

Production of Wax Esters

The present invention relates to the production of wax esters. More particularly this invention relates to the production of wax esters from palm oil.

Esters of short chain fatty acids and alcohols are important in the food industry as flavor and aroma constituent. Methyl and ethyl esters of long chain fatty acids are valuable oleo chemicals that may be used as replacement for diesel oil. Wax esters are long chain esters derived from fatty acids and alcohols both with chain lengths of 12 carbons or more. Unsaturated or liquid wax esters derived from natural sources such as jojoba oil and sperm whale oil have been dominantly used in the lubricants, plasticizers and cosmetics market. This is due to their unique properties of being able to impart wetting behavior at interfaces and having a non greasy feeling when applied on skin surfaces. However, the main obstacle to large-scale use of natural sources of unsaturated wax esters is its cost and availability.

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Since natural unsaturated wax esters are expensive and limited in access, the need to synthesize unsaturated wax esters has grown. Unsaturated wax esters can be synthesized using chemical-catalyzed and enzymatic-catalyzed methods. However, chemical-catalyzed method leads to high-energy consumption and degradation of the esters produced. Enzymatic catalyzed method offers mild reaction conditions and is an environmental friendly process.

Enzymatic synthesis of fatty esters has been known for a long time. An efficient process exists to enzymatically esterify purified fatty acids with

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alcohols but alcoholysis of oils and fats is simpler and the starting material is cheaper.

5 U.K. Patent No. GB2188057 discloses the preparation of alkyl esters from fats and oils and glyceride-containing fractions thereof by mixing a solution of the fat or oil in an inert organic solvent with an alkanol in the presence of a lipase and high content of water.

10 Japanese Patent No. JP63251089 discloses the preparation of wax esters from vegetables, animals or synthetic fats and oils by alcoholysis of the fats and oils using 6-24C mono- or dihydric aliphatic alcohol in the presence of a lipase and high content of water.

15 Stevenson et.al. published a method of near quantitative production of fatty acid alkyl esters by lipase-catalyzed alcoholysis of fats and oils with adsorption of glycerol by silica gel (Enzyme Microb. Technol. , 16:474-484 [1994]). In the alcoholysis process, the products are not only fatty acid alkyl esters but also glycerol. Glycerol may inhibit the reaction by
20 limiting the interaction of the substrate and the enzyme. When immobilized *Mucor miehei* lipase is used to catalyze the reaction of tallow with three molar equivalents of butanol, the yield of butyl esters did not exceed 70% (w/w). If silica gel is added to the reaction mixture, it adsorbed the glycerol produced during the reaction and the yield increased up to 98%.

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The present invention provides a method of producing wax esters from fats and oils, particularly palm oil by alcoholysis of the fats and oils with long chain alcohol, particularly oleyl alcohol in the presence of an immobilized lipase. Good yield (~80%) of wax esters can be expected

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without having to provide a high content of water or a means of glycerol adsorption.

5 Wax esters are prepared by reacting a solution of palm oil in an organic solvent with oleyl alcohol in the presence of an immobilized lipase wherein molar ratio of palm oil to oleyl alcohol is between 1:2 and 1:4. Immobilized lipase used is present in an amount which is equivalent to not less than 1000 μg of protein per milli-mole of palm oil used and the
 10 reaction is carried out at 40⁰C to 50⁰C for a period of not less than 5 hours. The organic solvent used has a value of log P not less than 3.5.

The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings
 15 which are given by way of illustration only, and thus are not limitative of the present invention, wherein:

Figure 1 shows the screening of enzyme. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), hexane (to a total volume of 10 cm^3) and enzyme. The reaction mixture is incubated at 40⁰ C and
 20 shaken at a speed of 150 rpm for 24 h. The enzymes tested were immobilized lipase from *Mucor miehei* (Lipozyme® produced by Novo Nordisk), immobilized lipase from *Candida antartica* (Novozym 435 produced by Novo Nordisk), immobilized lipase from *Candida rugosa*, *Rhizopus niveus* lipase, *Candida rugosa* lipase, *Aspergillus niger* lipase.

25 Designation - O.laurate : oleyl laurate, o.myristate : Oleyl myristate, O.palmitate : oleyl palmitate, O.stearate : oleyl stearate, O.oleate : oleyl oleate : O.linoleate : oleyl linoleate.

Figure 2 shows the effect of reaction time on the percentage yield of wax
 30 esters. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), hexane (to a total volume of 10 cm^3) and Lipozyme® (0.15 g).

The reaction mixture is incubated at 40⁰ C and shaken at a speed of 150 rpm. Designation - O.laurate : oleyl laurate, O.myristate : oleyl myristate, O.palmitate : oleyl palmitate, O. stearate : oleyl stearate, O. oleate : oleyl
 5 oleate, O. linoleate : oleyl linoleate.

Figure 3 shows the effect of temperature on the percentage yield of wax esters. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), hexane (to a total volume of 10 cm³) and Lipozyme® (0.15 g).
 10 The reaction mixture is shaken at a speed of 150 rpm for 5 h.
 Designation - O.laurate : oleyl laurate, O.myristate : oleyl myristate, O.palmitate : Oleyl palmitate, O. stearate : oleyl stearate, O. oleate : oleyl oleate, O. linoleate : Oleyl linoleate.

15 Figure 4 shows the effect of amount of enzyme on the percentage yield of wax esters. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), hexane (to a total volume of 10 cm³) and Lipozyme®. The reaction mixture is incubated at 50⁰ C and shaken at a speed of 150 rpm for 5 h. Designation - O.laurate : oleyl laurate, O.myristate : oleyl
 20 myristate, O.palmitate : oleyl palmitate, O. stearate : oleyl stearate, O. oleate : oleyl oleate, O. linoleate : oleyl linoleate.

Figure 5 shows the effect of molar ratio of substrate (oleyl alcohol, *n* mmol/palm oil, 1 mmol) on the percentage yield of wax esters. The
 25 reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3mmol), hexane (to a total volume of 10 cm³) and Lipozyme® (0.15 g). The reaction mixture is incubated at 50⁰ C and shaken at a speed of 150 rpm for 5 h.
 Designation - O.laurate ; oleyl laurate, O.myristate ; oleyl myristate,
 30 O.palmitate ; oleyl palmitate, O. stearate ; oleyl stearate, O. oleate ; oleyl oleate, O. linoleate ; oleyl linoleate.

- Figure 6 shows the effect of various organic solvents on the percentage yield of wax esters. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), solvents (to a total volume of 10 cm³) and Lipozyme® (0.15 g). The reaction mixture is incubated at 50⁰ C and shaken at a speed of 150 rpm for 5 h. The solvents used were acetonitrile (log P=0.33), ethyl acetate (log P=0.68), chloroform (log P= 2), hexane (log P= 3.5), heptane (log P=4.0), isooctane (log P=4.5) and nonane (log P=5.0).
- 10 Designation - O.laurate : Oleyl laurate, O.myristate : Oleyl myristate, O.palmitate : Oleyl palmitate, O. stearate : Oleyl stearate, O. oleate : Oleyl oleate, O. linoleate : Oleyl linoleate.

- Figure 7 shows the effect of initial water activity (a_w) on the percentage yield of wax esters. The reaction mixture consisted of palm oil (1 mmol), oleyl alcohol (3 mmol), hexane (to a total volume of 10 cm³) and Lipozyme® (0.15 g). The reaction mixture is incubated at 50⁰ C and shaken at a speed of 150 rpm for 5 h. The salts used were LiCl (0.11), MgCl₂·6H₂O (0.33), Mg(NO₃)₂·6H₂O (0.53), NaCl (0.75), KCl (0.86), KNO₃(0.90).
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Designation - O.laurate : oleyl laurate, O.myristate : oleyl myristate, O.palmitate : oleyl palmitate, O. stearate : oleyl stearate, O. oleate : oleyl oleate, O. linoleate : oleyl linoleate.

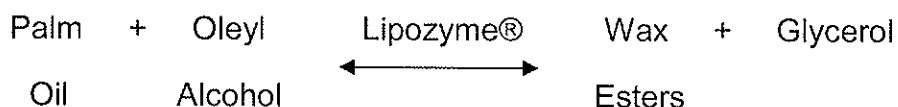
- 25 A general step for producing wax esters in the current invention is mixing 1 mmol of palm oil with 3 mmol of oleyl alcohol and 0.15 g of Lipozyme®. Then, hexane is added to the reaction mixture to a total volume of 10 cm³ or to a volume sufficient to solubilize palm oil. Finally, the reaction mixture is incubated in a horizontal shaker water bath with a speed of 150 rpm at 40⁰C for 24 hours to enable enzymatic alcoholysis
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reaction. These steps are followed to determine optimum conditions for producing wax esters unless otherwise stated.

5 Lipase from different sources is employed for catalyzing alcoholysis reaction between palm oil and oleyl alcohol. Six commercial lipases tested were 0.15 g of immobilized lipase from *Mucor miehei* (Lipozyme® produced by Novo Nordisk) containing 1098 µg of protein, 0.15 g of immobilized lipase from *Candida antarctica* (Novozym 435 produced by
10 Novo Nordisk) containing 1143 µg of protein, 0.13 g of immobilized lipase from *Candida rugosa* containing 1105 µg of protein, 0.07 g of lipase from *Rhizopus niveus* containing 2240 µg of protein, 0.21 g of lipase from *Candida rugosa* containing 2238 µg of protein and 0.1 g of lipase from *Aspergillus niger* containing 2228 µg of protein. The immobilized lipase
15 from *Candida rugosa* is produced by immobilizing lipase from *Candida rugosa* on Amberlite XAD 7. Protein content in various lipases is determined by using Lowry method with bovine serum albumin as standard. Percentage yield as determined is as shown in Figure 1.

20 Highest percentage yield is shown by using Lipozyme® (75%) followed by immobilized lipase from *Candida rugosa* and Novozym 435. Other lipases showed only low percentage yield (less than 30%).

Time course for enzymatic alcoholysis reaction is presented in
25 Figure 2. Percentage yield increased with increasing reaction time. Lipozyme® as biocatalyst gives high percentage yield within a reaction period of 5 to 7 hours. After 7 hours, the percentage yield is relatively constant. This may be due to the enzymatic alcoholysis reaction has achieved equilibrium state whereby the rate of forward reaction is equal to
30 the rate of backward reaction.



5 Furthermore, in the enzymatic alcoholysis reaction between palm oil and oleyl alcohol, wax esters are not the only product but glycerol as well. Accumulated glycerol will inhibit the alcoholysis reaction by limiting interaction of the substrate and the biocatalyst.

10 Enzymatic alcoholysis reaction between palm oil and oleyl alcohol is performed at 5 different temperatures for 5 hours each. Percentage yield of wax ester increased with increasing temperature from 30⁰C to 50⁰C as shown in Figure 3. Low percentage yield is observed at lower temperature (30⁰C) because of the relatively low enzyme activity. The percentage yield
15 of wax esters is decreased at 60⁰C to 70⁰C. This may be due to the denaturation of the enzyme at relatively higher temperatures.

Figure 4 shows the result of using different amount of Lipozyme[®] in enzymatic alcoholysis reaction between palm oil and oleyl alcohol. The
20 enzymatic alcoholysis reaction is conducted at 50⁰C for 5 hours each. Percentage yield of wax esters increased as the amount of Lipozyme[®] increased to 1.5% [weight of Lipozyme[®] (g) to total volume (cm³) of reaction mixture basis]. Excess Lipozyme[®] has little effect on the percentage yield of wax esters. This may be due to the limitation of the
25 amount of substrates used. Protein content in Lipozyme[®] as determined by using Lowry method with bovine serum albumin as standard is as shown in Table 1.

Amount of Lipozyme® used (g)	Protein Content (µg)
0.05	366
0.10	732
0.15	1098
0.20	1464
0.25	1830
0.30	2196

Table 1

Protein content in Lipozyme®

5 Effect of using different molar ratio of substrates in enzymatic
alcoholysis reaction between palm oil and oleyl alcohol at 50°C for 5 hours
each is shown in Figure 5. There is a relatively sharp optimum wax esters
yield around 3 equivalents of oleyl alcohol to 1 equivalent of palm oil. This
is similar with stoichiometric mixtures of reaction between palm oil and
10 oleyl alcohol.

 Polarity of various solvents in terms of their log-P values played the
most crucial role in the course of enzymatic alcoholysis reaction between
palm oil and oleyl alcohol. Effect of using various organic solvents in
15 forming the reaction mixtures is shown in Figure 6. The solvents used are
acetonitrile (log P = 0.33), ethyl acetate (log P = 0.68), chloroform (log P =
2), hexane (log P = 3.5), heptane (log P = 4.0), isooctane (log P = 4.5) and
nonane (log P = 5.0). The enzymatic alcoholysis reactions are conducted
at 50°C for 5 hours each. In general, it is observed that percentage yield
20 increased with increasing log P value of the solvent. The most suitable
organic solvents for forming reaction mixtures in the present invention are

solvents with relatively higher log P value, particularly solvents with log P value not less than 3.5.

5 Influence of water activity on synthesis of wax esters by enzymatic alcoholysis reaction using Lipozyme® as biocatalyst is determined by pre-equilibrating Lipozyme® and substrates with vapor of saturated salt solutions with different water activity (a_w) values at ambient temperature (approximately 25°C) in separate containers overnight for at least 16
10 hours. The salts used are LiCl ($a_w = 0.11$), $MgCl_2 \cdot 6H_2O$ ($a_w = 0.33$), $Mg(NO_3)_2 \cdot 6H_2O$ ($a_w = 0.53$), NaCl ($a_w = 0.75$), KCl ($a_w = 0.86$) and KNO_3 ($a_w = 0.9$). Enzymatic alcoholysis reactions are then conducted at 50°C for 5 hours each. The percentage yield of wax esters is shown in Figure 7. The percentage yield of wax esters is not much affected by the water activity
15 value of the reaction mixtures.

Thus, optimum yield is obtained by using optimum conditions for enzymatic alcoholysis reaction to synthesize wax esters. For optimum yield, hexane is added to a reaction mixture consists of 1 mmol palm oil, 3
20 mmol oleyl alcohol and 0.15 g Lipozyme® to a total volume of 10 cm³. The reaction mixture is then incubated in a horizontal shaker water bath with a speed of 150 rpm at 50°C for 5 hours to enable enzymatic alcoholysis reaction. Percentage yield of wax esters obtained is 80.62%.

Claims

- 5 1. A process for the preparation of wax esters which comprises reacting a solution of palm oil in an organic solvent with long chain alcohol in the presence of an immobilized lipase selected from any of those from *Mucor miehei*, *Candida antartica* and *Candida rugosa*.
- 10 2. A process according to claim 1 wherein the immobilized lipase is present in an amount which is equivalent to not less than 1000 µg of protein per milli-mole of palm oil used.
- 15 3. A process according to claim 1 wherein the organic solvent has a value of log P not less than 3.5.
4. A process according to claim 1 wherein the long chain alcohol is oleyl alcohol.
- 20 5. A process according to claim 4 wherein the molar ratio of palm oil to oleyl alcohol is between 1:2 and 1:4.
6. A process according to claim 4 wherein the process is carried out at a temperature ranging from 40°C to 50°C for a period of not less than 5 hours.
7. Wax esters produced by a process as claimed in any of the preceding claims.