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From Editor's Desk



It has been a great journey. I took the responsibility of editing the Journal of Lipid Science and Technology, the official journal of Oil Technologists' Association of India, from Dr RBN Prasad, an accomplished Lipid scientist. After completing two terms as the Editor, now, its time for me to pass the baton to Prof R P Singh, another eminent oil technologist. He will be your new editor from the next issue. Congratulations and very best wishes to him. It was real enriching time for me. I learnt a lot about the new happenings in the areas of oils, fats and allied products. I thank all the authors for sending their research findings to this journal. The success of a journal depends on the quality of research papers that are published. I am sure our journal will continue to get the patronage of the researchers from India and abroad. In this period, some new features were introduced to give our readers an idea about what is going on in the world of oils and fats. I am sure; some more new features will be added in near future. I will fail in my duties if I do not acknowledge the cooperation I received from all my Associate Editors Dr A Madhavan, Mrs KN Prasanna Rani, Dr KVSN Raju and Mr VV Rao. Their help and encouragements were always a source of inspiration for me. I thank all All India Presidents, the members of Central Executive Committee and all Zonal Executive Committee for having confidence on me. I thank one and all !!

Happy reading!!

(PRADOSH PRASAD CHAKRABARTI)

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PROCESS OPTIMIZATION FOR SYNTHESIS OF EPOXY RESIN FROM WASTE SOYABEAN OIL

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Abstract

Vegetable oil is triglycerides of higher molecular weight fatty acids and have high amount of unsaturated fatty acids. These unsaturated fatty acids can be converted into epoxy fatty acids. Epoxidized vegetable oils (EVO) are sustainable, renewable and environment friendly in nature and are therefore gaining importance as feedstock for the synthesis of plasticizers, lubricants, coating formulations, polyols etc. The unsaturation present in soyabean oil can be epoxidized to produce an eco-friendly and consumer-friendly product comparable to products obtained from petroleum origin. In this study waste soyabean oil was successfully used to produce economically efficient epoxy resin. The waste soyabean oil (WSBO) used was obtained from refined soyabean oil, after using it as frying medium for 16 hours.

50g waste soyabean oil having an iodine value 131and acid value 1.2 was reacted with peracetic acid at 60°C for 7 hours. An excess of 30% hydrogen per oxide was taken for higher conversion in the reaction. This reaction was completed with acetic acid as oxygen carrier in presence of H_2SO_4 as catalyst in situ. The product structure was analyzed by Fourier Transform Infrared Spectroscopy (FTIR) and Proton Nuclear Magnetic Resonance Spectroscopy(1H-NMR).

Keywords:Epoxidisedvegetable oil, waste soyabean oil, epoxidation,Fourier Transform Infrared Spectroscopy,Proton Nuclear Magnetic Resonance Spectroscopy

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Introduction

The vegetable oil based products are recognised as sustainable and biodegradable in nature which can contribute in reducing global warming effect. Thelesser biodegradability has forced the researchers to develop alternatives for petrochemical based resin such as epoxy. Though the petrochemical based resins have better material properties such as high stiffness and strength, but these resins also have serious drawbacks in terms of biodegradability, initial processing cost, energy consumption and health hazards. As a result there is a strong need to develop novel bio-based product from cheaper renewable feedstock.

The modified oils can serve as feedstock that can replace petroleum derived materials in many applications [1]. Therefore, the interest in using renewable and readily biodegradable resources has been increased rapidly in recent years. Further, to make the product cost effective, waste vegetable oil can be used to synthesize epoxy resins, which will also enhance the economic value of the vegetable oil. The rapid increase in the level of awareness regarding environment is also responsible for the continuous development of sustainable green materials. This paper is focused on the optimization of process conditions and various advantages of epoxy resin synthesized by waste soybean oil.

The double bonds present in the vegetable oil are used as reactive sites to insert various functional groups as per our need by carrying out epoxidation reaction. The epoxidation reaction insert the three- member oxirane ring in the unsaturated portion of the oil molecule, which increases its complexity and chemical

reactivity with a variety of compounds such as amines and carboxylic acid [2,3]. The conversion of unsaturation to epoxy groups can be directly monitored by determining the oxirane oxygen content, and indirectly by determining the iodine value[4]. Epoxidation can also be achieved in one step with peroxy acid produced in situ from acetic/formic acid. Epoxidized vegetable oils are widely used in polymer industry because of their excellent plasticizing action for poly vinyl chloride and an effective component for stabilizing polymer formulations[5,6]. Epoxides also find industrial application as diluents[7], lubricants[8] and coatings[9].

Experimental

Materials and Method

Waste soybean oil was obtained after 16 hours of frying of refined soyabean oil. Aceticacid(95%, CDH) and hydrogen peroxide(50%,RFCL) were used as reagents in the epoxidation reaction. Glacial Acetic acid(99.7%, Qualikems), crystal violet indicator(Thomas Baker) and 0.1N hydrobromic acid (48%, Thomas Baker ,in acetic acid) were used in titration for determining percentage of epoxide group.

Synthesis of epoxidized waste soybean oil

Epoxidation of waste soyabeanoil was carried out in a 500ml four necked round bottom flask equipped with a thermometer, a mechanical stirrer, a condenser and funnel as shown in **Figure1**. Waste soyabean oil was charged in the round bottom flask with acetic acid and the reaction temperature was maintained at 60°C. In the first step of epoxidation, 30% Hydrogen peroxide solution in the presence of small quantities(2ml) of concentrated sulphuric acid was added into flask slowly through a funnel over 2.5 h. The stirring rate was controlled at 800rpm so that oil can be completely dispersed in the mixture.

In the second step, after charging hydrogen per oxide, the reaction continued by mixing and controlling the temperature at 50-60°C for further 4.5 h. After completion of the reaction, the mixture was cooled down and neutralized with water. Diethyl ether was used for separation of oil phase from

water phase and the final product was made solvent free by heating at $50^\circ\mathrm{C}$



Figure.1. Experimental setup for Epoxidation Reaction Analysis

Titration of epoxy (oxirane oxygen)

Epoxy content is a most important character of epoxidised oils. AOCS Cd 9-57(oxirane oxygen in epoxidized materials)[10] is an official method of detection of epoxy functional group with their percents(by weight). Calculation of epoxy functionalities of waste ricebran oil were analysed by the following equation as,

Epoxy functionality(mole: mole)=[(%epoxy by weight(from AOCS Cd 9-57)] X 10)/16

FTIR and 1H NMR Spectrum

The absorption spectra of dry epoxidized samples was measured using Fourier Transform Infrared Spectroscopy(FTIR). The functional groups of dry epoxidized samples were observed by the absorption spectra. Samples were analyzed by Perkin Elmer Spectrum Version 10.03.06 and 1 H NMR version 4.3.2, JEOLLimited, Tokyo, Japan.

Results and Discussion

The fatty acid composition with properties of waste soyabean oil and epoxidized waste soyabean oil were analyzed (at 25°C) and are depicted in **Table 1**:

Table:1 Characterization of WSBO and ESBO

Characteristic value	WASTE SOYABEAN	EPOXIDISED
	OIL (WSBO)	WASTE SOYABEAN OIL (EWSBO)
Acid value(mg KOH/g)	1.2	0.9
Iodine value(gI ₂ /100g)	130	34.4
Oxirane value	0.68	3.6

Optimization of Process Conditions for Epoxidation Reaction Effect of Molar ratios of C=C to Hydrogen per oxide

To study the effect of molar ratio of molar ratio of C=C to hydrogen per oxide, the reaction was performed at 1:1, 1:1.2 and 1:1.5 molar ratios of C=C to hydrogen per oxide. The temperature during the reaction was fixed at 60° C. The effect on IV and oxirane values are depicted in **Table 2**.

Table2: Effect of molar ratios of C=C to hydrogen per oxide on epoxidation reaction at 60 C temperature and 9 hours

Molar ratios of C=C to Hydrogen per oxide	Temperature (C)	Time(h)	Iodine Value	Oxirane Value
1:1	60	9	34.8	2.7
1:1.2	60	9	35	3.6
1:1.5	60	9	36.2	3.1

Effect of reaction time

To study the effect of reaction time on epoxidation reaction, IV and oxirane value were determined at 9h, 7h and 6.5h respectively. The effect of reaction time on iodine value and oxirane value are depicted in **Table 3**.

Table3: Effect of reaction time onepoxidation at molar ratio of 1:1.2 and 60 C temperature

Molar ratios of C=C to Hydrogen per oxide	Temperature (C)	Time(h)	Iodine Value	Oxirane Value
1:1.2	60	9	34.8	2.9
1:1.2	60	7	35	3.6
1:1.2	60	6.5	36.3	2.7
			, ,	

Effect of temperature

To study the effect of temperature for optimization of process conditions for the synthesis of epoxidized oil the reaction was performed keeping 1:1.2 molar ratio of C=C to hydrogen per oxide and the temperature was varied from 55 to 65° C. **Table 4** shows the changes of IV and oxirane value at different temperatures.

Table4: Effect of temperatures on epoxidation reaction at a molar ratio of 1: 1.2 and time 7 hours

Molar ratios of C=C to Hydrogen per oxide	Temperature (C)	Time(h)	Iodine Value	Oxirane Value
1:1.2	55	7	35.8	2.2
1:1.2	60	7	35	3.6
1:1.2	65	7	36.3	2.8

FTIR Analysis

FTIR spectra of waste soyabean oil (WSBO) and epoxidised waste soyabean oil (ESBO) are shown in **Figure 2** and **3**. Main IR peaks with corresponding functional group of WSBO and ESBO are depicted in **Table 5**:

Characteristics of FTIR spectra of ESBO by which confirmation of epoxide functional group has taken place:

- Disappearance of the peak at:3007.7cm⁻¹ show C=C bond has been used up. This confirmed that almost all C=C bond had taken part in the epoxidation reaction. There was decrease in intensity of the other unsaturated bonds in comparison with used ricebran oil.
- The stretching of C=C-H at 3007cm⁻¹ have occurred after epoxidation reaction [11]. Appearance of peak at 3440.84 cm⁻¹ indicated the extent of hydrolysis of epoxidised waste ricebran oil, this derived from the epoxy functional group via partial epoxy ring opening reaction.

The epoxy ring opening reaction could have occurred by acid catalysis in the presence of water associated with aqueous solution of $H_2O_2[12]$.

Table:5 Peaks and corresponding bonds of WSBO and ESBO

IR Frequency Range (cm ⁻¹)	Frequency Bond and Functional Groups in Bonds and Func (cm ⁻¹) Waste soybean oil Groups in Epox waste soybean o			
3440.84	Not observed	Epoxy chain		
3007.70	C-H stretch of non conjugated unsaturation	Disappear		
2920-2855	C-H stretch of alkane	C-H stretch of alkane		





Fig. 3 : FTIR of Epoxidised Waste Soyabean Oil

NMR Analysis

Proton NMR spectra of epoxidisedsoybean oil and waste soybean oil are shown in **Figure 4** and **5**. The functional epoxy chain groups were observed at 2.2-2.4 ppm in spectra of epoxidised ricebran oil of 1H proton whereas NMR peak proton didn't appear or is weakly observed due to traces of unreacted group left. In the region of 4.1-4.4 ppm peak occurred in both waste soybean oil and epoxidized waste soybean oil as a quardet due to the coupling of adjacent two protons of the CH_2 group and cis coupling of the Proton attached to next sp2 hybridized carbon atom. The methyl proton of CH_2 backbone of the glycerol carbon was observed at the same region as double doublet in both cases of waste soybean oil as well as epoxidised waste soybean oil. The methyl proton of CH backbone of glycerol carbon was observed at 5.2-5.4 ppm as olefinic protons in both cases of waste soybean oil as well as epoxidised waste soybean oil. Thus the NMR analysis clearly identified peaks of aforementioned oils i.e. waste soybean oil and epoxidised waste soybean oil.







Figure.5. 1H-NMR of Epoxidised Waste Soybean Oil

Conclusion

The experimental results show that waste soybean oil can be successfully converted into epoxidised soybean oil by using performic acid generated in situ in presence of H_2SO_4 catalyst. The optimised parameters for epoxidation of waste soybean oil with minimum epoxy ring breaking were noted at temperature of 60°C with continuous stirring, waste soybeanoil to hydrogen per oxide molar ratio of 1:1.2 and a catalyst (H_2SO_4) loading of 2ml. FTIR spectra and 1H NMR support the successful synthesis of epoxidation reaction. At the optimized conditions as mentioned above 3.2 oxirane oxygen content in synthesized epoxidized soybean oil was obtained. The economically efficient epoxy resin obtained from WSBO can be used in many industrial applications such as plasticizers, lubricants, paint formulations, polymers etc.

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Preparation of Sodium *N*-acyl Condensates of *Terminalia bellirica* Protein Hydrolysates and Evaluation of their Surfactant Properties

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ABSTRACT

The present work describes the preparation of N-acyl condensates of protein hydrolysates obtained from the protein isolated from Terminalia bellirica deoiled cake and evaluation of their surfactant properties. The protein isolated was subjected to hydrolysis to get protein hydrolysates which was further reacted with the mixture of fatty acids of coconut and Terminalia bellirica seed oils by thermal condensation to obtain N-acyl condensates of Terminalia bellirica protein hydrolysates. The N-acyl condensates, thus prepared were converted into sodium salts and their surfactant properties like surface tension, foaming characteristic, emulsifying power, wetting property and calcium tolerance were further determined according to standard methods. The surfactant properties of N-acvl condensates were compared with commercial surfactant sodium lauryl sulphate (SLS). Promising results were observed for surface tension of N-acyl condensates of coconut (22.04 mN/m) and Terminalia (25.04 mN/m) fatty acid based protein hydrolysates. The emulsion properties were also found to be better compared to SLS. The foam stability was good for coconut (16 cm) compared to Terminalia (8.2 cm) fatty acid N-acyl condensates. The wetting properties of the N-acyl condensates (42 s for Terminalia bellirica and 17 s for coconut) were found to be inferior compared to SLS (2 s). The calcium tolerance were found to be superior compared to SLS and the results observed for coconut and Terminalia bellirica N-acyl condensates were more than 1000 ppm whereas SLS showed calcium tolerance of 75.9 ppm. The surfactants prepared from Terminalia bellirica protein hydrolysates can be commercially exploited as bio surfactants since the proteins are obtained from low value products such as deoiled cakes.

KEYWORDS: Terminalia bellirica seed oil, deoiled

*To whom correspondence should be addressed E-mail: pradosh@iict.res.in cake, protein, coconut oil, fatty acid mixture, *N*-acyl condensates, surfactant properties

INTRODUCTION

Terminalia bellirica traditionally known as 'Bahera' or 'Vibhitaki' is a valuable tree of Indian forest origin and distributed throughout the forests particularly in north-east region of India. Generally the tree grows to a height of 20-30 meters. Terminalia bellirica fruits are oval in shape and present in bunches with a narrow short stalk^{1, 2}. *Terminalia bellirica* fruit or the aqueous extract of bark are being used in traditional medicine for the treatment of varieties of diseases including anaemia, asthma, cancer, fever, cough, cold, cholera, diarrhoea, headache, eye infections, hypertension, respiratory infections, leucoderma, inflammation, rheumatism and as a diuretic to remove kidney stones³⁻⁶. Reports on application of fruits were available. However, only a few reports are available on Terminalia bellirica seed oil characterization. On the other hand, no reports are available on deoiled cake and its application for the preparation of protein based surfactants.

In an earlier study it was reported that, the Terminalia bellirica seed kernels contain 40% of oil and 35% of protein which are currently not used for edible purpose7. Terminalia bellirica seed oil was reported for use in low value products and for the preparation of soap by rural people⁸. Terminalia bellirica seed oil has potential as alternative feedstock for the production of biodiesel in north east region of India^{6,} ⁹. Organized farming of these plants and herbs has become a good business as growth of ayurvedic medicines is significant in our country. Terminalia bellirica tree is abundantly available in Uttar Pradesh. Madhya Pradesh, Chhattisgarh, Punjab, Maharashtra and almost all the north-eastern states. The plantation of *Terminalia bellirica* tree may stop the deforestation in the northeastern region of India and may help the biodiesel industry¹⁰.

The major by-product of biodiesel industry is the oilseed cake. The economics of biodiesel industry will largely depend on valorization of oil seedcakes. It was, therefore, decided to prepare some value added products from oilseed cakes. Once the biodiesel production starts by using *Terminalia bellirica* seed oil, the availability of deoiled cake will be more⁶. *Terminalia* seed was reported to be a good source for protein (35%). The deoiled cakes can be used as protein source for various non edible applications like household products, specialty chemicals, enzymes, pharmaceuticals, biological materials and surfactants^{11, 12}.

The proteins in deoiled meal of Terminalia bellirica seed can be utilized for the preparation of protein based surfactants. The protein based surfactants are reported earlier as well known applications for skin compatibility, biodegradability, having anti-bacterial properties and also as commercial source for various surfactant formulations having characteristic uses ¹³⁻¹⁵. Surfactants by modifying or with proper formulation can be used in cosmetics, agriculture, food, photography, leather industries and in drug delivery systems¹⁶. Raw materials from renewable sources like oils, cakes and proteins from low value products have several advantages as compared to petroleum based anionic surfactants. The reports are available for the preparation of protein based surfactants by utilizing the oil seed cakes of castor, cottonseed, neem and karanja etc.17. N-acyl condensates as anionic surfactants have good surfactant properties and also can be used in skin, hair care products like shampoo, body wash, face washing formulations¹⁸. *N*-acyl amino acids were also known to exhibit cytotoxic activity¹⁹. Crude proteins from deoil seed cakes were extracted using standard alkaline extraction method followed by the precipitation of the crude protein at its isoelectric pH¹⁷. The isolated crude protein hydrolyzed in to protein hydrolysates in alkaline medium. Protein based surfactants were obtained by the condensation of fatty acids with hydrolyzed proteins isolated from oil seed cakes.

In the present study, *Terminalia bellirica* protein was isolated from deoiled cake and hydrolyzed to obtain protein hydrolysates by alkaline hydrolysis. The protein hydrolysates were further reacted with the mixture of fatty acids obtained from coconut and *Terminalia bellirica* oils to get *N*-acyl condensates of *Terminalia bellirica* protein hydrolysates. The *N*-acyl condensates were evaluated for surfactant properties and compared with commercial surfactant SLS.

MATERIALS AND METHODS Materials

Terminalia bellirica (TB) fruits were collected from the forests of Tripura State situated in north-east region of India. The dried seeds after separation of pulp were used for the extraction of oil and the deoiled cake was used further for the isolation of crude protein. The coconut oil (Manufactured by Marico Ltd, Mumbai) was purchased from local market in Hyderabad. Standards of fatty acid mixtures (C4-22) were purchased from M/s Sigma Chemicals, St Louis, USA. Pre-coated thin layer chromatography (TLC) plates (silica gel 60 F_{254}) were procured from Merck, Darmstadt, Germany. Sodium lauryl sulfate (SLS) and other reagent grade chemicals and solvents were procured from M/s S D Fine Chemicals Pvt Ltd, Mumbai, India.

Methods

Extraction of Terminalia bellirica seed oil: Terminalia bellirica seeds were dried completely after removal of pulp. The dried seeds were crushed to get the powder and the oil was extracted using Soxhlet apparatus with hexane as solvent²⁰. About 8 hours of extraction time was given at reflux temperature of solvent. After complete extraction of oil, the solvent was removed using rotary evaporator and dried completely to get *Terminalia bellirica* seed oil. The deolied cake collected after removal of oil was air dried and further used for the isolation of *T. bellirica* protein. The protein content in the deoiled cake was analyzed by Kjeldahl method²¹.

Hydrolysis of fatty acids: Terminalia bellirica seed oil (20 g) was taken into 500 ml three necked r b flask connected with mechanical stirrer and was kept in a heating mantle. Preparation of vegetable oil fatty acids usually carried out by the conventional alkaline hydrolysis method²². The aqueous NaOH solution (2.28N, 50 ml) was added slowly to oil while constant stirring. The temperature of the reaction was raised to 90°C and maintained similar conditions for 4-5 hours. The progress of the reaction was monitored by TLC (90:10, hexane: ethyl acetate, vol/ vol) for the confirmation of hydrolysis of fatty acids. After completion of the reaction, the contents were neutralized using dil. HCI solution. The fatty acid layer washed with distilled water till free of mineral acid and dried completely to obtain the Terminalia bellirica fatty acid (TBFA) mixtures (17 g, 94.4% yield). The similar procedure was followed for coconut oil to get fatty acid mixtures with an isolated yield of 95.5%.

Preparation of fatty acid Methyl Esters: Terminalia bellirica seed oil fatty acid methyl esters were prepared by following the earlier reported method²³. The extracted seed oil (10-20 mg) was taken in round

bottom flask and added 15 ml of 2% of H_2SO_4 in methanol and continued reflux for 4 hours. The reaction was monitored by TLC, after complete conversion of methyl esters the solvent was partially removed and the mixture was extracted with ethyl acetate (2 x 20 ml). The ethyl acetate layers were combined and were washed with water until neutral. The ethyl acetate extract was passed over anhydrous sodium sulfate and evaporated using rotary evaporator under vacuum to obtain fatty acid methyl esters. The coconut oil fatty acid methyl esters were also prepared by following the similar procedure.

Gas Chromatography Analysis: Terminalia bellirica fatty acid methyl ester analysis was performed on Agilent 6890N Series Gas Chromatograph equipped with a flame ionization detector (FID) and the capillary column DB- 225 (30 m X 0.25 mm i.d. X 0.5 μ m film thickness, J & W Scientific, USA). The injector and detector temperatures were maintained at 230 and 250°C respectively. The oven temperature was programmed for 2 minutes at 160°C, further increased to 230°C at 5°C/minute and finally maintained for 20 minutes at 230°C. The injection volume was 1 μ l, with a split ratio of 50:1. The carrier gas, nitrogen was used at a flow rate of 1.5 ml/minute. The fatty acids were identified by the comparison of retention times of corresponding commercial standard fatty acids.

Terminalia Bellirica Protein isolation: The crude protein was extracted from Terminalia bellirica deoiled cake by alkaline extraction method. The deoiled cake (200 g) was taken in 5 lit round bottom flask and added to this 3.6 lit of aqueous NaOH solution (0.5 N)¹⁷. The contents were stirred for 3 hours using mechanical stirrer at 30°C. After 3 hr, the mixture was centrifuged at 7500 rpm for 30 minutes to separate alkali insoluble residues. The collected alkali soluble portion was checked for isoelectric point and adjusted its isoelectric point at pH 3.56 using dil. hydrochloric acid solution to precipitate the crude protein. The mixture of precipitate was once again centrifuged at 7500 rpm for 30 minutes. The crude protein was separated by decanting the supernatant and dried (66.4 g) at 90-100°C using hot air oven. The similar procedure was followed to collect more protein.

Preparation of Protein Hydrolysates: Protein (100 g) isolated from *Terminalia bellirica* deoiled cake was taken in 2 lit autoclave reactor and added to this 430 ml of aqueous NaOH solution (1.7 N), closed the reactor. The contents were stirred and the temperature was increased to 110°C. The pressure developed in the reactor was 2.5 bar and continued the reaction for 3 hr by monitoring the hydrolysis of protein²⁴⁻²⁶. After, the contents were cooled and discharged the material from the reactor. The pH of the solution. The protein hydrolysates solution found to contain 0.5 g solid/ ml of solution.

Preparation of N-acyl condensates of Terminalia bellirica protein hydrolysates: Terminalia bellirica protein hydrolysates (15.0 g, 30 ml) were taken in round bottom flask and the liquid solution was concentrated up to 80% of solid. The fatty acid mixture (7.5 g, 1:0.5 ratio wt/wt of protein hydrolysates/fatty acids) of Terminalia belliricawas added slowly at 120°C while the contents were stirring. The temperature of the reaction was increased slowly to 210°C and maintained the conditions for 30 minutes²⁷. Then the reaction temperature was cooled to ~100°C and the pasty mass (21.5 g) was removed from the round bottom flask. The unreacted fatty acid was extracted with hexane from the reaction product by dissolving in the water. Similar procedure was followed for the preparation of Terminalia bellirica protein hydrolysates with the mixture of fatty acids of coconut oil to obtain N-acyl condensates.

Preparation of sodium N-acyl Condensates of Terminalia bellirica protein hydrolysates: N-acyl condensates of Terminalia bellirica protein hydrolysates (20 g) were treated by the addition of 10 wt% of aqueous NaOH solution by maintaining pH 9.0 at 50°C for 30 min to obtain sodium N-acyl protein hydrolysates²⁴. N-acyl condensates were prepared using Terminalia bellirica and coconut oil fatty acid mixtures by thermal condensation (**Figure 1**) reaction with Terminalia bellirica protein hydrolysates. The reaction product was cooled to room temperature and used for the evaluation of surfactant properties by dissolving in distilled water.



Fig. 1 : Preparation of Sodium *N*-acyl *Terminalia bellirica* protein hydrolysates

Evaluation of Surfactant Properties: Aqueous solutions of sodium *N*-acyl *Terminalia bellirica* protein hydrolysates with different concentrations (1, 0.5 and 0.25 wt %) were prepared and surfactant properties were evaluated. The surface tension of the surfactant solution was measured using Kruss K100 tensiometer. The emulsifying property was analyzed by following the method described by Subrahmanyam and Achaya²⁸. The foaming property of surfactant was determined by using a pour foam apparatus²⁹. The calcium tolerance for the surfactants was also determined according to the method described by Vijayalakshmi *et al* ³⁰. The wetting power of the solutions were estimated by the method according to IS specification³¹.

RESULTS AND DISCUSSION

After drying the seeds collected from forests of Tripura, the oil was extracted from Terminalia bellirica seeds with hexane as solvent using Soxhlet apparatus. The oil content was found to be 36.8%. The major aim of this investigation was to utilize the low value byproduct, the deoiled cake, for its value addition. It was also aimed to utilize the oil seed protein to prepare protein based surfactants. The quality of N-acyl condensates of protein based surfactants also depends on the type of fatty acid mixture used in the condensation reactions. Keeping in mind the lower price it was decided to use Terminalia belliricafatty acid mixture. Coconut oil fatty acids are known as a suitable raw material for superior surfactant preparation as it contains more short and medium chain fatty acids. It was, therefore, decided to prepare N-acyl condensates using Terminalia bellirica protein hydrolysates and

coconut oil fatty acids. The surfactant properties of N-acyl condensates of protein hydrolysates were compared with commercially important surfactant of sodium lauryl sulfate (SLS). The fatty acid mixtures were obtained by alkaline hydrolysis of both the oils and the fatty acid composition are reported in Table 1.

The data showed that, oleic acid as the major fatty acid (46.3%) followed by palmitic (23.6%), linoleic (18.7%) and stearic acid (9.8%) in Terminalia bellirica mixed fatty acids. The total saturated fatty acids were found to be 34.3% in Terminalia bellirica oil and unsaturated fatty acids was about 65.7%. In the case of coconut oil fatty acids lauric acid is the major fatty acid (46.4%), followed by myristic (21), oleic (11.4) and palmitic (10.5%). The total saturated fatty acids present in coconut oil fatty acids were about 86.6% and unsaturated fatty acids were about 13.4%. Coconut oil mixture of fatty acids was found to have short, medium chain fatty acids and Terminalia bellirica mixture of fatty acids had long chain fatty acids. Both these fatty acid mixtures were used for the preparation of N-acyl condensates of protein hydrolysates.

Terminalia bellirica protein was isolated from deoiled cake by alkali extraction, isoelctric precipitation method and found to be 45.8%. The purity of the protein isolated from *Terminalia bellirica* deoiled cake was found to be 85.5%. The extracted protein was subjected to alkaline hydrolysis to get protein hydrolysates. These hydrolysates were used to prepare *N*-acyl condensates using *T. bellirica* and coconut oil fatty acid mixtures by thermal condensation. The *N*-acyl condensates of both the protein hydrolysates

Fatty acid	Terminalia bellirica fatty acids	Coconut fatty acids
8:0	-	0.7
10:0	-	3.5
12:0	-	46.4
14:0	-	21
16:0	23.6	10.5
16:1	0.5	-
18:0	9.8	4.1
18:1	46.3	11.4
18:2	18.7	2.4
20:0	0.7	-
20:1	0.3	-
22:0	0.2	-

TABLE 1Fatty Acid Composition ofTerminalia bellirica and Coconut Oils

were further converted to their sodium salts. The sodium salts of *N*-acyl condensates were completely soluble in distilled water and formed clear solutions. Different concentrations (1, 0.5 and 0.25%) of aqueous solutions were prepared and their surfactant properties like foaming power, wetting property, surface tension, emulsion stability and calcium tolerance were measured. The surfactant properties were also compared with the commercial surfactant SLS. The surfactant properties of sodium *N*-acyl condensates of *Terminalia bellirica* protein hydrolysates and SLS were shown in Table 2 and 3.

The data revealed that, the surface tension lowering ability of *Terminalia bellirica* and coconut fatty acid based protein surfactants showed better than that of sodium lauryl sulphate. The surface tension of coconut oil fatty acid (having short and medium chain length) *N*-acyl condensates showed the best surface tension lowering ability compared to *Terminalia bellirica* fatty acid (having long chain fatty acids) N-acyl condensates. This clearly indicates that, the surface tension lowering ability of the products decreased with the increase in the fatty acid chain length. The same trend was observed in an earlier communication²⁴.

The wetting ability of sodium N-acyl condensates of coconut fatty acid and Terminalia bellirica fatty acid based protein hydrolysates decreased by decreasing concentrations of surfactant solutions (from 1.0 to 0.25%). The wetting ability was found to be 17 s for coconut fatty acids and for Terminalia bellirica 42 s, where as for SLS it was 2 s (at the concentration of 1% of solution). The wetting ability was observed to be better for coconut compared to Terminalia bellirica N-acyl condensates. It may be due to short and medium chain fatty acids present in coconut oil. The earlier studies also reported that, the wetting ability was enhanced in presence of short and medium chain saturated fatty acids²². The anionic surfactants having good wetting properties can be used in textile industry³².

TABLE 2Surfactant Properties of Sodium N-acyl Condensates of
Terminalia bellirica Protein Hydrolysates

Surfactants	Surface tension (mN/m)			Wetting time (Sec)			Foam height (Cm)					
							Initial			After 5 min		
Conc. Wt%	1.0	0.5	0.25	1.0	0.5	0.25	1.0	0.5	0.25	1.0	0.5	0.25
TBFA <i>N</i> -acyl condensates	25.04	25.07	25.13	42	54	78	8.7	8.2	7.5	6.4	6.0	5.8
Coconut fatty acid <i>N</i> -acyl condensates	22.04	22.23	24.43	17	22	26	19.0	16.0	14.0	15.8	15.5	13.0
SLS	30.30	32.67	33.23	02	03	04	19.8	17.4	16.8	17.3	16.8	15.0

TABLE 3

Surfactant Properties of Sodium N-acyl Condensates of Terminalia bellirica Protein Hydrolysates

	Emulsifying power (sec)							
Surfactants	Time fo	or 10 ml of	separation	Time for	Calcium tolerance			
	1.0% Conc.	0.5% Conc.	0.25% Conc.	1.0% Conc.	0.5% Conc.	0.25% Conc.	(ppm)	
TBFA <i>N</i> -acyl condensates	307	215	185	686	426	358	>1000	
Coconut fatty acid <i>N</i> -acyl condensates	213	160	140	390	257	196	>1000	
SLS	155	140	117	410	350	308	75.97	

According to data reported earlier, the emulsifying power and stability of the surfactant increases by increasing the fatty alkyl chain length^{33, 34}. In the present study, the results observed for emulsion stability of *Terminalia bellirica N*-acyl condensates were found to be superior compared to *N*-acyl condensates of coconut fatty acids. The emulsifying property was enhanced by increasing the concentration of surfactant solution from 0.25 to 1.0%. It was also observed that emulsifying property of *Terminalia* and coconut fatty acid based *N*-acyl condensates of protein hydrolysates of *T. bellirica* seed protein were better compared to SLS.

The data of foam properties revealed that, the foam stability for coconut fatty acid based *N*-acyl condensates was 16.0 cm, for *Terminalia bellirica* fatty acid *N*-acyl condensates 8.2 cm and for SLS 17.4 cm at 0.5% concentration of the surfactants. *Terminalia bellirica N*-acyl condensates are poor stable compared to SLS. However the coconut fatty acid *N*-acyl condensates (16 cm) are comparable with SLS (17.4 cm). The foaming property was decreased by decreasing the concentration of surfactant solution from 1.0% to 0.25%. These surfactants however can be used for wide range of applications in industrial cleaning as well as household products³⁵.

The calcium tolerance was observed very much higher (>1000 ppm) for coconut and *Terminalia bellirica N*-acyl condensates compared to sodium lauryl sulphate (75.9 ppm) depicting the stability of surfactants to calcium ions. This indicates that the surfactants can function effectively in water having more hardness. The *N*-acyl condensates of both coconut and *Terminalia bellirica* are more tolerant to calcium ions compared to SLS. The effective calcium tolerance property of these surfactants can be used in the formulation of detergents.

CONCLUSIONS

In the present work, *N*-acyl condensates of *Terminalia bellirica* protein hydrolysates were prepared by thermal condensation reaction using fatty acids mixture obtained from coconut and *Terminalia bellirica* seed oils. Both coconut and *Terminalia bellirica* fatty acid *N*-acyl condensates showed good surface active properties. The *N*-acyl condensates of both surfactants were found to have more tolerance to calcium ions compared to SLS. The surfactants were prepared utilizing a low value product of *Terminalia bellirica* deoiled cake and can be used effectively in industrial applications as well as in detergent formulations. Thus, it was proved that T. bellirica seed protein can be a good source of protein based surfactants for different industrial and household applications.

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V

Preparation of polyester polyols from castor oil as bio source and dibasic fatty acids

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ABSTRACT

Polyurethanes are used in a wide range of industrial applications due to their chemical versatility, high performance and low cost. They find use in building and construction, consumer products, furniture and fixtures, transportation and in industrial applications. Polyurethane manufacturers are looking for alternatives so as to reduce carbon footprint, and at the same time positively impact the product quality and economics of production. Thermoplastic polyurethane manufacturers in particular are more inclined towards adopting bio based alternatives and increasing the bio based content in their product by using polyester polyols made from natural and renewable raw materials. The most common sources of natural oil polyols are castor oil, soy oil, peanut oil and canola oil. Castor oil accounts for the majority of natural oil polyol as it contains a ready hydroxyl group unlike the others, where hydroxyl group needs to be introduced by prior processes. Series of experiments were carried out taking castor oil as one of the reactant for making polyester polyols. Castor oil was reacted with different dibasic fatty acids in presence of acidic catalyst at elevated temperature. The progress of reaction was measured by measuring the acid value of the reaction media. Different types of acid catalyst were used to evaluate the progress of reaction. Further, the series of experiments were conducted with different amount of catalyst. It was found that the tin based catalyst showed more rate of reaction than the conventional acid catalyst. 0.15% by wt. of tin based catalyst showed more rate of reaction than 0.015% by wt. polyester polyols prepared from castor oil. Resulting polyester polyols were characterized for physical properties like density, viscosity, color and moisture content.

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INTRODUCTION

Polyurethanes are used in a wide range of industrial applications due to their chemical versatility, high performance and low cost ¹. They find use in building and construction, consumer products, furniture and fixtures, transportation and in industrial applications²⁻⁵. Polyurethane is traditionally a downstream derivative of crude oil, rendering it susceptible to the crude oil market fluctuations. Moreover in this age of the consumers, and the global inclination towards green products and sustainable development, bio based alternative for crude oil is the need of the day.

Polyurethane manufacturers are looking for alternatives so as to reduce carbon footprint, and at the same time positively impact the product quality and economics of production. Thermoplastic polyurethane manufacturers in particular are more inclined towards adopting bio based alternatives and increase the bio based content in their product by using polyester polyols made from natural and renewable raw materials. The main demand for bio based polyurethane is derived from application segments such as automotive, footwear and apparel. Uses in applications such as electronics, carpets, and furniture among others are also gaining momentum.

Petroleum based product, and some other di-acids are the conventional raw materials for manufacturing polyurethanes. However, natural oil polyols (NOP) or biopolyols, which are derived from vegetable oils by different methods, are used in the production of bio based polyurethane. The most common sources of natural oil polyols are castor oil, soy oil, peanut oil and canola oil. No. of publications had been reported for natural oil based polyester polyols for preparation of polyurethane⁶⁻¹⁶.Castor oil accounts for the majority of natural oil polyol as it contains a ready hydroxyl group unlike the others, where hydroxyl group needs to be introduced by prior processes. Natural oil polyols have similar origins and applications but the materials are

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different depending on their manufacturing process. In order to meet the global challenges for specific properties of polyester polyols used in polyurethane, modifications in the raw bio product is necessary. In case of castor oil, modifications can be made by modifying the long carbon chain of ricinoleic acid by reacting it with different types of fatty acids.

Chemicals used

In house FSG castor oil was used as bio source for polyester polyols having free fatty acid content and moisture content less than 1% and 0.25% respectively. Dibasic fatty acids, like succinic acid, adipic acid and sebacic acid, were purchased from Finar Chemicals with 99% purity. Tin catalyst (92.5-100% pure) was purchased from Sigma-Aldrich. Diethylene glycol was purchased from Sigma-Aldrich with 99% purity. Extra pure sulfuric acid (99% purity) was purchased from Finar Chemicals.

Experimental

Castor oil was reacted with dibasic fatty acids e.g. succinic acid, adipic acid and sebacic acid in presence of acidic catalyst. Molar ratio of castor oil to dibasic fatty acid was taken as 1. The reaction mixture was heated to temperature range of 230-250°C in a stepwise manner. Nitrogen gas was used to provide inert atmosphere and to prevent oxidation as it might lead to degradation of the product. Series of experiment was designed with different dibasic fatty acids and different catalyst and different amount of the catalyst. Decrease in acid value of the reaction mixture was taken as a control parameter to ensure the progress of esterification and transesterification process. Once the acid value dropped down below 10, reaction mixture was capped with the calculated amount of diethylene glycol followed by cooling to room temperature. Prepared polyester polyols were characterized for physical properties such as density, viscosity, moisture content and colour. Schematic diagram of reaction is shown in figure 1.





RESULTS AND DISCUSSION

When sulfuric acid was used as a catalyst, process of the esterification reaction was slow compared to that with the tin based catalyst. Use of sulfuric acid lead to darken the colour of the reaction mixture and final product also. In the temperature range of 230-250°C, it cuased charing of some fraction of the reaction mixture and product. The effect of catalyst on color of product is shown in figure 2. Approximately 40%, 49% and 44% of increase in color of polyester polyols was observed in case of polyester polyols prepared from Castero oil and Succinic acid, adipic acid and sebacic acid respectively. Two different amount of the tin catalyst, 0.015 and 0.15%, were tried to determine the progress of esterification reaction. It was observed that the reaction went fast with the higher amount of catalyst. Colour of final polyester polyols wasn't affected by higher amount of catalyst. Figure 3 shows the effect of amount of tin catalyst on the process time. Physical properties of polyester polyols is shown in table 1.





Fig. 2 : Effect of catalyst on color of polyester polyols

Fig. 3 : Effect of amount of catalyst on reaction time

 TABLE 1

 Physical properties of castor oil based polyester polyols

	Daharatan				Physical	Properties	
Sr. No.	Polyester Polyol	Reactant		Density (g/cc)	Viscosity (cp)	Colour Gardner	Moisture Content (%)
1	CSU101YA	Castor oil	Succinic acid	0.96	8920	5.2	0.27
2	CAD101YA	Castor oil	Adipic acid	0.96	6588	5.7	0.29
3	CSE101YA	Castor oil Sebacic acid		0.96	8600	4.8	0.26

Prepared polyester polyols has density less than 1 and high viscosity. Colour of polyester polyols are light brown to light redish. It was also observed that with tme the viscosity of polyester polyols increases due to extent of post ploymerisation of the same. Addition of diethylene glycol to polyester polyols help to prevent the post polymerization and controls the viscosity of prepared polyester polyols.

CONCLUSION

Polyester polyols can be synthesized using castor oil as a biosource. Reaction temperature depends on the type of fatty acid being reacted to castor oil. Use of tin based catalysts showed effectiveness in progress of esterification process. It was also found that the amount of catalyst used have profound effect on the rate of progrees of esterification reaction. Higher the catalytic amount, higher will be the rate of reaction. Therefoere, amount of catalyst can be taken as one important control point for the reaction in order to control any exothermic reaction in case if happens. Polyester polyols prepared showed post polymerization resulting in increase of viscosity. Capping with diethylene glycol showed profound decrease in the rate of increae in viscosity.

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V

News Section

immobilized by **Mohadese Babaki** *et al* on epoxyfunctionalized silica. The immobilized lipases were used to produce biodiesel by transesterification of canola oil with methanol. It was found that lipases immobilized on silica provided biocatalyst derivatives with lower cost compared with the cost of commercially available Novozym 435 [**Biochemical Engineering Journal101**, 23-31(2015)]. Thermal stability of the immobilized derivatives and the influence of methanol on the catalytic activity were also evaluated. Optimum oil to methanol ratio at 1:3 was observed for CALB and RML in biodiesel production; the corresponding fatty acid methyl ester (FAME) yields obtained after

96 h were 68% and 45% at 50°C respectively. The lipase from *T. lanuginosus* immobilized on epoxyfunctionalized silica displayed particularly high catalytic ability regarding reaction rate and final yield. TLL also gave high FAME contents in the reaction mixture with up to 6 molar equivalents of methanol to oil (98%). The immobilized TLL was quite stable and can be reused for 16 cycles without significant loss in activity (5%). The immobilized preparations of RML and CALB also presented a good reusability, keeping 85% of their initial activities after 16 cycles of the reaction.

Strategic planning design of microalgae biomass-to- biodiesel supply chain network: Multi-period deterministic model

Many studies have developed mathematical programming models for optimal design of supply chains for agricultural or lingocellulosic biomassderived bioethanol production. However, because of the shortcomings of using agricultural (food supply problems) and lingo-cellulosic biomass (low biomass availability and processing yield) as feedstock, use of micro-algal biomass has been considered for use as a feedstock for biodiesel (biofuel). Thus, in this study, Yu-Chan Ahn et al developed a deterministic mathematical programming model for strategic planning design of a microalgae biomass-to-biodiesel supply chain network (MBBSCN) from feedstock fields to end users that simultaneously satisfies resource constraints, demand constraints, and technology over a long-term planning horizon. The proposed deterministic model can help to determine where and how much feedstock to be transported, and where and how many refineries to be constructed to minimize the expected total cost including the co-product (naphtha and power) benefit [Applied Energy,154, 528-542 (2015)]. To demonstrate the feasibility of the proposed model, we conducted a case study based on the Korea biodiesel market data. In this case study, the optimized (i.e., most cost-effective) supply chain design can be gained at a reliable cost of \$US 5.91/ gal (\$US 1.56/I). In particular, this study can help to identify the technological bottlenecks and major cost drivers for the microalgae-to-diesel strategy, and can be also a guideline for development of various mathematical programming models for optimal design of microalgae biomass-derived biofuel supply chain like lingo-cellulosic biomass-based optimization studies.

Process optimization and kinetics of biodiesel production from neem oil using copper doped zinc oxide heterogeneous nanocatalyst

Heterogeneous nanocatalyst has become the choice of researchers for better transesterification of vegetable oils to biodiesel. In the present study, transesterification reaction was optimized and kinetics was studied for biodiesel production from neem oil using CZO nanocatalyst by Baskar Gurunathan et al. The highly porous and non-uniform surface of the CZO nanocatalyst was confirmed by AFM analysis, which leads to the aggregation of CZO nanoparticles in the form of multi layered nanostructures [Bioresource Technology, 190, 424-428(2015)]. The 97.18% biodiesel yield was obtained in 60 min reaction time at 55 °C using 10% (w/w) CZO nanocatalyst and 1:10 (v:v) oil:methanol ratio. Biodiesel yield of 73.95% was obtained using recycled nanocatalyst in sixth cycle. The obtained biodiesel was confirmed using GC-MS and ¹H NMR analysis. Reaction kinetic models were tested on biodiesel production, first order kinetic model was found fit with experimental data ($R^2 = 0.9452$). The activation energy of 233.88 kJ/mol was required for transesterification of neem oil into biodiesel using CZO nanocatalyst.

Enhancing biodiesel production via a synergic effect between immobilized Rhizopus oryzaelipase and Novozym 435

Industrialization of enzyme-catalyzed biodiesel production has been hindered by low conversion efficiency and long reaction time. As a representative example, Rhizopus oryzae lipase (ROL) exhibited a poor performance in biodiesel production. However, higher yields and shorter reaction time could be achieved by screening different lipases that could synergically catalyze the reaction with ROL. The results by Feng Su et al showed that Novozym 435 combined with ROL displayed the best performance, with a biodiesel yield that was 30% higher than that of ROL alone in 30 h [Fuel Processing Technology137, 298-304 (2015)]. Hence, the use of a synergic strategy was investigated systematically. Under optimized conditions, the biodiesel yield was as high as 98.3% and the reaction time was successfully shortened from 60 h to 21 h. Moreover, the combined lipases retained

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immobilized by **Mohadese Babaki** *et al* on epoxyfunctionalized silica. The immobilized lipases were used to produce biodiesel by transesterification of canola oil with methanol. It was found that lipases immobilized on silica provided biocatalyst derivatives with lower cost compared with the cost of commercially available Novozym 435 [**Biochemical Engineering Journal101**, 23-31(2015)]. Thermal stability of the immobilized derivatives and the influence of methanol on the catalytic activity were also evaluated. Optimum oil to methanol ratio at 1:3 was observed for CALB and RML in biodiesel production; the corresponding fatty acid methyl ester (FAME) yields obtained after

96 h were 68% and 45% at 50°C respectively. The lipase from *T. lanuginosus* immobilized on epoxyfunctionalized silica displayed particularly high catalytic ability regarding reaction rate and final yield. TLL also gave high FAME contents in the reaction mixture with up to 6 molar equivalents of methanol to oil (98%). The immobilized TLL was quite stable and can be reused for 16 cycles without significant loss in activity (5%). The immobilized preparations of RML and CALB also presented a good reusability, keeping 85% of their initial activities after 16 cycles of the reaction.

Strategic planning design of microalgae biomass-to- biodiesel supply chain network: Multi-period deterministic model

Many studies have developed mathematical programming models for optimal design of supply chains for agricultural or lingocellulosic biomassderived bioethanol production. However, because of the shortcomings of using agricultural (food supply problems) and lingo-cellulosic biomass (low biomass availability and processing yield) as feedstock, use of micro-algal biomass has been considered for use as a feedstock for biodiesel (biofuel). Thus, in this study, Yu-Chan Ahn et al developed a deterministic mathematical programming model for strategic planning design of a microalgae biomass-to-biodiesel supply chain network (MBBSCN) from feedstock fields to end users that simultaneously satisfies resource constraints, demand constraints, and technology over a long-term planning horizon. The proposed deterministic model can help to determine where and how much feedstock to be transported, and where and how many refineries to be constructed to minimize the expected total cost including the co-product (naphtha and power) benefit [Applied Energy,154, 528-542 (2015)]. To demonstrate the feasibility of the proposed model, we conducted a case study based on the Korea biodiesel market data. In this case study, the optimized (i.e., most cost-effective) supply chain design can be gained at a reliable cost of \$US 5.91/ gal (\$US 1.56/I). In particular, this study can help to identify the technological bottlenecks and major cost drivers for the microalgae-to-diesel strategy, and can be also a guideline for development of various mathematical programming models for optimal design of microalgae biomass-derived biofuel supply chain like lingo-cellulosic biomass-based optimization studies.

Process optimization and kinetics of biodiesel production from neem oil using copper doped zinc oxide heterogeneous nanocatalyst

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a yield of about 80% after 20 cycles in a solvent-free system. In addition to ROL, the performance of other lipases whose regioselectivity were similar to ROL was improved when they were combined with Novozym 435. In conclusion, synergic catalysis is a promising strategy for enhancing biodiesel yield and minimizing reaction time for ROL.

An ultrasound-assisted system for the optimization of biodiesel production from chicken fat oil using a genetic algorithm and response surface methodology

Biodiesel is a green (clean), renewable energy source and is an alternative for diesel fuel. Biodiesel can be produced from vegetable oil, animal fat and waste cooking oil or fat. Fats and oils react with alcohol to produce methyl ester, which is generally known as biodiesel. Because vegetable oil and animal fat wastes are cheaper, the tendency to produce biodiesel from these materials is increasing. In this research, the effect of some parameters such as the alcohol-to-oil molar ratio (4:1, 6:1, 8:1), the catalyst concentration (0.75%, 1% and 1.25% w/w) and the time for the transesterification reaction using ultrasonication on the rate of the fatty acids-to-methyl ester (biodiesel) conversion percentage have been studied (3, 6 and 9 min) by Fayyazi et al. In biodiesel production from chicken fat, when increasing the catalyst concentration up to 1%, the oil-to-biodiesel conversion percentage was first increased and then decreased. Upon increasing the molar ratio from 4:1 to 6:1 and then to 8:1, the oil-to-biodiesel conversion percentage increased by 21.9% and then 22.8%, respectively [Ultrasonics Sonochemistry 26, 312-320, (2015)]. The optimal point is determined by response surface methodology (RSM) and genetic algorithms (GAs). The biodiesel production from chicken fat by ultrasonic waves with a 1% w/w catalyst percentage, 7:1 alcoholto-oil molar ratio and 9 min reaction time was equal to 94.8%. For biodiesel that was produced by ultrasonic waves under a similar conversion percentage condition compared to the conventional method, the reaction time was decreased by approximately 87.5%. The time reduction for the ultrasonic method compared to the conventional method makes the ultrasonic method superior.

A route to produce renewable diesel from algae: Synthesis and characterization of biodiesel via in situ transesterification of Chlorell alga and its catalytic deoxygenation to renewable diesel

In situ transesterification of Chlorella alga was performed by Carolina Vieira Viegas et al using

5-20 wt% sulfuric acid as a catalyst at either 60 or 100 °C. The maximum ester yield in the range of 96-98% is comparative to the specification of ester content in biodiesel, 96%. A high excess of methanol was used in transesterification ensured also a high ester yield [Fuel 155, 144-154 (2015)]. The FAME was purified via adsorption of chlorophyll and carotenoids onto a clay. Properties of the purified biodiesel were investigated with several methods. The results showed that the Chlorella based biodiesel exhibits slightly lower oxidative and thermal stability compared to soybean based biodiesel due to the presence of polyunsaturated FAMEs. In addition to biodiesel, also the residual biomass was characterized showing that it contained sugars and proteins. An additional hydrogenation would increase the oxidative stability. Hydrodeoxygenation of Chlorella based biodiesel was also demonstrated over 5 wt% Ni-HY-80 zeolite with SiO₂/Al₂O₂ ratio of 80 and with 5 wt% Pd/C at 300 °C and 30 bar in dodecane as a solvent. Ni-HY-80 was superior to Pd/C catalyst giving more than 95% yield of hydrocarbons.

Environmental and economic performance of a biodiesel plant using waste cooking oil

This paper by Shogo Eguchi et al evaluates the environmental and economic performance of a biodiesel plant by using the data envelopment analysis framework considering two outputs (biodiesel and glycerin as a by-product of the biodiesel) and five inputs (waste cooking oil, methanol (MeOH), potassium hydroxide (KOH), power consumption used for operating the biodiesel plant, and truck diesel fuel used for the collection of waste cooking oil) [Journal of Cleaner Production, 101, 245-250(2015)]. From the results estimated using the time series database on monthly biodiesel production during August 2010 to March 2013, we found that there were many technologically inefficient production activities during the study period. We also demonstrate that a reduction of input costs for the study period of about 5% is possible and life-cycle CO₂ emissions associated with biodiesel productions can be further reduced, while the "first best" production activity in both cases of including and excluding external costs for life-cycle CO₂ emissions associated with biodiesel productions occurred in February 2013 and the minimum unit production cost was attained in this month.

Purification of biodiesel by dry washing, employing starch and cellulose as natural adsorbents

Michelle Garcia Gomes *et al* describes a study of the purification of biodiesel produced from sunflower

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oil by dry cold washing using natural adsorbents as cellulose and starch from different sources (corn, potato, cassava and rice), and the comparison with dry cold washing with a commercial adsorbent Select 450® and with the conventional wet washing with hot water [Fuel, 155, 1-6 (2015)]. The purification by dry washing was carried out by varying the amount of adsorbents in 1%, 2%, 5% and 10% (w/v) at 25 °C for 10 min. For the purification by wet washing, the biodiesel was successively washed with acidified water and pure water at 85 °C until neutralisation. The efficiency of the processes for the removal of biodiesel impurities was evaluated by determining the acidity index, combined alkalinity, free glycerine and turbidity of the biodiesel. All adsorbents studied presented good efficiency in the removal of the impurities and showed similar behaviour independent of the kind or amount of adsorbent employed. The use of natural adsorbents for the purification of biodiesel have been shown to be a promissory process to be applied as an industrial stage of the purification of biodiesel during their production.

Tailoring fuel properties using jatropha, palm and coconut biodiesel to improve CI engine performance and emission characteristics

Biodiesel can be used effectively as engine fuel despite several limitations in its fuel properties. A set of experiment was Md. Arbab Iqbal et al by conducted to improve fuel properties by blending palm biodiesel (PB) with coconut biodiesel (CB) and jatropha biodiesel (JB). MATLAB optimization tool was used to identify the optimum blend ratio for good fuel properties [Journal of Cleaner Production, 101, 262-270 (2015)]. A linear relationship among fuel properties was considered for MATLAB coding. The resulting optimum blend ratio and the equations of the MATLAB code were used to predict the fuel property values and were compared with the experimental values of the optimum blend fuel properties. Two new biodiesel blends were developed, namely, the optimum blends of palmcoconut (PC) biodiesels and jatropha-palm-coconut (JPC) biodiesels. Both biodiesels demonstrated overall improved fuel properties compared with those of the individual biodiesels presented in the blends. Engine performance and emission were tested using 20% blend of each biodiesel (JB, PB, CB, PC, and JPC) with petroleum diesel (OD). The engine performance and emission characteristics for the PC and JPC blends were then compared with those of OD. The average engine power for the blend of 20% JPC biodiesel and 80% OD (JPC20) was maximum at lower fuel consumption than the blend of 20% PC biodiesel and 80% OD (PC20) at full load condition. The emission

characteristics of JPC20 were also comparable to or lower than those of OD, except for HC. However, when both engine performance and emission were considered, JPC20 was found to be the best fuel compared with OD and other fuel blends.

Thermogravimetric analysis as a rapid and simple method to determine the degradation degree of soy biodiesel

This work by **T. Vega-Lizama** *et al* describes the use of the residual mass observed in a thermal decomposition curve for a soy biodiesel sample as a measure of its degradation degree. The difference in thermal stability between esters and oxidation products is the key point to make the determination[**Fuel**,156, 158-162(2015)]. Using residual mass, the acceptance or rejection of a biodiesel becomes a non-subjective process and does not require knowledge of the biodiesel oxidation process. The residual mass data were compared with those of kinematic viscosity, UV spectroscopy and nuclear magnetic resonance. The good agreement found between these data justifies the utilization of this method to determine the biodiesel oxidation degree.

Detection of virgin coconut oil adulteration with animal fats using quantitative cholesterol by GC × GC–TOF/MS analysis

A new method based on the cholesterol level was developed by Baocheng Xu et al to detect the presence of animal fats in virgin coconut oil (VCO). In this study, the sterols in VCO and animal fats was separated using conventional one-dimensional gas chromatography (1D GC) and comprehensive two-dimensional gas chromatography (GC × GC). Compared with 1D GC, the GC × GC system could obtain a complete baseline separation of the sterol trimethylsilyl ethers derived from cholesterol and cholestanol, so that the cholesterol content in pure VCO and false VCO adulterated with animal fats could be accurately determined [Food Chemistry,178, 128-135 (2015)]. Cholesterol, a main sterol found in animal fats, represented less than 5 mg/kg of VCO. The study demonstrated that the determination of the cholesterol level in VCO could be used for reliable detection of the presence of lard, chicken fat, mutton tallow, beef tallow, or their mixture in VCO at a level as little as 0.25%.

Schleichera oleosa L oil as feedstock for biodiesel production

The non-edible oil from *Schleichera oleosa* possesses the potential as a feedstock for biodiesel

production. The biodiesel production was performed using two-step transesterification process on a laboratory scale by A.S. Silitonga et al . The parameters studied were reaction temperature, molar ratio of methanol to oil, catalyst concentration, reaction time and catalysts type [Fuel,156, 63-70(2015)]. An analysis of variance (ANOVA) was used to determine the methyl ester yield. The optimum conditions were obtained as follows: reaction temperature at 55 °C, methanol to oil molar ratio of 8:1, 1 wt.% of hydroxide catalyst (KOH and NaOH) and 1 wt.% methoxide catalyst (CH₃OK and CH₃ONa) for reaction time 90 min. Based from these optimum conditions, the observed ester yields from different catalysts were average 96%, 93%, 91% and 88% for KOH, NaOH, CH₂OK and CH₃ONa respectively as the catalyst. S. oleosa methyl ester (SOME) exhibited a satisfying oxidative stability of 7.23 h and high cetane number (50.6) compared to petrol diesel (49.7). Besides, SOME has good pour and cloud point of -3.0 °C and -1.0 °C respectively due to high unsaturated fatty chain. As a conclusion, this study reveals that biodiesel production from SOME, as one of non-edible feedstock, is able to be an alternative for petrol diesel. Moreover, the produced biodiesel from SOME could be used in diesel engine without major modification due to its properties and can be used in cold regions.

Properties of adsorbents used for bleaching of vegetable oils and animal fats

Two types of bleaching earths used in the production of green diesel, namely, sepiolite and palygorskite, were characterized by various physicochemical methods, such as nitrogen adsorption, Hg porosimetry, scanning electron microscopy, transmission electron microscopy, energy dispersive X-ray analysis, Fourier transfom infrared spectroscopy, pH of the clay slurry, thermogravimetrical analysis (TGA) and X-ray diffraction analysis. The characteristics of fresh, spent and extracted bleaching earths were compared in the current study by Vilppu Kuuluvainen et al. The results showed that particle sizes of the extracted adsorbents have decreased. Furthermore, some leaching of elements was confirmed by elemental analysis. A decrease in specific surface area of the adsorbents was observed thus compromising the economical feasibility of the reuse of these clays [Journal of Chemical Technology and Biotechnology, 90, 9, 1579-1591(2015)]. TGA results showed that the oil content in spent sepiolite and palygorskite, which could be extracted was 35% and 12%, respectively. Extraction efficiencies were affected by the specific surface area of the clay. Structural characterization of extracted bleaching earths showed that some changes

occurred for sepiolite and palygorskite during bleaching and extraction in addition to decrease in their particle sizes. The specific surface areas of the extracted bleaching earths decreased substantially compared with those determined for fresh bleaching earths. This result indicates that reuse of spent, extracted bleaching earths might not be economically feasible.

Epoxy fatty acids in used frying fats and oils, edible oils and chocolate and their formation in oils during heating

The occurrence of monoepoxy fatty acids in used frying oils and in other common foods has been determined. Monoepoxy fatty acids with trans-9,10- and cis-9,10-epoxystearate and trans-12,13-, trans-9,10-, cis-12,13- and cis- 9,10-epoxyoctadecenoate were found at average levels of 3.7 g/kg in used frying fats and oils by Ludger Brühl et al but also at about 2 g/kg in the fat fraction of chocolate. They were also detected in pumpkin seed, sweet almond, groundnut, sunflower, and olive oils at average levels of 3.4, 1.7, 1.4, 1.0, and 0.2 g/kg, respectively. Their formation during heating at 175°C was observed for sunflower, rapeseed, soybean, and linseed oil and compared with the increase of polar compounds and polymerized triacylolycerols as other important quality indicators for frying oils. During heating for 16h, the level of monoepoxy fatty acids increased to about 30, 18, 8, and 4 g/kg for olive, sunflower, linseed, and rapeseed oils, respectively [European Journal of Lipid Science and Technology, 118, 425-435 (2015)]. The influence of the heating temperature was surveyed for refined soybean oil at 160, 170, 180, and 200°C. Heating of two sets of five different refined and virgin rapeseed oils revealed a significant lower formation of monoepoxy fatty acids for refined oils at a median level of 4.6 g/ kg compared to7.7 g/kg for virgin oils.

Heterogeneous catalyst of mixed K compounds/ ca-al-graphite oxide for the transesterification of soybean oil to biodiesel

A novel heterogeneous solid base catalyst was prepared by loading of Ca-Al-graphite oxide with mixed potassium salts and applied in the transesterification of soybean oil with methanol to produce biodiesel by **Chuanjia Sun et al**. The catalysts were characterized by Hammett indicators, X-ray diffraction, Fourier transform infrared spectroscopy, scanning electron microscopy, energy dispersive X-ray spectrometry, and transmission electron microscopy[**Chemical Engineering & Technology, 38**, 9, 1557–1564 (2015)]. The effects of the methanol-to-oil molar ratio, catalyst amount, reaction temperature, stirring rate, and reaction time were investigated to optimize the

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transesterification reaction conditions. Moreover, the prepared catalyst retains its activity after being used for four cycles. In particular, the solid base catalyst can be effectively and easily separated from the reaction system, which may provide significant benefits for the development of an environmentally benign and continuous process for preparing biodiesel.

Run-to-run optimization of biodiesel production using probabilistic tendency models: a simulation study

Variability of the composition and properties of raw materials used for biodiesel production may cause a loss of productivity, since the same operating conditions give rise to different yields for alternative feedstock sources. The capability to re-optimize the process when the raw materials change may lead to a significant improvement in productivity. For yield optimization, first-principles models of a biodiesel reactor have limited prediction capabilities due to the complex kinetics involving transesterification and saponification reactions, which demands active learning of relevant data through optimal design of experiments. In this work by Martin F. Luna et al, a Bayesian approach for integrating experimentation with imperfect models is proposed to optimize biodiesel production on a run-to-run basis. Parameter distributions in a probabilistic tendency model for the transesterification of triglycerides are re-estimated using data from a sequence of experiments designed to guide policy improvement. Global sensitivity analysis is used to formulate the optimal sampling strategy in each dynamic experiment as an optimization problem [The Canadian Journal of Chemical Engineering, **93**, 9, 1613–1623(2015)]. Results obtained highlight that, even when there are significant errors in the tendency model structure and reduced information content in samples, a significant increase in biodiesel production can be achieved after a handful of runs

Study on residual oil recovery from empty fruit bunch by combination of water and steam process

In this study, the recovery of residual oil from the spikelet of oil palm empty fruit bunches (OPEFB) was conducted by **Javier Chavarro Gomez** *et al.* Residual oil was present in the OPEFB due to mechanical processes such as the loading of fruit into the sterilizer cage, sterilization and threshing, in which a certain portion of the oil from the fruitlet was impregnated mainly on the surface of the spikelet rather than on the stalk of OPEFB [Journal of Food Process Engineering,38, 4, 385–394(2015)]. The highest residual oil content was found mainly in the small

OPEFB (28.49 \pm 5.20% dry basis). The oil extraction process was introduced as hydro solvent-assisted steam extraction, which comprises of four main steps, i.e., flooding, injection, soaking and draining. The overall process resulted in above 83% residual oil removal from the spikelet. The proposed method can be an option to be implemented in the palm oil mill because it is a chemical-free, environment-friendly and novel process.

Ultrasound-assisted extraction kinetics, fatty acid profile, total phenolic content and antioxidant activity of green solvents' extracted passion fruit oil

The main objective of this current work by Sin Yee Lee et al was to evaluate the feasibility of green solvent's application on passion fruit oil extraction. In this study, the effects of green solvent on oil yield, fatty acid profile, oil physicochemical properties, total phenolic content and antioxidant activity associated with extracted oil were compared to those of conventional solvent, hexane application [International Journal of Food Science & Technology, 50, 1831-1838(2015)]. Therefore, this study may provide supplementary information on previous studies that focused on oil recovery. Oilseeds' proximate composition and the influence of oilseeds-to-solvent (w/v) ratio on oil yield were investigated. The oilseeds contained high fibre, fat and protein. Oilseeds-to-solvent (w/v) ratio (1:8) provided the highest oil yield. Overall, acetone was suggested as a suitable hexane replacer due to its higher oil recovery, similar fatty acid profile and oil physicochemical properties with higher antioxidant activity. Ethanol-extracted oil contained higher amounts of omega-9 MUFA, which may indicate the influence of extraction solvent on final fatty acid composition and thus final oil application.

Kinetics of the epoxidation of soybean oil with H_2O_2 catalyzed by phosphotungstic heteropoly acid in the presence of polyethylene glycol

In this work, the kinetics of "in situ" epoxidation of soybean oil with H_2O_2 (30% w/w), catalyzed by phosphotungstic heteropoly acid $[\pi-C_5H_5N(CH_2)_{15}CH_3]_3[PW_4O_{16}]$ (PHA) phase transfer catalyst and polyethylene glycol (PEG) as interfacial agent in dichloroethane, were investigated by Weiwei Cheng *et al* at 40, 50, 60, and 70°C European Journal of Lipid Science and Technology,117,1185–1191(2015)]. Assuming that the epoxidation reaction occurred in the pseudo-homogeneous catalytic system and the side reaction of epoxy ring cleavage was negligible, the results appeared that the epoxidation reaction of soybean oil in the presence of PEG was a second-

order with respect to double bond concentration and a first-order to the H_2O_2 concentration. The corresponding apparent activation energy (42.12 kJ/mol) was lower than that of PHA alone (49.23 kJ/mol), indicating that PEG could decrease the activation energy and speed up the epoxidation reaction of soybean oil.

A kinetic study for the noncatalytic esterification of palm fatty acid distillate

In this work, the reaction scheme for the esterification of palm fatty acid distillate performed under the noncatalytic and high-temperature condition (230-290°C) was investigated by Seok Won Hong et al with a rigorous mathematical modeling. The esterification reaction was assumed to be the pseudohomogeneous second-order reversible reaction, and the mass transfer effectiveness factor (n) was introduced in the modeling framework to systematically and collectively consider both evaporation and reaction, which are simultaneously and competitively occurred in the liquid phase [International Journal of Chemical Kinetics,47, 489-500(2015)]. The nonlinear programming problem was constructed with the objective function consisting of the errors between experimental data and the estimated values from the reaction model. The problem was solved by using the Nelder-Mead simplex algorithm to identify kinetic parameters, reaction rate constants, and mass transfer coefficients. The values of mass transfer coefficients were found to follow the Hertz-Knudsen relation and expressed as a function of reaction temperature. From the reaction rate constants obtained from the proposed kinetic models, the apparent activation energy was estimated to be 43.98 kJ/mol, which is lower than the value obtained from the reaction using heterogeneous catalysts. This low value indicates that reactants and products behave as an acid catalyst at relatively high operating temperature and constant pressure.

Heterogeneously catalyzed hydrogenation of squalene to squalane under mild conditions

The full chemoselective hydrogenation of highly unsaturated all-*trans* linear squalene by **Valerica Pandarus** *et al* into valuable fully saturated squalane is achieved smoothly under mild conditions over the sol–gel-entrapped Pd catalyst Silia*Cat* Pd . The catalysis is truly heterogeneous, and the catalyst is stable and recyclable, which opens the route to an easier and less expensive hydrogenation of squalene [**ChemCatChem**, 14, 2071–2076 (2015)].

Kinetic modeling of multi-component crystallization of industrial-grade oils and fats

Transient crystallization kinetics is investigated by Jeppe L. Hjorth et al for complex, industrialgrade vegetable oils consisting of more than ten triacylglycerols (TAG). The classical nucleation model has been used to describe primary nucleation, while secondary nucleation has been described by a semi-empirical approach. Growth is modeled using a modified Burton-Cabrera-Frank (BCF) model. Surface tensions and growth constants have been determined using focused-beam-reflectance measurements (FBRM) [European Journal of Lipid Science and Technology, 117, 1066-1078 (2015)]. The required adjustable parameters in the model have been fitted to overall crystallization curves obtained by solidfat content (SFC) measurements for a given oil at different cooling rates and degrees of dilution. The developed model can accommodate more polymorphs simultaneously and performs well with respect to predicting crystallization onset, rate of crystallization and final SFC value. It can also qualitatively describe how higher cooling rates lead to formation of more meta-stable crystals and smaller mean-crystal sizes.

Investigation on biodiesel production from cotton seed oil using microwave irradiated transesterfication process

In this study, cotton seed oil was investigated by K. Thirugnanasambandham et al under different operating conditions such as ethanol: oil molar ratio, temperature, mixing rate, time, and microwave power to produce the biodiesel [Environmental Progress & Sustainable Energy, 34, 1229-1235 (2015)]. Five factors with three levels Box-Behnken response surface design (BBD) was used to optimize and investigate the effect of process variables on the biodiesel production. three-dimensional response surface plots were used to study the interactive effects of the process variables. Numerical optimization technique was used to to findout the optimum conditions for the maximizing the biodiesel production and it was found to be 99.5%. The fuel properties of produced biodiesel were compared with ASTM D6751 for biodiesel standards.

Chlorophyta and Rhodophyta macroalgae: A source of health promoting phytochemicals

A detailed study of the lipophilic composition of *Codium tomentosum*, *Ulva lactuca*, *Gracilaria vermiculophylla* and *Chondrus crispus* macroalgae

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cultivated in the Portuguese coast was carried out by Sonia A.O. Santos et al by gas chromatography-mass spectrometry before and after alkaline hydrolysis [Food Chemistry, 183, 122-128 (2015)]. Their long-chain aliphatic alcohols and monoglycerides compositions are reported for the first time. Additionally, other new compounds were also identified: phytol and neophytadiene in C. tomentosum, U. lactuca and G. vermiculophylla and stigmasterol, α-tocopherol and 24-methylenecholesterol in C. tomentosum . The lipophilic fraction of the studied macroalgae are mainly constituted by fatty acids (110.1-1030.5 mg kgof dry material) and sterols (14.8-1309.1 mg kg⁻¹ of dry material). C. tomentosum showed to be a valuable source of stigmasterol (1229.0 mg kg⁻¹ of dry material) and α-tocopherol (21.8 mg kg⁻¹ of dry material). These results are a relevant contribution for the valorisation of these macroalgae species as sources of valuable phytochemicals.

Fatty acid profile of Sacha Inchi oil and blends by ¹H NMR and GC–FID

This study by Juarez Vicente et al aimed at the characterization of blends of Sacha Inchi oil (SIO) with different ratios of SO (soybean oil) and CO (corn oil) by nuclear magnetic resonance (¹H NMR), compared with the data obtained by gas chromatography with a flame ionization detector (GC-FID). The ¹H NMR and GC-FID data from different ratios of SIO were adjusted by a second order polynomial equation [Food Chemistry, 181, 215-221, (2015)]. The two techniques were highly correlated (R² values ranged from 0.995 to 0.999), revealing that ¹H NMR is an efficient methodology for the quantification of omega-3 fatty acids in oils rich in omega-6 fatty acids or vice versa such as SO and CO and, on the other hand, can be used to quantify ω -6 in oils rich in ω -3, such as SIO.

[Contributed by KN Prasanna Rani]



Member of OTAI deeply mourn the sudden and untimely demise of their beloved leader Mr. M K Janardan. Janrdan Saahaab, as he was known to the OTAI fraternity was the former Vice Presdent of OTAI and former President of Western Zone. A towering and humble personality, Mr Janardan was dedicated to OTAI well being and he contributed significantly for the growth of this organization. He was the MD of Japro Engineering Pvt Ltd and an eminent expert on Oils and Oleochemicals Processing Plants. He was recipient of many Awards, especially Prof JG Kane Memorial Award and SCODET Lifetime Achievement Award. Members of OTAI express deep condolences to the bereaved family members and pray to almighty to give them the strength to bear the huge loss.

FORTHCOMING EVENTS

- 25th Canadian Conference on Fats and Oils, at Hotel Delta Quebec, Quebec City, Canada during October 4-6, 2015. For details, contact: Consortium de recherche et innovations en bioprocédés industriels au Québec, Le Delta 3 Building, 2875, boul. Laurier, office D3-620 Quebec,(Quebec),G1V2M2, Tel.: (418) 914-1608; E-mail: cribiq@cribiq.qc.ca.
- SODEOPEC 2015, Soaps, Detegents, Oleochemicals and Personal Care, Practical Challenges for Tomorrow's Challenges, at Hyatt Regency, Miami, Florida, USA during October 27-30, 2015. For details, contact: Doren Berning, Phone: +12176934813; Fax: +12176934857; E-mail: doreenb@aocs.org; Website:www.aocs. org.
- 70th Annual Convention of Oil Technologists' Association of India and National Conference on Process and Products Development for Better Economy Benefits of the Fats and Oils Industry at Central Glass and Ceramic Research Institute, Kolkata, India during November 20-22, 2015. For details, contact: Dr Mahua Ghosh, Conference Convenor, OTAI Eastern Zone. Phone: +91-9433112273, Fax:+913323519755. E-mail: otaiez@gmail.com; website:www.otai.org.
- 4. 107th AOCS Annual Meeting and Expo, at Salt Palace Convention Centre, Salt Lake City, Utah, USA during May 1-4, 2016. For details, contact: Doren Berning, Phone: +12176934813; Fax: +12176934857; E-mail: doreenb@aocs.org; Website:www.aocs.org.
- IFT16: Where Science Feeds Innovation, Organized by Institute of Food Technologists, Chicogo, Illinois. For details, contact: Institute of Food Technologists, 525 W. Van Buren, Ste 1000, Chicago,IL60607. Phone: +1.312.782.8424 | Fax: +1.312.782.8348, Email: info@ift.org.
- Oils & Fats International India 2016, at Hyderabad International Convention Centre, Hyderabad, India during April 13-14, 2016. For details, Contact: +44 (0) 1737 855068.
- World Conference on Fabric and Home Care at Hotel Shangri-La, Singapore during October 4-6, 2016. For details, contact: 2710 South Boulder Drive, Urbana, Illinois, USA. E-mail: meetings@ aocs.org. Phone +1217-693-4821.

NEW BOOKS PUBLISHED

- Indigenous Fermented Foods of South Asia by V K Joshi, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN: 9781439887837, £127.00, 2015.
- Chemistry of Sustainable Energy by Nancy E Carpenter, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN : 9781466575325, \$71.96, 2014.
- Biomass and Biofuels: Advanced Biorefinery for Sustainable Production and Distribution by Shibu Jose and Thallada Bhaskar, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN: 9781466595316, £76.99, 2014.
- 4. Refining Used Lubricating Oils, by James Speight and Douglas I Exall, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN: 9781466551497, \$161.96, 2014.
- Sunflower: Chemistry, Production, Processing and Utilization Edited by Enrique Mertinez-Force, Nurhan Turgut Dunford and Joaquin J Salas American Oil Chemists' Society Press, Champaign, Illinois, USA, ISBN: 9781893997943. \$ 230.00, 2015.
- Methods in Food Analysis by Rui M S Cruz, Igor Khmelinsku and Margarida Vieira, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN: 9781482231953, \$116.96, 2014.
- Polar Lipids: Biology, Chemistry and Technology Edited by Moghis U Ahmad and Xuebing Xu, American Oil Chemists' Society Press, Champaign, Illinois, USA, ISBN: 9781630670443. \$ 155.00, 2015.
- Food Borne Pathogens and Food Safety, by Md. Latiful Bari and Dike O Ukuku, CRC Press, Cheriton House, North Way, Andover, Hants, SP10 5BE, UK. ISBN: 9781498724081, £95.00, 2015.

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OTAI ANNUAL MERIT AWARDS

- 1. Dr. S Hussain Zaheer Memorial Award (Single Person Award for Basic Research): Annual Cash Award of Rs. 5,000/- was instituted with the support of Zaheer Science Foundation, New Delhi. The award is for excellence in research contribution in Oil Chemistry and Technology, Surface Coatings and Allied Subjects, through research papers, which include applicants name among the authors and which appeared during the previous three calendar years.
- 2. Dr. S D Tirumala Rao Memorial Award (Single Person Award for Applied Research): Annual Cash Award of Rs. 5,000/- was instituted with the support of Anantapur Chapter of OTAI (SZ). The award is for excellence in research contributions in relevant subject Wealth from Waste or Value-added Products from the Waste generated in Vegetable Oil Industry through research papers, which include applicants name among the authors and which appeared during the previous three calendar years.
- 3. RBGV Swaika Memorial Award (Team Award for Applied Research): Annual Cash Award of Rs. 5,000/- was instituted with support of Shri B K Swaika and Shri N K Swaika of M/s Swaika Vanaspati Products, Kolkatta. The award is for excellence in Specific Process or Product Development or Innovation or Improvement in the Oils, Oilseeds, Surface Coating and Allied Field over three calendar years.
- 4. Dr. Santinath Ghosh Memorial Research Award: Annual Cash Award of Rs.10,000/- and citation was instituted by OTAI (EZ) with corpus fund donated by Dr. Pubali Ghosh Dhar in memory of Dr. Santinath Ghosh for the Young Researcher (age below 35 years as on 1st January of the particular year). The award is for excellence in the field of Oil Technology and Allied Sciences with Best Social / Industrial Implication through patent / research paper, which include applicants name among the authors which appeared during the previous calendar year.
- 5. S R Bhatnagar (SARBI) Memorial Research Award: Annual Cash Award of Rs 15,000/- and citation was instituted by OTAI (WZ) with the Corpus fund of donated by Mrs. Cherry Churi, Director, Ms Sarbi Petroleum & Chemicals Pvt. Ltd. in memory of Late Mr. S R Bhatnagar for the post graduate students. The award is for excellence in the research in the field of Tribology / Lubricant and allied fields for the research papers published which include applicants name among the authors which appeared during the previous or current calendar year.
- 6. O P Narula OTAI (SZ) Technology Award: Annual Cash Award of Rs. 7,500/- was instituted with the support of Shri O P Narula, New Delhi and OTAI (SZ). The award is for the best project report prepared for a specific topic identified by OTAI (SZ). The applicant has to submit a 10 to 15 page report (5 copies) on the above topic to the Secretary, OTAI (SZ).
- 7. O P Narula OTAI (SZ) Young Scientist Award: Annual Cash Award of Rs. 5000/- was instituted with the support of Shri O P Narula, New Delhi and OTAI (SZ). This award is for a researcher who is engaged in Oils & Allied Products and should not have completed 35 years of age as on 1st January of the particular year. The award is for Publications/Patents which include applicants name among the authors.

For further details and prescribed proforma for Award Nos. 1, 2 & 3, the applicants may contact Shri R K Srivastava, Hony. General Secretary, Oil Technologists Association of India, C/o. HBTI, Kanpur 208 002. For Award No. 4, the applicants may contact Dr. Mahua Ghosh, Hony. Secretary (EZ), C/o. Dept. of Chemical Technology, University of Calcutta, 92, A.P.C. Road. Kolkata 700 009, West Bengal. For Award No. 5, the applicants may contact Dr Rajeev Churi, C/o Oils, Surfactants & Oleochemicals Div., ICT, Matunga, Mumbai-19. For Award No. 6 and 7, the applicants may contact Dr. B V S K Rao, Hony.Secretary, OTAI (SZ), C/o CSIR-IICT, Hyderabad 500 007. Any member of the OTAI engaged in an Academic or Industrial Research Organization or in industry is eligible for all the awards. The same award may be given second or more times to the same person, but only after the lapse of three years.

8. Prof. R K Khanna Memorial Award: Annual Cash Award of Rs. 5,000/- was instituted with the support of OTAI (Central Zone) in memory of Prof. R K Khanna. This team award is for the best research paper published in all issues of the Journal of Lipid Science and Technology, which appeared during previous calendar year. No application is required for this award.



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