which was known as good cholesterol, increased significantly ($p<0.01$) by incorporating MCFA rich RBOs in the diets of the rat. The increase in the HDL level was much more in case of caprylic acid rich RBO in comparison with capric and lauric acid rich RBO.

The plasma lipid profile of the hypercholesterolemic rats fed with dietary lipids is also shown in Table-5. The levels of all the lipid parameters increased in case of hyperlipidemia in comparison with normal case. Treating the rats with the MCFA rich RBO again decreased the levels of plasma total cholesterol, non-HDL cholesterol and triglyceride levels and increased the level of HDL cholesterol ($p<0.05$). Here also the hypolipidemic effect was much more in case of caprylic acid rich RBO in comparison with capric and lauric acid rich RBO ($p<0.05$).

3.5 Effect of the Different Dietary Lipids on Lipid Parameters of Liver

The liver is an important site for lipid metabolism. Table- 6 depicts the liver lipid profiles of normal and hypercholesterolemic rats fed with dietary lipids. Total cholesterol of liver of rats fed with control oil was 72.34mg/g tissue in case of normal rats and 200.98mg/g tissue in case of hypercholesterolemic rats. These levels of total cholesterol were decreased significantly ($p<0.05$) by treating the rats with RBO and MCFA rich RBOs both in normal and hypercholesterolemic cases. The liver triglyceride concentration was also altered by the type of fat given to the rats. There was a decrease in the triglyceride concentration by 35.89%, 21.8% and 16.24% in normal rats fed with caprylic, capric and lauric acid rich RBO respectively and by 46.98%, 43.92% and 37.88% in hypercholesterolemic rats fed with caprylic, capric and lauric acid rich RBO respectively. There was an increase in the level of phospholipid by treating the rats with the experimental oils. The changes were more in case of MCFA rich RBO than native RBO. Among the three MCFA rich RBOs the effect of caprylic acid rich RBO was maximum.

3.6. Effect of the Different Dietary Lipids on Lipid Parameters of Brain

Table- 7 depicts the brain lipid profiles of normal and hypercholesterolemic rats fed with dietary lipids. Total cholesterol of brain of rats fed with control oil was 58.14mg/dL in case of normal rats and 60.20mg/dL in case of hypercholesterolemic rats. There was no significant change in the levels of total cholesterol by treating the rats with MCFA rich RBO and RBO both in normal and hypercholesterolemic cases. There was an increase in the level of phospholipid by treating the rats with the experimental oils.

3.7 Changes in phospholipid composition of brain

Treatment with the MCFA rich RBO increased the levels of phospholipids both in normal and hypercholesterolemic cases (Table- 8). The effect of the caprylic acid rich RBO was greater than other MCFA rich RBOs.

3.8 Changes in Haematological Parameters

The blood haematological parameters in normal and hypercholesterolemic case that were

considered in the studies are shown in Table- 9. The results show that there were no significant variations in the platelet count, total WBC counts and total RBC counts in the rats fed with control and experimental oils in normal case. However, the haemoglobin level of the rats fed with control oil was lower in comparison with its level in rats fed with experimental oil in normal case. The results show that there was significant increase in the platelet counts from $5.82x10^9$/L in normal case to $9.60x10^9$/L in hypercholesterolemic case. The platelet count was lowered with the administration of all the experimental oils. There was lowering of the haemoglobin level in hypercholesterolemia which was raised by feeding the rats with RBO and MCFA rich RBOs Among the experimental oils, the effect of caprylic acid rich RBO was better than the other MCFA rich RBOs.

3.9 Changes in in vitro platelet aggregation

Table- 10 depicts the changes in platelet aggregation by treatment of the normal and hypercholesterolemic rats with RBO and MCFA rich oils. Both RBO and MCFA rich oils fed rats showed a significant decrease ($p<0.05$) in percent aggregation of platelets. The decrease in percent aggregation was much more pronounced in case of MCFA rich RBO than in case of native RBO both in normal and hypercholesterolemic subjects. The percent of ADP induced platelet aggregation was increased to a very high degree in case of hypercholesterolemia which was decreased significantly ($p<0.05$) by administration with RBO and MCFA rich oils. Among the three MCFA rich oils caprylic acid rich RBO showed the best effect in lowering platelet aggregation.

3.10 Histopathological changes

Microscopic examination of the liver cells of the ten groups was performed and the histopathological slides are shown in Figure- 1. Figure 1a highlighted the hepatic histology of the control rats. Figure 1b highlighted the abnormal fatty change in the liver due to hypercholesterolemia. Figure 1c and d highlighted the treatment of the livers with RBO in normal and hypercholesterolemic cases. Figure 1e and f highlighted the treatment of the livers with caprylic acid rich RBO in normal and hypercholesterolemic cases. The fatty change seen in hypercholesterolemic case was fully cured in case of the treatment with caprylic acid rich RBO. Figure 1g and h highlighted the treatment of the livers with capric acid rich RBO in normal and hypercholesterolemic cases. Figure 1i and j highlighted the treatment of the livers with lauric acid rich RBO in normal and hypercholesterolemic cases. The effect of treatment of the rats with caprylic acid rich RBO was maximum in comparison with other MCFA rich RBOs.

3.11 Changes in Marker Enzymes levels

Table- 11 reveals alterations in hepatic tissue enzyme activities of HCD fed groups and the effect of RBO and MCFA rich RBO treatments compared with controls. In normal case the rats fed with RBO and MCFA rich RBO showed better effects in comparison to normal control rats. In the hypercholesterolemic model of early phase atherogenic fatty changes, the above enzymes exhibit significant elevation in their activities ($p<0.05$). Treatment with RBO and MCFA rich RBO restored their activities to normal level, but the effect of MCFA rich RBO was much better in comparison to native RBO. Among the three MCFA rich RBOs caprylic acid rich RBO showed the maximum ameliorative effect.

3.12 Correlation between HMG-CoA/ Mevalonate Ratio and liver cholesterol

The total cholesterol levels increased in cholesterol stressed groups. With the increase in the total cholesterol level there was a decrease in the HMG CoA: Mevalonate ratio. In the treated groups the level of total cholesterol decreased with the increase in the HMG CoA: Mevalonate ratio (Table- 12).

3.13 Effect of MCFA rich rice bran oil on brain amino acid status

MCFA rich RBO treatments resulted in an increase in glutamic acid content and aspartic acid content and a decrease in the glycine content (Figure- 2). Both RBO and MCFA rich RBO produced

significant change. In comparison to capric acid and lauric acid rich RBO caprylic acid rich RBO produced better effect.

3.14 Osmotic fragility of erythrocytes

The effect of dietary intake of different oils on the osmotic fragility of erythrocytes of the rats fed with different lipids is presented in Table- 13. In normal control rats, the mean cell fragility (50% haemolysis) was being evident at 0.52% NaCl concentration. In hypercholesterolaemic control rats, the mean cell fragility (50% haemolysis) was at 0.95% NaCl concentration. Thus, the osmotic fragility data suggested that the red blood cells of high cholesterol diet fed animals were relatively fragile.

The increased osmotic fragility of red blood cells evidenced in hypercholesterolemic rats was partially reversed by dietary RBO and MCFA rich RBOs as shown in Table 2. The mean cell fragility of red blood cells was reduced to 0.82% NaCl concentration by administration of RBO. The mean cell fragility of red blood cells was further reduced to 0.6, 0.64 and 0.71% NaCl concentration under caprylic, capric and lauric acid rich RBO treatments respectively. This showed that caprylic acid rich RBO was more useful in decreasing membrane fragility.

3.15 Changes in erythrocyte membrane lipid profile

Lipid profiles of erythrocyte membranes of different rats fed with different dietary oils are presented in Table -14. The amount of membrane cholesterol was lower and phospholipid was higher in the normal control rats fed groundnut oil than in the hypercholesterolemic rats in comparison to normal rats. All the experimental oils significantly lowered the alteration in cholesterol and increased slightly the phospholipid content in both normal and hypercholesterolemic condition. Therefore the experimental oils also decreased the C:P ratio to a significant level ($p<0.05$).

4. DISCUSSION

The present study was undertaken to examine the effect of MCFA (caprylic, capric and lauric acid) rich RBO in comparison to the effects of native RBO. Interesterification of rice bran oil with MCFAs resulted in the production of caprylic acid rich RBO containing 14.00% caprylic acid (C8), capric acid rich RBO containing 13.73% capric acid (C10) and lauric acid rich RBO containing 13.11% lauric acid (C12). Both the procedures resulted in the decrease in the contents of polyunsaturated fatty acids from RBO.

The type of oil consumed greatly influences the growth response of the rats. The rats fed with MCFA rich RBO showed a decrease in body weight gain due to the presence of MCT in the oil. Substituting MCFA in a high cholesterol diet resulted in the limitation of the body weight gain produced by hypercholesterolemia. The reason of the effect of weight control by MCFA was due to the fact that MCFA seems to offer a triple approach to weight loss- it has a low calorie content, it is minimally stored as fat and contribute to enhanced metabolism to burn even more calories (Babayan, 1981; Fushiki, *et al*., 1995).

In comparison with the normal subjects the hypercholesterolemic subjects are shown to have hepatomegaly in the liver which was compatible with the study of Trepstra *et al* and Sanchez-Muniz *et al* (Terpstra, et al., 1982, Sanchez-Muniz, *et al*., 1992]. The hepatomegalic condition was reduced by treatment of the rats with MCFA rich RBO and RBO. Triglyceride containing medium chain fatty acids (MCFA) is transported to the liver via the portal vein versus the lymphatic route taken by the long chain fatty acids (LCFA) contained in the triglyceride containing LCFA. MCFA is more rapidly oxidized nearly approaching like a carbohydrate fuel and appears less conducive to fat deposition when compared to LCFA. Therefore the chance of MCT getting deposited in the liver is very less. Therefore the weight and lipid content of the liver of the rats fed with MCFA rich RBO was less compared to RBO fed groups.

The possible harmful effect of hypercholesterolemia is that it leads to increased plasma total cholesterol, plasma non-HDL

cholesterol and plasma triglyceride levels. There is a positive correlation between atherosclerosis and hypercholesterolemia. Triglyceride containing MCFA also has a number of properties that are beneficial towards atherosclerosis. The present study indicated that oil enriched with MCFA resulted in the decrease in total cholesterol levels in plasma. This was due to the fact that in the plasma MCFA readily coverts free cholesterol to cholesterol ester which decreases the content of the former in the plasma. Our data conforms to the above mentioned fact and shows that MCFA rich RBO lowers cholesterol level in plasma.

The data related to liver lipid profile showed that there was a significant decrease in the liver total cholesterol level, non-HDL cholesterol level and triglyceride level by treating the rats with MCFA rich RBO both in normal and hypercholesterolemic condition. In the liver, MCFA contained in MCT is readily β–oxidized to form acetyl-CoA, which is the starting material for cholesterol biosynthesis. The number of acetyl CoA molecules produced by MCFA is much less in comparison with the LCFA, therefore sequentially the synthesis of cholesterol decreases. Thus triglyceride containing MCFA has a cholesterol lowering property in the liver and so MCFA rich RBO was able to reduce total cholesterol in the liver.

There was no significant change in the cholesterol level of the brain of different dietary groups. Cholesterol is the mother of all fat molecules in our bodies. It maintains neurotransmitter and brain function, builds brain and nerve tissue, and nourishes the immune system. It is important in the development of memory and is necessary for the uptake of hormones in the brain. Serotonin, the body's feel good chemical, does not work properly when cholesterol levels drop too low. Cholesterol is the main organic molecule in the brain, making up half the dry weight of the brain. Thus as there is no change in the cholesterol level of the brain lipids, the normal functioning of the brain continues. The phospholipid level however was increased by the administration of both MCFA rich RBO and native RBO in brain lipids both in normal and hypercholesterolemic conditions. **Phospholipids are found in high concentrations in the lining of practically every cell of the body, including brain cells. They help brain cells to communicate and influence the receptors to function properly. Phospholipids** play key **roles** in the structure and function of **brain** cell membranes and cell signaling. Thus the increase in the phospholipids by the experimental oils enhances the protective role of phospholipids on brain.

Hypercholesterolemia increases markedly the platelet count. Their increase in the blood serves as important markers of vascular disease such as microangiopathy and macroangiopathy. The treatment of the hypercholesterolemic rats with MCFA rich RBO decreases the platelet count and thus decreases the chances of vascular disease.

The *in vitro* model of platelet accumulation used in this study has previously been validated and provides a reliable and reproducible method of assessing platelet aggregation responses. It reflects true accumulation of platelets in the pulmonary vasculature that is not simply a consequence of changes in blood flow or distribution. Our results show that the platelets of hypercholesterolemic rats are significantly more responsive to ADP-induced aggregation in vitro than normal rats in terms of peak height. Our study shows that cholesterol is responsible for the observed changes in platelet reactivity, as acute elevation in the cholesterol level had significant effect on ADP-induced platelet aggregation. In the present work, we have only studied aggregation responses to ADP, which is considered to be an important physiological mediator of platelet aggregation. It is released from dense granules of platelets, and acts principally through the platelet $P2Y_{12}$ receptor to induce platelet activation and subsequent aggregation. Clinically, the $P2Y_{12}$ receptor antagonist clopidogrel is widely used for the prevention of arterial thrombotic disease. This may be possibly related to an increase in ADP sensitivity of platelets. This confirms the importance of ADP as a stimulus for thrombotic

disease especially in hypercholesterolemic patients. The results of this study show that, in an animal model of hypercholesterolemia, platelet aggregation was increased *in vitro*, as determined by accumulation of platelets in response to ADP. This may contribute to the increase in arterial thrombotic events seen in this condition, so that an increased ability of platelets to aggregate coupled with endothelial dysfunction and vascular damage which combine to give rise to both macrovascular and microvascular disease. Treatment of the rats with MCFA rich RBO seems to produce an inhibitory effect on platelet aggregation thus reducing the chances of vascular diseases and finally atherosclerosis. Caprylic acid rich RBO produced the best result.

The hallmark of atherosclerosis is the accumulation of cells containing excessive lipids and this is notable in the histopathological observation of the present study where, there was an increased lipid infiltration in hepatocytes of HCD fed rats. Furthermore, the cholesterol levels in the liver of HCD fed rats were also increased. It is reported that supplementation of MCFA rich RBO reduced the lipid infiltration in hepatocytes. The ameliorative effect of caprylic acid rich RBO was more than other two MCFA rich RBOs. This was because supplementation of MCFA rich RBO results in increased excretion of cholesterol from animal, by increasing the transfer of cholesterol into bile. Thus, MCFA rich RBO efficiently reduced the increased lipid infiltration and cholesterol level in hepatic tissue of hypercholesterolemic rats.

Hypercholesterolemia inactivates cell constituents by oxidation or cause oxidative stress by undergoing radical chain reaction ultimately leading to loss of membrane integrity. It is reported that rats fed atherogenic diet results in increased activities of hepatic marker enzymes. This is consistent with our findings in HCD fed rats of present study where we observed increase in the activities of these enzymes in hepatic tissue. This might result from increased oxidative stress as evidenced from oxidation of major biomolecules and diminished antioxidant defense system. MCFA rich RBOs diminished the activities of these marker enzymes. MCFA rich RBO reduced ROS induced inflammation of hepatocytes in HCD fed rats.

Phospholipids are an important component of brain membrane and changes in their membrane composition lead to neurological disorders. The present study also showed that there was a decrease in the levels of different types of phospholipids due to hypercholesterolemia. MCFA rich RBOs showed an increase in the level of different phospholipids. This was due to the presence of MCFAs in MCFA rich RBO.

Amino acid neurotransmitters play important roles in controlling the learning and memory process. Glutamic acid and aspartic acid are two of the most abundant amino acids in the central nervous system (CNS) including the cerebral cortex, the dentate gyrus of the hippocampus and striatum, where they correlate with the mediation of cognitive performance as excitatory neurotransmitters (Cotman, *et al*., 1987). These amino acids play important roles in cognitive functions including memory formation (Cotman, *et al*., 1987). Glycine on the other hand is an inhibitory neurotransmitter which decreases memory performance. The present findings suggest that hypercholesterolemia decrease the levels of Glu and Asp and increase the level of Gly. Thus the MCFA rich RBOs increased the levels of excitatory neurotransmitter and decreased the levels of inhibitory neurotransmitters and this may be significance for memory and learning processes.

The fluidity of the erythrocyte membrane was determined by a number of factors among which cholesterol content have significant influences (Parker and Peterson, 1965; Evans and Hochmuth, 1977). The interactions of these factors seem to affect the physiological properties of the membranes to a varying degree. Erythrocyte membrane composition could be altered by different dietary administration. The basic features of the fatty acid composition were largely

dependent on the diet that is mainly on the degree of saturated and unsaturated fatty acids in the diet. In a number of investigations there have been attempts to correlate the osmotic fragility of erythrocytes to their lipid and fatty acid composition of the lipid being fed. As a result, the stabilization of erythrocyte membrane has been generally attributed to increased cholesterol/phospholipid ratio and increased unsaturated fatty acids. The rate of osmotic haemolysis measures the cell rupture process which follows the cell swelling process. Thus due to the reduction of unsaturated fatty acids in MCFA rich RBO there has been a reduction in osmotic fragility of erythrocyte membrane.

In the present study the membrane composition was altered by feeding a hypercholesterolemic diet to rats. In hypercholesterolemic situation, where the cholesterol content of plasma was increased, the concomitantly higher cholesterol to phospholipids (C/P) ratio in the blood would have a direct influence on cholesterol transfer from plasma to erythrocytes, resulting in the accumulation of cholesterol in the erythrocyte membrane. Where there was an alteration in membrane lipid composition, changes in membrane properties was expected. This study could report that in erythrocytes from rats under alimentary hyperlipidemia/hypercholesterolemia, membrane fluidity was slightly diminished while these cells featured higher C/P ratio. Inclusion of different experimental oils in the diet improved the erythrocyte fluidity, concomitant with the partial restoration of the altered C/P ratio in the membrane.

Membrane cholesterol and phospholipid was measured from the membrane lipid extract. The diet supplemented with 1% cholesterol induced an increase in the erythrocyte membrane cholesterol and phospholipid level compared to the basal or control diet. However the administration of different experimental diets produced hypocholesterolemic effect in hypercholesterolemic subjects and thus reduced the membrane cholesterol and phospholipid levels due to increase in the unsaturated fatty acids in the membrane lipids of experimental animals. Erythrocyte membrane cholesterol decreased both in normal and hypercholesterolemic group. Most mammalian somatic cells, including erythrocytes, are unable to catabolize cholesterol and need to export cholesterol in order to maintain cholesterol homeostasis. Reportedly, at least two independent mechanism have been identified to account for cholesterol homeostasis. One is a non-specific diffusion-mediated cholesterol efflux from the surface of cell. Cholesterol molecule desorbed from cell can be trapped by various extracellular acceptor including lipoprotein and albumin, and extracellular cholesterol esterification mainly on HDL may new a driving force for the net removal of cell cholesterol by maintaining a cholesterol gradient between lipoprotein surface and cell membrane. The other mechanism is an apo-lipoprotein-mediated process to generate HDL by removing cellular cholesterol and phospholipids. In this study, the diet containing experimental oils induced an decrease in total and LDL cholesterol and triglyceride levels and a increase in HDL cholesterol level in comparison with diet containing control oil. In hypercholesterolemic subjects also the experimental oils showed a hypolipidemic effect. This suggests that all the three MCFA rich RBOs have hypolipidemic effect.

The hypercholesterolemic situation achieved in these animals by maintaining on cholesterol enriched diet also resulted in a significant enrichment of erythrocyte membranes with cholesterol. Although membrane phospholipid concentration was altered to a lesser extent, the ratio of erythrocyte membrane cholesterol: phospholipid was increased in cholesterol enriched diets. This increased C:P ratio was enough to produce changes in osmotic sensitivity of red blood cells. It is said that cholesterol leads to an increase in the anisotropic emotional ordering of the lipid bilayer of the membrane due to the effects of its rigid sterol structure on lipid components on the membrane (Shinitzky, M., Barenholz, Y, 1974). Thus, an increase of C:P ratio of the erythrocytes from hyperlipidemic rats should promote an important reduction of membrane fluidity which

was evidenced by a significant decrease in the membrane osmotic fragility. Dietary oils have significantly reversed this alteration in C:P ratio of the erythrocytes by reducing the cholesterol enrichment in their membranes. It was probable that the decreased membrane fluidity of hypercholesterolemic rats was also reversed by these dietary oils, as suggested by the osmotic fragility data. In conclusion, rat erythrocytes appear to be deformed and became more fragile in cholesterol rich blood. This deformity and fragility was partially reversed by experimental oils by virtue of their ability to lower the extent of hypercholesterolemia.

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Table- 1: Fatty acid composition of native rice bran oil and medium chain fatty acid rich rice bran oils.

Fatty acid / Sample	Fatty Acid (% w/w)								
	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Rice Bran Oil	-	-	-	0.28	17.10	1.90	48.27	31.35	1.1
Caprylic acid rich RBO	**14.00**	-	-	0.29	13.77	1.90	40.76	28.28	1.0
Capric acid rich RBO	-	**13.43**	-	0.27	10.44	1.89	43.39	29.58	1.0
Lauric acid rich RBO	-	-	**13.11**	0.27	10.56	1.88	45.29	27.89	1.0

Table- 2 : Effect of feeding dietary lipids on body weight gain of rats.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Food intake(g/day/rat)	8.05± 0.20[a]	8.05± 0.08[a]	8.44± 0.70[a]	8.45± 0.18[a]	7.99± 0.23[a]	8.00± 0.19[a]	8.10± 0.11[a]	8.70± 0.23[a]	8.05± 0.56[a]	7.90± 0.22[a]
Body weight gain(g)	34.56± 0.23[a]	62.89± 0.11[b]	30.29± 1.21[c]	53.45± 1.11[d]	23.45± 1.82[e]	38.55± 1.85[f]	25.67± 1.02[g]	43.34± 0.66[h]	28.09± 0.34[i]	49.00± 0.21[j]
Food efficiency ratio	0.23± 0.03[a]	0.13± 0.08[b]	0.28± 0.02[c]	0.16± 0.01[d]	0.34± 0.01[e]	0.21± 0.01[f]	0.32± 0.03[g]	0.20± 0.01[h]	0.29± 0.02[i]	0.16± 0.01[d]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 3: Effect of feeding dietary lipids on organ weight of rats.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Liver (g)	3.79± 0.13[a]	4.88± 0.11[b]	3.41± 0.21[c]	4.09± 0.11[d]	2.27± 0.12[e]	3.14± 0.05[f]	2.63± 0.02[g]	3.56± 0.16[h]	2.89± 0.14[i]	3.87± 0.21[j]
Brain (g)	1.44± 0.03[a]	1.75± 0.08[b]	1.22± 0.02[c]	1.51± 0.01[d]	0.92± 0.01[e]	1.13± 0.01[f]	1.08± 0.03[g]	1.21± 0.01[h]	1.14± 0.02[i]	1.32± 0.01[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 4: Changes in apparent fat and protein digestibility in rats fed with dietary oils.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Apparent fat digestibility	0.89± 0.03[a]	0.75± 0.01[b]	0.90± 0.01[c]	0.80± 0.01[d]	0.96± 0.02[e]	0.87± 0.05[f]	0.92± 0.02[g]	0.84± 0.06[h]	0.90± 0.04[i]	0.82± 0.01[j]
Apparent protein digestibility	0.89± 0.03[a]	0.85± 0.08[b]	0.98± 0.02[c]	0.89± 0.01[d]	0.99± 0.01[e]	0.90± 0.01[f]	0.94± 0.03[g]	0.92± 0.01[h]	0.92± 0.02[i]	0.89± 0.01[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 5: Plasma lipid concentrations (mg/dL) in rats fed the different diets.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Total cholesterol	150.12± 1.20[a]	340.60± 0.98[b]	130.30± 2.70[c]	214.67± 2.98[d]	65.33± 0.23[e]	139.31± 1.89[f]	73.33± 0.11[g]	154.00± 1.23[h]	106.67± 0.56[i]	166.17± 1.22[j]
HDL-cholesterol	18.69± 0.23[a]	11.21± 0.11[b]	23.00± 1.21[c]	16.92± 1.11[d]	30.62± 1.82[e]	24.00± 1.85[f]	28.24± 1.02[g]	22.33± 0.66[h]	26.27± 0.34[i]	17.67± 0.21[j]
Non-HDL cholesterol	118.72± 2.13[a]	305.82± 1.88[b]	96.65± 1.78[c]	177.63± 2.31[d]	28.60± 1.01[e]	101.47± 0.77[f]	36.27± 1.23[g]	116.98± 2.30[h]	70.65± 1.02[i]	132.03± 1.30[j]
Triacylglycerol	63.57± 1.20[a]	117.87± 0.45[b]	53.23± 0.20[c]	100.60± 1.29[d]	30.57± 0.34[e]	69.20± 0.10[f]	44.11± 1.00[g]	73.45± 1.20[h]	48.76± 0.87[i]	82.36.± 0.20[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 6: Liver lipid concentrations (mg/g tissue) in rats fed the different diets.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Total cholesterol	72.34 ±2.33[a]	200.98 ±4.50[b]	60.12 ±2.00[c]	154.22 ±1.78[d]	45.66 ±3.22[e]	92.39 ±1.50[f]	50.99 ±2.33[g]	113.43± 1.23[h]	56.67± 0.56[i]	134.17± 1.22[j]
Triglyceride	112.85±2.50[a]	253.80± 2.90[b]	108.59±0.56[c]	200.02±1.90[d]	72.34±2.30[e]	134.56±2.80[f]	88.24± 1.02[g]	142.33± 0.66[h]	94.52± 0.34[i]	157.67± 0.21[j]
Phospholpid	172.49±3.50[a]	61.64±2.80[b]	230.54±1.67[c]	80.99±2.89[d]	286.33±0.99[e]	120.70±0.50[f]	262.34±3.50[g]	111.67± 2.30[h]	243.00± 1.02[i]	100.65± 1.30[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 7: Brain lipid concentrations (mg/g tissue) in rats fed the different diets.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Total cholesterol	58.14 ±2.10	60.20 ±3.50	58.12 ±2.00	59.88 ±1.18	55.66 ±2.10	58.72 ±1.04	57.88 ±2.00	59.01± 2.30	57.99± 2.09	59.90± 1.22
Phospholpid	190.90±3.00[a]	100.23± 2.01[b]	240.55±1.99[c]	120.30±2.01[d]	280.90±0.90[e]	180.89±1.50[f]	260.67±3.50[g]	172.34± 0.99[h]	250.00± 1.02[i]	165.54± 1.10[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 8: Effect of different dietary oils on phospholipid composition.

Phospholipids (g/100g phospholipids)	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Phosphatidyl ethanolamine	7.30±0.13[a]	4.97±0.34[b]	8.27±0.15[c]	6.22±0.10[d]	10.98±0.19[e]	5.21±0.01[f]	10.30±0.13[g]	5.00±0.03[h]	9.00±0.16[i]	4.20±0.12[j]
Phosphatidyl choline	30.36±0.08[a]	11.15±0.99[b]	34.14±1.30[c]	14.32±0.90[d]	44.58±0.98[e]	25.05±0.55[f]	41.36±1.08[g]	22.56±0.26[h]	38.09±0.14[i]	19.08±0.21[j]
Sphingomyelin	15.88±1.02[a]	10.65±0.22[b]	16.89±0.33[c]	11.28±0.50[d]	20.57±0.10[e]	14.42±0.45[f]	18.88±1.02[g]	13.67±0.30[h]	17.00±0.02[i]	12.65±0.30[j]
Lysophosphatidylcholine	2.61±0.01	1.69±0.02[a]	2.99±0.01[b]	1.86±0.03[b]	4.69±0.10[b]	3.06±0.05[b]	4.12±0.01[b]	2.86±0.03[b]	3.69±0.10[b]	2.06±0.05[b]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 9: Comparison between haematological parameters of rats fed with control and experimental oils in normal and hypercholesterolemic condition.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Platelets(x 10^9/L)	5.82±0.18[a]	9.60±0.12[b]	5.35±0.10[a]	8.98±0.08[c]	5.00±0.39[a]	6.00±0.20[d]	5.20±0.34[a]	6.89±0.13[e]	5.25±0.46[a]	7.56±0.02[f]
Haemoglobin(g/dl)	21.36±1.08[a]	15.15±0.99[b]	28.14±2.30[c]	22.32±1.90[d]	28.58±0.98[e]	28.05±1.55[f]	25.36±1.08[g]	26.56±0.26[h]	21.09±0.14[i]	24.08±0.21[j]
Total WBC(x 10^9/L)	5.12±0.20[a]	8.77±0.12[b]	4.98±0.06[a]	7.47±0.17[c]	4.29±0.12[a]	6.29±0.88[c]	4.76±0.20[a]	6.47±0.12[d]	4.99±0.06[a]	7.00±1.30[e]
Total RBC (x 10^9/L)	6.50±0.22[a]	8.71±0.18[b]	6.44±0.28[a]	7.50±0.56[c]	6.19±0.28[a]	6.24±0.10[d]	6.30±0.56[a]	6.89±0.28[e]	6.34±0.50[a]	7.19±0.18[f]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 10: Platelet aggregations in rats fed with MCFA rich RBOs in comparison with the rats fed with control RBO in normal and hypercholesterolemic condition.

	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
ADP induced platelet aggregation (%)	21.25±0.98[a]	75.00±3.67[b]	20.00±0.45[c]	55.25±1.88[d]	17.75±0.39[e]	23.75±2.76[f]	19.08±0.34[g]	28.79±0.13[h]	19.78±0.46[i]	42.55±0.02[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 11: Alterations in hepatic tissue enzyme activities of rats fed with different diets.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Aspartate transaminase	7.45±0.67[a]	24.61±0.19[b]	6.45±0.43[c]	20.36±0.78[d]	5.00±0.20[e]	10.15±0.29[f]	5.20±0.80[g]	12.30±0.23[h]	6.00±0.56[i]	14.00±0.22[j]
Alanine transaminase	10.21±0.56[a]	29.94±0.17[b]	8.77±0.03[c]	23.50±0.90[d]	6.50±0.50[b,e]	12.30±0.67[f]	7.02±0.22[g]	14.56±0.26[h]	8.09±0.14[i]	19.08±0.21[j]
Alkaline phosphatase	30.16±1.45[a]	71.64±1.89[b]	28.77±0.50[c]	60.92±1.50[b]	19.82±0.12[b,c]	34.55±1.00[b]	21.93±2.65[b,d]	41.67±2.30[h]	24.00±1.02[i]	50.65±1.30[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 12: Liver total cholesterol and HMG CoA reductase activity in different dietary groups.

Parameters	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Total cholesterol	72.34 ±2.33[a]	200.98 ±4.50[b]	60.12 ±2.00[c]	154.22 ±1.78[d]	45.66 ±3.22[e]	92.39 ±1.50[f]	50.99 ±2.33[g]	113.43±1.23[h]	56.67±0.56[i]	134.17±1.22[j]
HMG CoA: Mevalonate	0.89±0.02[a]	0.38±0.01[b]	1.00±0.01[c]	0.56±0.05[d]	1.78±0.05[b,e]	0.80±0.01[f]	1.50±0.02[g]	0.75±0.02[h]	1.25±0.01[i]	0.60±0.02[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant (p<0.05).

Table- 13: Osmotic fragility changes at different dietary conditions.

	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
NaCl concentration(%) causing 50% haemolysis	0.52±0.01[a]	0.95±0.03[b]	0.46±0.03[c]	0.82±0.01[d]	0.30±0.02[e]	0.60±0.01[f]	0.35±0.04[g]	0.64±0.03[h]	0.40±0.01[i]	0.71±0.02[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Table- 14: The effect of dietary oils on lipid profile of erythrocyte membrane of different rats.

	Normal Control		Rice bran oil		Caprylic acid-enriched rice bran oil		Capric acid-enriched rice bran oil		Lauric acid-enriched rice bran oil	
	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol	No added cholesterol	+ cholesterol
Total Cholesterol(g/l)	2.52±0.02[a]	6.10±0.05[b]	2.01±0.01[c]	5.00±0.04[d]	1.21±0.01[e]	3.22±0.01[f]	1.30±0.01[g]	3.70±0.01[h]	1.63±0.03[i]	4.04±0.01[j]
Phospholipid(g/l)	10.20±0.12[a]	5.60±0.18[b]	12.44±0.06[c]	6.13±0.10[d]	17.82±0.01[e]	8.91±0.19[f]	15.91±0.09[g]	7.32±0.11[h]	13.76±0.12[i]	7.68±0.06[j]
C/P ratio	0.25±0.01[a]	1.09±0.03[b]	0.16±0.03[c]	0.82±0.02[d]	0.07±0.01[e]	0.36±0.02[f]	0.08±0.01[g]	0.51±0.02[h]	0.12±0.02[i]	0.53±0.04[j]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

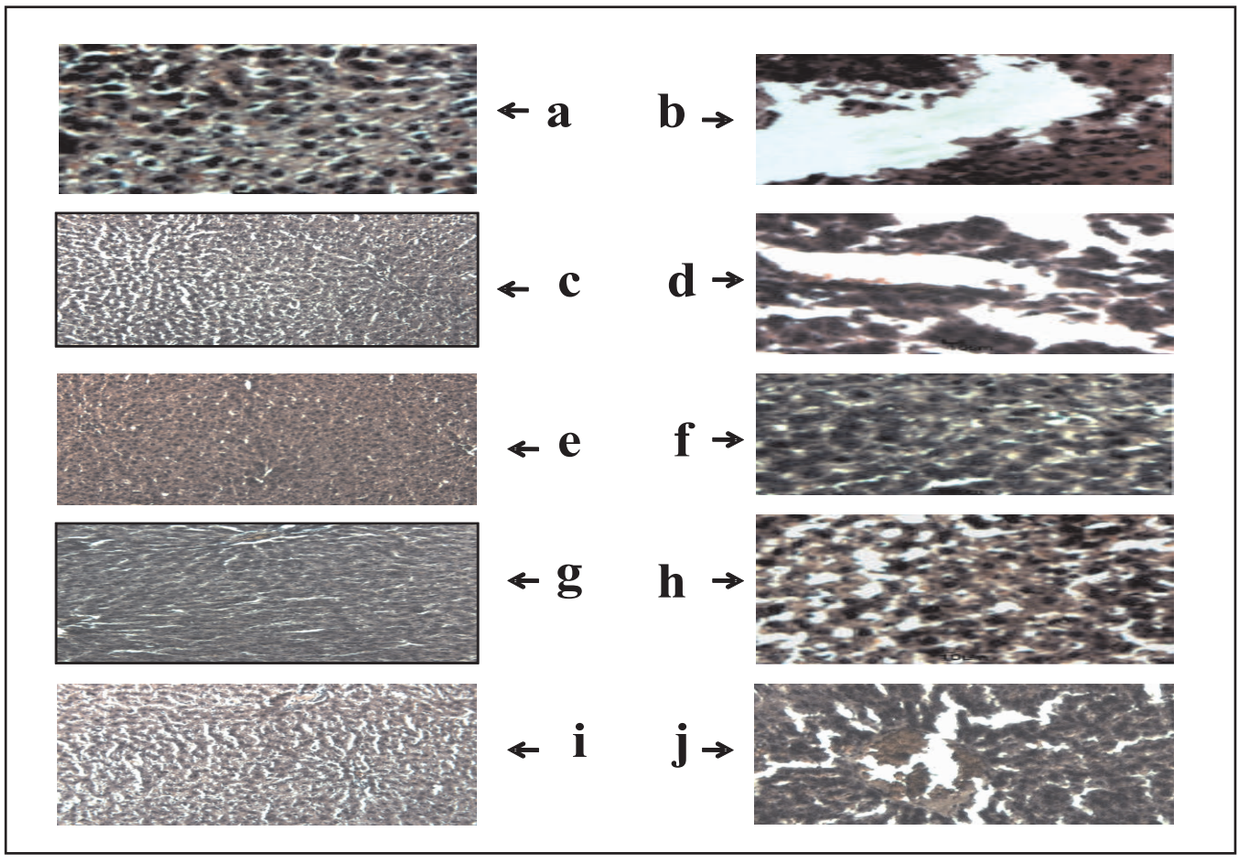

Figure- 1: Pictomicrographs of Liver Cells [a-Normal Control; b-Hypercholesterolemic Control; c-Rice bran oil (RBO) Normal; d-Rice bran oil hypercholesterolemic; e-Caprylic acid rich RBO Normal; f-Caprylic acid rich RBO Hypercholesterolemic; g-Capric acid rich RBO Normal; h-Capric acid rich RBO Hypercholesterolemic; i-Lauric acid rich RBO Normal; j-Lauric acid rich RBO Hypercholesterolemic]

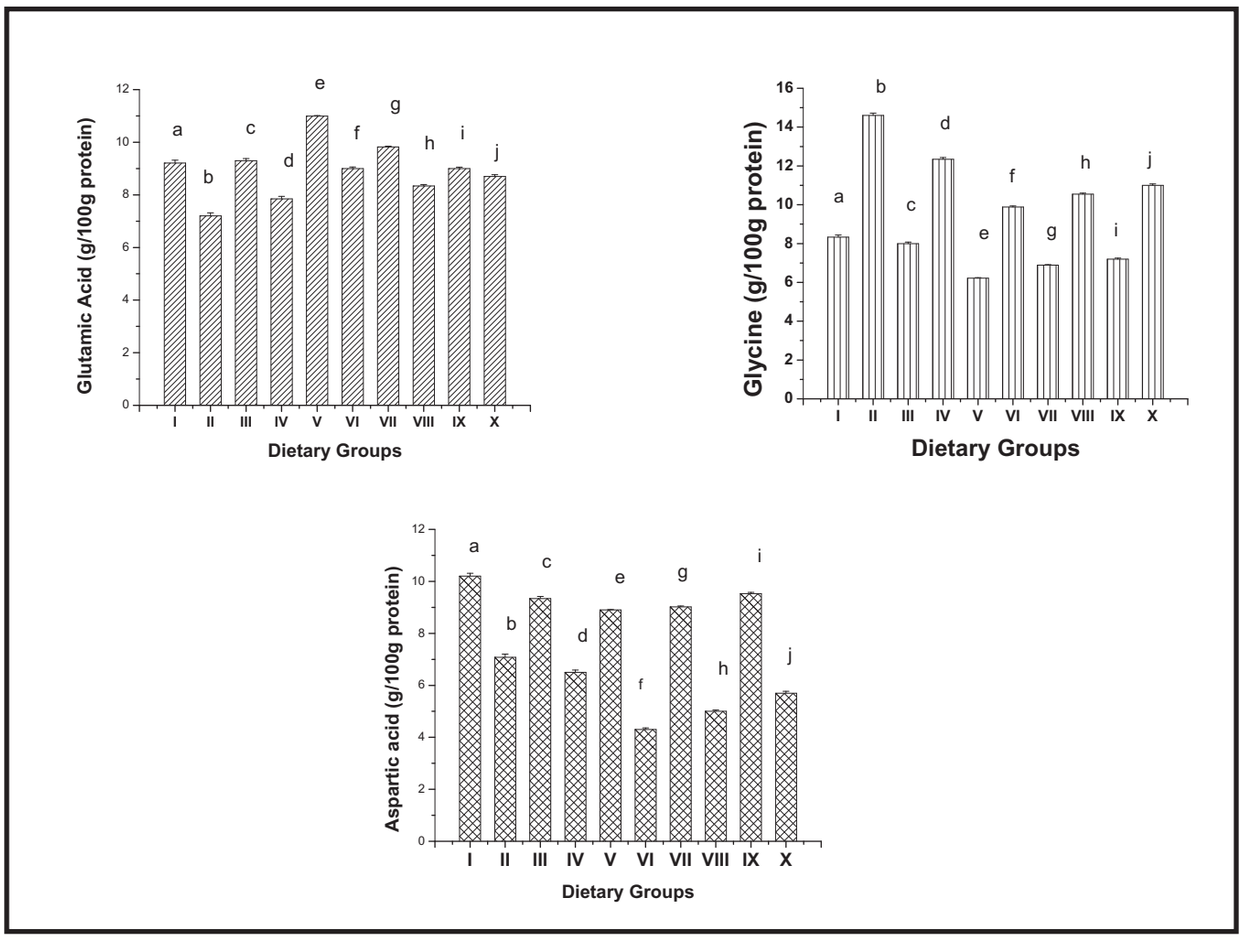

Figure- 2: [I-Normal Control; II-Hypercholesterolemic Control; III-Rice bran oil (RBO) Normal; IV Rice bran oil hypercholesterolemic; V-Caprylic acid rich RBO Normal; VI- Caprylic acid rich RBO Hypercholesterolemic; VII-Capric acid rich RBO Normal; VIII- Capric acid rich RBO Hypercholesterolemic; IX-Lauric acid rich RBO Normal; X-Lauric acid rich RBO Hypercholesterolemic]

Values are mean±SEM (n=6 rats per diet group) Values not sharing a common superscript within a row are statistically significant ($p<0.05$).

Research Roundup April-June 2021

New volume translation functions for biodiesel density prediction with the Peng-Robinson Equation of state in terms of its raw materials

Biodiesel final product specifications must fit in a narrow property range. Density is an example of an important fuel property that strongly depends on the structure of the components and may largely vary among the vegetable oils and animal fats. Therefore, it is interesting to have a model capable to predict the biofuel density as a function of its raw materials. Meanwhile, it is also interesting to model the behavior of a fuel under working conditions and it is done using thermodynamic models. However, the deficiency of these models in the calculation of volumetric properties is well known. So, the objective of this work is the development of new volume translation functions for predicting the density of biodiesel from different raw material sources using the Peng-Robinson equation of state, with critical properties calculated with the Constantinou-Gani group contribution method. Volume translation is made as a function of temperature and average molar mass. The functions were statistically evaluated for the quality of their parameters, the adequacy of the fit, and the prediction confidence interval. Then, the best functions were selected, and their robustness was proved with good results obtained in the prediction of several literature data at different conditions. With this approach, **Gutierri Salgueiro *et al*** provided an extensible model, applicable to all kinds of biodiesel and more likely to be extrapolated to more severe temperature and pressure conditions. Hence, density calculations can be done with a simple and readily available model at any stage of production and application [**Fuel, 293**, Article 120254, (2021)].

Optimizing temperature-dependent molar volume fraction of biodiesel fuel in a pseudo-binary mixture through Bragg fiber waveguide sensor having defect layer

In the present communication, the temperature-dependent molar volume fraction of various kinds of renewable biodiesel fuel resources in a pseudo-binary mixture is theoretically optimized by **Nitesh K. Chourasia *et al*** through the Bragg fiber waveguide (BFW) sensor with a geometrical defect in periodic cylindrical Bragg reflectors. BFW structure is modelled using a transfer matrix method (TMM) and Henkel formalism in a cylindrical coordinate system[**Fuel, 293,** Article 120489, (2021)]. The temperature dependence molar volume fraction is linked to the change in the refractive index of the pseudo-binary mixture, which is further predicted using the capacity of various models; Lorentz-Lorenz, Dale-Gladstone, Eykman, Newton, and Kay. In the presence of a geometric defect layer, a sharp transmission peak of 0.1*nm*full width at half maxima (FWHM) is obtained in the considered photonic band gap (PBG), which is sensitive to the change in core refractive index. The temperature-dependent (due to different weather conditions) maximum sensitivity of the proposed sensor is found to be 1280 *nm/RIU,* which is further compared with the phoxonic crystal-based static temperature sensor having sensitivity 142 *nm/RIU* only. Along with improved sensitivity in the proposed sensor, other sensing performance parameters detection accuracy and quality parameter (which are inversely proportional to the FWHM) are also improved due to least FWHM of resonant transmission peak about 0.1 *nm* comparatively.

Crude oil volatility and the biodiesel feedstock market in Malaysia during the 2014 oil price decline and the COVID-19 outbreak

Although the global crude oil market plays a significant role in pricing edible oils, the association between energy price uncertainty and the Malaysian palm oil industry remains understudied. Given that palm oil is widely used as a cheap feedstock for biodiesel, it is important to investigate whether risk transmits from the oil market to the Malaysian palm oil industry. Employing GARCH-jump models, this study extends the scant literature. The results reveal that

the crude oil volatility index (OVX) significantly influences palm oil prices suggesting that an upturn in oil market volatility negatively impacts palm oil prices. Subsample analyses show that the negative impact of OVX intensified during the 2014 oil price decline and the COVID-19 outbreak. The effect of OVX is asymmetric, implying that changes (upward and downward shifts) in oil price variance exert a heterogeneous impact on the price levels of this edible oil. It is also observed by **Anupam Dutta *et al*** that palm oil prices experience time-dependent jumps. We show that volatility significantly transfers from the crude oil to the palm oil market during periods of high uncertainty[**Fuel, 292**, Article 120221, (2021)]. Hence, investors and policymakers could use the information content of OVX for forecasting future trends in palm oil prices.

Graphitic carbon embedded FeNi nanoparticles for efficient deoxygenation of stearic acid without using hydrogen and solvent

[**Fuel, 292,** Article 120248, (2021)]

Jin Zhong *et al*

Upgrading fatty acids to hydrocarbons via deoxygenation is significant for the synthesis of high-grade biofuels. Developing economic reaction conditions without using noble metal-based catalysts in the absence of hydrogen and solvent has promising application prospects. Herein, carbon-coated bimetallic FeNi nanoparticles were prepared via an in-situ carbonization-reduction strategy using double-metal cyanide at different temperatures for the deoxygenation of stearic acid. The size of the alloy core and the thickness of the carbon shell were found to be easily adjusted by varying temperature. Compared with monometallic Fe/C and Ni/C catalysts, the alloy catalyst exhibits an obvious improvement in both the conversion of stearic acid and the selectivity of heptadecane. ATR-IR spectra show that the insertion of the inert Fe element into Ni nanoparticles can promote carboxylic acid group adsorption but restrain hydrocarbon group adsorption. The synergistic effect of Fe and Ni elements leads to the promotion of direct decarboxylation of stearic acid and suppression of the C–C cracking reaction. Among different alloy catalysts studied, FeNi@C-800 exhibits the greatest catalytic performance with a 99.9% conversion of stearic acid and 76.8% selectivity for heptadecane. Furthermore, the catalyst can still maintain a stable catalytic performance against the leaching and ripening of metal through the protection afforded by the carbon shell. This work not only provides a powerful reaction system for the decarboxylation of stearic acid but also demonstrates an alternative catalyst to noble metals based on a convenient carbonization-reduction strategy.

Vegetable tannins-based additive as antioxidant for biodiesel

The development of more sustainable antioxidants alternatives for the improvement of biodiesel oxidation stability is gaining importance. Vegetable tannins are known for their antioxidant properties. In this work, acacia (*Acacia mearnsii*), chestnut (*Castanea sativa*) and quebracho (*Schinopsis lorentzii*) tannins extracts were used by **Lívia S. Schaumlöffel *et al*** in mixture with triethanolamine as antioxidants for soybean biodiesel [**Fuel, 292**, Article 120198, (2021)]. Tannins were characterized by Folin-Ciocalteau method for the determination of total phenolic content (TPC) and against DPPH (1,1-diphenyl-2-picryl-hydracyl) radical for scavenging capacity. When applied to the biodiesel at a concentration of 350 mg L^{-1} in mixture with 1.59 %wt of triethanolamine, tannins were highly effective in enhancing oxidative stability with superior performance than synthetic antioxidant *tert*-Butylhydroquinone (TBHQ). These findings indicate that vegetal tannins can be used as a renewable alternative to enhance biodiesel oxidation stability.

Amine and aldehyde functionalized mesoporous silica on magnetic nanoparticles for enhanced lipase immobilization, biodiesel production, and facile separation

Fahimeh Esmi *et al* synthesed of fatty acid methyl ester (FAME) from olive oil as model feedstock was carried out in the presence of *Rhizopus oryzae* lipase (ROL) that was immobilized on the mesoporous silica magnetic nanoparticles (MNPs) [**Fuel, 291**, Article 120126, (2021)]. MNPs were coated with mesoporous silica (MS) functionalized by amine and aldehyde groups used for immobilization of a lipase, used for biodiesel production, and easy magnetic separation of the immobilized lipase from the biodiesel product. MNPs were synthesized by using the co-precipitation method and coated with MS by sol-gel synthesis using cetyltrimethylammonium bromide (CTAB) as a template for mesoporous formation. ROL was immobilized on these supports via physical adsorption and covalent attachment. Enzyme loading efficiency on mesoporous was doubled compared to that on bare MNPs. Also, the covalent bonding led to an increase in enzyme loading from 67.8 to 82.4%. The physico-chemical properties of MNPs were determined by XRD, EDX, VSM, FESEM, BET, and FTIR and were correlated with their activities for biodiesel synthesis. The evaluations of hydrolytic activity and kinetic parameters revealed that MNPs@MS-AP-GA is a suitable nanomaterial for ROL immobilization. Transesterification of olive oil using ROL-MNPs@MS-AP-GA showed the highest biodiesel production of 84.6% among other nanobiocatalysts.

Monitoring of polar pesticides and contaminants in edible oils and nuts by liquid chromatography-tandem mass spectrometry

A single method was developed for the determination of polar pesticides (fosetyl-Al and its metabolite, phosphonic acid, and ethephon) and environmental contaminants (chlorate and perchlorate) in edible oils and nuts. Two extraction methods based on QuPPe-PO approach (Quick Polar Pesticides Method for products of Plant Origin) were optimized. In oils, a single extraction using water acidified with formic acid (1%) was performed by **José L. Hidalgo-Ruiz *et al***, while in nuts, the clean-up step was modified [**Food Chemistry, 343**, Article 128495, (2021)]. C18 was used as sorbent and an extra cleaning step with *n*-hexane was added. The extracts were analysed by liquid chromatography coupled to a triple quadrupole mass analyser (LC-QqQ-MS/MS). The method was validated and the limit of quantification was 0.01 mg kg^{-1} for all analyte-matrix combination. Recoveries from 70 to 120%, and intra and inter-day precision values $\leq$20% were obtained. Forty samples of edible oils and nuts were analysed, detecting phosphonic acid in nuts at concentrations up to 4.6 mg kg^{-1}.

Physicochemical characterization and nano-emulsification of three species of pumpkin seed oils with focus on their physical stability

Maria Isabel Ordoñez Lozada *et al* present the chemical composition, quality parameters and antioxidant capacity of pumpkin seed oils (PSO) from *Cucurbita pepo*, *Cucurbita maxima*, and *Cucurbita moschata* cultivated in Brazil. In addition, PSO nanoemulsions (nanopepo, nanomax and nanomosc) were developed and their physical stabilities were assessed under long-term storage at two temperatures [**Food Chemistry, 343**, Article 128512, (2021)]. Among the PSO, *C. pepo* presented the highest contents of polyunsaturated fatty acids, total carotenoids, and chlorophylls, but the lowest oxidative stability. Conversely, *C. maxima* PSO showed highest oxidative stability and total tocopherol content but the lowest chlorophyll content. Nanomax and nanopepo were more stable to droplet growth at 4 °C, while nanomosc was more stable at 25 °C. Nanopepo was the most stable formulation after the heating–cooling cycles, whereas nanomax was the most stable under centrifugation regardless the temperature. Overall, all nanoemulsions presented droplet diameter lower than 200 nm and ζ-potential approaching - 30 mV until the end of storage.

Action of phytosterols on thermally induced trans fatty acids in peanut oil

The effects of six phytosterols on thermally induced *trans* fatty acids (TFAs) in peanut oil were

investigated by **Qin Guo *et al***. Peanut oil, triolein, trilinolein and trilinolenin heated at 180 °C for 12 and 24 h with or without phytosterols were analyzed by GC-FID [**Food Chemistry, 344**, Article 128637, (2021)]. The atomic net charge distribution, frontier molecular orbital energy (FMOE), and bond dissociation energy (BDE) of six phytosterols were calculated by density functional theory. Results showed that six phytosterols inhibited the formation of *trans* oleic acid, *trans* linoleic acids, *trans* linolenic acids, and total TFAs. The anti-isomerization effects of phytosterols were mainly associated with hydroxyl site activities, which were affected by the double bond position in the main skeleton of cyclopentane tetrahydrophenanthrene and the number of double bonds on the C17 branch chain. The FMOE difference and BDE of phytosterol molecules were closely related to their anti-isomerization rates. The anti-isomerization mechanisms of phytosterols on TFAs in peanut oil were proposed.

Modification of palm-based oil blend via interesterification: Physicochemical properties, crystallization behaviors and oxidative stabilities

Interesterification is widely employed as an effective technique to modify oils and fats. This study utilizes palm-based oil (palm olein: palm kernel oil: palm stearin, 5:3:2, w/w/w) as the raw material for the interesterification process performed by **Zhen Zhang *et al*** in a pilot-scale packed bed reactor. Enzymatic interesterification (EIE) was catalyzed by Lipozyme TL IM (813.0 g) at 60℃ with reaction flow rate of 100 mL/min [**Food Chemistry, 347**, Article 129070, (2021)]. Chemical interesterification (CIE) was catalyzed using sodium methoxide (0.3 wt%) as catalyst at 105 °C for 30 min. The results showed that the EIE fats had lower solid fat content tendency compared to that of CIE fats. The crystallization onset temperature was higher in EIE fats (23.09℃) compared to that of CIE (19.08℃). The results were consistent with the crystallization kinetics whereby the *Avrami* K constants of EIE fats were higher than that of CIE fats at various temperatures, indicating rapid crystallization and instant nucleation. Linear growth mechanism was dominant and the crystals formed were smaller in size as observed using polarized light microscope. The interesterified fats exhibited the presence of β and β'-crystals. While most of the tocopherol content was retained after EIE (386.18 ug/g), the molecular distillation process reduced the tocopherol concentration (110.01 ug/g) which consequently affected the oxidative stability. The findings in this work contribute to the fundamental understanding on the differences between CIE and EIE fats and provides data to support the preparation of modified fats via EIE that shows great potential as a controllable technique for industrialization.

Biodiesel production from edible oils using algal biochar/CaO/K2CO3 as a heterogeneous and recyclable catalyst

A new heterogeneous biochar/CaO/K_2CO_3 catalyst was fabricated by **Rauf Foroutan *et al*** to produce biodiesel from waste edible oil. In this catalyst, the biochar was produced from brown algae of *Sargassum oligocystum* and CaO from eggshells [**Renewable Energy, 168**, Pages 1207-1216, (2021)]. The XRD result showed that the biochar, CaO, and synthesized catalyst have a crystalline structure. Response surface methodology-central composite design (RSM-CCD) and artificial neural network (ANN) methods were used to investigate the effect of parameters and determine optimal conditions. Also, the maximum efficiency of biodiesel production (98.83%) was predicted by the RSM-CCD method at 65 °C, 4 wt% catalyst content, 200 min duration, and 18: 1 methanol to oil ratio. The process of biodiesel production was exothermic. The activation energy and frequency factor were calculated 45.53 kJ/mol and $6.03 \times 10^{+4}$ min^{-1}, respectively. Biodiesel properties were evaluated according to international standards (ASTM D6751 and EN14214). The catalyst was reused for up to 90% efficiency in up to 5 steps.

Comparative energy and economic analysis of different vegetable oil plants for biodiesel production in India

Carbon emissions due to the exploitation of conventional sources of energy like coal, diesel, and petrol are the primary source of global warming. In recent years, biodiesel has emerged as one of the potential candidates, to be used as alternate and renewable source of energy, for reducing the carbon footprints. Thus, for the growth and development of biodiesel it is essential to evaluate the energy and economic output of various vegetable oil plants used to produce biodiesel. The present study by **Ajeet Kumar *et al*** aims to select the vegetable oil plants for biodiesel production in India by using the life cycle assessment (LCA) approach [**Renewable Energy, 169**, Pages 266-282, (2021)]. This study conducts a comparative energy and economic analyses of biodiesel production from jatropha, mahua, neem, palm, coconut, karanja, jojoba, and tung. The results indicated that the net energy is positive for all the plants, where, neem was recognized as a higher energy ratio (5.5164) and energy productivity (0.0567 kg MJ^{-1}), which could be deal with as a higher contributor for reducing CO_2 emission (g CO_2 eq/MJ) in diesel blending. Higher gross production values (222.27 R kg^{-1}), gross returns (168.70 R kg^{-1}), net returns (144.13 R kg^{-1}), benefit to cost ratios (2.84) productivity (0.0122 kg $Rs^{-}1$) obtained for neem.

A novel approach for enhancing lipid recovery for biodiesel production from wet energy biomass using surfactants-assisted extraction

Black soldier fly larvae with high contents of lipids can be used as a novel biomass feed-stock. An efficient approach involving surfactants assisted extraction of lipid from the wet biomass in this study by **Weiliang Feng *et al***. Surfactants with functional molecular structure were found to be helpful to extract lipids in the extraction process. Control experiments were performed to investigate the influence of different factors (surfactant types, surfactant concentration, salt concentration, and extraction temperature) on the lipid extraction process from the wet energy biomass [**Renewable Energy, 170,** Pages 462-470, (2021)]. These results suggested that the extraction capacity of lipid was 78.99% at the defined condition (solvent:water = 50 mL:30 mL, biomass:solvent = 30 g:50 mL, surfactant concentration = 0.5%, extraction time = 60 s, extraction temperature = 60 °C). In addition, the purities of saponifiable lipids for these surfactants used were more than 80% in the present work. Surfactant treatment had a weak effect on lipids compositions. The kinetic model of the surfactants assisted lipid extraction process was proposed. During solvent extraction, the extraction process is divided to the two main processes: washing process and diffusion process. The rate constants were 4.17×10^{-2} to 5.94×10^{-2} in the first stage and 1.43×10^{-3} to 2.78×10^{-3} in the second stage for surfactants treatment, respectively. The second stage constitutes the limitation step in the extraction process. Further, the results of thermodynamic parameters were determined from thermodynamic study of lipid extraction process. This research showed the surfactant assisted route is a high efficiency technique.

High-efficient production of biofuels using spent fluid catalytic cracking (FCC) catalysts and high acid value waste cooking oils

The conversion of high acid value (AV) waste cooking oils (WCOs) into biofuels was studied by **Nguyen Le-Phuc *et al*** using the cracking process over spent fluid catalytic cracking (SFCC) catalysts [**Renewable Energy, 168**, Pages 57-63, (2021)]. The processing of WCO was carried out in a fluid catalytic cracking lab-scale unit with temperatures ranging from 450 to 520 °C. From 480 °C, whatever the spent catalysts, WCOs with AV in range of 6–22 mgKOH/g can be converted to liquid fuels with the near zero AV (AV < 0.5 mgKOH/g). The yields of diesel, gasoline, LPG are in range of 25–29 wt%, 40–42 wt% and 14–18 wt%, respectively, while the coke formation is

limited at 5–6 wt%. The increase of temperature to 520 °C enhances the conversion of diesel to gasoline and LPG. The presence of ZSM-5 in SFCC catalyst leads to an increase in propylene and LPG yields. Otherwise, higher rare earth content could limit the zeolite destruction, resulting in a better catalytic cracking activity. This study reports a remarkable approach that encourages the simultaneous utilization of multiple hazardous substances, SFCC catalysts and WCOs, as low-cost raw materials for biofuel production. Finally, after biofuel production, the SFCC catalysts can also be reused to produce high purity of a concentrate of La and Ce.

Kinetics models of transesterification reaction for biodiesel production: A theoretical analysis

The kinetics of the transesterification reaction has been explored theoretically by **Rohollah Ezzati *et al***. A general rate equation (GRE) was obtained for kinetics modeling of transesterification at the entire time of reaction based on a three-step mechanism [**Renewable Energy, 168**, Pages 280-296, (2021)]. It has been shown that the GRE model converts to a Second-Order (SO) model at short initial times of reaction and it converts to Pseudo-First-Order (PFO) model at short initial times of reaction and high concentration of alcohol. Also, a modified form of the Second-Order model (MSO) was derived when the reaction is spontaneous (at $\Delta rG \ll 0$ conditions or at short initial times of reaction). The accuracy of theoretical models and our assumptions was evaluated by three sets of experimental data selected at literature. It has been shown that the accuracy of PFO, SO, and MSO models followed the order of MSO > SO > PFO at short initial times while the GRE model is a suitable kinetics model at the entire times of reaction. Also, our research, contrary to what has been reported so far in published papers, shows that pseudo-first-order and second-order models are only accurate for kinetics modeling of the transesterification reaction at short initial times of reaction.

Techno-economical and energy analysis of sunflower oil biodiesel synthesis assisted with waste ginger leaves derived catalysts

Monnie John *et al* investigated biodiesel production via transesterification of sunflower oil employing heterogeneous catalyst derived from indigenous ginger (Zingiber Officinale) leaves [**Renewable Energy, 168,** Pages 815-828, (2021)]. It also aims to compare the techno-economy performance of the ginger-based catalysts in 3 different forms viz. calcinated (CGL), activated by KOH (KGL) and NaOH (NGL). The plant-based catalysts were characterised by Scanning electron microscopy (SEM), Brunauer-Emmett-Teller (BET) and Fourier transform infrared spectroscopy (FTIR). The parametric effects on the biodiesel production such as reaction time, methanol to oil ratio and catalyst loading were investigated. The experimental result shows that 1.6 wt % catalyst, 6:1 M ratio of alcohol to oil, 1 h 30 min of reaction time with a speed of 200 rpm gave the best results. It was found that the KGL obtained highest biodiesel yield of 93.83% under optimum conditions. Subsequently, the specific energy and energy productivity of KGL catalyst was found to be 1.2728, 26.1544 MJ/kg and 0.0382 kg/MJ, respectively, per 1 L of biodiesel. Meanwhile, the renewable energy to non-renewable energy ratio for CGL, KGL and NGL is found to be 3.17, 4.01 and 3.67, respectively. A higher sustainable renewable energy-yield ratio and overall economical profit cost ratio are preferable for the biodiesel production process.

Wastes to energy: Improving the poor properties of waste tire pyrolysis oil with waste cooking oil methyl ester and waste fusel alcohol – A detailed assessment on the combustion, emission, and performance characteristics of a CI engine

The core objective of this study by **Ümit Ağbulut *et al*** is to pull back the worsened combustion, emission, and performance characteristics of a CI engine fuelled with waste tire pyrolysis oil - diesel fuel blends [**Energy, 222**, Article 119942, (2021)]. Four fuels are tested in the experiments. These are

(1) 100% diesel fuel, (2) 20% waste tire pyrolysis oil + 80% diesel fuel, (3) 10% pyrolysis oil and 80% diesel fuel containing 10% waste biodiesel, and finally, (4) 10% waste tire pyrolysis oil and 80% diesel fuel containing 10% waste fusel oil. The tests are performed at a constant engine speed of 2400 rpm, and varying engine loads from 3 to 12 Nm with intervals of 3 Nm. In the results, it is noticed that using of waste tire pyrolysis oil - diesel fuel blend is reducing the brake thermal efficiency down to 9.13% for waste tire pyrolysis oil - diesel fuel blends, however, this reduction is being pulled back by 7.51%, and 3.82% with the addition of waste biodiesel, and fusel oil, respectively as compared to that of diesel fuel. On the other hand, waste tire pyrolysis oil - diesel fuel blend increased the brake specific fuel consumption by 21.78%, however, this increase is being pulled back by 8.89%, and 12.57% for waste biodiesel, and fusel oil, respectively. The increase in carbon monoxide for waste tire pyrolysis oil-diesel fuel is 7.09% in comparison with that of diesel fuel. However, with the addition of biofuels, carbon monoxide is being dropped by 7.69% for waste biodiesel, and 19.23% for fusel oil due to the high oxygen contents of waste biofuels. Moreover, waste tire pyrolysis oil-diesel fuel blend is increasing nitrogen oxide by 7.09%, but this increase by 4.64% with the addition of waste biodiesel. On the other hand, the addition of fusel oil is converting the increasing trend of nitrogen oxide into a reduction of 3.09% owing to fusel oil's water content. As a consequence, this research is proving that the waste biofuels are able to improve poor combustion, emission, and performance characteristics of binary waste tire pyrolysis oil – diesel blend with the doping of waste biofuels, and suggesting ternary blends rather than waste tire pyrolysis oil alone for diesel engines. Moreover, it is noticed that burning waste products is a very effective tool for both waste management and alternate to fossil fuels.

Biodiesel preparation from Thlaspi arvense L. seed oil utilizing a novel ionic liquid core-shell magnetic catalyst

In order to produce an alternative energy of biodiesel using field pennycress (*Thlaspi arvense* L.) seed oil, a novel Fe_3O_4/graphene oxide-phenylalanine bisulfate ionic liquid core-shell magnetic catalyst was developed by **Ru Zhao *et al***. Ferroferric oxide nanoparticles and graphene oxide (GO) were employed to prepare a magnetic carrier of Fe_3O_4@GO nanocomposite which applied to immobilize phenylalanine bisulfate ionic liquid (PBIL) [**Industrial Crops and Products, 162**, Article 113316, (2021)]. The immobilized PBIL was characterized by the means of characterization. The heterogeneous Fe_3O_4@GO@PBIL catalyst was demonstrated to have a high catalytic efficiency that reached 92.38 % of biodiesel yield under the optimal conditions (methanol/oil molar ratio of 10:1, reaction temperature of 60 °C, reaction time of 4 h, catalyst dosage of 25 wt%, stirring speed of 1500 r/min). After transesterification processes, the catalyst could be easily removed from the reaction mixture with an external magnet and showed little deactivation after multiple recycles. The main properties of biodiesel product were reconcilable with the range of test standards of ASTM D6751 and EN 14214. In summary, the prepared Fe_3O_4@GO@PBIL catalyst behaved a superiorly catalytic performance, which made the produced biodiesel possess the possibility of application to biofuel as an ideal substitution.

Microencapsulation of pomegranate seed oil using a succinylated taro starch: Characterization and bioaccessibility study

Pomegranate and taro are domesticated and underutilized crops in Mexico. Particularly, pomegranate seed oil (PSO), which exhibits health benefits, is scarcely exploited in the food industry due to oxidative degradation. This work by **M. C. Cortez-Trejo *et al*** evaluates the microencapsulation of pomegranate seed oil by spray drying using succinylated taro starch (STS) and β-cyclodextrin (β-CD), as an alternative strategy to protect and deliver PSO [**Food Bioscience, 41**, Article 100929, (2021)]. A Central Composite Design (CCD) was applied and the treatment with the highest PSO encapsulation

efficiency (61.09 ± 0.41%) was selected. PSO-loaded microparticles obtained with 15% feed solids using 190 °C inlet air temperature, showed low a_w (0.08 ± 0.01), moisture (1.26 ± 0.05%), hygroscopicity (11.69 ± 0.57%), and water solubility (9.81 ± 0.24%). The microencapsulation improved PSO oxidative stability. The *in vitro* bioaccessibility study and the kinetic analysis, on the other hand, evidenced that microparticles of succinylated taro starch obtained by spray drying are suitable as carriers for active compounds to be released at the small intestine following a swelling-controlled release mechanism.

Selective separation of α-tocopherol using eco-friendly choline chloride – Based deep eutectic solvents (DESs) via liquid-liquid extraction

The extraction of α-tocopherol was studied by **Behrouz Mohammadi *et al*** using some recently introduced novel, simple and green deep eutectic solvents (DESs) [**Colloids and Surfaces A: Physicochemical and Engineering Aspects, 617** Article 126317, (2021)]. Liquid – liquid extraction measurements were conducted on ternary mixtures of {*n*-hexane + (α-, β-, γ-, δ-) tocopherol + DESs}. The recently studied DESs including (mono-, di- and tri-) ethylene glycol, (mono-, di- and tri-) ethanolamine, and sucrose in combination with ChCl for the first time were used for this extraction. The various parameters affected on extraction efficiency including kind of DESs, temperature (298.15–308.15 K) and extraction time (12, 24 and 48 h) were evaluated. The calculated selectivity (S) and solute distribution coefficient (β) showed good performance of the selected DESs for α-tocopherol. The non-random liquid equation (NTRL) was utilized to correlate measured experimental LLE results, prediction of activity coefficient at infinite dilution (γ^{∞}) and capacity of solvent for solute (C^{∞}). Moreover, higher selectivity, lower contamination of extracted α-tocopherol (with solvents) and immiscibility of eutectic solvents in vitamin E were other advantages of this extraction.

Continuous biodiesel production based on hand blender technology for sustainable household utilization

Biodiesel is a widely-used, renewable and environmentally-friendly fuel. The 700 W commercial household hand blender was proposed by **Manita Kamjam *et al*** as simple and effective continuous FAME production technique using a homogeneous catalyst based on fresh re□ned palm oil, waste cooking oil (WCO), and various vegetable oils as feedstocks [**Journal of Cleaner Production, 297**, Article 126737, (2021)]. The continuous system was designed and the effects of reaction volume, oil and methanol flow rate, reaction temperature and sodium hydroxide catalyst loading on FAME yield and yield efficiency were explored. The steady-state FAME yield of higher than 96.5% can be achieved from both fresh re□ned palm oil and WCO with the energy ef□ciency of 18.0×10^{-4} g/J (fresh re□ned palm oil) and 19.0×10^{-4} g/J (WCO) (6:1 methanol to oil molar ratio, reaction volume of 200 mL, total flow rate 12 mL/min, 60 °C, 0.8 wt% sodium hydroxide for palm oil and 1.5 wt% sodium hydroxide for WCO, highest stirring speed (10,640 rpm) at 220 V, no insulation), indicating that WCO shows good potential as a feedstock of biodiesel production. All properties of the synthesized FAMEs satisfy the EN 14214 and ASTM D 6751 standards. FAME produced from palm oil showed the highest FAME content, followed by sunflower oil and corn oil. The simple and low-cost kitchen hand blender is an alternative process intensification device to efficiently produce good quality FAME for household users, which is a convenient and environmentally-friendly method. WCO can also be recycled to produce a product with high economic value.

Biodiesel preparation from Thlaspi arvense L. seed oil utilizing a novel ionic liquid core-shell magnetic catalyst

In order to produce an alternative energy of biodiesel using field pennycress (*Thlaspi arvense* L.) seed oil, a novel Fe_3O_4/graphene oxide-phenylalanine bisulfate ionic liquid core-shell

magnetic catalyst was developed by **Ru Zhao *et al***. Ferroferric oxide nanoparticles and graphene oxide (GO) were employed to prepare a magnetic carrier of Fe_3O_4@GO nanocomposite which applied to immobilize phenylalanine bisulfate ionic liquid (PBIL) **[Industrial Crops and Products, 162**, Article 113316, (2021)]. The immobilized PBIL was characterized by the means of characterization. The heterogeneous Fe_3O_4@GO@PBIL catalyst was demonstrated to have a high catalytic efficiency that reached 92.38 % of biodiesel yield under the optimal conditions (methanol/oil molar ratio of 10:1, reaction temperature of 60 °C, reaction time of 4 h, catalyst dosage of 25 wt%, stirring speed of 1500 r/min). After transesterification processes, the catalyst could be easily removed from the reaction mixture with an external magnet and showed little deactivation after multiple recycles. The main properties of biodiesel product were reconcilable with the range of test standards of ASTM D6751 and EN 14214. In summary, the prepared Fe_3O_4@GO@PBIL catalyst behaved a superiorly catalytic performance, which made the produced biodiesel possess the possibility of application to biofuel as an ideal substitution.

Emission and performance behavior of hemp seed oil biodiesel/diesel blends in DI diesel engine

Hemp seed oil is chosen as a feedstock for biodiesel production, methanol and KOH were used in the biodiesel production. The properties like chemical and physical of hemp oil biodiesel are measured by **M. A. Asokan *et al*** to investigate the engine emission and performance characteristics of diesel engine [**Materials Today: Proceedings 46**, Part 17, Pages 8127-8132, (2021)] . From the results, B20 blend performance is best among other fuels tested. Besides, the Brake Specific Fuel consumption (BSFC) at full load (0.3 kg/kW h) for B20 is slightly lesser than diesel fuel (0.32 kg/kW h). This indicates that the lower diesel/hemp seed oil biodiesel blends will increase the performance as well as decrease the fuel consumption. Considering, the emissions from exhaust exhibited that Carbon Monoxide (CO), Hydrocarbon (HC) and Nitrox oxide (NOx) were lowered for all hemp seed oil biodiesel/diesel blends. However, smoke emission increased slightly than diesel. In general, the results concluded that hemp oil biodiesel is a best alternative as well as good substitute fuel to diesel.

Ester oils prepared from fully renewable resources and their lubricant base oil properties

Chenghong Hu *et al* report the physicochemical and tribological properties of gallate ester oils prepared from fully renewable resources, such as gallic acid and fatty acids [**ACS Omega, 6**, 16343-16355, (2021)]. The ester structures were identified by proton nuclear magnetic resonance spectroscopy (^{1}H NMR), carbon nuclear magnetic resonance spectroscopy (^{13}C NMR) and high-resolution mass spectra (HRMS) data. The density at 20 °C (d_{20}), kinematic viscosity (KV), viscosity index (VI), pour point (PP), flash point (FP), thermal and oxidative stabilities, friction-reducing and antiwear properties of gallate ester oils were evaluated. The tribological properties of gallate ester oils as lubricants for steel, copper, and aluminum tribo-pairs can be compared with those of the commercially available lubricating oil tris(2-ethylhexyl) trimellitate (Phe–3C_{i8}), but their viscosity-temperature characteristics, thermal and oxidative stabilities are better than those of Phe–3C_{i8}. More importantly, they have much higher biodegradabilities than Phe–3C_{i8}. The study of the lubrication mechanism shows that the physical and/or chemical adsorption film formed by gallate ester molecules between friction pairs is the key factor for them to obtain friction-reducing and antiwear properties.

Conversion of high-solids hydrothermally pretreated bioenergy sorghum to lipids and ethanol using yeast cultures

Glucose and xylose are the major sugars present in cellulosic hydrolysates. The cellulosic sugars can be used for the production of platform chemicals. In this study, productions of lipid and ethanol by yeasts were compared by **Ming-Hsun Cheng *et al***

for concentrated bioenergy sorghum syrup **[ACS Sustainable Chemistry & Engineering, 9**, 8515-8525, (2021)]. Bioenergy sorghum was hydrothermally pretreated at 50% w/w solids in a continuous industrial reactor and sequentially mechanically refined using a burr mill to improve biomass accessibility for hydrolysis. Fed-batch enzymatic hydrolysis was conducted with 50% w/v solids loading and cellulase cocktail (50 FPU/g biomass) to achieve 230 g/L sugar concentration. Various strains of *Rhodosporidium toruloides* were evaluated for converting sugars into lipids, and strain Y-6987 had the highest lipid titer (9.2 g/L). The lipid titer was improved to 19.0 g/L by implementing a two-stage culture scheme, where the first stage was optimized for yeast growth and the second for lipid production. For ethanol production, the engineered *Saccharomyces cerevisiae* SR8ΔADH6 was utilized to coferment glucose and xylose. Ethanol fermentation was optimized for media nutrients (YP, YNB/urea, and urea), cellulosic sugar concentration, and sulfite conditioning to maximize the ethanol concentration from sorghum syrups. Fermentation of 70% v/v concentrated hydrolysate conditioned with sulfite produces 50.1 g/L ethanol from 141 g/L of sugars.

Lipid oxidation: role of membrane phase-separated domains

Lipid oxidation is associated with several inflammatory and neurodegenerative diseases, but many questions to unravel its effects on biomembranes are still open due to the complexity of the topic. For instance, recent studies indicated that phase-separated domains can have a significant effect on membrane function. It is reported that domain interfaces are “hot spots” for pore formation, but the underlying mechanisms and the effect of oxidation-induced phase separation on membranes remain elusive. Thus, to evaluate the permeability of the membrane coexisting of liquid-ordered (Lo) and liquid-disordered (Ld) domains, **Maria C. Oliveira *et al*** performed atomistic molecular dynamics simulations. Specifically, they studied the membrane permeability of nonoxidized or oxidized homogeneous membranes (single-phase) and at the Lo/Ld domain interfaces of heterogeneous membranes, where the Ld domain is composed of either oxidized or nonoxidized lipids [**Journal of Chemical Information and Modeling 61**, 2857-2868, (2021)]. Our simulation results reveal that the addition of only 1.5% of lipid aldehyde molecules at the Lo/Ld domain interfaces of heterogeneous membranes increases the membrane permeability, whereas their addition at homogeneous membranes does not have any effect. This study is of interest for a better understanding of cancer treatment methods based on oxidative stress (causing among others lipid oxidation), such as plasma medicine and photodynamic therapy.

A review on functional and nutritional properties of noni fruit seed (Morinda citrifolia L.) and its oil

Noni (*Morinda citrifolia* L.) is native to the Polynesian and recognized in the tropical and subtropical countries as a sustainable crop with feasible commercial applications. It has been reported that the interest in developing noni plant as a novel source of bioactive compounds are increasing by the day. This review by **M. H. A. Jahurul *et al*** describes the safety, nutritional values, and the properties of noni seed oil (NSO) with potential industrial uses. In particular, the bioactive compounds, anti-nutrients, antioxidant activity, and IC_{50} values of noni seed and the chemical composition of NSO are also described [**Food Bioscience, 41,** Article 101000 (2021)]. NSO has high contents of polyunsaturated fatty acids, total phytosterols and tocopherols that could be better choices for patients with high cholesterol and cardiovascular diseases. Extracts of noni seed have been shown to possess bioactive compounds that exhibit antioxidant, anti-mutagenic, anti-tumor, anti-inflammatory, anti-allergic, anti-viral, anti-fungal, anti-microbial, and anti-carcinogenic properties. Bioactive compound-rich noni fruit seed could be a potential source of functional foods. Moreover, noni seeds could be a valuable

new source of vegetable oil because of its nutritional properties and non-toxic nature along with the increasing supply of seeds as by-products from noni juice industry. Comprehensive studies are needed on NSO to explore more potential product development. Moreover, further study is needed on the development of nutraceutical food products from noni seed by-products.

Comparison of different ultrafiltration membranes as first step for the recovery of phenolic compounds from olive-oil washing wastewater

The production of olive oil generates wastewater with a high organic load and toxicity due to the high concentration of phenolic compounds. In recent years, the study on the treatments of these waters has been intensified together with the search for a process to recover these phenolic compounds due to their great antioxidant potential. All this with the aim of implementing the concept of circular economy. In this study, four different organic ultrafiltration membranes were evaluated by **Magdalena Cifuentes-Cabezas *et al*** in order to recover the phenolic compounds present in olive oil washing wastewater (OOWW) from an oil mill in the Valencian Community (Spain) [**Process Safety and Environmental Protection, 149,** Pages 724-734, (2021)]. The tested membranes differ in materials and molecular weight cut-off (MWCO): two permanently hydrophilic polyethersulfone (PESH) membranes with MWCO of 4 and 50 kDa, respectively, one polyethersulfone (PES) membrane with a MWCO of 5 kDa and a regenerated cellulose acetate (RCA) membrane with a MWCO of 10 kDa. Transmembrane pressure (TMP) and crossflow velocity (CFV) were varied from 1 to 3 bar and from 1.5 to 3.4 $m \cdot s^{-1}$, respectively. The effectiveness of the different membranes and operating conditions were evaluated comparing the permeate flux and the rejection of chemical oxygen demand (COD) and total phenolic compounds (TPhs). The membranes with lower MWCO showed stable permeate fluxes without significant changes over time, while the 50 kDa membrane showed a gradual decrease, without achieving a stable flux. Low rejection of phenolic compounds was observed in all cases, while the rejection of COD varied between 19.5 % and 62.9 % depending on the membrane and operating conditions tested. Except for the 50 kDa PESH membrane, initial permeability recovery greater than 95 % was achieved with a 35 °C water rinse, indicating that membrane fouling was not severe. Since the aim was to recover the TPhs in the permeate stream and separate them from the organic matter, the 5 kDa PES membrane at 2 bar and 2.5 $m \cdot s^{-1}$ was considered to be the best option. At those conditions a stable permeate flux of 40 $L \cdot h^{-1} \cdot m^{-2}$ was obtained, while the lowest TPhs rejection was observed (8.01 %) with a high COD rejection (61.18 %).

Kinetics and performance study of ultrasonic-assisted membrane anaerobic system using monod model for palm oil mill effluent (POME) treatment

The discharge of Palm Oil Mill Effluent (POME) to river or sewage has caused serious environmental problems for the past several decades. This has prompted many researchers to find alternative technologies such as the use of an ultrasonic-assisted membrane anaerobic system, also known as UMAS. However, further use of UMAS in treating POME tends to create blockage on the membrane surface, which is commonly known as membrane fouling. In this study, kinetic parameters of POME samples which contributed to the fouling were investigated by **Ayub Md Som and Asdarina Yahya**, namely; the biomass growth rate, μ_{max} and substrate utilization rate, K_s. Two different sources of POME samples were taken from namely; a final discharge pond at Felda Sungai Tengi, Selangor and decanter processing units at Felda Jengka, Pahang[**, 23**, Article 100075 (2021)]. The POME samples were treated by UMAS in a 26-Litre laboratory reactor which operated 5 □h per day for a HRT of 7 days so as to observe their performance in terms of percentage COD removal and CH_4 production. Performance results revealed that maximum COD removal

efficiencies were 82.75% and 94.43% for the final discharge pond and decanter processing unit samples respectively. All these data were collected and curve fitting methods were then used to construct appropriate profiles for μ_{max} and K_s following a Monod model. It was found that the high OLR sample (decanter) apparently yielded better efficiency of POME treatment (i.e. calculated μ_{max} of 0.327 day^{-1}, K_s of 0.361 □g COD/g VSS. d, and volume of CH_4 gas produced at 25 □m^3) compared to that of low OLR sample from ponds (i.e. calculated μ_{max} of 0.237 day^{-1}, K_s of 0.1674 □g COD/VSS. d, and volume of CH_4 gas produced at 9 □m^3). In conclusion, it shows that UMAS is a promising treatment to treat POME in which its calculated kinetic coefficients of μ_{max} and K_s are similar to the theoretical values when Monod Model is employed in this study.

Obtention of methyl esters from macauba oil using egg shell catalyst

Considering that conventional fossil fuels have limited resources and are not environmentally friendly, while energetic demand grows exponentially, the searching for alternative energetic supply is becoming more and more attractive. Biodiesel is considered an alternative energetic supply reality and is composed by fatty acids methyl esters obtained through esterification and/or transesterification reactions. Although a reality, the increase in use of biodiesel depends on lowering its production costs. In order to reach this goal, this paper by **Beatriz de Souza Gonçalves Proença *et al*** describes a way to produce a low cost catalyst for biodiesel production by egg shell calcination, as well as demostrate paremeters optimum conditions by statistical analysis [**Chemical Engineering Research and Design, 169**, Pages 288-296,(2021)]. Biodiesel samples were produced from macauba seed oil and methanol using an egg shell catalyst in a batch reactor. Parameters such as oil/methanol molar ratio, catalyst amount and temperature were evaluated for biodiesel conversion yield. The results were considered satisfactory as the esters conversion yield reached about 91% and parameters study revealed the stronger influence of temperature and catalyst content in ester conversion.

In-depth characterization of palm-based diacylglycerol-virgin coconut oil blends with enhanced techno-functional properties

Siou Pei Ng *et al* provide an overview of the physicochemical characteristics and the thermal profile of palm olein-based diacylglycerol (POL-DAG), virgin coconut oil (VCO) and their binary blends at specific ratios [**LWT, 145,** Article 111327, (2021)]. The characterization of the POL-DAG/VCO blends, including their fatty acid composition, acylglycerol composition, functional group based on Fourier-transform infrared (FTIR) spectra, thermal performance, solid fat content and iodine value were carefully evaluated. The fatty acid composition and iodine value indicated the increased unsaturation levels of the oil blends with increasing POL-DAG oil incorporation. Based on the acylglycerol composition, the DAG content of the binary blends increased proportionally from 346.7 g/kg to 816.0 g/kg with the increased concentration of POL-DAG. Furthermore, the oil blends exhibited lower solid fat content values than the plain VCO. The melting and crystallization results also showed that blending produced a significant effect on the temperature transition, the peak sharpness and the onset temperature ($p < 0.05$) as the POL-DAG concentration increased. The FTIR spectra were also consistent with this finding as POL-DAG contains more unsaturated fatty acids than VCO. All in all, the blending of POL-DAG with VCO enhanced the techno-functional properties of the oil and could widen the range of applications and useful for product diversifications.

Two-stage continuous production process for fatty acid methyl ester from high FFA crude palm oil using rotor-stator hydrocavitation

Two-stage continuous production process for fatty acid methyl ester (FAME) from crude palm oil was performed by **Ye Min Oo *et al*** using the

rotor–stator hydrocavitation reactor [**, 73**, Article 105529, (2021)]. The novel ABS filament printed rotor having spherical holes on the surface of the rotor which is an efficient, fast and cost-effective procedure, was installed in the stainless steel stator of hydrosonic reactor. The 3D printed hydrosonic reactor was used to treat the FFA-rich in MCPO by esterification and followed by transesterification to produce the methyl ester. The optimum conditions of both esterification and transesterification processes were determined using the response surface methodology (RSM). For the 1st step esterification, the conditions of methanol 17.7 vol%, sulfuric acid 2.9 vol%, 3000 rpm rotor speed, hole's diameter and depth 4 and 6 mm, and 25 L/h MCPO, were used for decreasing the FFA from 11.456 to 1.028 wt%. For the 2nd step, transesterification was employed with the optimal condition of 28.6 vol% methanol, 6.2 g/L of potassium hydroxide, 3000 rpm rotor speed, the dimension of the spherical holes on the rotor's surface having diameter of 6.4 mm and 6.2 mm in depth, and esterified oil flow rate 25 L/h, for producing the methyl ester to over 99.163 wt%. Moreover, the purified biodiesel yields and the average energy consumption for the entire two-stage continuous process between hydrosonic and ultrasonic clamp reactors were compared. The results of purified methyl ester clearly indicate that the methyl esters of 99.163 wt% and 97.814 wt% were achieved from hydrosonic and ultrasonic clamp reactors, respectively, under the same optimized conditions. The maximum yields of purified biodiesel were 97.51 vol% and 88.69 vol% using hydrosonic and ultrasonic clamp reactors, respectively. The average energy consumption for the entire continuous two-stage process for both hydrosonic and ultrasonic clamp reactors were 0.049 and 0.056 kW h/L, respectively. For practical industrial processes, stainless steel rotors inside the stator was manufactured by CNC machine, which was also verified under the optimum conditions. The results showed that 1.07 wt% FFA and 99.221 wt% methyl ester of were obtained from first step and second step, respectively.

Experimental measurement and correlation of phase equilibria of palmitic, stearic, oleic, linoleic, and linolenic acids in supercritical carbon dioxide

Supercritical carbon dioxide (SC-CO_2) represents a promising solvent in the synthesis of biodiesel given its enhanced mass transfer properties as well as its high affinity to the fatty acids. In this work, the phase equilibria data of 5 major fatty acids: palmitic, stearic, oleic, linoleic, and linolenic acid in SC-CO_2 were studied by **Jason Yi Juang Yeo *et al*** experimentally at temperature between 343.15 to 373.15 K and pressures between 8 to 24 MPa [**Journal of Industrial and Engineering Chemistry, 97,** Pages 485-491, (2021)]. The experimental data were correlated using Peng–Robinson Equation of State with van der Waals (PR-vdW), Panagiotopoulos-Reid (PR-PR), and Stryjek-Vera (PR-SV) combining rules. The fitting result by PR-PR was shown to be more accurate and consistent than those of PR-vdW and PR-SV. From these data, we found that oleic acid has the greatest solubility in SC-CO_2, followed by linoleic acid, palmitic acid, stearic acid, and lastly, linolenic acid.

Low-oxygenated biofuels production from palm oil through hydrocracking process using the enhanced Spent RFCC catalysts

Utilization of the enhanced Spent Residue Fluid Catalytic Cracking (SRFCC) catalysts through the acid treatment was conducted by **Istadi *et al*** for the palm oil hydrocracking process to produce biofuels. The catalysts were characterized using Pyridine-probed Fourier Transform Infrared (Pyridine-FTIR) spectroscopy and Brunauer-Emmett-Teller-Barrett-Joyner-Halenda (BET-BJH) method [**Bioresource Technology Reports, 14**, Article 100677, (2021)]. The higher number of Brønsted acid sites on the enhanced SRFCC catalysts leads to the lower conversion of palm oil as well as lower deoxygenation activity because of the slower carbocations formation process as the initiation reaction. On the other hand, the Lewis acid sites on the enhanced SRFCC catalysts have a significant

role in the deoxygenation reaction mechanism. Meanwhile, the catalysts surface area and pore size are responsible for tailoring the diffusion mechanism of the mass transfer process of reactant molecules. The introduction of hydrogen gas in the reaction system has a significant role in deoxygenation, double bond cleavage, and de-coking process mechanisms.

Microalgae to biodiesel - Review of recent progress

Microalgae with potentially high lipid yields of certain strains and relatively small environmental footprints offer a medium to long term biodiesel supply. Substantial challenges need to be resolved before they can be developed commercially on a large scale. There have been some significant technological breakthroughs made in recent years that offer the potential to achieve this. The ability to genetically engineer algal strains more efficiently and precisely to stabilize their growth and improve lipid yield is one approach. Others include one-step harvesting and lipid extraction from wet biomass, filtering incident light to focus on red photons, combining solar photovoltaics with high-rate algal ponds, and using wastewater and effluent to provide the ideal nutrient mix to promote algal growth and lipid yield. Additionally, microalgal extracts offer some value-added, high-margin co-products, such as poly-unsaturated fatty acids and nutrient-rich biofertilizers. Multi-product integrated biorefineries embracing offer the best route to large-scale, eco-friendly biodiesel commercialization as described by **David A. Wood** [**Bioresource Technology Reports, 14,** Article 100665, (2021)].

Azadirchta excelsa seed oil, a potential non-conventional biodiesel feedstock

The fact that 60% of the Indian population is dependent on Agricultural practices for their livelihood means that there is a huge potential for the development of second-generation Biofuel. The current work by **Tenzin Lhawang *et al*** involves the use of *Azadirchta excelsa* seeds to obtain biofuel. It is a commercial crop grown in Southern parts of India such as Karnataka [**Environmental Challenges, 3**, Article 100057, (2021)]. It is mainly grown to get timber for building houses and for manufacturing of match sticks. Soxhlet extraction method was used to extract oil from the seeds, with hexane being the choice of solvent and a yield of 35% was obtained. The oil was transesterified using Base (NaOH) catalyst method to produce oil methyl ester. The conversion rate of oil was found to be 50%. The physicochemical parameters of the biodiesel produced were analyzed of other basic parameters. The results lied within the range of American society of testing material (ASTM D6751) standards and Indian Standards (IS) 15607 specifications for biodiesel samples, which conclude that *A.excelsa* seed oil can be satisfactorily used as a feed-stock for biodiesel production.

Gas chromatography – mass spectrometry for characterisation, assessment of quality and authentication of seed and vegetable oils

Seed and vegetable oils are complex mixtures of components, with the major classes including mono-, di- and triacylglycerols, fatty acids, phytosterols, tocopherols and tocotrienols. An overview of recent advances in the analysis of seed and vegetable oils by both one-dimensional (1D) and multidimensional gas chromatography (MDGC) methodologies is presented by **Maria Fernanda S. Mota *et al***. Authenticity of food oils continues to be important, and use of various classes of compounds as markers for adulteration are highlighted. Selected applications of contaminants analysis, including pesticides, hydrocarbons and plasticisers, are emphasised. A brief comparison of the separation technologies gas chromatography (GC) and liquid chromatography (LC) is also included [**TrAC Trends in Analytical Chemistry, 138,** Article 116238, (2021)]. The review concludes by highlighting recent advances and future trends.

Selective separation of α-tocopherol using eco-friendly choline chloride – Based deep eutectic solvents (DESs) via liquid-liquid extraction

The extraction of α-tocopherol was studied by **Behrouz Mohammadi *et al*** using some recently introduced novel, simple and green deep eutectic solvents (DESs) [

Colloids and Surfaces A: Physicochemical and Engineering Aspects, 617, Article 126317, (2021)]. Liquid – liquid extraction measurements were conducted on ternary mixtures of {*n*-hexane + (α-, β-, γ-, δ-) tocopherol + DESs}. The recently studied DESs including (mono-, di- and tri-) ethylene glycol, (mono-, di- and tri-) ethanolamine, and sucrose in combination with ChCl for the first time were used for this extraction. The various parameters affected on extraction efficiency including kind of DESs, temperature (298.15–308.15 K) and extraction time (12, 24 and 48 h) were evaluated. The calculated selectivity (S) and solute distribution coefficient (β) showed good performance of the selected DESs for α-tocopherol. The non-random liquid equation (NTRL) was utilized to correlate measured experimental LLE results, prediction of activity coefficient at infinite dilution (γ^{∞}) and capacity of solvent for solute (C^{∞}). Moreover, higher selectivity, lower contamination of extracted α-tocopherol (with solvents) and immiscibility of eutectic solvents in vitamin E were other advantages of this extraction.

Evaluation of 3-monochloropropanol esters and glycidyl esters during the production and concentration of diacylglycerol by two-stage short-path molecular distillation

Diacylglycerol (DAG) has been drawing increased global attention due to its health benefits; however, there is a biggest challenge raised by 3-monochloropropyl esters (3-MCPDEs) and glycidyl esters (GEs) during its preparation and concentration. Herein, a model firstly was clarified and evaluated by **Chuan-Guo Ma *et al*** for the preparation of 48.9% DAG achieved by enzymatic glycerolysis of soybean oil in a solvent-free system though Response Surface Methodology [**LWT, 144,** Article 111145, (2021)]. Subsequently, the resulted DAG was concentrated to 79.7%, involving 75.1% 1,3-diacylglycerol and 24.9% 1,2-diacylglycerol due to the steric effect and/or acyl migration, thought two-stage short path molecular distillation (SPD), and 3-MCPDEs and GEs were concomitantly evaluated during the concentration. Comparative investigation of various SPD parameters (*e.g.*, temperature, scraping speed and feed rate), temperature was dominant and dependency in both 3-MCPDEs and GEs formation during the primary molecular distillation. However, it has a less effect on the formation of 3-MCPDEs and more effect on levels of GEs during the secondary molecular distillation process. Nonetheless, the DAG and chloride increases the probability of formation of both 3-MCPDEs and GEs. The results may promote the engineering production of DAG with high purity and quality.

Inter-relationships between composition, physicochemical properties and functionality of lecithin ingredients

Lecithin is widely used as an ingredient in the food industry due to its diverse functionality, mainly attributed to phospholipids (PL), the principal constituents. However, a systematic understanding of the functional properties of lecithin ingredients is missing in the literature.This review outlines recent developments in lecithin from botanical origin and reviews the complex inter-relationships between physicochemical properties of PL in lecithin and selected techno-functional properties in micelles, liposomes and oil-in-water emulsions.Attributed to their polar phosphatide group and non-polar fatty acids, PL have specific molecular geometries, dissociation constants and charge, which strongly influence their functional properties in micelles, liposomes and oil-in-water emulsions. The PL profile and extrinsic factors (e.g., water, oil, hexane) influence the formation of micelles during separation of lecithin from oil using membrane filtration. In liposomes, PL profile and the presence of surface modifiers (i.e., sterols) affect the particle size and encapsulation efficiency. In emulsion systems, PL and their interaction with minerals and other functional ingredients (e.g., proteins), influence the particle

size and physical stability of the oil droplets. This work by **Francesca Bot *et al*** provides an integrated review of the links between the composition and physicochemical properties of PL, and in turn, scientifically underpins the links between physicochemical and functional properties of lecithin [**Trends in Food Science & Technology, 111,** Pages 261-270, (2021)].

Fabrication of magnetic nanoparticles supported ionic liquid catalyst for transesterification of vegetable oil to produce biodiesel

Mu. Naushad *et al* have fabricated novel magnetic ionic liquid based nanocomposites using 1-butylimidazole, (3-bromopropyl)-trimethoxysilane and $NiFe_2O_4$ nanoparticles. $[NiFe_2O_4$@-BMSI$]HSO_4$ was synthesized from $[NiFe_2O_4$@-BMSI$]$Br via ion-exchange process [**Journal of Molecular Liquids, 330**, Article 115648, (2021)]. The fabricated nanocomposites were characterized by various analytical techniques. The surface area was determined using N_2 adsorption-desorption analysis and the BET surface area of $[NiFe_2O_4$@BMSI$]$Br and $[NiFe_2O_4$@BMSI$]HSO_4$ was noted to be 89.21 and 87.21 m^2/g, respectively. The fabricated nanocomposites were used as catalyst for the transesterification of palm oil (VO) for the production of biodiesel. The results revealed that $[NiFe_2O_4$@BMSI$]HSO_4$ exhibited better performance in terms of biodiesel yield; a maximum i.e. 86.4% yield was obtained using $[NiFe_2O_4$@BMSI$]HSO_4$ while in the case of $NiFe_2O_4$@BMSI]Br, about ~74.6% yield was found with 5% (w/w) catalyst loading, 353 K and to CH_3OH ratio of 1:12 in 8 h. The reusability of the catalyst results revealed that the catalytic activity of the catalysts still remained about 92.7% and 88.1% with $NiFe_2O_4$@BMSI$]HSO_4$ and $NiFe_2O_4$@BMSI]Br, respectively after six cycles which may be accredited to the handling loss during the manipulation process.

Life cycle assessment of biodiesel production utilising waste date seed oil and a novel magnetic catalyst: A circular bioeconomy approach

The utilisation of waste biomass in biodiesel production as a sustainable energy source can lead to the incorporation of circular bioeconomy principles in the current economic systems. Herein, **Kamla S. Al-Mawali *et al*** synthesised a magnetically recyclable solid acid catalyst for the esterification of waste date seed oil [**Renewable Energy, 170**, Pages 832-846, (2021)]. The catalysts possessed superparamagnetic behaviour and high saturation magnetisation, allowing them to be easily separated from the reaction mixture using an external magnetic field. The esterification reaction was modelled and optimised by RSM (Design Expert program) and parametric study. The magnetic solid acid catalyst showed high catalytic performance with 91.4% biodiesel yield with optimum conditions of residence time, catalyst loading and temperature of 47 min, 1.5 wt %, and 55 °C, respectively. The solid catalyst was easily recovered by simple magnetic decantation and reused five consecutive times without significant degradation in its catalytic activity. This approach of using waste date seed coupled with cheap magnetic solid acid catalyst has the potential to create more sustainable and cost-effective catalytic systems for biodiesel production. This will complete the full cycle of waste date seed sustainably and facilitate the development of circular bioeconomy. The LCA results by using CML-IA baseline V3.06 midpoint indicators, for 1000 kg of biodiesel production showed the cumulative abiotic depletion of fossil resources over all the processes as 19037 MJ, global warming potential as 1114 kg CO_2 eq, and human health toxicity as 633 kg 1,4-DB eq (kg 1,4 dichlorobenzene equivalent). The highest damage in all categories was observed during catalyst preparation, and reuse, which was also confirmed in endpoint LCA findings performed using ReCiPe 2016 Endpoint (E) V1.04.

A promoter effect on hydrodeoxygenation reactions of oleic acid by zeolite beta catalysts

Various metal-modified zeolite beta-based

catalysts such as $La_{(10)}zeo_{(90)}$, $Co_{(10)}zeo_{(90)}$, $Fe_{(10)}zeo_{(90)}$, $Mg_{(10)}zeo_{(90)}$, $Mn_{(10)}zeo_{(90)}$ and $Zn_{(10)}zeo_{(90)}$ were investigated by **Nur Azreena *et al*** in the hydrodeoxygenation (HDO) of oleic acid (OA) to produce renewable diesel [**Journal of Analytical and Applied Pyrolysis, 155**, Article 105044, (2021)]. The $La_{(10)}zeo_{(90)}$ catalyst showed a conversion of OA up to 99 % with 83 % C_{15} and C_{17} selectivity after the reaction at 350□°C for 2□h under 4□MPa H_2 pressure. The superior activity of $La_{(10)}zeo_{(90)}$ was attributed to the synergistic interaction between La-Si-Al, a sufficient amount of weak□+□medium acid sites and excellent textural properties (large pore diameter). Larger pore diameter of $La_{(10)}zeo_{(90)}$ is highly desirable as it will generate greater diffusion of bulky molecules, thereby improving the accessibility of the reactant and hence excellent catalytic activity. The vacuum distillation was used to purify the crude liquid product (CLP), producing high-quality diesel fractions mainly comprising C_{14}, C_{15}, and C_{17} fractions.

Intensified synthesis of palm olein designer lipids using sonication

Intensified synthesis of designer lipids with application of ultrasound based on biocatalyzed reaction between long chain triglyceride and medium chain fatty acid was carried out by **Harsh B. Jadhav *et al***. The effects of various reaction conditions like molar ratio of reactant, reaction temperature, and enzyme loading along with the effect of ultrasound parameters such as duty cycle and irradiation time on the rate of formation of designer lipids has been investigated [**Ultrasonics Sonochemistry, 73**, Article 105478, (2021)]. The ultrasound assisted process was also compared with the traditional process so as to clearly bring out the intensification effects. During the study, it was clearly demonstrated that the optimum reaction conditions for maximum yield of designer lipids as 92% was molar ratio of medium chain fatty acid to long chain triglyceride as 4:1, reaction temperature of 40 °C, enzyme loading of 3%, duty cycle of 70%, 240 W as power dissipation and 360 min as reaction time. The recyclability study of enzyme showed its effectiveness up to 10 cycles. The synthesized designer lipid showed higher oxidative stability for 35 days and also showed Newtonian behaviour with eye appealing colour. The current study demonstrates development of an eco-friendly technique for intensified synthesis of designer lipids having numerous nutraceutical benefits.

Enzymatic production of biodiesel from alperujo oil in supercritical CO2

The synthesis of fatty acid methyl esters (FAMEs) as biodiesel from alperujo oil was studied by **L. Quintana-Gómez *et al*** in $scCO_2$ using a mixture of Novozym 435 and Lipozyme TL IM at 10% as a catalyst to enhance the productivity [**The Journal of Supercritical Fluids, 171**, 105184, (2021)]. The reaction performance was investigated at different temperatures (40–60 °C), reaction times (1–48 h) and with a mixture of methylating agents in molar ratios of oil:methanol:methyl acetate from 1:0:40 to 1:5:35. Conversion of triglycerides achieved values up to 96% at>50 °C and reaction times of 24 h with FAMEs yields of over 90%. The presence of methyl acetate and the use of $scCO_2$ as solvent improved the oil conversion and FAMEs yield in comparison with other works. The residual activity of the enzymes dropped at high reaction temperatures (>40 °C), reaction times (>1 h) and if the molar oil: methanol ratio was increased from 1:1 to 1:2 or higher.

Thermodynamic analysis of syngas production from biodiesel via chemical looping reforming

In this study, thermodynamic analysis of the syngas production using biodiesel derived from waste cooking oil is studied by **Chia-Hsuan Liao and Reiyu Chein** based on the chemical looping reforming (CLR) process [**International Journal of Hydrogen Energy, 46**,Pages 16591-16602, (2021)]. The NiO is used as the oxygen carrier to carry out the thermodynamic analysis. Syngas with various H_2/CO ratios can be obtained by chemical looping dry reforming (CL-DR) or steam reforming (CL-SR). It is found that the syngas

obtained from CL-DR is suitable for long-chain carbon fuel synthesis while syngas obtained from CL-SR is suitable for methanol synthesis. The carbon-free syngas production can be obtained when reforming temperature is higher than 700 °C for all processes. To convert the carbon resulted from biodiesel coking and operate the CLR with a lower oxygen carrier flow rate, a carbon reactor is introduced between the air and fuel reactors for removing the carbon using H_2O or CO_2 as the oxidizing agent. Because of the endothermic nature of both Boudouard and water-gas reactions, the carbon conversion in the carbon reactor increases with increased reaction temperature. High purity H_2 or CO yield can be obtained when the carbon reactor is operated with high reaction temperature and oxidizing agent flow.

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