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(54) **PROCESSES AND SYSTEMS FOR CATALYTIC MANUFACTURE OF WAX ESTER DERIVATIVES**

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(57) **ABSTRACT**

Processes for transesterifying wax esters. Implementations may include providing a feedstock including wax esters, introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons where the alcohol is selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, and any combination thereof. The process may include contacting the feedstock with a lipase, and catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product. The enzymatically transesterified product may be adapted to produce a finished product having a certain formula that has a viscosity that substantially matches a viscosity of a finished product having the same certain formula including chemically catalyzed transesterified wax esters.

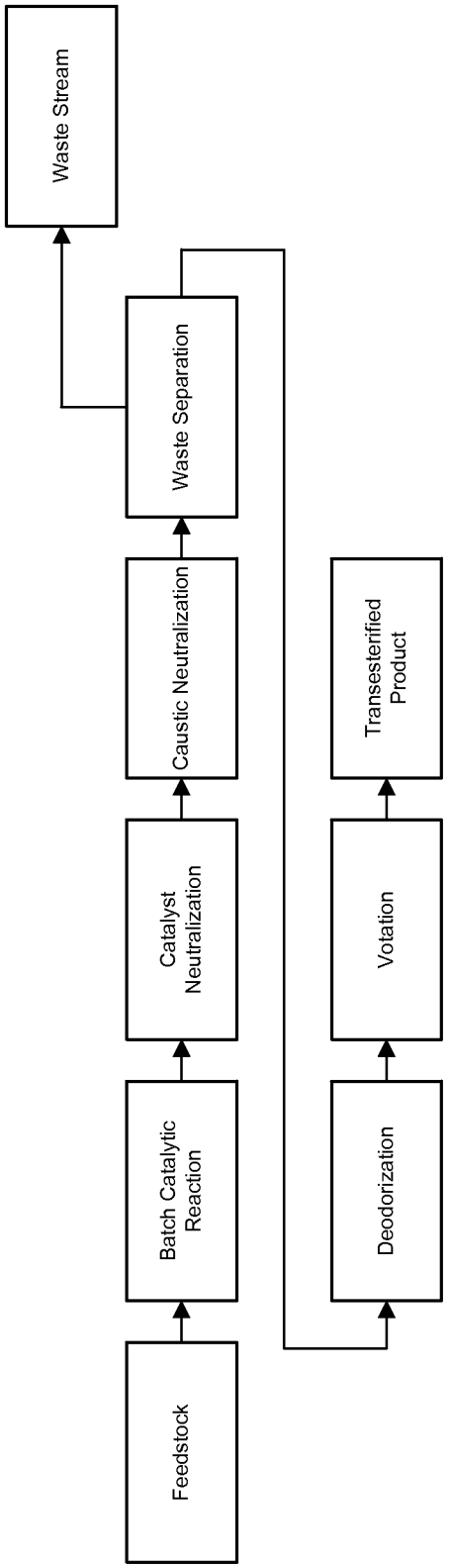

Feedstock
Batch Catalytic Reaction
Catalyst Neutralization
Caustic Neutralization
Waste Separation
Waste Stream
Deodorization
Votation
Transesterified Product

FIG. 1

Feedstock
Continuous Catalytic Reaction
Deodorization
Votation
Transesterified Product

FIG. 2

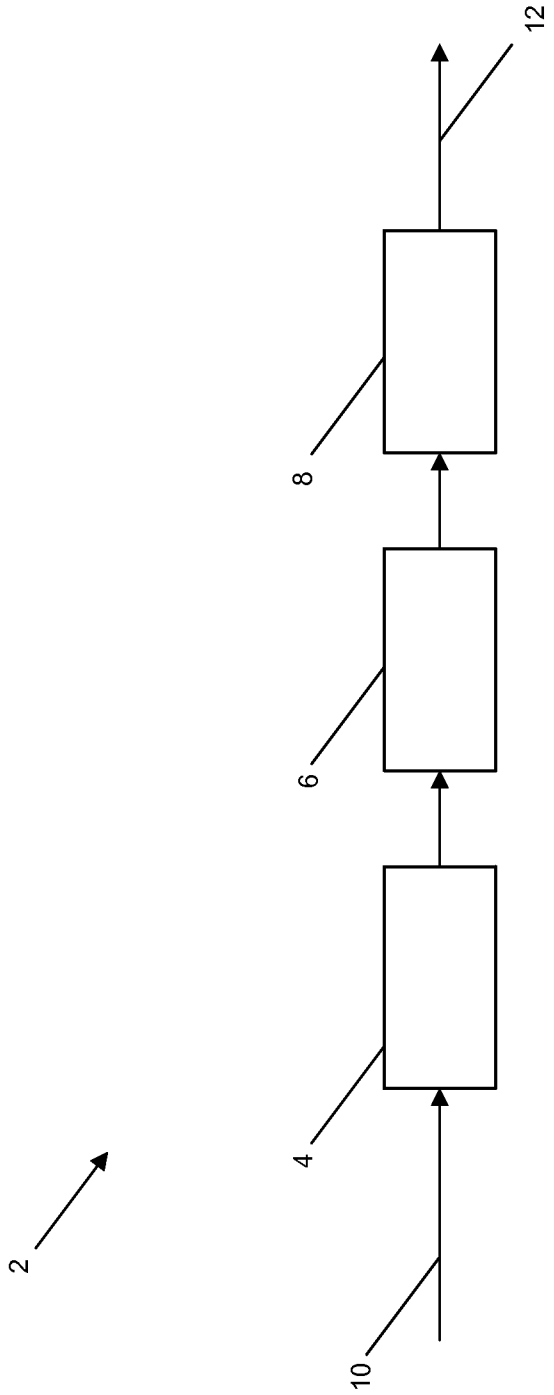


FIG. 3

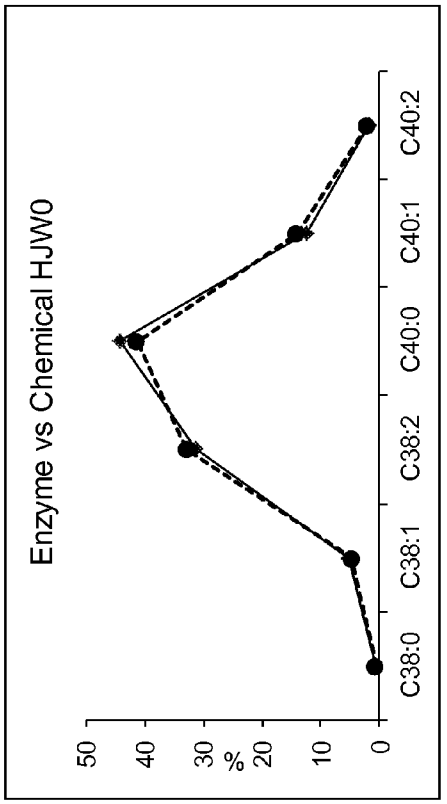

Enzyme vs Chemical HJW0
50
40
30
%
20
10
0
C38:0
C38:1
C38:2
C40:0
C40:1
C40:2

FIG. 4

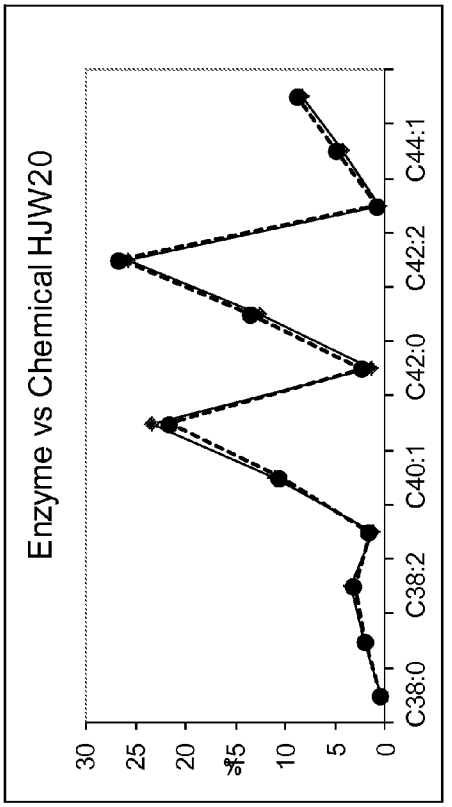

Enzyme vs Chemical HJW20
30
25
20
%
15
10
5
0
C38:0
C38:2
C40:1
C42:0
C42:2
C44:1

FIG. 5

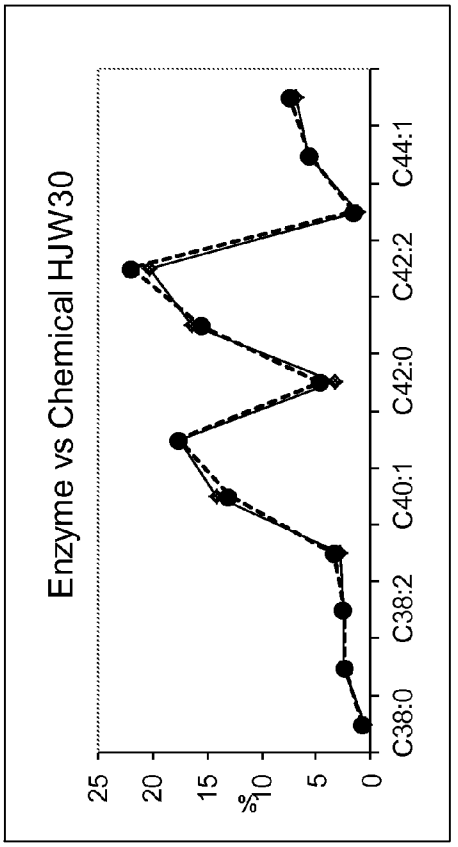

Enzyme vs Chemical HJW30
25
20
15
10
5
0
%
C38:0
C38:2
C40:1
C42:0
C42:2
C44:1

FIG. 6

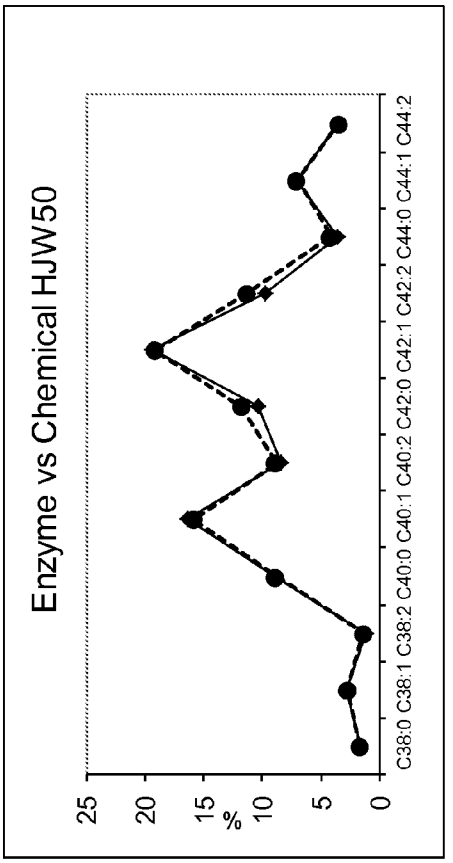

Enzyme vs Chemical HJW50
25
20
15
10
5
0
%
C38:0 C38:1 C38:2 C40:0 C40:1 C40:2 C42:0 C42:1 C42:2 C44:0 C44:1 C44:2

FIG. 7

PROCESSES AND SYSTEMS FOR CATALYTIC MANUFACTURE OF WAX ESTER DERIVATIVES

BACKGROUND

[0001] 1. Technical Field

[0002] Aspects of this document relate generally to systems and processes for reacting and processing wax esters and wax ester derivatives.

[0003] 2. Background Art

[0004] A wax ester is formed from the chemical reaction of a fatty acid and a fatty alcohol, which results in the formation of an ester group that links two carbon chains. Wax esters are found in various animals and plants, including the jojoba plant (*Simmondsia chinensis*). Wax esters are used in various applications, including in cosmetic and personal care products.

SUMMARY

[0005] Implementations of processes for modifying the viscosity of a finished product including transesterified wax esters may include: providing a feedstock including wax esters, introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons where the alcohol is selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, or any combination thereof. The process may also include contacting the feedstock with a lipase, and catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product. The method may include increasing a viscosity of a finished product including catalytically transesterified wax esters by including the transesterified product as an ingredient of the finished product.

[0006] Implementations of processes for modifying the viscosity of a finished product including transesterified wax esters may include one, all, or any of the following:

[0007] The feedstock may further include an antioxidant and catalytically transesterifying the wax esters in the feedstock with the lipase may further include catalytically transesterifying without one of removing and degrading the antioxidant in the feedstock.

[0008] The alcohol may also selected from the group consisted of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

[0009] The wax esters of the feedstock may be jojoba wax esters.

[0010] The jojoba wax esters may further include hydrogenated jojoba wax esters.

[0011] The alcohol may be oleyl alcohol.

[0012] The alcohol may include 0.01% to 2.5% of the feedstock by weight of the feedstock.

[0013] Implementations of a process for transesterifying wax esters may include providing a feedstock including wax esters, introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons where the alcohol is selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, and any combination thereof. The process may include contacting the feedstock with a lipase, and catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product. The enzymatically transesterified product may be adapted to produce a finished product having a certain formula that has a viscosity that substantially matches a viscosity of a finished product having the same certain formula including chemically catalyzed transesterified wax esters.

[0014] Implementations of processes for transesterifying wax esters may include one, all or any of the following:

[0015] The alcohol may also be selected from the group consisting of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

[0016] The feedstock may further include an antioxidant and catalytically transesterifying the wax esters in the feedstock with the lipase may further include catalytically transesterifying without removing or degrading the antioxidant in the feedstock.

[0017] The wax esters of the feedstock may be jojoba wax esters.

[0018] The jojoba wax esters may further include hydrogenated jojoba wax esters.

[0019] The alcohol may be oleyl alcohol.

[0020] The alcohol may include 0.01% to 2.5% of the feedstock by weight of the feedstock.

[0021] Implementations of processes for modifying the viscosity of a finished product including transesterified wax esters may include: providing a feedstock including wax esters, introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons where the alcohol is selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, or any combination thereof. The process may also include, after introducing the alcohol into the feedstock, contacting the feedstock with a lipase, and catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product. The method may include increasing a viscosity of a finished product including catalytically transesterified wax esters by including the transesterified product as an ingredient of the finished product.

[0022] Implementations of processes for modifying the viscosity of a finished product including transesterified wax esters may include one, all, or any of the following:

[0023] The alcohol may also selected from the group consisted of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

[0024] The wax esters of the feedstock may be jojoba wax esters.

[0025] The jojoba wax esters may further include hydrogenated jojoba wax esters.

[0026] The alcohol may be oleyl alcohol.

[0027] The alcohol may include 0.01% to 2.5% of the feedstock by weight of the feedstock.

[0028] The foregoing and other aspects, features, and advantages will be apparent to those artisans of ordinary skill in the art from the DESCRIPTION and DRAWINGS, and from the CLAIMS.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Implementations will hereinafter be described in conjunction with the appended drawings, where like designations denote like elements, and:

[0030] FIG. **1** is a flow chart of a conventional chemically catalyzed transesterification process;

[0031] FIG. **2** is a flow chart of an enzymatically catalyzed transesterification process;

[0032] FIG. **3** is a process diagram showing an implementation of three enzymatically catalyzed transesterification reactors in series;

[0033] FIG. **4** is a comparison chart showing the distribution of jojoba wax ester carbon lengths in a transesterified product stream from a jojoba wax ester feedstock for a chemically catalyzed process and an enzyme catalyzed process;

[0034] FIG. **5** is a comparison chart showing the distribution of jojoba wax ester carbon lengths in a transesterified product stream from a jojoba wax ester combined with about 20% by weight of hydrogenated jojoba wax ester feedstock for a chemically catalyzed process and an enzyme catalyzed process;

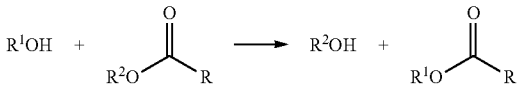
[0035] FIG. **6** is a comparison chart showing the distribution of jojoba wax ester carbon lengths in a transesterified product stream from a jojoba wax ester combined with about 30% by weight of hydrogenated jojoba wax ester feedstock for a chemically catalyzed process and an enzyme catalyzed process;

[0036] FIG. **7** is a comparison chart showing the distribution of jojoba wax ester carbon lengths in a transesterified product stream from a jojoba wax ester combined with about 50% by weight of hydrogenated jojoba wax ester feedstock for a chemically catalyzed process and an enzyme catalyzed process.

DESCRIPTION

[0037] This disclosure, its aspects and implementations, are not limited to the specific components, assembly procedures or method elements disclosed herein. Many additional components, assembly procedures and/or method elements known in the art consistent with the intended processes and systems for transesterifying wax esters will become apparent for use with particular implementations from this disclosure. Accordingly, for example, although particular implementations are disclosed, such implementations and implementing components may comprise any shape, size, style, type, model, version, measurement, concentration, material, quantity, method element, step, and/or the like as is known in the art for such processes and systems for transesterifying wax esters, and other implementing components and methods, consistent with the intended operation and methods.

[0038] Transesterification involves the process of exchanging acyl groups located on each side of a ester group with an acyl group contained in an alcohol group, as illustrated below:



[0039] Transesterification for naturally occurring or structured or synthetic esters permits altering of various physical properties of the transesterified product when compared to the original feedstock. By non-limiting example, physical properties such as viscosity, dropping point, oil (oxidative) stability index (OSI), carbon chain distribution, and other properties of the transesterified product may be greater, equal to, or less than the corresponding values of the original wax ester-containing feedstocks. These changes take place at least in part because the chain lengths of the resulting ester products are randomized compared to the distribution in the original wax ester feedstock, which may alter the functionality of the transesterified material in a mixture and/or the thermal properties of the material.

[0040] Conventionally, transesterification of wax esters is accomplished using several different methods. Methods and systems for transesterifying jojoba oil that include the use of an acidic bentonite-type clay at temperatures between 150 C-350 C are disclosed in U.S. Pat. No. 4,329,298 to Brown, et al., entitled "Isomerization of Jojoba Oil and Products Thereof," filed Aug. 15, 1980 and issued May 11, 1982 and in U.S. Pat. No. 4,360,387 to Brown, et al., entitled "Isomorphous Jojoba Oil Compositions Containing Trans-Isomerized Jojoba Oil," filed Mar. 9, 1981, issued Nov. 23, 1982, the disclosures of both of which are hereby incorporated entirely herein by reference. When using the process described in the foregoing patents for transesterification, a 5%-10% loss of the original jojoba oil was observed.

[0041] Other conventional transesterification reactions use a chemical catalyst, such as sodium methylate (methoxide) or sodium hydroxide. While the reaction is catalytic, side reactions between the catalyst and components of the feedstock and/or reactants occur during transesterification process. These side reactions create byproducts that reduce the yield of the process and alter the properties of the transesterified product. Some of the property changes occur because of damage/changes to the feedstock esters caused by the high temperatures (100 C-230 C) and low pressures (<7 mmHg) required to carry out chemical catalytic transesterification. Other property changes occur because these conditions and/or the chemical catalysts themselves degrade, destroy, or reduce the effectiveness of other subcomponents of the wax ester feedstock. Where the wax ester feedstock is derived from a natural source, such as in a jojoba wax ester feedstock, existing antioxidants, sterols, hydrocarbons, and other volatile compounds (volatile in comparison to the volatility of the wax esters) react with the chemical catalyst in side reactions. The resulting transesterified product may have little or none of any of these components remaining intact following chemical catalytic transesterification and/or may reduce the effectiveness of these components. Furthermore, the transesterified product may include artifacts of these components which are undesirable or have undesirable effects in the product or subsequent mixtures that include the product.

[0042] Chemically catalyzed transesterification of wax esters is carried out in a batch reactor, and the catalyst cannot, accordingly, be recovered for reuse from the transesterification product. Referring to FIG. **1**, a process flow diagram for a conventional transesterification process is illustrated. As illustrated, the feedstock containing wax esters is processed in a batch catalytic reaction. Following batch processing, the reaction is stopped using an acid and/or water such as citric acid to neutralize the remaining catalyst. At this point, the reactor contents are then checked for the presence of free fatty acids, which, if present requires the use of a neutralization process for the free fatty acids. The batch reactants are then moved into a waste separation step, in which the solution is washed with soft water to remove soaps and salts in the reactor material and separate them from the oil/lipid portion of the reactor material that contains the transesterified product to form a waste stream and a transesterified product stream. The transesterified product in the transesterified product stream is then bleached to remove remaining color bodies, soaps, and other undesirable byproducts formed during the

chemically catalyzed transesterification reaction. The transesterified product stream is then deodorized and votated to produce a finished transesterified product. The process of votation is a controlled crystallization process or tempering process in which the transesterified product is agitated under controlled conditions to form a transesterified product with a desired consistency and crystalline structure for later use. Votation includes various heating, chilling, flash chilling, and other pressure adjustments to provide the desired consistency and/or structure.

[0043] In this document, various processes for transesterifying wax esters are disclosed that use enzymes to catalytically facilitate the transesterification reaction. In particular implementations, the enzymes are lipases, which are proteins that various biological organisms use to catalyze the hydrolysis and/or esterification of various compounds, such as lipids. As used herein, "lipase" means any enzyme or protein capable of being used in a transesterification reaction of a wax ester.

[0044] Referring to FIG. **2**, a process flow diagram for an enzymatically catalyzed transesterification process is illustrated. As illustrated, the wax ester feedstock passes through one or more catalytic reactors that allow a continuous catalytic transesterification reaction to take place. While it is possible to batch process wax ester feedstocks using enzymes, continuous processing has many well-known advantages over batch processing. Following the continuous catalytic transesterification reaction, the transesterified product is deodorized and votated to produce a finished transesterified product stream. As can be observed, there are fewer process steps in an enzymatically catalyzed transesterification process. Furthermore, as will be discussed in detail below, because there are little or no side reactions between the enzyme catalysts and the reactants, while the transesterification results of the enzyme catalyzed process are very similar to chemically catalyzed process, the properties and components of an enzyme catalyzed transesterified product stream differ in important ways while retaining essentially the same functional characteristics.

[0045] Referring to FIG. **3**, a process flow diagram of an implementation of a continuous enzymatic reactor system **2** for enzymatic catalyzed transesterification of wax esters is illustrated. As illustrated, the system **2** includes three reactors **4**, **6**, **8** connected in series. Each reactor contains the enzyme and is designed to place the incoming wax ester feedstock **10** in contact with the enzyme. Following processing, the transesterified product **12** exits the final reactor **8** for subsequent processing/collection. In particular implementations, the enzyme is immobilized on a substrate material designed to facilitate interaction of the incoming wax ester feedstock. In other implementations, the enzyme is immobilized on the internal structure(s) of the reactor itself or is free flowing within the reactor system and recycled back to the reactor(s). In the implementation illustrated in FIG. **3**, the reactors are packed bed reactors. Those of ordinary skill in the art will readily be able to select various reactor components and other piping, pumps, filters, and other process equipment to facilitate the use of the enzymatic reactors using the principles disclosed herein.

[0046] Many different enzymes may be employed in enzymatic catalytic transesterification reactions for wax esters, including those that are derived/obtained from biological organisms, those made synthetically, and those that are entirely artificial, whether made biologically and/or synthetically. For those enzymes that are lipases, these may include, one, some, any, or any combination of lipases derived from the following organisms: *Aspergillus niger, Aspergillus oryzae, Bacillus subtilis, Bacillus thermocatenulatus, Burkholderia cepacia, Burkholderia glumae, Candida rugosa, Candida antarctica* A, *Candida antarctica* B, *Candida cylindracea, Candida parapsilosis, Chromobacterium viscosum, Geotrichum candidum, Geotrichum* sp., *Mucor miehei, Humicola lanuginose, Penicillium camembertii, Penicillium chrysogenum, Penicillium roquefortii, Pseudomonas cepacia, Pseudomonas aeruginosa, Pseudomonas fluorenscens, Pseudomonas fragi, Pseudomonas alcaligenes, Pseudomonas mendocina, Rhizopus arrhizus, Rhizomucor miehe, Staphylococcus hyicus, Staphylococcus aereus, Staphylococcus epidermidis, Staphylococcus warneria, Staphylococcus xylosus, Thermomyces lanuginosus, Aspergillus* sp., *Bacillus* sp., *Burkholderia* sp., *Candida* sp., *Chromobacterium* sp., *Geotrichum* sp, *Mucor* sp, *Humicola* sp, *Penicillium* sp, *Pseudomonas* sp, *Rhizopus* sp., *Staphylococcus* sp, and *Thermomyces* sp.

[0047] In particular implementations, the lipase may be the following: a lipase from *Thermomyces lanuginosus* marketed under the tradenames LIPOZYME TL IM or LIPEX by Novozymes A/S of Bagsvaerd, Denmark and immobilized on a substrate also manufactured by Novozymes. A representative sequence listing of the lipase is included as SEQ ID NO: 1 herein. In other implemenations, the lipase may be that marketed under the tradename NOVOZYM by Novozymes, A/S derived from *Candida antarctica*, a representative sequence listing for which is included as SEQ ID NO: 2 herein. In various implementations, the lipases may be any of the following: those marketed under the tradenames CALB L, NOVOZYME 435, NOVOCOR AD L, AND LIPOLASE 100L by Novozymes; those marketed under the tradenames CALB, CALA, and CRL by c-LEcta, GMBH of Leipzig, Germany; those marketed under the tradenames LIPASE A "AMANO" 12, LIPASE AY "AMANO" 30SD, LIPASE G "AMANO" 50, LIPASE R "AMANO", LIPASE DF "AMANO" 15, LIPASE MER "AMANO", and NEWLASE F by Amano Enzyme Inc. of Nagoya, Japan; those marketed under the tradenames LIPASE MY, LIPASE OF, LIPASE PL, LIPASE PLC/PLG, LIPASE QLM, LIPASE QLC/QLG, LIPASE SL, and LIPASE TL by Meito Sangyo Co., Ltd., of Nagoya, Japan.

[0048] In other implementations, the lipase may be a lipase from *Candida antarctica* A, a lipase from *Candida antarctica* B, *Candida rugosa* or any combination thereof. In various implementations, the lipases may be any disclosed in U.S. Patent Application Publication No. 20140017741 (the '714 publication) to Nielsen, et al., entitled "Esterification Process," filed Oct. 1, 2013 and published Jan. 16, 2014, the disclosure of which is hereby entirely incorporated herein by reference. Those lipases disclosed in the sequence listings for the various patent applications listed in para. [0026]-[0029] in the '741 publication, previously incorporated by reference, each of which applications are hereby entirely incorporated by reference herein, may also be those utilized in particular implementations. In various implementations, the lipases may be those have at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or even at least 99% identity to any of the lipases disclosed herein, in the '714 publication, and in the patent applications disclosed in the '714 publication, all of which have been previously incorporated by reference.

[0049] A wide variety of wax esters may be processed using the enzymatic catalytic transesterification processes disclosed herein. By non-limiting example, wax esters contained in the following materials may be included in the wax ester feedstocks processed using the principles disclosed herein: beeswax, Chinese wax, shellac wax, whale spermaceti, lanolin, carnauba wax, ouricuri wax, jojoba oil, candelilla wax, esparto wax, Japan wax, rice bran oil, sunflower wax, ozocerite, ozokerite, and montan wax. Any other natural or synthetically produced wax esters may also be processed using the principles disclosed herein. Various examples are discussed in this document regarding wax esters in jojoba oil feedstocks, but these examples are merely given to illustrate the principles disclosed herein.

[0050] Jojoba oil derived from the seeds of the jojoba plant contains wax esters and other components that have been noted to be useful for various functions. These include steryl esters, sterols, and various hydrocarbons that can be useful as skin conditioning agents in cosmetics and personal care products. Antioxidants, like tocopherols, are also included, along with various volatile ingredients naturally present in the oil, which are volatile in comparison with the wax esters. The wax esters in jojoba oil generally vary between 34 and 48 carbons in length. A detailed analysis of the wax ester distribution, structural characteristics, and other components in jojoba oil may be found in the paper by Thomas K. Miwa, entitled "Structural Determination and Uses of Jojoba Oil," J. Amer. Oil Chem. Soc., Vol. 61, No. 2 (February 1984), p. 407-410, the disclosure of which is hereby incorporated entirely herein by reference. It has been observed that jojoba oil derived from plants from South America, Israel, and North America differ somewhat in chemical composition, but these differences are slight and have not been observed to produce any effect on the product functional characteristics. Details on the composition of jojoba oil from Chile may be found in the article by Cappillino et al., entitled "Composition of Chilean Jojoba Seeds," *Ind. Crops and Prod.*, v. 17, p. 177-182 (2003), the disclosure of which is hereby incorporated entirely herein by reference. Additional information on the differences in jojoba oil produced from jojoba seeds from Chile, North America, Israel, and the rest of South America may be found in the presentation by Cappillino et al., "Composition of Chilean Jojoba Seed," given at the 5th New Crops Symposium in Atlanta, Ga. Nov. 10-13, 2001, a copy of which is included herewith at Appendix B, the disclosure of which is hereby incorporated entirely herein by reference.

[0051] Transesterification of jojoba oil has conventionally been done using the chemically catalyzed processes discussed herein. When such chemical catalyzed processes are used, side reactions form various fatty acid methyl esters and leave various free fatty alcohols when sodium methoxide is used. The resulting transesterified product stream may include 5% or less by weight of these fatty acid methyl esters, which may function as an emollient, and the free fatty alcohols, which may function as an emollient and viscosity controller. As was previously discussed however, the reaction of the chemical catalyst removes or degrades the steryl esters, sterols, tocopherols, hydrocarbons, and volatile ingredients in the jojoba oil. This degradation and/or removal of these components changes the functionality and physical properties of the transesterified product stream. In particular, the degradation and/or removal of the tocopherols and other naturally occurring antioxidants reduces the OSI of the transesterified product to below the OSI of the original jojoba oil. As jojoba oil includes between about 0 to about 500 ppm of tocopherols with the major component being gamma-tocopherol, elimination of the natural tocopherols has a significant effect on the oxidative stability of the mixture. An addition of 500 ppm of tocopherols can enhance the oxidative stability of the material by about 50% to about 200% of the original oxidative stability.

[0052] Table 1 lists some process parameters and some characteristics of the transesterified product stream for a chemically catalyzed transesterification process and those for an enzymatically catalyzed transesterification process.

TABLE 1

Process Parameter	Chemical Catalyst	Enzymatic Catalyst
Reaction Temperature	100 C.-230 C.	10 C.-70 C.
Reaction Pressure	<7 mmHg	760 mmHg (ambient)
Product Color	Increased (changes color)	No changes
Soap Formation	Yes	No change
Transesterification Yield	85%-95%	>98%

[0053] Table 2 shows observed effect of the chemically catalyzed process and various enzymatically catalyzed processes on the various naturally present components in jojoba oil as well as side reaction byproducts.

TABLE 2

Transesterified Product Component	Skin Care Formula Function	Chemical Catalyst	Enzyme Catalyst
Steryl Esters	Skin Conditioning Agent	Removed/Degraded	Functionally Unaffected
Sterols	Skin Conditioning Agent	Removed/Degraded	Functionally Unaffected
Tocopherols	Antioxidant	Removed/Degraded	Functionally Unaffected
Hydrocarbons	Skin Conditioning Agent	Removed/Degraded	Unchanged
Fatty Acid Methyl Esters	Emollient	Formed, <5%	Not formed
Free Fatty Alcohols	Emollient, Viscosity Controller	Formed, <5%	Not formed
Volatile Ingredients	Sensory Attributes	Removed/Degraded	Functionally Unaffected

[0054] As can be observed from the table, the enzymatic transesterification process takes place at the melting point of the jojoba oil (and any hydrogenated jojoba oil included in the feedstock) under substantially atmospheric pressure. The reaction also proceeds without removing/degrading the tocopherols or volatiles naturally contained in the jojoba oil. Also, the enzyme catalyzed process does not create methyl esters or free fatty alcohols which may limit the applications of the transesterified product as they affect the emollient and/or viscosity behavior of the product. Furthermore, the degradation/removal of the tocopherols in the chemically catalyzed process adversely affects the oxidative stability (measured by the OSI) and accordingly, the shelf life, of the transesterified product. The addition of fatty acid methyl esters creates different material spreading and refractive properties in the chemically transesterified product, even at levels up to about 5% by weight.

[0055] Several examples of chemically catalyzed transesterification reactions compared with enzymatically catalyzed

transesterification reactions are disclosed in this document, including in FIGS. **4-7**. These will be considered in turn.

Example 1

Chemical Catalytic Batch Process vs. Enzymatically Catalyzed Batch Process

[0056] A 1 liter 3-necked glass flask equipped with an agitating blade was loaded with 800 g of refined jojoba oil. The oil was heated to 110 C and dried under vacuum for 30 minutes. After drying was completed, a small amount of sodium methylate (0.3% by weight) was added to the mixture. The transesterification reaction was agitated under vacuum at 120 C for two hours. The catalyst was then neutralized with 1 g of citric acid and then treated with a silica and bleaching clay mixture to remove color induced by the reaction and other residual impurities. The transesterified product was a yellow liquid.

[0057] A 2 liter jacketed glass reactor equipped with an agitating blade was loaded with 1.2 kg of refined jojoba oil and 48 g (4% by weight) of LIPOZYME TL IM (*Thermomyces lanuginosus* lipase) from Novozymes. A layer of nitrogen was blanketed over the oil and the mixture was agitated at ambient temperature. After five hours, the lipase was removed from the mixture and the jojoba derivative was analyzed. The transesterified product was a slightly yellow liquid similar in texture and color to the initial feedstock. Measurement of the wax ester distributions for the feedstock and both transesterified products was done using an Hewlett Packard GC 5980 Series II gas chromatograph with a Restek MxT-65TG 30 meter, 0.25 mm ID capillary chromatographic column with a Crossbond 65% diphenyl/35% dimethyl polysiloxane film thickness of 0.1 microns. The gas chromatograph has split/splitless injection and uses an FID detector. Operating parameters of the gas chromatograph were as follows: injection port: 300 C, detector: 325 C, split ratio: 100:1, 1 microliter injection with oven temperature ramping from 280 C to 350 C over 20 minutes. Helium carrier gas was used. The concentration of tocopherols was measured using HPLC rather than the gas chromatograph. The equipment used was an Agilent LC 1100 series with an autosampler, quaternary pump, diode array detector (DAD), and an Alltech 2000 ELSD operating with a drift tube temperature of 40.0° C. with 1.7 mL/min Nitrogen. The column used was an Agilent RX-SIL 4.6×50 mm 1.8 um normal phase silica column kept at 40.0° C. The DAD was set to detect UV at wavelengths 210 nm and 295 nm to identify the optically active portion of the tocopherols as they eluted from the column. The mobile phase consisted of an isocratic flow of 98% hexane and 2% isopropanol at 0.5 mL/min with a total run time of 15.00 minutes. Table 3 summarizes the results of both experiments.

TABLE 3

Components	Feedstock Composition	Chemical Catalyst	% Change	Enzyme Catalyst	% Change
Tocopherols	0.04%	0.00%	−0.04%	0.04%	0.00%
Fatty Acid Methyl Esters	0.00%	3.10%	3.10%	0.00%	0.00%
Free Fatty Alcohols	0.00%	1.80%	1.80%	0.00%	0.00%

TABLE 3-continued

Components	Feedstock Composition	Chemical Catalyst	% Change	Enzyme Catalyst	% Change
OSI (hours)	26.5	21.5	−18.87%	38.6	45.66%
Wax Ester Content	98.00%	93.10%	−4.90%	98.00%	0.00%
Wax Ester Distribution					
C36:1	1.12%	1.30%	0.180%	1.20%	0.080%
C38:2	6.02%	4.90%	−0.120%	4.80%	−1.220%
C40:2	27.95%	35.76%	7.810%	34.34%	6.390%
C42:2	50.28%	40.64%	−9.640%	40.92%	−9.360%
C44:2	9.94%	13.75%	3.811%	14.93%	4.991%
C46:2	1.20%	1.89%	0.690%	2.23%	1.030%

[0058] Examining the results shows that the formation of fatty acid methyl esters and free fatty alcohols in the chemically catalyzed transesterification reaction produces a product with a lower wax-ester percentage than the original starting material. The results also indicate that the chemically catalyzed reaction destroys the original amount of tocopherols present in the feedstock, which reduces the OSI of the transesterified product. Surprisingly, however, the OSI of the enzymatically catalyzed transesterified product is greater than that of the feedstock. This result indicates that the enzymatic catalysis has an unexpected positive effect on OSI that is not explainable simply by the enzymatic catalyst preserving the natural tocopherols originally present in the feedstock during the reaction. The OSI was measured using an Omnion Scientific Services machine, Model OSI-8-110, according to the procedures set forth in the American Oil Chemist's Society (AOCS) Official Method Cd 12b-92, a copy of which is submitted herewith as Appendix A and incorporated entirely herein by reference.

[0059] In all of the above examples, no significant difference in the viscosity between the chemically catalyzed and the enzymatically catalyzed transesterified products was observed.

[0060] The chemically catalyzed and enzymatically catalyzed transesterified products were tested for performance in a typical cream formulation. Each cream formulation used 3% by weight of each transesterified product (chemically or enzymatically catalyzed) created in the previous experiment. Table 4 shows the formulation details of the cream along with the components and suppliers. Following Table 4 is the mixing procedure used.

TABLE 4

Phase	Tradename	International Nomenclature Cosmetic Ingredient (INCI)	Supplier	Weight percent % (of total)
A	Deionized Water	Water	—	66.27
	VERSENE Na2 Crystals	Disodium EDTA	The Dow Chemical Co.	0.03
B	Glycerin, USP	Glycerin	The Dow Chemical Co.	5.00
	KELTROL CG-T	Xanthan Gum	CP Kelco	0.30
C	FLORAMAC Macadamia Oil.	*Macadamia integrifolia* seed oil.	Floratech	3.00

TABLE 4-continued

Phase	Tradename	International Nomenclature Cosmetic Ingredient (INCI)	Supplier	Weight percent % (of total)
	FLORAESTERS 30	Jojoba Esters (and) Tocopherol	Floratech	3.00
	Transesterified Wax Esters	Jojoba Derivative being examined	—	3.00
	Cocoa Butter	*Theobroma cacao* (Cocoa) seed butter	Cognis Corporation	5.00
	FLORASUN 90	*Helianthus annuus* (Sunflower) seed oil (and) Tocopherol	Floratech	2.00
	BOTANISIL CP-33	Cyclopentasiloxane	Botanigenics, Inc.	4.00
	DOW CORNING 200 Fluid	Dimethicone	Dow Corning Corporation	0.50
	LEXEMUL 561	Glyceryl Stearate (and) PEG-100 Stearate	Inolex Chemicals	4.00
	EMULGADE PL	Cetearyl Glucoside (and) Cetearyl Alcohol	Cognis Corporation	3.00
D	PHENONIP	Phenoxyethanol (and) Methylparaben (and) Ethylparaben (and) Butylparaben (and) Propylparaben (and) Isobutylparaben	Clariant Corporation	0.90
			Total	100

[0061] The cream was prepared as follows: Step 1: Dissolve the VERSENE Na2 crystals into the deionized water with stirring at 75 C to form phase A. Step 2: Mix the KELTROL CG-T in the glycerin USP to form phase B. Add phase A to phase B with rapid stirring to form phase AB. Step 3: Combine all ingredients of phase C and 75 C using propeller agitation. Add phase C to phase AB at 75 C using propeller agitation to form phase ABC. Step 4: Reduce the temperature of the cream to 50 C and add phase D to phase ABC with propeller agitation. Cool the batch with moderate agitation to room temperature.

[0062] Table 5 summarizes the viscosity and appearance differences between the two cream formulations. While a viscometer can be used to measure the viscosity of such materials, the test used to calculate the viscosities, a method of calculating the viscosity without a viscometer, includes placing a sample weighting 0.5 g on a piece of horizontally oriented paper and drawing a starting line immediately next to the sample. The paper is then oriented vertically for 30 seconds and then laid flat again. A line is then drawn at the edge of where the sample has finished flowing down the paper. A ruler is then used to measure the distance between the starting line and the ending line. By developing a calibration curve for this method using materials of known viscosity and measuring the length of travel down the paper, a correlation can be developed between the length of travel of the material and the viscosity of the material.

TABLE 5

Transesterified Product Type in Cream	Viscosity	Appearance
Chemically Catalyzed	120,900 cP	White, semi-solid phase
Enzymatically Catalyzed	78,585 cP	White, liquid phase, glossy

[0063] Table 5 indicates that the use of enzymatically catalyzed transesterified jojoba oil created a cream formulation that had a viscosity drop of nearly 35% from the viscosity of the chemically catalyzed cream. This data indicates that the enzymatically catalyzed transesterified jojoba oil has the functional effect of lowering the resulting product viscosity compared to chemically catalyzed product. The difference in appearance between the two cream formulations (i.e., the enzymatically catalyzed product having less shine and gloss when applied to a surface) is due the relative abundance of fatty acid methyl esters in the chemically catalyzed product.

Example 2. Continuous Flow Enzymatically Catalyzed Transesterification Using Lipase

[0064] A 10 cm×100 cm stainless steel cylinder was filled with 0.5 kg of LIPOZYME TL IM immobilized on substrates. The cylinder was equipped with mesh screening material on both ends to secure the enzyme substrates and was sealed and conditioned by evacuating the catalyst of excess moisture and salts used in the enzyme manufacturing process. The cylinder was connected to a metering pump and a pressure gauge monitored by a solenoid that automatically shut down flow if the pressure at the entrance to the cylinder rose above 15 psi. Flow rate was calculated by the rate of conversion obtained from batch reactions using the same enzymatic catalyst and was 0.8 kg/hr. A stock of refined jojoba oil was fed to the reactor cylinder at a constant temperature and pressure, as the cylinder was submerged in a water batch to keep the reactor temperature constant. The resulting product exiting the cylinder was slightly yellow and liquid at room temperature. The properties of the transesterified product produced are summarized in Table 6.

TABLE 6

Components	Feedstock Composition	Enzymatically Catalyzed	% Change
Tocopherols	0.04%	0.04%	0.00%
Fatty Acid Methyl Esters	0.00%	0.00%	0.00%
Free Fatty Alcohols	0.00%	0.00%	0.00%
OSI (hours)	26.5	36.2	36.6%
Wax Ester Content	98%	98%	0%
Wax Ester Distribution			
C36:1	1.12	1.20	0.080%
C38:2	6.02	4.91	−1.110%
C40:2	27.95	35.30	7.350%
C42:2	50.28	41.20	−9.080%
C44:2	9.94	14.79	4.851%
C46:2	1.2	2.14	0.940%

[0065] As can be observed, the continuous process created a fully randomized transesterified jojoba oil product that reached full conversion before exiting the reactor. Again, the increase in OSI from the feedstock material was again surprisingly noted. The transesterified product in this example was included in a cream formulation like that in Table 4 and

similar visual appearance and viscosity results to the enzymatically catalyzed cream in Table 5 were observed.

Example 3

Continuous Enzymatically Catalyzed Transesterification Using Jojoba Oil and Hydrogenated Jojoba Oil

[0066] The same experimental system as in Example 2 was used but modified to operate at 70 C in order to maintain a homogenous feedstock mixture of jojoba oil and hydrogenated jojoba oil entering the reactor in the feedstock. Various additional background information on the structure, use, and of transesterification reactions using hydrogenated jojoba wax esters may be found in the articles by James Brown and Robert Kleiman "Trans Isomers in Cosmetics", Parts 1 and 2, *Soap & Cosmetics*, May 2001, p. 33-36 and June 2001, as well as in Sessa et al., "Differential Scanning calorimetry Index for Estimating Level of Saturation in Transeesterified Wax Esters," *J. Amer. Oil Chem. Soc.*, v. 73, 271-273 (1996), and David J. Sessa, "Derivation of a Cocoa Butter Equivalent from Jojoba Transesterified Ester via a Differential Scanning calorimetry Index," *J. Sci. Food Agric.*, v. 72, p. 295-298 (1996) the disclosures of all of which are hereby entirely incorporated herein by reference.

[0067] Because of the absence of unsaturated wax esters in the hydrogenated jojoba wax esters (HJW), the progress of the reaction can be measured by observing the formation of monounsaturated wax esters during the reaction. The dropping point, or the temperature at which the transesterified product transitions from a semi-solid to a liquid state, was also monitored. The dropping point was calculated using the method outlined in ASTM D127-63. The results of the processing, with a comparison to a feedstock containing no hydrogenated jojoba wax esters, are included in Table 7.

TABLE 7

Components	Feedstock Composition	0% HJW	20% HJW	30% HJW
Tocopherols	0.04%	0.04%	0.04%	0.04%
Fatty Acid Methyl Esters	0.00%	0.00%	0.00%	0.00%
Free Fatty Alcohols	0.00%	0.00%	0.00%	0.00%
Wax Ester Content	98%	98%	98%	98%
% Monounsaturated Wax Ester	3	3	31.98	41.50
% Conversion	N/A	99.96%	100.55%	100.01%
Dropping Point (degrees C.)	8	8	44	49

[0068] The percent conversion in Table 7 was calculated based on ideal monounsaturated wax ester values derived from the fatty acid and fatty alcohol proportions of the feedstock. These proportions (and the other wax ester distribution data in this document) were determined using the Hewlett Packard gas chromatograph disclosed herein and a solvent to solubilize the samples. During testing, approximately 1 drop of sample was diluted with 10 drops of solvent and 1.0 uL of the resulting mixture was injected into the gas chromatograph. Based on historical data for jojoba wax esters previously obtained and a theoretical randomization of the percentage of the various chain lengths (assuming all esters were transesterified), an ideal value for each wax ester species (i.e., C36:2, C42:2, etc.) can be determined. Since the C42:2 ester is the one that has the largest change from pre- to post-transesterification, it is the one used in Example 3 to monitor conversion of the reactants. The ideal percentage of C42:2 in pure jojoba oil is 41.28% following a complete and total randomization. Accordingly, the conversion of pure jojoba oil can be calculated as:

$$\%\ \text{Conversion HJW0} = (\%\ C42{:}2)/41.28 \times 100$$

[0069] Where HJW0 is a jojoba oil feedstock that does not contain any hydrogenated jojoba wax esters. For the feedstocks that include hydrogenated jojoba oil and wax esters, the percent conversion is monitored by the formation of the monounsaturated species. The species monitored in these reactions include C38:1, C40:1, C42:1, C44:1, and C46:1. The same gas chromatographic procedures used in this document are used to monitor the various reactants during and following the transesterification reaction. Table 8 contains the ideal overall values for monounsaturated wax esters (representing all the individual species percentages added together) for a feedstock containing 20%, 30%, and 50% hydrogenated jojoba wax esters (HJW20, HJW30, and HJW50, respectively).

TABLE 8

Product	Ideal % of Monounsaturated Wax Esters
HJW20	31.20
HJW30	40.00
HJW50	46.50

[0070] These values can be used to calculate the percent conversion of jojoba wax esters to the ideal mixture of monounsaturated wax esters given the percentage of the monounsaturated components by weight in the feedstock. The calculation is given as follows:

$$\%\ \text{Conversion} = (\%\ \text{Monounsaturates})/(\text{Ideal}\ \%\ \text{Monounsaturates}) \times 100$$

[0071] Because of the nature of the calculation it is possible for the calculation to be greater than 100% depending upon measurement results and the fact that the ideal number is based on historical average data for jojoba oil.

[0072] Referring to FIGS. **4-7**, various comparison graphs of wax ester distributions for chemically catalyzed transesterified and enzyme catalyzed transesterified jojoba wax esters are illustrated. FIG. **4** is for a pure jojoba oil product (HJW0). The solid line shows the wax ester distribution for the chemically catalyzed process and the dotted line shows the wax ester distribution for the enzymatically catalyzed process. By observation, it is clear that the enzymatically catalyzed process successfully randomizes the various esters very similarly to the chemically catalyzed process. FIGS. **5**, **6**, and **7** show the wax ester distributions for transesterification products that have 20%, 30%, and 50% by weight hydrogenated jojoba wax esters added in, respectively. The similarity between the solid lines (chemical) and dotted (enzyme) demonstrate how the conversion rates of the enzymatic catalyzed process track those of the chemical catalyzed process. The differences between the two processes may contribute in part to the differences in functional performance and physical properties of the enzymatically catalyzed processed material from the chemically catalyzed material.

[0073] Lipases like those disclosed herein are conventionally used for processing triglycerides, and some have been specifically selected for processing triglycerides in particular ways. For example, some lipases are known as 1, 3 specific as they are capable of scissioning the alkyl esters in the 1 and 3 positions in a triglyceride while not affecting the alkyl ester at the 2 position. Such a lipase interacts with the triglyceride molecule on the exterior of the lipase surface. Other lipases operate when the alkyl ester is inserted into the lipase molecule itself. Obviously, 1, 3 lipases will differ in their ability to process various triglyceride molecules based on the structure of the alkyl esters and the triglyceride molecule due to various factors, including steric hindrance and other steric effects.

[0074] Interestingly, both 1, 3 lipases and lipases that operate using insertion of a triglyceride work equally well when used in jojoba ester transesterification reactions. This result is unexpected, as these lipases sterically interact quite differently with the molecules they are involved in catalyzing. Without being bound by any theory, it is possible that because a jojoba ester is primarily a long carbon chain without much molecular bending due to the ester group, both 1, 3 lipases and lipases that operate using insertion are able to interact sterically with the jojoba esters in ways that produce substantially the same catalytic effect. In other words, the long chain jojoba ester can fit into the opening in an insertion lipase and also slide into the active areas of a 1, 3 lipase. As this processing characteristic for lipase catalytic processing of jojoba wax esters is not a predictable result, this illustrates a unique aspect of processing jojoba wax esters using lipases.

[0075] Furthermore, conventional processing of triglycerides using lipases typically yields up to 4000 kg of product per kg of catalyst before the catalyst must be replaced. A wide variety of factors are attributed to the eventual denaturing of the catalyst, including gumming and contamination of the catalyst with water in the triglyceride feedstock. An example of a conventional transesterification process of a triglyceride vegetable oil feedstock may be found in U.S. Patent Application Publication No. 20130149414 to Favre et al., entitled "Processing of Vegetable Oils," filed Jun. 28, 2011, and published Jun. 13, 2013, the disclosure of which is incorporated entirely herein by reference. Testing using continuous flow reactors containing immobilized lipases on substrates demonstrated 96 days of 100% conversion using 0.46 kg of catalyst in each column. At the conclusion of this time period at which the catalyst needed to be replaced, 2305.15 kg of product was produced, which resulted in a kg of product to kg of catalyst ratio of 5011 to 1. This ratio of kg of product to kg of immobilized catalyst is over 20% greater than the ratio when the same lipase is used for triglyceride production. This result when the lipase is used for catalytic transesterification of jojoba oil significantly exceeds the conventional expectations for the lipase, and is an unexpected result that is not predicted by the results of conventional enzymatic triglyceride processing. In various implementations, the yield of an enzymatically transesterified wax ester reaction may yield least 4001 kg product/kg immobilized catalyst, at least 4100 kg product/kg immobilized catalyst, at least 4200 kg product/kg immobilized catalyst, at least 4300 kg product/kg immobilized catalyst, at least 4500 kg product/kg immobilized catalyst, at least 4700 kg product/kg immobilized catalyst, at least 48000 kg product/kg of immobilized catalyst, at least 4900 kg product/kg of immobilized catalyst, or even at least 5000 kg product/kg of immobilized catalyst.

[0076] In various implementations of enzymatic catalytic transesterification systems and processes, implementations of a process/method of modifying the viscosity of a product that includes catalytically transesterified wax esters may be used. In these implementations, an alcohol that has a carbon number ranging from 1 to 34 carbons may be introduced into the feedstock of the process. This introduction is typically done prior to contacting the feedstock with the enzymatic catalyst (which may be any disclosed herein), but in various implementations the introduction may occur simultaneously with or after contacting with the enzymatic catalyst, or even after the enzymatic catalyzed reaction may be completed. For the alcohol to be involved most fully during the reaction, introduction prior to or simultaneous with contact with the enzymatic catalyst may be needed. The alcohol may be a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, or any combination of straight chain and branched chain alcohols. Furthermore, any of the straight chain and/or branched chain alcohols used may be fully saturated, mono-unsaturation, polyunsaturated, or any combination of fully saturated, mono-unsaturated, or polyunsaturated.

[0077] As noted in the data in Table 5, the viscosity of the finished product using enzymatically catalyzed transesterified product is measurably and unexpectedly lower than the viscosity of the finished product using the chemically catalyzed transesterified product. In various situations, it may be desirable for the viscosity of the finished product that uses an enzymatically catalyzed transesterified product to substantially match the viscosity of a finished product using chemically catalyzed transesterified product. Table 9 shows the data of Table 5 with an additional row showing the viscosity of a finished product produced using a process where 1.75% by weight of feedstock of oleyl alcohol was introduced into the feedstock prior to the enzymatic catalytic reaction began. The viscosity of the finished product was measured using the same method described as used the other products of Table 5.

TABLE 9

Transesterified Product Type in Cream	Viscosity	Appearance
Chemically Catalyzed	120,900 cP	White, semi-solid phase
Enzymatically Catalyzed	78,585 cP	White, liquid phase, glossy
Modified Enzymatically Catalyzed	132,509	White, semi-solid phase

Example 4

Batch Enzymatic Transesterification with Additional of Alcohols Pre- and Post-Reaction

[0078] A series of experiments were run that involved the interesterification of refined jojoba oil and hydrogenated jojoba oil using an enzymatically catalyzed batch process with an alcohol. The catalyst was an immobilized lipase catalyst like those disclosed in this document. The alcohol was added to the feedstock material either before the reaction began or after the reaction had finished. One component of the feedstock used was a product with no hydrogenated jojoba oil (HJW0) and the other component of the feedstock was a product with 20% hydrogenated jojoba oil (HJW20) added. The alcohols tested included decanol, oleyl alcohol, and behenyl alcohol. Table 10 details the coding of the experimental runs:

TABLE 10

Experiment	#
Alcohol addition pre-reaction	1
Alcohol addition post-reaction	2
Alcohol	
Decanol	1
Oleyl Alcohol	2
Behenyl Alcohol	3
Product	
HJW0	1
HJW20	2

[0079] Table 11 outlines the quantities of materials that made up each feedstock, including the quantity of alcohol, that were used for each batch run. Table 11 shows the feedstock composition for the alcohol added pre-reaction runs.

TABLE 11

Product (coded)	Jojoba Oil (g)	Hyd. Jojoba Oil (g)	Alcohol (g)
111	50	0	0.85
121	50	0	0.85
131	50	0	0.85
112	40	10	0.85
122	40	10	0.85
132	40	10	0.85

[0080] Table 12 outlines the feedstock compositions for the alcohol added post-reaction runs.

TABLE 12

Product (coded)	Jojoba Oil (g)	Hyd. Jojoba Oil (g)	Alcohol (g)
211	50	0	0.85
221	50	0	0.85
231	50	0	0.85
212	40	10	0.85
222	40	10	0.85
232	40	10	0.85

[0081] The resulting transesterified product from each run was used in an evaluation anti-aging lotion formulation which is set forth in Table 13.

TABLE 13

Phase	Tradename	International Nomenclature Cosmetic Ingredient (INCI)	Supplier	Weight percent % (of total)
A	Deionized Water	Water	—	63.4
	CARBOPOL ULTREZ 10	Carbomer	Noveon	0.25
	Glycerin, USP	Glycerin	The Dow Chemical Co.	3.5
	Methylparaben	Preservative		0.2
	Propylparaben			0.15
B	BRIJ S10-S0-(MH)	Steareth-10	Croda, Inc.	1.5
	CRODAFOSCES	Cetearyl Alcohol, Dicetyl Phosphate, and Ceteth-10 Phosphate	Croda, Inc.	3.5
	Dimethicone DC 200 10CST	Dimethicone	Dow Corning	2
	Floraesters 15 (Experiment 1)	Jojoba Esters	Floratech	0 or 3
	Floraesters 20 (Experiment 2, transesterified)	Jojoba Esters	Floratech	0 or 3
	Floraesters 30	Jojoba Esters	Floratech	3
	Span 60	Sorbitan Stearate	Croda, Inc.	0.4
C	Sodium Benzoate NF	Sodium Benzoate	American International	0.1
D	Deionized Water	Water		9
	Floraesters K-20W Jojoba	Hydrolyzed Jojoba Esters and Water (Aqua)	Floratech	4
E	Deionized Water	Water		5
	Florasolvs PEG-150 Hydrogenated Jojoba	Jojoba oil PEG-150 Esters	Hallstar	1

[0082] The mixing procedure for the formula takes places as follows: The ULTREZ 10 polymer is sifted into the water with stirring at room temperature. After allowing 20 minutes mixing time for the polymer to hydrate, the solution was heated to 70 C with mixing. This premix phase was then added to Phase A with mixing. All components of Phase B were then added together and heated to 70 C with stirring. With fast propeller agitation, Phase B was added to Phase A to form an emulsion. The sodium benzoate of Phase C was then added to Phase AB with stirring and then moved to a homogenizer and agitated until a smooth cream was formed. The Floraesters 15 or 20 (1 or 2 in the experiment) was then dissolved in the water of Phase D and added to Phase ABC using the homogenizer to blend the formula. The Florasolvs PEG-150 Hydrogenated Jojoba was then dissolved in the water of Phase E at 70 C. Phase E was then added to Phase ABCD using the homogenizer to blend the formula. The mixture was then cooled to room temperature and then put into tubes or jars for subsequent viscosity testing.

[0083] Table 14 outlines the measured viscosity of the formula created using the materials in Table 13 and using the mixing procedure outlined above. The viscosity was measured using a Brookfield digital viscometer model RvDv-E using a standard RV spindle set (#1-7). The procedure for measuring the viscosity using the viscometer is set forth in Appendix C, the disclosure of which is hereby incorporated entirely herein by reference.

Product	Viscosity (cP)	Product	Viscosity (cP)
111	27760	211	24000
111	27360	211	24167
111	27120	211	19280
121	28880	221	26500
121	28000	221	26380
121	27600	221	27880
131	29600	231	27330
131	28400	231	27500
131	28160	231	26660
112	19440	212	17960
112	20200	212	13540
112	20040	212	15900

-continued

Product	Viscosity (cP)	Product	Viscosity (cP)
122	20400	222	18699
122	20320	222	18020
122	20240	222	16900
132	20400	232	17300
132	19840	232	20600
132	19760	232	17920

[0084] With only one exception, the viscosity of the product created using material where the alcohol was added pre-reaction to the feedstock is higher than the viscosity of the product using material where the alcohol was added post-reaction. This result indicates that it appears that the alcohol participates in the transesterification reaction and it influences the viscosity of the transesterified product through altering the chemical structure of the product as well as physically through the unreacted alcohol still present in the finished transesterified product.

[0085] In various implementations, adding the alcohol to the feedstock in a range of about 0.01% to about 2.5% alcohol by weight of feedstock have demonstrated viscosity increasing behavior in formulations created using the enzymatically catalyzed transesterified byproduct. In various implementations, oleyl alcohol may be used. As can be seen in the experimental results in Table 14, where shorter chain alcohols are used, the increasing viscosity effect is greater. This appears to be the result of improved emulsification behavior of the product due to the presence of the shorter chain alcohol. Those of ordinary skill will appreciate that many alcohols and alcohol combinations like those disclosed herein may be selected using the principles disclosed herein to allow for tuning of the viscosity of finished products that include the enzymatically catalytically transesterified product. In various implementations, the tuning may permit the viscosity of the finished product using enzymatically catalytically transesterified material including the alcohol to be substantially the same as the viscosity of the finished product using chemically catalyzed transesterified material, as illustrated in the examples disclosed herein.

[0086] In places where the description above refers to particular implementations of enzymatic catalytic transesterification systems, processes, and implementing components, sub-components, methods and sub-methods, it should be readily apparent that a number of modifications may be made without departing from the spirit thereof and that these implementations, implementing components, sub-components, methods and sub-methods may be applied to other enzymatic catalytic transesterification systems and processes.

What is claimed is:

1. A process for modifying the viscosity of a finished product including catalytically transesterified wax esters, the process comprising:

providing a feedstock comprising wax esters;

introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons, the alcohol selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, and any combination thereof;

contacting the feedstock with a lipase;

catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product;

increasing a viscosity of a finished product comprising catalytically transesterified wax esters by including the transesterified product as an ingredient of the finished product.

2. The process of claim **1**, wherein the feedstock further comprises an antioxidant and catalytically transesterifying the wax esters in the feedstock with the lipase further comprises catalytically transesterifying without one of removing and degrading the antioxidant in the feedstock.

3. The process of claim **1**, wherein the alcohol is also selected from the group consisting of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

4. The process of claim **1**, wherein the wax esters of the feedstock are jojoba wax esters.

5. The process of claim **5**, wherein the jojoba wax esters further comprise hydrogenated jojoba wax esters.

6. The process of claim **1**, wherein the alcohol is oleyl alcohol.

7. The process of claim **1**, wherein the alcohol comprises 0.01% to 2.5% of the feedstock by weight of the feedstock.

8. A process for transesterifying wax esters, the process comprising:

providing a feedstock comprising wax esters;

introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons, the alcohol selected from the group consisting of a straight chain alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, and any combination thereof;

contacting the feedstock with a lipase;

catalytically transesterifying the wax esters in the feedstock with the lipase to form a enzymatically transesterified product;

wherein the enzymatically transesterified product is adapted to produce a finished product having a certain formula that has a viscosity that substantially matches a viscosity of a finished product having the same certain formula comprising chemically catalyzed transesterified wax esters.

9. The process of claim **8**, wherein the alcohol is also selected from the group consisting of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

10. The process of claim **8**, wherein the feedstock further comprises an antioxidant and catalytically transesterifying the wax esters in the feedstock with the lipase further comprises catalytically transesterifying without one of removing and degrading the antioxidant in the feedstock.

11. The process of claim **8**, wherein the wax esters of the feedstock are jojoba wax esters.

12. The process of claim **11**, wherein the jojoba wax esters further comprise hydrogenated jojoba wax esters.

13. The process of claim **8**, wherein the alcohol is oleyl alcohol.

14. The process of claim **8**, wherein the alcohol comprises 0.01% to 2.5% of the feedstock by weight of the feedstock.

15. A process for modifying the viscosity of a finished product including catalytically transesterified wax esters, the process comprising:

providing a feedstock comprising wax esters;

introducing into the feedstock an alcohol with a carbon number ranging from 1 to 34 carbons, the alcohol selected from the group consisting of a straight chain

alcohol, a branched chain alcohol, any combination of straight chain alcohols, any combination of branched chain alcohols, and any combination thereof;

after introducing the alcohol into the feedstock, contacting the feedstock with a lipase;

catalytically transesterifying the wax esters in the feedstock with the lipase to form a transesterified product;

increasing a viscosity of a finished product comprising catalytically transesterified wax esters by including the transesterified product as an ingredient of the finished product.

16. The process of claim **15**, wherein the alcohol is also selected from the group consisting of fully saturated alcohols, mono-unsaturated alcohols, polyunsaturated alcohols, and any combination thereof.

17. The process of claim **15**, wherein the wax esters of the feedstock are jojoba wax esters.

18. The process of claim **17**, wherein the jojoba wax esters further comprise hydrogenated jojoba wax esters.

19. The process of claim **15**, wherein the alcohol is oleyl alcohol.

20. The process of claim **15**, wherein the alcohol comprises 0.01% to 2.5% of the feedstock by weight of the feedstock.

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