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Enhancing Oil Recovery from Oilseeds and Microorganisms as Alternative Source of Oil

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Abstract
This article deals with the ways of increasing or enhancing the oil extraction or yield from the oilseeds and also, the extraction of Oil from the microorganism as alternative to oilseeds.

Keywords: *Microorganism, Enzyme, Oilseeds, Extraction, Aqueous, Recovery, Permeability, Solvent, Clogging, Surfactant*

1. Introduction

All over the world an ever increasing demand for oil from oilseeds is being witnessed. So, the sole objective is to increase productivity of oilseeds, in the wake of ever increasing urbanization and industrialization. The demand for vegetable oils is increasing over supply in order to meet the gap, additional oilseeds are required or there is need of some competing source of edible oil which can meet the demand. The recovery of oil from the oilseeds can be enhanced by the use of some microorganisms and by the use of some enzymes. The other major and cheap source of oil can be microorganism itself, from which the oil can be extracted to meet the competing demand of oil. There is always some other alternative source which the world is looking for the production of the oil, leaving that from the oilseeds, due to land under agriculture is decreasing year by year.

2. Enhancement of oil recovery from oilseeds by use of enzymes

All over the world an ever increasing demand for oil from oilseeds is being witnessed. So, the sole objective is to increase productivity of oilseeds, in the wake of ever increasing urbanization and industrialization. The demand for vegetable oils is increasing over supply in order to meet the gap, additional oilseeds are required.

The ever increasing demand would necessitate a critical examination of look into extraction and processing technologies. It entails adoption of most modern technologies in extraction and processing of oils. The use of supercritical fluid (CO_2), the enzymes and membrane technology have scope in future. According to oil technologists all around the world, it is clear that more land will not be available for oilseed crop production. On the other hand, more pressure cannot be put on agriculture biotechnologists and scientists to increase crop yields. Enzyme based technology have emerged as one of the most eco-friendly, in recent times.

A method for treatment of oilseeds with enzymes for softening and increasing the porosity of oilseeds to enhance the rate of oil recovery, has to be developed to minimized residual oil in oilseeds cake and refining of high free fatty acid and dark color oil. The article aim the potential of eco-friendly approach for oil recovery from oilseeds.

Table 1 Enzymatic hydrolysis of oilseeds for enhancing oil Extraction

Sl no.	Materials	Effect on hydrolysis
1	a) Melon seeds b) Ground soyabeans c) Rape seeds	i) Extra oil release ii) Better oil quality
2	a) Crushed soyabeans b) Cotton seeds c) Castors Bean	Enhanced release of extractable oil

3	Canola Flakes	i) Enhanced release of extratable oil ii) Reduction in oil extraction time
4	Soyabeans	i) Enhanced release of extratable oil ii) Enhance oil recovery

Aqueous Enzymatic Oil Extraction (AEOE) – Aqueous Extraction Process (AEP) using water alone as the medium, was an alternative to solvent extraction of oil as a safer and cheaper method. The unit operations involved in AEP are:

i) Size reduction (grinding) of oilseeds/ fruits materials
ii) Extraction
iii) Solid-liquid separation
iv) Separation of oil rich phase
v) De-emulsification for further recovery of oil and
vi) Drying to remove moisture

Its naturally make sense to use all cell-wall degrading enzymes to facilitate the release of oil. The approach has several advantages, some inherent in the AEP, and some arising out of use of enzymes.

i) It eliminated the use of organic solvents resulting in saving the cost of such solvent and possibly low investment in infrastructure.
ii) Simultaneous recovery of oil and protein fractions. It was one of the early driving forces which motivated people to explore AEP.
iii) Quality of oil obtained by enzymes were very different from the one obtained by conventional means.
iv) Degumming may not be needed.

Enzyme based oil extraction-Enzymes digests the complex cell wall of oil seed, alternating permeability favoring oil extraction. After enzymatic treatment individual components protein, oil and polysaccharide could be conveniently separated with further processing. The treatment appeared to increase the productivity, efficiency and provide quality output in agro-industrial processing in many developing countries. Enzyme enhance extraction and providing quality output in agro-industrial processing in many developed countries. Enzyme enhances extraction and separation processes, eliminate toxic and anti-nutritional factors, catalyze carbohydrate, protein and lipid conversion through their antioxidants and bio-catalytic activities. The energy costs associated with processing were reduced and nutritional quality and safety of foods improved, and the processing times were shortened. New products maybe generated and alternative application for several agricultural product may be realized after enzymatic treatment.

Enzymatically treated oilseeds showed an increase in the oil yield in comparison to untreated samples. Regardless of the type of enzymes the quality of the oil was good and its composition was not affected by the treatment. Enzyme may either be directly incorporated or may be immobilized on inert support matrices and allowed to a act. The oil composition and extraction conditions determine the choice of enzymes combinations and extraction conditions. In future enzyme technology would play a big role in improving the yield and quality of oils. Enzyme mixtures gave better results compared to that with individual enzymes.

Table 2 Parameters suitable for enzyme action on oilseeds

Oil seeds	pH	Temperature ^{0}C	Enzyme	Extracted oil percent
Rape seeds	6.6	70	Protease, α-1,4 glacturonide acids	78
Soyabeans	4.5	-	Proteolytic	86
Sunflower	5.0	Room temperature	Cellulase, α-1,4 glacturonide acids	52
Peanut	4-10	60-65	Portease, Cellulase	74-78

3. Increasing oil yield from oilseeds by use of microorganisms

History

It was in 1926 when Beckam proposed the utilisation of microorganisms as agents for recovering the remnant oil entrapped in porous media. Since that time numerous investigations have been developed, and are extensively reviewed.

Microbial Enhanced Oil Recovery (MEOR) is a biological based technology consisting in manipulating function or structure, or both, of microbial environments existing in oil seeds bed. The ultimate aim of MEOR is to improve the recovery of oil entrapped in porous media while increasing economic profits. MEOR is a tertiary oil extraction technology allowing the partial recovery of the commonly residual two-thirds of oil, thus increasing the life of mature oilseeds.

MEOR is a multidisciplinary field incorporating, among others: chemistry, microbiology, fluid mechanics, food engineering, environmental engineering and chemical engineering.

Microbial enhanced oil recovery (MEOR) is a tertiary oil recovery process where microorganisms and/or their metabolic by products are utilized for the mobilization of crude oil trapped in mature oilseeds bed. The proposed MEOR mechanisms leading to oil recovery fall into two broad categories: alteration of oil/water/seeds interfacial properties and changes in flow behavior due to bio-clogging. Numerous reports show the efficacy of MEOR at the lab-scale; however, a complete understanding of the mechanisms involved is lacking, and the effectiveness of each mechanism for different oilseeds bed parameters (such as wettability) is unknown.

As stated by, three general strategies exist for the implementation of **MEOR**: (1) injection of nutrients to stimulate indigenous microorganisms, (2) injection of exogenous microorganisms(s) and nutrients, or (3) injection of ex situ produced products. The first two strategies have the added difficulty of dealing with subsurface bacterial transport, competition for nutrients among the desired organism and other indigenous microorganisms, and maintaining nutrient levels throughout a reservoir for extended periods of time. Therefore, it is likely that the third strategy is the simplest, and thus, the most likely for success at the field-scale.

Reduction of interfacial tension (IFT) via biosurfactant production, changes in wettability, and bioclogging. Nonuniform wettability can distort the capillary pressure curve such that it no longer represents the true pore-size distribution. The findings of indicate that wettability can have a dramatic effect on residual oil entrapment. Residual oil blobs increase in size and length as the porous medium is composed of fewer oil-wet surfaces.

So far, the outcomes of MEOR are explained based on two predominant rationales:

Increment in oil production- This is done by modifying the interfacial properties of the system oil-water-cake, with the aim of facilitating oil movement through porous media. In such a system, microbial activity affects fluidity (viscosity reduction, miscible flooding); displacement efficiency (decrease of interfacial tension, increase of permeability); sweep efficiency (mobility control, selective plugging) and driving force (reservoir pressure).

Upgrading. In this case, microbial activity acts may promote the degradation of heavy oils into lighter ones. Alternatively, it can promote desulphurization due to de-nitrification.

MEOR Advantages

Advantages can be summarized as follows:

i) Injected microbes and nutrients are cheap; easy to handle in the field and independent of oil prices.

ii) Economically attractive for oil expelled oil cakes before abandonment.

iii) Increases oil production.

iv) Existing facilities require slight modifications.

v) Easy application.

vi) Less expensive set up.

vii) Low energy input requirement for microbes to produce MEOR agents.

viii) More efficient than other enhance oil recovery (EOR) methods

ix) Microbial activity increases with microbial growth. This is opposite to the case of other EOR additives in time and distance.

x) Cellular products are biodegradable and therefore can be considered environmentally friendly.

MEOR Advantages

i) The oxygen deployed in aerobic MEOR can act as oxidizing agent

ii) Anaerobic MEOR requires large amounts of sugar limiting its applicability

iii) Exogenous microbes require facilities for their cultivation.

iv) Indigenous microbes need a standardized framework for evaluating microbial activity, e.g. specialized size reduction and sampling techniques.

v) Microbial growth depends on layer permeability, temperature, pH depth of oilseeds bed.

Microbial processes (MEOR)- In this method, nutrients and suitable bacteria, which can grow under the anaerobic reservoir conditions, are injected into the reservoir. The microbial metabolic products that include biosurfactants, biopolymers, acids, solvents, gases, and also enzymes modify the properties of the oil and the interactions between oil, water, and the porous media, which increase the mobility of the oil and consequently the recovery of oil especially from depleted and marginal reservoirs; thus extending the producing life of the wells. Bacillus strains grown on glucose mineral salts medium are one of the most utilized bacteria in MEOR technologies, specifically when oil viscosity reduction is not the primary aim of the operation.

Clogging Mechanism- One method of microbial improving oil recovery is by modifying the fluid flow through the oilseeds by shifting fluid flow from the high permeability zones in a oilseeds to the moderate or low permeability zones thus increasing the sweep efficiency by forcing the injected water to pass through previously by-passed oil zones of the oilseeds. The changes in flow pattern can be achieved by an increase in microbial cell mass within the oilseeds bed. Stimulating either indigenous microbial populations or injecting microorganisms together with nutrients produce biomass and hence microbial plugging. The injected nutrient and microbes preferentially flow into the high permeability zones of the reservoir and as a result of cell growth, the biomass selectively plugs these zones to a greater extent than the moderate or low permeability zones.

MEOR is promoted by injecting exogenous microbes, which may be adapted to oil reservoir conditions and be capable of producing desired MEOR agents (Table 3).

Table 3. Possible applications of products and MEOR agents produced by microorganism.

MEOR agents	Microbes	Product	Possible MEOR application
Surfactants	Acinetobacter	Emulsan and alasan	Emulsification and de-emulsification through reduction of interfacial tension
	Bacillus sp.	Surfactin, rhamnolipid, lichenysin	
	Pseudomonas	Rhamnolipid, glycolipids	
	Rhodococcus sp.	Viscosin and trehaloselipids	
	Arthrobacter		
Biopolymers	Xanthomonas sp.	Xanthan gum	Injectivity profile and viscosity modification, selective plugging
	Aureobasidium sp.	Pullulan	
	Bacillus sp.	Levan	
	Alcaligeness sp.	Curdlan	
	Leuconostoc sp.	Dextran	
	Sclerotium sp.	Scleroglucan	
	Brevibacterium		
Solvents	Clostridium, Zymomonas and Klebsiella	Acetone, butanol, propan-2-diol	Oilseeds cake dissolution for increasing permeability, oil viscosity reduction
Acids	Clostridium	Propionic and butyric acids	Permeability increase, emulsification
	Enterobacter		
	Mixed acidogens		
Gases	Clostridium	Methane and hydrogen	Increased pressure, oil swelling, reduction of interfacial section and viscosity; increase permeability
	Enterobacter		
	Methanobacterium		

Biosurfactants

Microbial produced surfactants, i.e. biosurfactants reduce the interfacial tension between water and oil, and therefore a lower hydrostatic pressure is required to move the liquid entrapped in the pores to overcome the capillary effect. Secondly, biosurfactants contribute to the formation of micelles providing a physical mechanism to mobilise oil in a moving aqueous phase. Hydrophobic and hydrophilic compounds are in play and have attracted attention in MEOR.

Gas and solvents

In this old practice, the production of gas has a positive effect in oil recovery by increasing the differential pressure driving the oil movement. Anaerobically produced methane from oil degradation have a low effect on MEOR due to its high solubility at high pressures. Carbon dioxide is also a good MEOR agent. The miscible CO_2 is condensed into the liquid phase when light hydrocarbons are vaporised into the gas phase. Immiscible CO_2 helps to saturate oil, resulting in swelling and reduction of viscosity of the liquid phase and consequently improving mobilization by extra driving pressure.

4. Oil production from Microorganisms

The oil can be produce from the microorganisms which are rich in lipid content.
The main factors to evaluate the potential of a microorganism for oil production are:

i) The amount of oil produced; the more oil a microbial cell can accumulate, the more attractive it will be from a commercial viewpoint.
ii) The quality of the oil produce; the profile of fatty acid varied a lot from microorganism to microorganism. Some fungi and microalgae produce polyunsaturated fatty acids with a carbon chain length and degree of unsaturation greater than those found in plants.
iii)The capacity to use cheap raw material: the cost of raw material represents the overriding cost source. These three parameters have become the key of the recent researches on the production of microbial oils.

Table 4 The lipid content and productivity of general edible oil plants (O'Brien, 2008).

Oil	Lipid content (%wt)	Oil yiel (kg/ha/yr)
Oilseeds		
Rapseed	45	591–664
Peanut	50	1260–1400
Soybean	20	450–506
Sunflower	45	517–664
Tree fruits and kernels		
Coconut	50	731–979
Olive	15–35	101–292
Palm	50	3004–5006
Palm kernel	50	300–500

Table 5. The productivity of selected oleaginous yeasts, fungi and bacteria (Sawangkeaw, *et al.*, 2013).

Yeasts, fungi or bacteria strains	Lipid content (% w/w)	Productivity (kg/m3/yr)	
		Biomass	Lipid
Yeasts			
Candida curvata	29–58	691	315
Cryptococcus albidus	33–60	252	146
Cryptococcus curvatus	25–46	1990	1154
Lipomyces starkeyi	61–68	636	410
Rhodosporidium toruloides	58–68	3362	2120
Fungi			
Mucor mucedo	62		
Aspergillus oryzae	18–57	377	215
Cunninghamella echinulata	35–58	232	134
Mortierella isabellina	50–55	1276	679
Bacteria			
Arthrobacter sp.	>40	N/R	N/R
Acinetobacter calcoaceticus	27–38	N/R	N/R
Rhodococcus opacus	24–26	N/R	N/R
Bacillus alcalophilus	18–24	N/R	N/R

N/R = not reported.

Table 6. The lipid content, biomass and oil productivity of selected microalgae (Sawangkeaw, *et al.*, 2013).

Microalgae strain	Lipid content (% w/w)	Productivity (kg/m3/yr)	
		Biomass	Lipid
Chlorella sp.	22–32	159	54
Scenedesmus obliquus	13–58	153	54
Chaetoceros muelleri	25–52	150	57
Chlorella zofingiensis	52	216	112
Crypthecodinium Cohnii	23	672	134
Nannochloropsis oculata	23	870	200
Chlorella protothecoides	48–64	412	231
Chaetoceros gracilis	15–60	1065	404
Schizochytrium mangrovei	68*	732	498
Schizochytrium limacinum	50*	1044	525

Oleaginous microorganisms are defined as oleaginous species with oil contents excess of 20% of biomass weigh. Microbial oils, also called single cell oils, are produced by some oleaginous microorganisms, such yeast, fungi, bacteria and microalgae. While the eukaryotic yeast, fungi and microalgae can synthetize triacylglycerol (TAG), which are similar with the composition of vegetable oils, prokaryotic bacteria can synthetize specific lipids.

Lipids are an effective form of energy storage with a high energy value about 39 kJ/g (9 kcal/g). Esterified as TAG and sterol esters, lipids are energy storage molecules localized in specific organelles of the cell: lipid bodies of oil seed or oleaginous microorganisms and adipose tissue of mammals. In addition to their role as energy storage, these organelles are also able to provide fatty acids and sterols for the biogenesis and maintenance of cell membranes.

Lipid metabolism is present in all microorganisms. compared, in term of their chemical compositions, to the oils obtained from oils seeds. Compared to yeast, oleaginous fungi and microalgae have a lower lipid accumulation capacity.

5. Conclusion

Therefore we can conclude that by use of enzymes and microorganism we can increase the oil yield from the oilseeds and also, Microorganism can be used as a source for oil production alternative to oilseeds with faster growth rate.

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