

RICE BRAN / RICE BRAN OIL: VALUE ADDED PRODUCTS DEVELOPED @ CSIR-IICT, HYDERABAD

80 Glorious Years



Presented during "ICRBO-2023 @ Hyderabad, India"

21-23 April 2023



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SOCIETY
President: Prime Minister
Vice President: Minister of S&T
Society Members



Governing Body
Members



Advisory Board



Director General



Performance Appraisal Boards

CSIR HQ



Management Council



Laboratories (37)
Head: Director



Research Council



CSIR- INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY

Council of Scientific and Industrial Research,
Ministry of Science and Technology, Government of India

Dr. D. Srinivasa Reddy
Director



History – Major contributions over 7 decades since 1944

1950's &
60's
Coal,
Ceramics
Oils & Fats

1970's & 80's
Agrochemicals

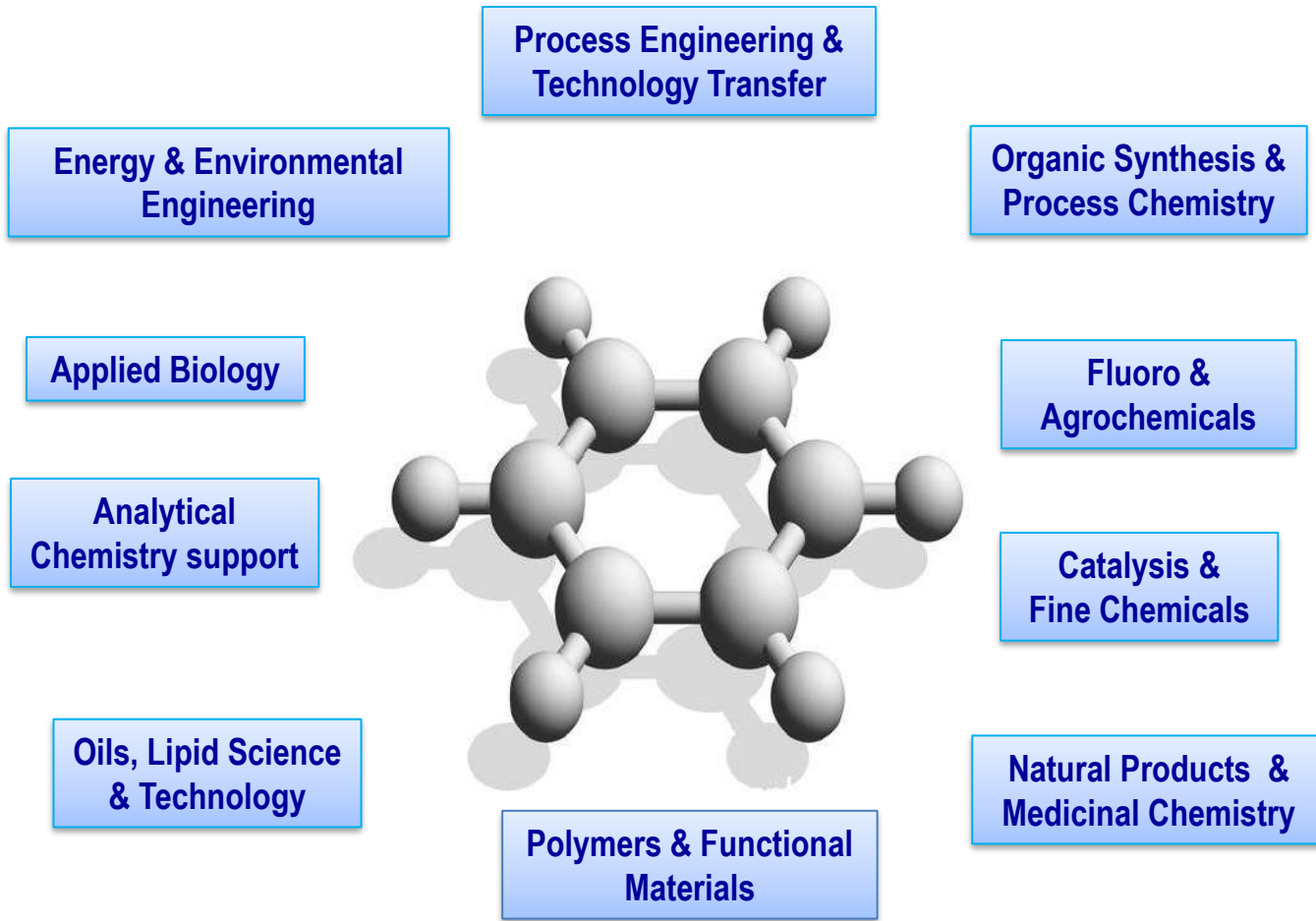
1980's & 90's
Generic
Drugs

2000 &
2010
Specialty
Chemicals
& Materials

2010 & 2020
API's
Impurities &
Drug
discovery

2020 & forward
Repurposed
Drugs, Adjuvants
& Clinical trials of
API's for COVID

VISION: To serve society by creating an outstanding knowledgebase in
chemistry & chemical technology



10 Departments

Total No. of Scientists : **165**
Tech and Non-Tech Staff : **263**
Admin Staff : **94**
Research Scholars : **600**



➤ **Dedicated Group for Oils & Fats-based R&D**

➤ **Dedicated National Facilities**

- Oils & Fats, Biodiesel, Lubricants & Vegetable Oil Processing Pilot Plant

➤ **Skill Development:**

- ✓ Refresher Course on “Processing and Analytical Methodologies of Oils & Fats” during Feb., March at CSIR-IICT, Hyderabad – Since 2008
- ✓ Business Meets & Conferences (National & International)

- Oil Technologists
- Organic Chemists
- Chemical Engineers

FSSAI Notified National Referral Laboratory (NRL) for Oils & Fats & NABL Accredited (ISO/IEC17025:2017) Testing Facility for Oils & Fats

CORE COMPETENCE

- Newer Extraction & Processing Methodologies for Vegetable Oils, Fats and Allied Products
- Value-added Products from By-products of Vegetable Oils Processing Industry
- Synthetic Aviation Lubricants • Vegetable Oil-based Bio-Lubricants • Biodiesel • Surfactants • Perfumery Chemicals
- Nutraceuticals • Structured Lipids • Designer Lipids • Synthetic Bioactive Lipids
- Membrane Applications for Vegetable Oils
- Glycerol-based Carbon Catalysts for Green Processes
- Phospholipids • Lipid Excipients
- Chromatographic (GC, GC-MS, GC-MS/MS, HPLC, LC-MS) & Spectral (UV, FT-IR, MS, Pulsed-NMR) Analysis



SUSTAINABLE DEVELOPMENT GOALS

ENERGY



- Biodiesel
- Value addition to Oilseed Cakes and Glycerol
- Biolubricants

INDUSTRY



- Castor Oils Derivatives
- Platform Chemicals
- Surfactants
- Cosmetics
- Fat Liquors
- Specialty Oleochemicals



HEALTH



- Nutraceuticals
- Phospholipids
- Lipid Excipients
- Microbial Lipids
- Reduced Calorie Fats
- Adjuvants



FOOD

- Newer Processing Methods
- High Quality Oils
- Structured Fats
- Eripupal Oil
- Newer/Lesser Known Oils



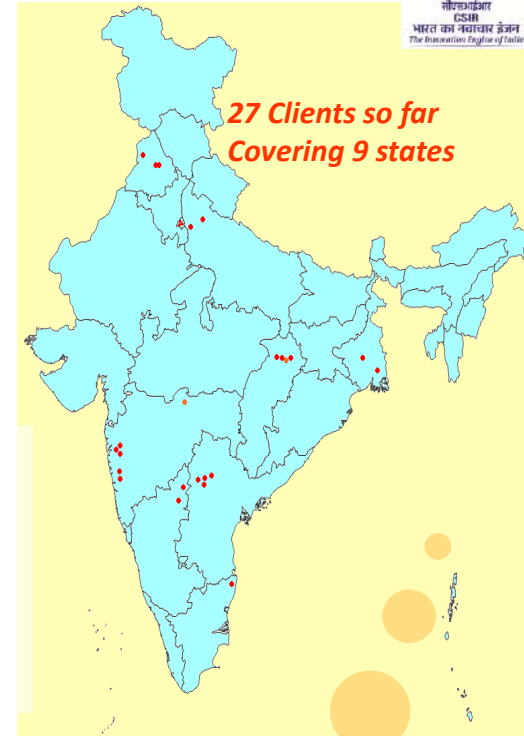
Popularly Known as Heart Oil

- Generally considered as the highest quality vegetable oil for cooking in terms of its fatty acid profile, cooking quality and shelf life
- **Balanced Fatty Acid Profile ... Closer to the Recommended Levels of Health Organizations**
- **Contains 1-2% of ALA - Meets the Requirement of n-3 Fatty Acids**
- RBO differs from other oils due to the presence of **oryzanol** and **high content of Free Fatty Acids, Unsaponifiables, Wax, Polar lipids including Glycolipids and Pigments**
- **Presence of a Host of Biologically and Nutritionally Active Constituents – Three Natural Antioxidants**
 - **Oryzanol**
 - **Tocopherols**
 - **Tocotrienols**
 - **Steryl Esters**
 - **Squalene**
 - **Diglyceride**
- **When use for frying, takes less time and food absorbed 15% less oil leading to its economy**
- **More stable at higher temperature, gives better taste and flavour to foods**
- **RBO has very high smoke point of 254 °C and mild flavour, making it suitable for high temperature cooking such as deep frying and stir frying**

IICT'S CONTRIBUTIONS TO INDIAN RICE BRAN OIL INDUSTRY ARE SIGNIFICANT

- **Selective Hydrolysis of Phospholipids Present Oil using Phospholipase A1 (PLA1)**
- **Green Process without any Effluents – Indian & US Patents - 50 TPD Scale**
- **Solved Most of the Problems of Physical Refining of Rice Bran Oil**
- **Higher yields of Oil; Less consumption of water**
- **~ 5 Lakh Tons of Rice Bran Oil is being Processed (~50% of Total Production)**
- **Transferred to 27 Clients Covering 9 States (2002-2010)**

- ❖ **Indian Patent No. 202379 (2006); US Patent No. 7,494,676 (2009) ; VN 1-0008605 (2010) & IDP0033123 (2013)**
- ❖ **IICT Process Requires Less Water and Releases No Effluent**
- ❖ **Technology Developed and Demonstrated at Commercial Scale (50 TPD)**
- ❖ **Investment Required for Switching Over to Enzymatic Degumming from Conventional Degumming in the Existing 50 TPD Refinery : Rs 15 Lakhs**



IMPACT ON INDIAN RICE BRAN OIL INDUSTRY

Total Annual Production of RBO in India : ~ 10 lakh tons
Production of RBO using IICT Process : ~ 5 to 6 lakh tons

If Total Production of RBO Routes through IICT Process...

• Extra Oil Recovery @ 1 to 1.5 %	9500 to 14,250 tons (Rs.48 to 70Crore)
• Extra Fatty Acid Recovery @ 0.3 to 0.6 %	2,850 to 5700 tons (Rs. 8 to 15 Crores)
• Minimum Water Saving @ 10 % of Crude oil	95,000 KL

**New Industries Established Employing IICT's Enzymatic Degumming Process
 Annually Producing about 4 Lakh Tons of RBO (Worth of > Rs. 2000 crores) –
 Helping the Nation in Saving Foreign Exchange to Import Edible Oils**

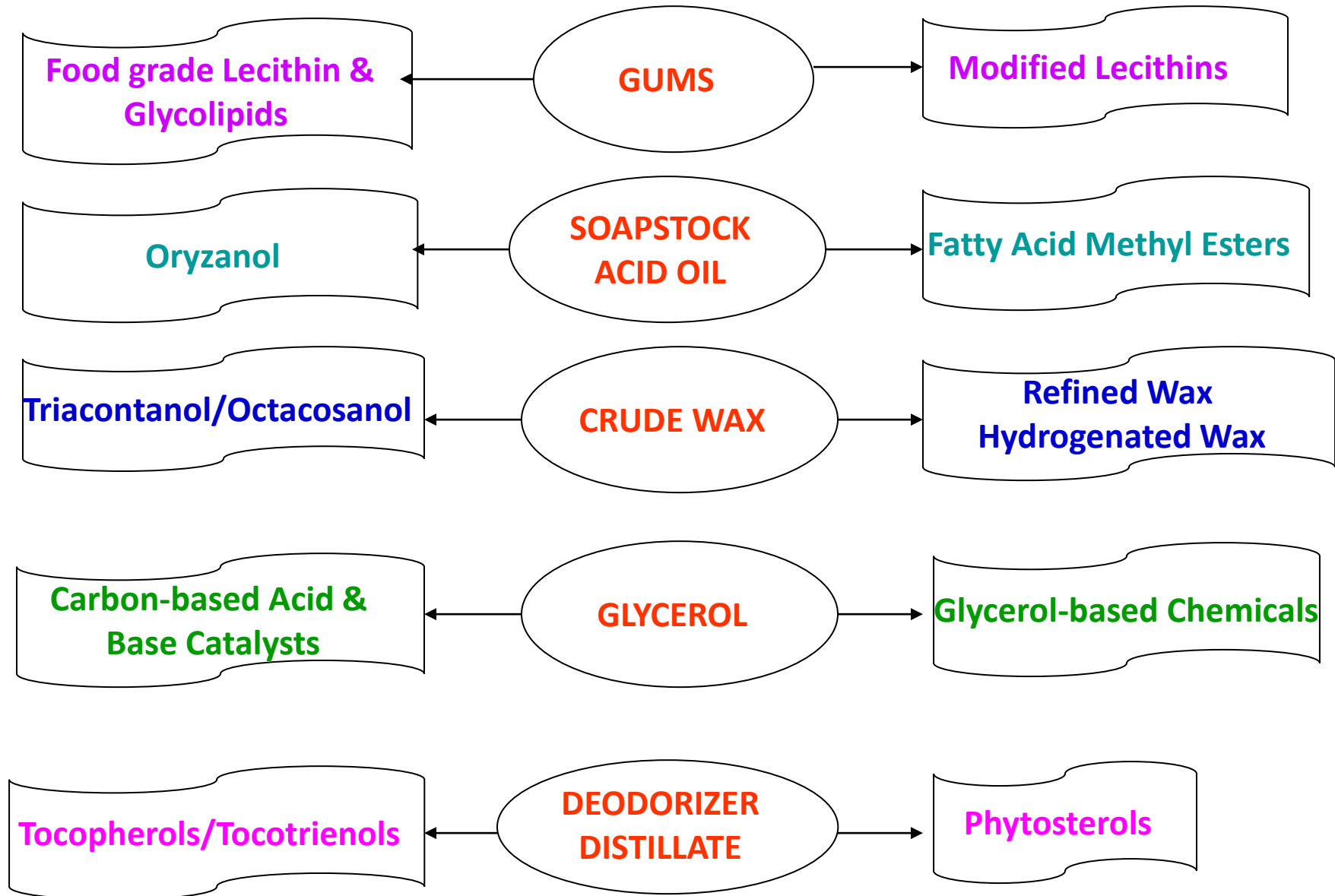
**SEA Golden Jubilee
 Award-2013**

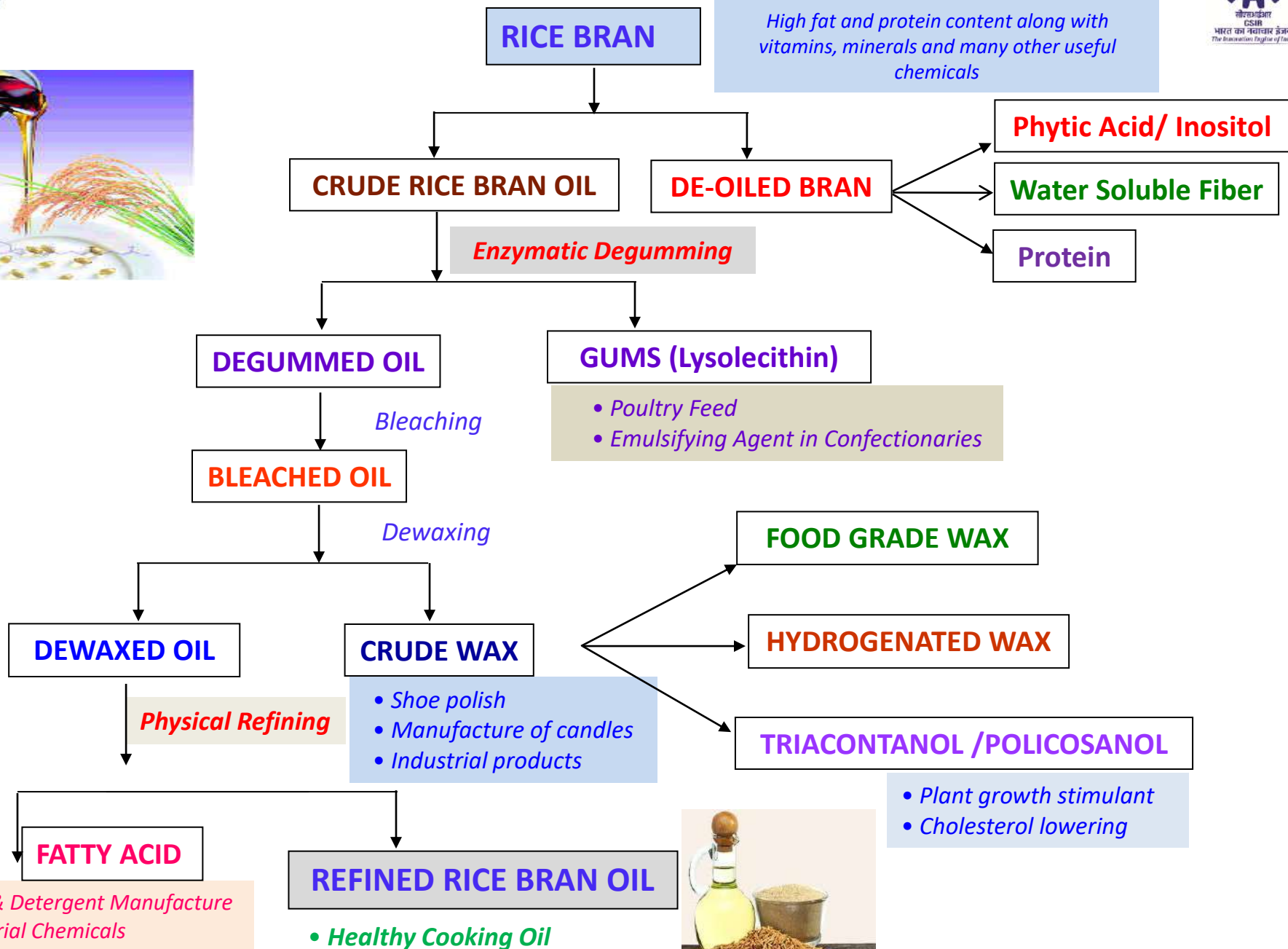
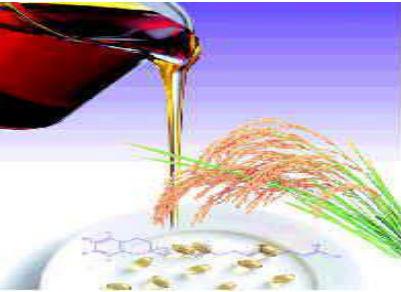
**First Industrial
 Green Chemistry
 Award – 2009**

**CSIR Technology
 Prize-2005**

**TDB National Award
 2009**

VALUE ADDITION TO BY-PRODUCTS OF VEGETABLE OIL PROCESSING INDUSTRY





REFINED RICE BRAN OIL

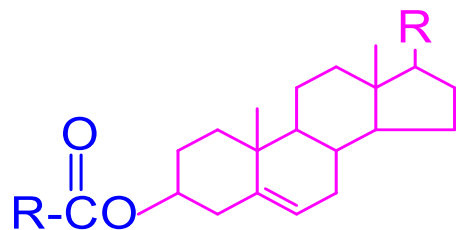
Silica Gel Column Chromatography

	HC	SE	TG	Polar Components
Sample 1	0.36	2.84	86.3	10.50
Sample 2 *	0.32	3.00	86.5	10.00
Sample 3 *	0.30	2.90	86.4	10.40
Sample 4	0.30	3.00	86.5	9.84
Sample 5	0.35	3.10	86.8	9.66
Sample 6*	0.35	3.05	86.8	9.80

* Chemical refined RBO

Fatty Acid Composition (Wt.%) of Refined Rice Bran Oil

14:0	16:0	18:0	18:1	18:2	18:3	20:0	20:1
0.3 – 0.4	19 – 22	1.4 – 2.5	37– 46	30 – 37	1 – 2	< 0.2	<0.5



Cholesterol Lowering Property

FATTY ACID PORTION

Fatty acid	Wt (%)
14:0	0.4
16:0	14.3
18:0	1.3
18:1	46.2
18:2	35.2
20:0	1.1
22:0	Tr
24:0	1.6

STEROL PORTION

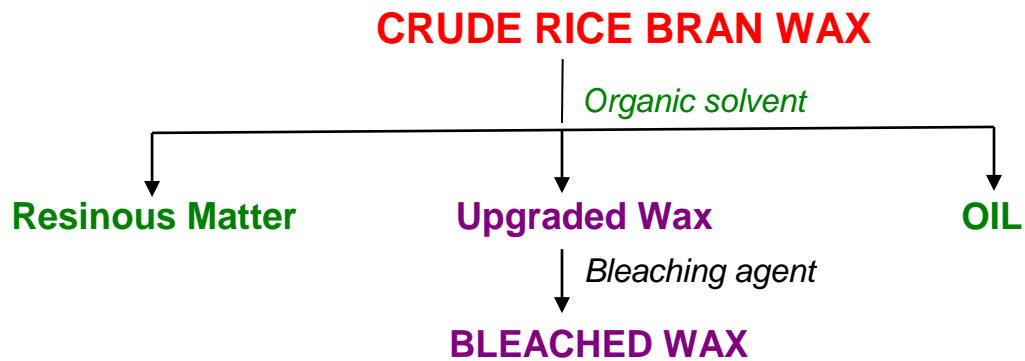
Sterol	Wt %
Campesterol	19.8
Stigmasterol	11.2
β -Sitosterol	54.3
Other sterols and Triterpenols	14.7

RBO polar Fraction	% Oryzanol
Sample 1	8.0
Sample 2 *	4.2
Sample 3*	2.2
Sample 4	10.5

* Chemical refined RBO

Unsaponifiable Matter (wt %)

Refined RBO	Unsap (wt%)
Sample 1	4.0
Sample 2*	3.2
Sample 3	3.7
Sample 4	4.0
Sample 5 *	2.3.
Sample 6*	3.0



Physical and Chemical Characteristics of Bleached Rice Bran Wax and Carnauba Wax

	M.P. (°C)	A.V.	S.V.	I.V.
Bleached Rice Bran Wax (IICT-H)	79-80	0-5	75-90	8-15
Rice Bran Wax (FDA specifications)	75-80	20 (max)	75-120	20 (max)
Carnauba Wax	83-86	3-8	72-85	8-12

A good substitute of carnauba wax

- Applications:**

Paper coating, Polish (floor, furniture, shoe), Fruit & Vegetable coatings, Adhesives, Greases, Electric insulation, Water proofing, Lubricants, Carbon paper, Printing inks, Type writer ribbons, Textile & Leather sizing, Candles, Cosmetics, Chewing gums, Pharmaceuticals

- Indian Patent IN 228674 & Japanese Patents JP 4125532

Technology Transferred to... 10 Industries

TRIACONTANOL/POLYCOSANOL/FATTY ALCOHOL MIXTURE/OCTACOSANOL FROM RICE BRAN WAX

DEFATTED RICE BRAN WAX

Saponification

SOAP

SOAP

Hydrolysis

Fatty Acids

TRIACONTANOL

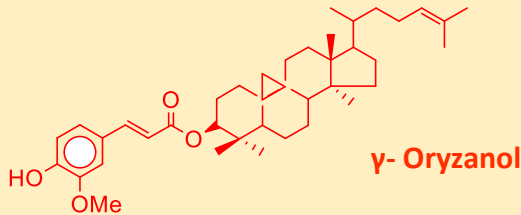
C_{24} - 4%, C_{26} - 8.4%, C_{28} - 14%, C_{30} - 26%, C_{32} - 20%, C_{34} - 17%, C_{36} - 9% & C_{38} - 2%

C_{16} - 4%, C_{18} - 2%, C_{20} - 5%, C_{22} - 26%, C_{24} - 40%, C_{26} - 11%, C_{28} - 7%, C_{30} - 3%, C_{32} - 1%

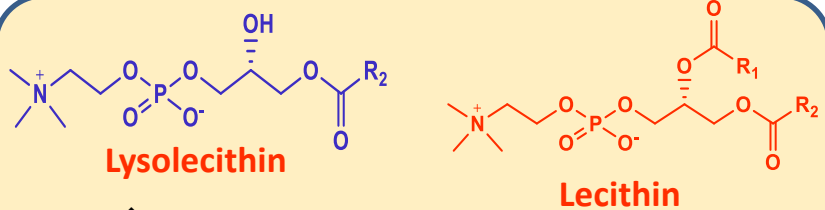
- Triacontanol Yield – 25-30% of defatted rice bran wax
- Applications: Plant growth stimulant
- Indian Patent: **184307**

Technology Transferred to 8 Industries

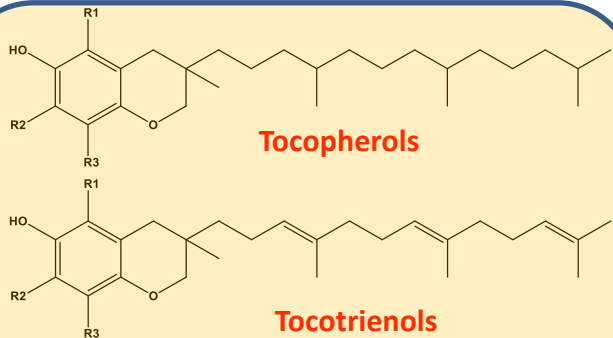
- *Nutritionally Improved Functional Food having Proven Health Benefit*



- ❖ Source: Rice Bran Oil Soap Stock
- ❖ Activity: Antioxidant, Anticancer Hypocholesterolemic

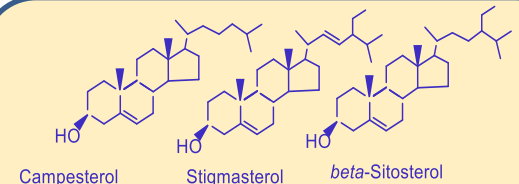


- ❖ Source: Rice Bran Gums
- ❖ Activity: Antioxidant, Food grade emulsifier



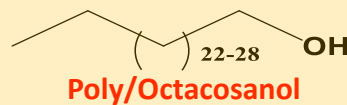
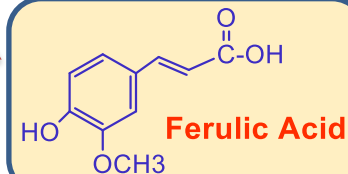
- ❖ Source: RBO DOD
- ❖ Activity: Antioxidant, Anticancer, Hypocholesterolemic

RBO

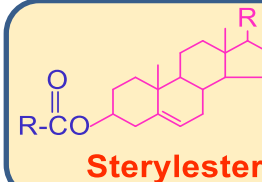


Phytosterols

- ❖ Source: RBO, Soya & Sunflower Oil
- Activity: Antioxidant

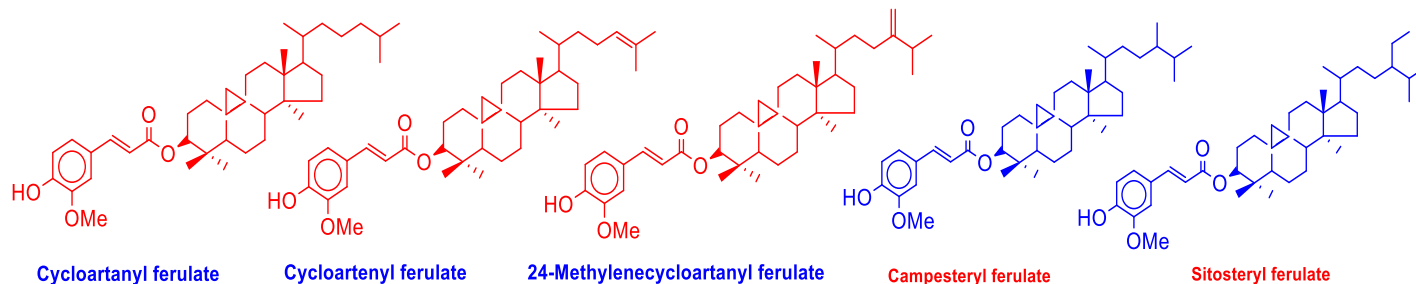


- ❖ Source: Rice Bran Wax
- Activity: Antistress, Antioxidant, Antiinflammatory



ENRICHMENT OF γ -ORYZANOL (80-90%)

- A Group of Naturally occurring Compounds of Ferulic Acid Esters of Triterpene Alcohols and Phytosterols
- Natural Antioxidant and Lowers Serum Cholesterol
- Rice Bran Oil contains 1 to 2% of Oryzanol



- IICT Developed a Lab Scale process for the isolation and purification of γ -Oryzanol with 85-90% purity in ~45% yield from soap-stock, a by-product of a chemical refining process of RBO

- Process involves conversion of soap stock to soap noodles
- Extraction of unsaponifiables from soap noodles
- Isolation of crude oryzanol (~60%) by crystallization
- Purification of crude oryzanol up to 85-90% by adsorption & techniques



Market Potential:

- ✓ It has high potential as a nutraceutical, cosmetic & natural antioxidant
- ✓ Process Know-how transferred to one industry in India

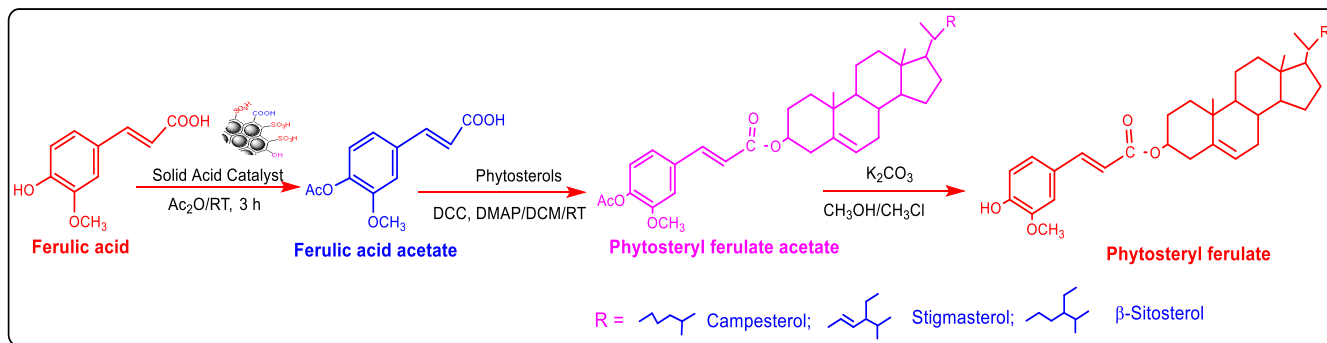
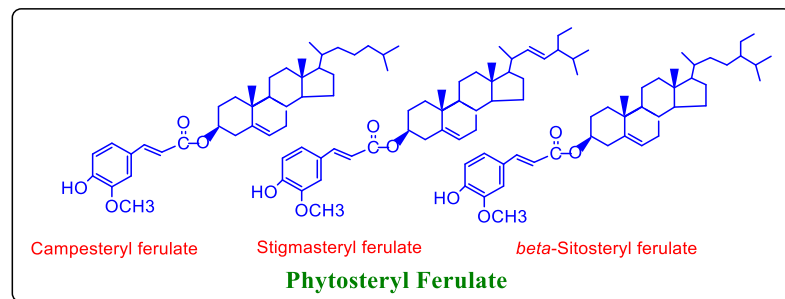
PHYTOSTERYL FERULATE (Synthetic Oryzanol)

JP5730789 (2015)

Indian Patent 271040 (2017)

- Replacement for Natural Oryzanol for Cholesterol Lowering

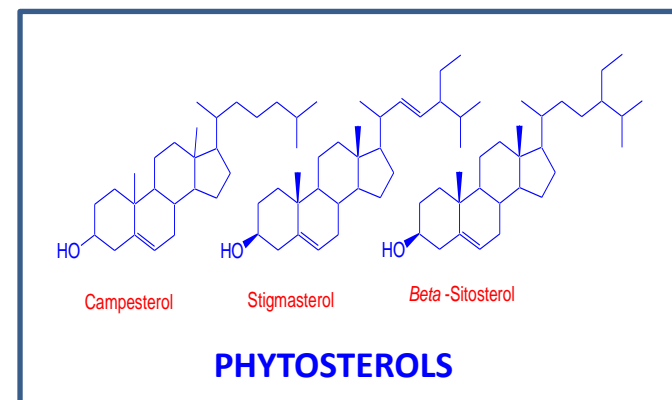
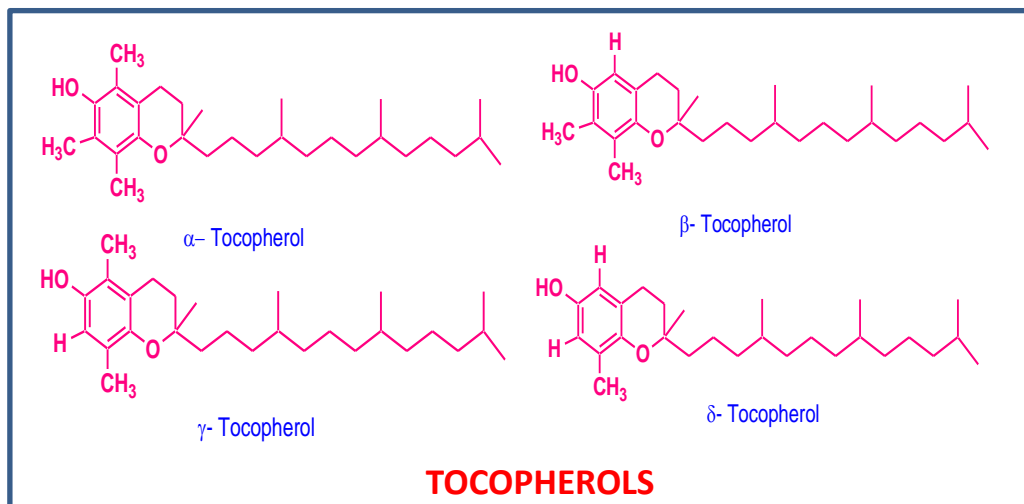
- Synthetic Oryzanol is a mixture of Ferulic Acid Esters of Phytosterols
- Synthetic Oryzanol (>95% Purity) was prepared from Ferulic Acid and Phytosterols Isolated from (isolated from Soybean Deodorizer Distillate) by Chemical Method



- Synthetic Oryzanol Exhibited Hypocholesteremic activity Similar to that of Natural γ-Oryzanol in Animal Model
- Palm oil and Sunflower Oils were Fortified with 0.3 and 1 % Synthetic Oryzanol and studied the Hypocholesteremic Activity in Hamsters in comparison with that of Native Oils and Rice Bran Oil & showed Positive Effect as that of Rice Bran Oil
- Fortified Palm and sunflower oils with synthetic oryzanol exhibited significant cholesterol lowering effect in Hamsters in comparison with that of native oils

TOCOPHEROLS & PHYTOSTEROLS

- Deodorizer Distillate (DOD) is a by-product obtained during the Refining of Vegetable Oils
- DOD is a Good Source for Natural Phytosterols & Tocopherols
- CSIR-IICT Developed a Process for the Isolation & Enrichment of Phytosterols (>95% purity) & Tocopherols (>50 -70%) purity from Soybean Oil DOD
 - Process involves esterification and transesterification of DOD to fatty acid methyl esters
 - Isolation and enrichment of phytosterols & tocopherols by crystallization and distillation methods
 - 70% Tocopherol & 95% Phytosterols Enriched from Soybean DOD
 - Scale of Demonstration: 3 Kg DOD/batch

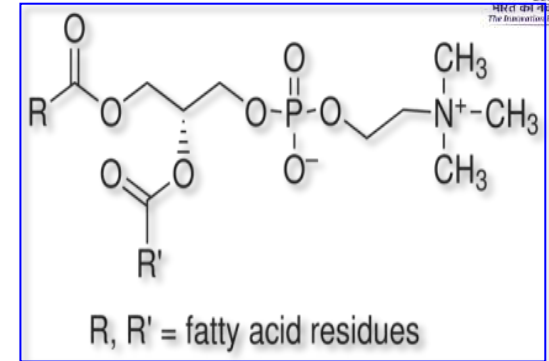


Market Potential:

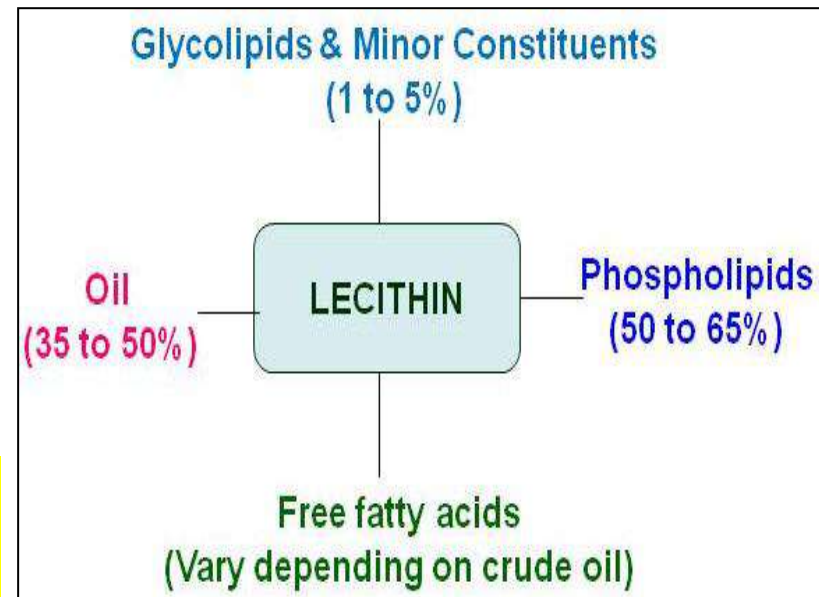
- ✓ It has high export potential as nutraceutical & natural antioxidant
- ✓ Process Know-how transferred to 2 industries in India

SOYA LECITHIN

- Lecithin is a By-product obtained during the Degumming of Vegetable Oil Refining Process
- Multifunctional Additive for Food, Pharmaceutical & Industrial Applications



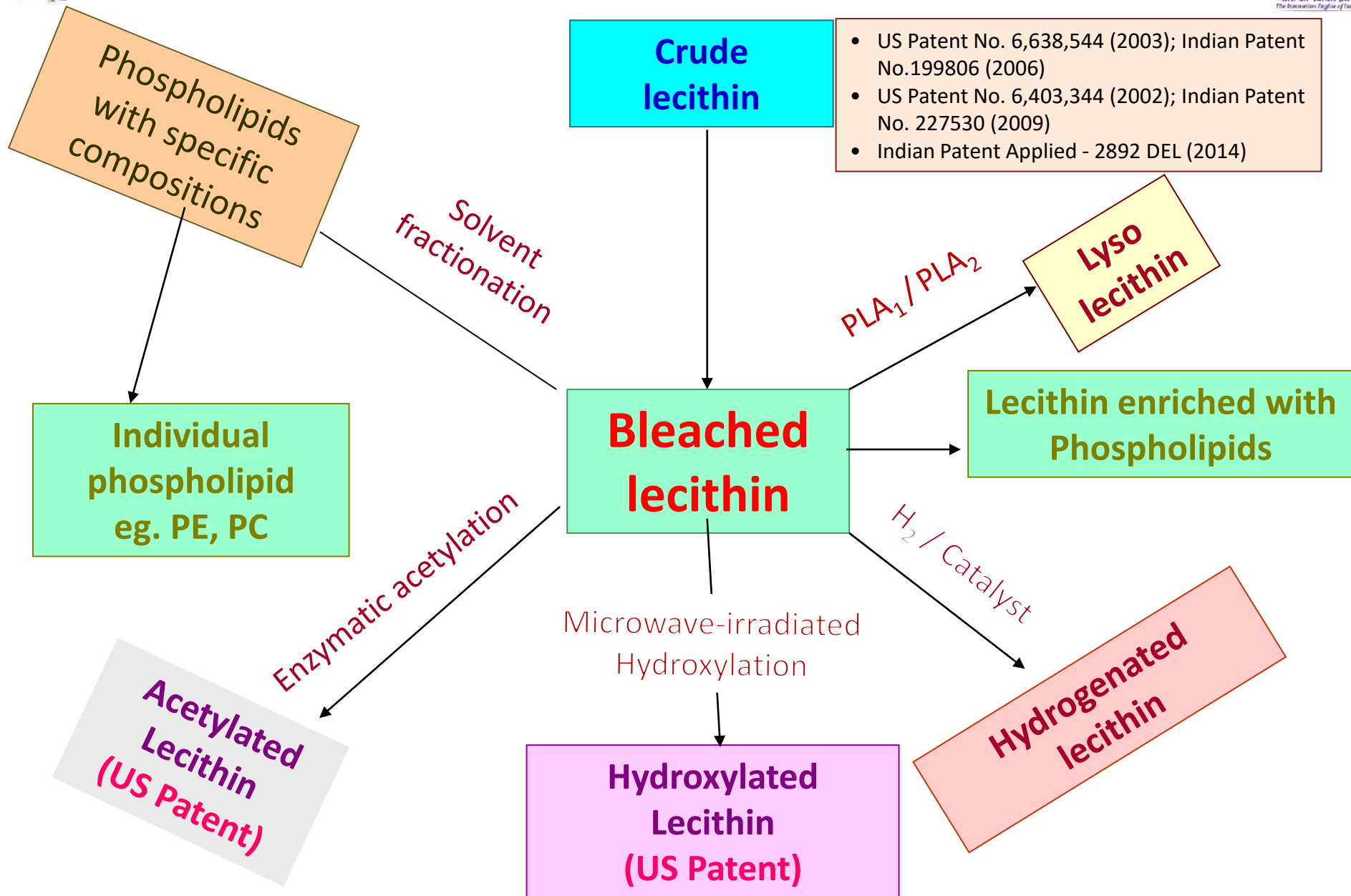
- **CSIR-IICT** - Process involves pre-treatment followed by chemical bleaching
- Commercial lecithin possess a colour of 18+ units on Gardner scale
- CSIR-IICT's food-grade lecithin possess a colour of 12 units



Market Potential:

- ✓ It has high export potential as an emulsifier in bakery foods

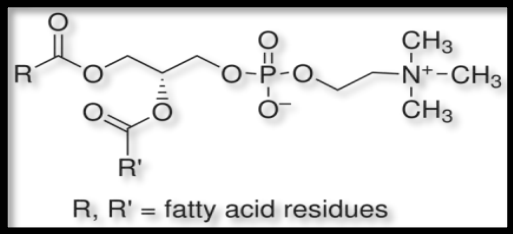
VALUE-ADDED PRODUCTS FROM SOYA LECITHIN



RICE BRAN LECITHIN

MSME

Lecithin is a natural emulsifier used in many industries



- Advantages of Rice Bran Lecithin over Soya Lecithin:**
- Enhanced oxidative stability
 - No limitations associated with GM foods
 - Presence of Oryzanol

FATTY ACID	SOYA LECITHIN	RICE BRAN LECITHIN	RICE BRAN LYSO LECITHIN
14:0	-	0.2	-
16:0	10.8	19.1	18.2
18:0	4.0	1.4	1.5
18:1	24.2	43.2	43.5
18:2	54.8	35.2	35.1
18:3	6.3	0.9	1.7

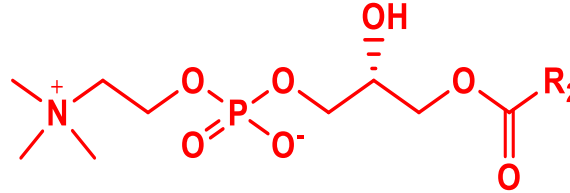


- ❖ Issues on Technology Development**
- Usual Degumming Process Practiced by Industry to be Modified
 - Technological Interventions at Solvent Extraction Process/Raw Material Handling
 - CSIR-IICT Developed Process at Bench Scale
 - Commercial Scale Process – Collaboration with Industry
 - Negotiating with Potential Industries

Worldwide market for Lecithin:
1.1 Billion \$ by 2020

- ❖ Rice Bran Production in India : 1 million tones
- ❖ Potential Rice Bran Lecithin Production : 20,000 tones (@Rs 50/- per kg)

RICE BRAN LYSOLECITHIN



- **By-product of Rice Bran Oil Enzymatic Degumming Process**
- **In 100 TPD Plant, around 1 to 1.5 Tons of Lysolecithin would be Produced per day**
- **Huge Amount of Rice Bran Lysolecithin Available for the First Time in the World**
- **Contains Less Oil (15-30%) – Difficult to Convert into Soap**
- **Alternative Uses to be Developed for Value Addition to Lysolecithin**

Food Grade Emulsifier

Superior surfactant properties compared to other standard Soybean, Rice bran, ADM Powdered and ADM Lecithins

Poultry Feed



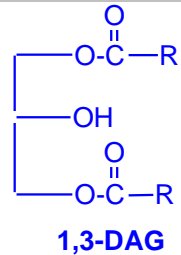
- Improved the growth rate, Feed consumption, Feed efficiency
- No adverse effect on liver, giblets, gizzard of the birds
- Immunity traits were comparable with control samples
- Rice bran lyso lecithin can be used as energy source in poultry feed formulation instead of vegetable oil to an extent of 5%

STRUCTURED LIPIDS

- Tailored Lipids with Specific Positioning of Fatty Acids over the Glycerol Backbone
- Design is based on Metabolic Pathway and Nutritional Importance of Fatty Acids

DIACEYLGLYCEROL (DAG) RICH OIL (Anti Obese Oil)

Indian Patent Filed - 98/DEL/2015



- Developed a Nutritionally improved DAG Enriched Oil from RBO:SFO with Balanced Fatty Acid Profile, Low Calorie & Hypolipidemic Activity
- Metabolic Studies on Rat (at CFTRI) - Reduced Calorific Value (6.45 kcal/g) and Hypocholesterolemic Effect
- Completed Toxicity Studies at NIN – DAG Oil is Non-toxic
- Useful for Cooking/Frying Applications for the Premium Category People Catering the need for Obese and Atherogenic People

- Phase I trial completed
- Interacting with Industry for Clinical Studies + FSSAI approval & Upscaling

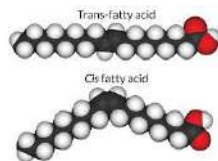


TRANS-FREE FATS/OILS

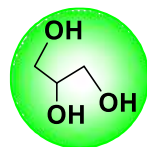
CSIR-IICT & MPOB, Malaysia - Collaborative Project (~USD 60,000)

Prepared Healthy Oil Blends/ Interesterified Oils using Indigenous Oils with Palm Fractions to obtain Trans-free Oils and Fats

- Different blends of indigenous oils with palm oil were prepared to obtain an oil blend containing 1:1:1 (S:MUFA:PUFA) WHO recommended Fatty Acid Composition
- Prepared trans-free oils and fats by the enzymatic interesterification of palmolein blends

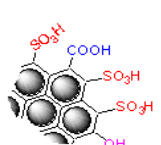


GLYCEROL-BASED CARBON CATALYSTS



GLYCEROL

In situ Carbonization & Sulfonation



ACID CATALYST

Aq. NaOH

BASE CATALYST

IN 290563 (13/12/2017)

ChemistrySelect, 2 (2017) 1925–1931. [IF: 1.505]

Aq. CuCl₂

COPPER CATALYST

ChemistrySelect, 4 (2019) 10133-10142 [IF: 1.716]

Aq. PdCl₂

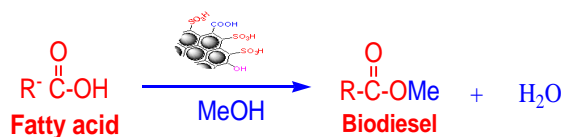


Unpublished Results

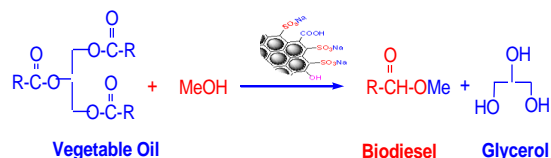
PALLADIUM CATALYST

US Patent 8,445,400; AU2007357284; German DE112007003607; Indonesia- IDP0032300; Indian Patent 2623409

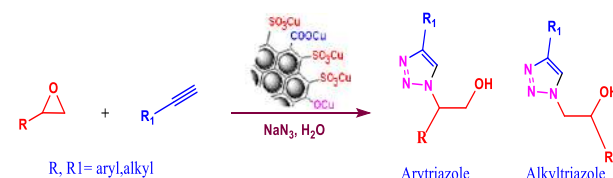
➤ Esterification of Fatty Acids to Biodiesel



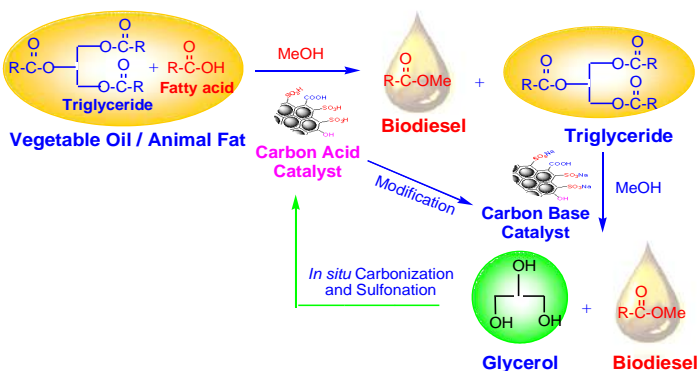
➤ Transesterification of Vegetable Oils to Biodiesel



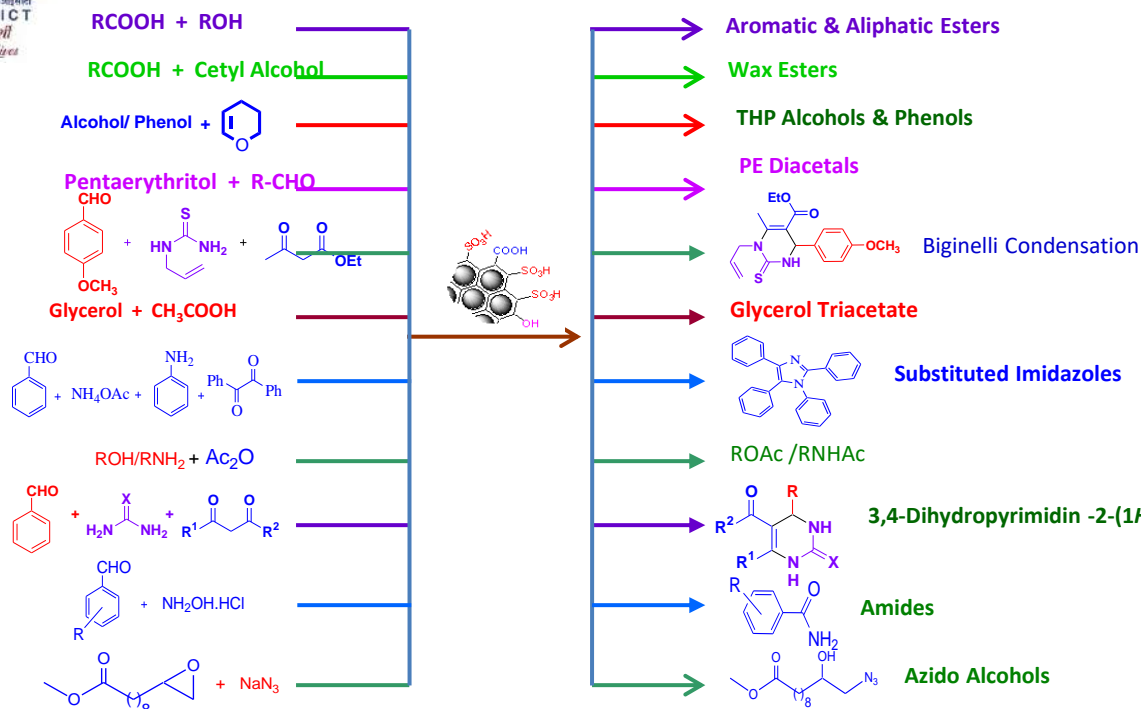
➤ Multicomponent synthesis of β-hydroxy 1, 2, 3-triazoles



➤ Biodiesel Production From Non-edible Oils / Animal Fat / Used Cooking Oils



- Green Biodiesel Process for Non-edible Oils (~10% FFA) and Clean Oils - Replaces H₂SO₄, Alkali and Water
- Effluent- Free & Cost Effective Process
- Reusable Catalysts
- Biodiesel obtained with ASTM/EN/BIS Specifications



Awards

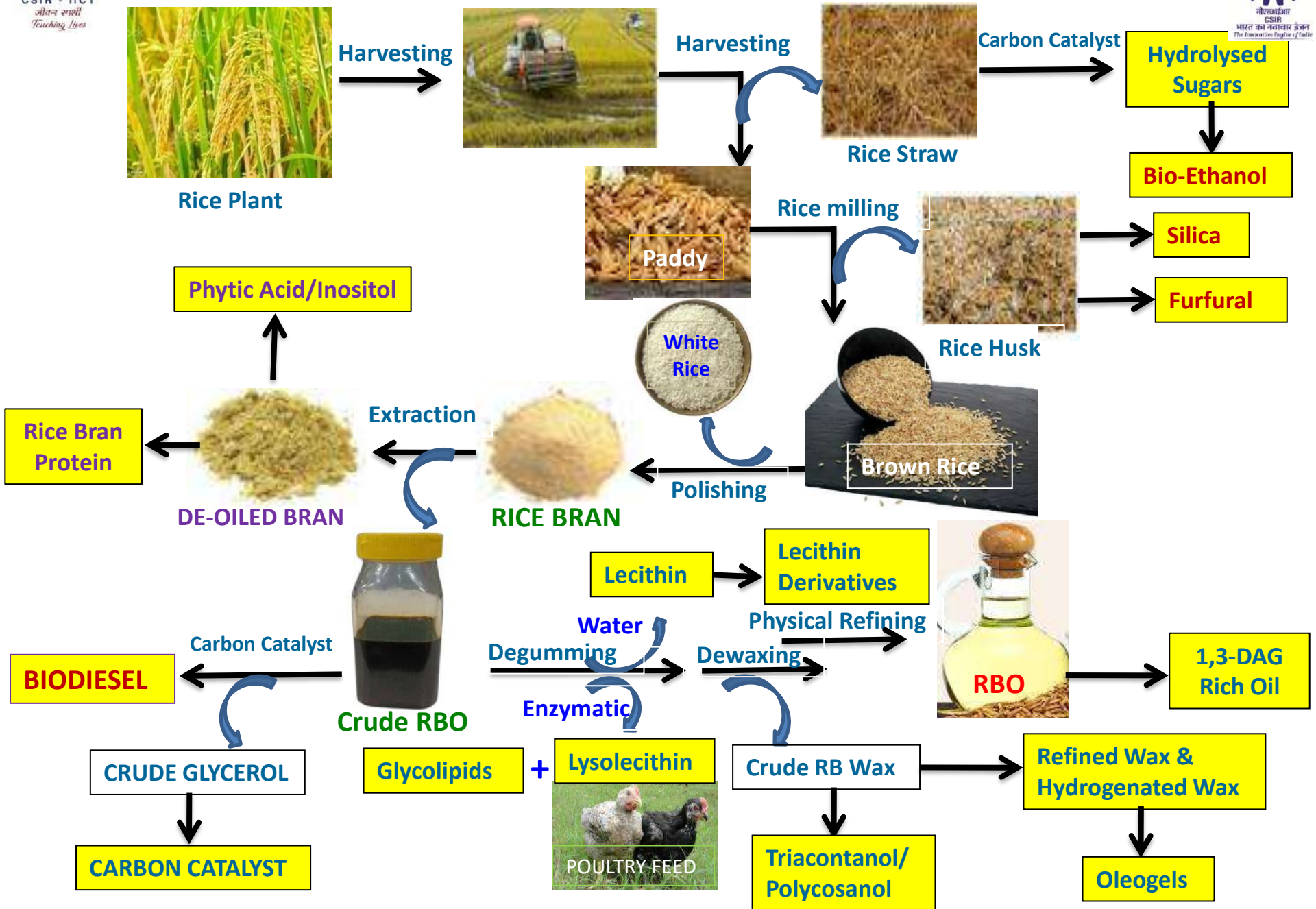
- **2013-** IGCW-Green Chemistry Innovation Award of Green ChemisTree Foundation
- **2013-** ACI/NBB Glycerine Innovation Award of American Oil Chemists' Society (**AOCS**)
- **2011-** Dr. S. D. Tirumala Rao Memorial Award of **OTAI** for "Generation of Wealth from Waste" for Utilizing Glycerol for the Development of Carbon Catalysts.
- **2010-** Dr RBGV Swaika Memorial Award of **OTAI** for development of carbon acid catalyst from glycerol.

• **Publications: 26; Citations: ~400; Patents: 6; Awards: 5**

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Work is in Progress for More Applications to Replace H₂SO₄

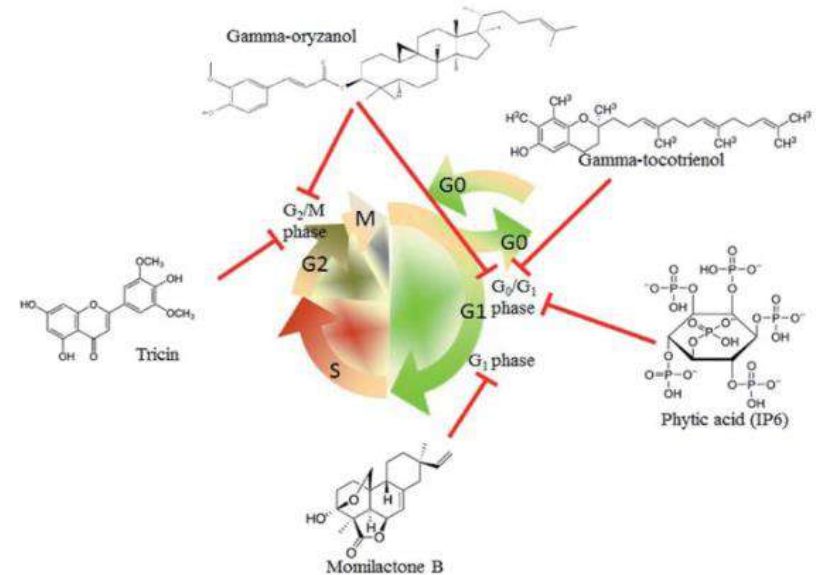
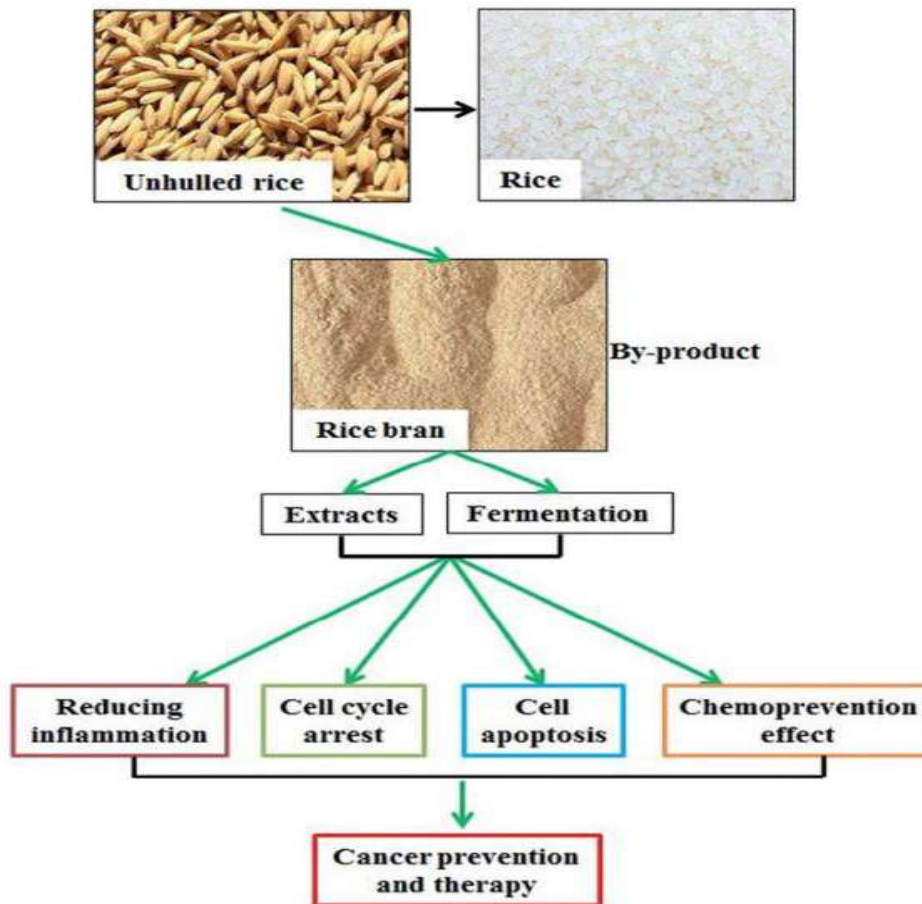
RICE BRAN BIOREFINERY – IICT CONTRIBUTIONS



ANTICANCER & POTENTIAL CLINICAL APPLICATION OF RICE BRAN EXTRACTS AND FERMENTATION PRODUCTS

Yonghui Yu, Jingjie Zhang, Jing Wang* and Baogao Suna, *RSC Adv.*, 2019, 9, 18060

- Bioactive components of Rice Bran Extracts and Fermented Products exert important roles in cancer prevention and therapy
- Administration of these bioactive components contributes to reducing inflammatory reactions, arresting the cell cycle, promoting cell apoptosis, and preventing cancer occurrence



- **γ-Tocotrienol**, **γ-oryzanol**, and **phytic acid (IP6)** arrested the cell cycle at the G₀/G₁ phase of **gastric adenocarcinoma SGC-7901 cells**; prostate cells DU145, colon cancer cells HT-29, and breast cancer cells MCF-7
- **Momilactone B** treatment resulted in human **leukemia cell U937** arrest at the G₁ phase
- **Tricin** and **γ-oryzanol** could also arrest the **breast cancer cells MDA-MB-468** and **prostate cell lines (PC3 and LNCaP)** at the G₂/M phase.



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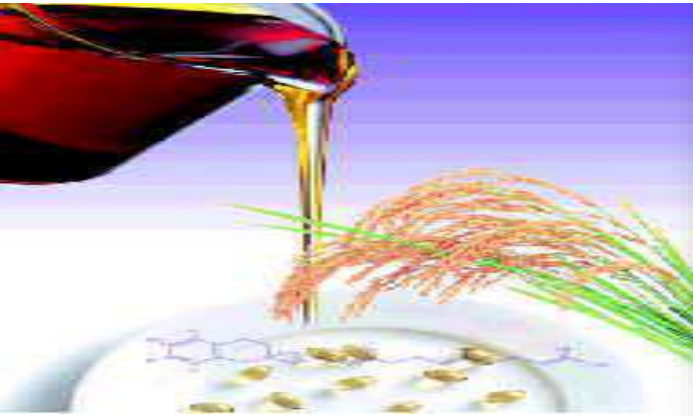


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*Thank
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