

A METHOD OF PURIFYING A DICARBOXYLIC ACID COMPOUND

FIELD OF THE INVENTION

[0001] The present invention relates to a method of purifying a dicarboxylic acid compound obtained from the oxidative ozonolysis of ethylenically unsaturated compounds, and an apparatus for carrying out the method.

BACKGROUND OF THE INVENTION

[0002] Commercial production of azelaic acid and pelargonic acid has been realized via an oxidative cleavage of an alkenyl ($-C=C-$) unit in oleic acid. For example, azelaic acid has been prepared from oleic acid by oxidation with chromium sulfate, as disclosed in U.S. Patent No. 2,450,858. However, because stoichiometric use of chromium reagents is undesirable, a more efficient approach utilizing ozone has been developed, as disclosed and described in U.S. Patent Nos. 2,813,113; 5,801,275; 5,883,269; and 5,973,173.

[0003] The basic process will be best understood by referring to the description in the accompanying FIG. 1, which is a diagrammatic flow chart indicating the pieces of equipment used and their relationship in the ozonolysis process. Referring to FIG. 1, oleic acid is supplied to a feed tank 10 and then to an ozone absorber 13, wherein the oleic acid is flowed counter-current to a continuous flow of an oxygen/ozone gas mixture introduced to the ozone absorber 13. The ozone absorber 13 is cooled or refrigerated to substantially control the temperature of the reaction occurring therein.

[0004] The ozone absorber 13 receives ozonized oxygen gas by a continuous closed system through which the oxygen circulates. Thus, a given portion of oxygen is used and reused multiple times and the system need be bled and fed only to a small extent to maintain the oxygen content at a predetermined high level. The circulating oxygen system comprises an oxygen supply 16 that leads to a dehydrator 19. From the dehydrator 19, the oxygen is

transferred to an ozone generator 22, which converts a quantity of the oxygen to ozone by using electricity. From the ozone generator 22, a gaseous mixture of ozone and oxygen passes into the ozone absorber 13 in which substantially all of its ozone content is absorbed by the oleic acid to form an oleic acid ozonide. During the residence time of the oleic acid ozonide mixture in the ozone absorber 13, the mixture may increase in viscosity. If desired, the viscosity of the mixture may be reduced by introducing compatible solvents, as discussed further below.

[0005] Upon exiting the ozone absorber 13, the gas mixture, now substantially devoid of ozone, passes to an electrostatic precipitator 25, which removes any fine mist organic matter that may have been picked up in the ozone absorber 13. The purified gas mixture then passes from the electrostatic precipitator 25 through a compression pump 28 to a cooler 31 and then returns to the dehydrator 19, in which substantially all moisture is removed from the gas mixture. Between the cooler 31 and the dehydrator 19, oxygen-containing gas, which may be obtained from or bled from the system through an ozone generating system valve 34, may be supplied to the ozonide decomposing system reactor 37.

[0006] The aforementioned absorption of ozone by oleic acid forms oleic acid ozonides, which are transferred to the ozonide decomposing system reactor 37 and treated with oxygen bled from the ozone generating system valve 34. The ozonide decomposing system reactor 37 may be any type device which is adapted to provide substantial interfacial contact between a liquid and a gas and which may be cooled to moderate the temperature of the reaction. The oxygen bled from the ozone generating system is fed into the bottom of the ozonide decomposing system reactor 37 and is agitated with the liquid in each tank by means of mechanical agitators which are not shown.

[0007] While only one integral ozonide decomposing system reactor 37 is shown in the drawing, it is to be understood that the reactor 37 may comprise distinct regions

configured for independent temperature, independent pressure control, or both. Alternatively, any number of reactors may be used depending upon the size of the reactors, the rate of the flow of the ozonides and their decomposition products, and the efficiency of the agitation in effecting contact between the oxygen gas and the liquid being treated. Further, alternative embodiments having more than one reactor may be connected in series configuration, parallel configuration, or both.

[0008] Temperature control is an important operating parameter for the ozonide decomposing system reactor 37. More specifically, the incoming stream of ozonides must be heated to reach a suitable reaction temperature at which the ozonide moiety may efficiently undergo oxidative decomposition upon exposure to one or more catalysts to preferentially form an aldehyde and a carboxylic acid. The ozonide decomposition catalysts may include Brønsted–Lowry acids, Brønsted–Lowry bases, Lewis acids, Lewis bases, metals, or salts and soaps thereof. Exemplary ozonide decomposition catalysts may include at least in part, Na, K, B, Sn, Zn, Pt, Pd, Rh, Ag, Mn, Cu, Ni, titania/silica or titania/P₂O₅ composites, and combinations thereof. The catalyst can be introduced into the process in the form of a soluble material or in the form of a solid or supported catalyst.

[0009] After reaching a suitable reaction temperature, further oxidation of the aldehyde functional group to a carboxylic acid functional group may occur at a rate sufficient to generate heat, which may in turn contribute to elevating the temperature of the incoming stream of ozonides. However, cooling water may need to be supplied in order to prevent the temperature from rising above a predetermined level. As such, the temperature is controlled in order to be suitable for efficient oxidation to convert the ozonides to mixed oxidation products. In FIG. 1, the heating and cooling apparatus are not shown.

[0010] From the ozonide decomposing system reactor 37, the mixed oxidation products pass to a first distillation unit 40 wherein pelargonic acid and other carboxylic acids

are distilled from the mixed oxidation products to form a first distillate and a first residue of the mixed oxidation products. The first distillate, which contains pelargonic acid, is converted to a liquid in a first condenser 43 and then is delivered to a crude pelargonic acid storage tank 46. However, some of the crude pelargonic acid may be used to dilute the oleic acid reactant and the oleic acid ozonides in the absorber 13 if desired. Thus, pelargonic acid, which may be crude or further purified, may be added to the ozone absorber 13 in order to reduce the viscosity of the ozonides in the absorber 13. The amount of recycled pelargonic acid supplied to the absorber 13 may be controlled with a valve 49.

[0011] It should be noted that other viscosity reducers and diluents may be used. The diluents can be known materials which do not readily react with ozone and which are compatible with the ozonides or the reaction products, or can be a portion of the reaction product. Such diluents include, but are not limited to, saturated short chain acids such as acetic acid, butanoic acid, caproic acid, heptanoic acid, caprylic acid, pelargonic acid, and capric acid; esters such as ethyl acetate and butyl acetate; and alkanes such as hexane, octane, and decane. However, the use of pelargonic acid is recommended because, as an end product of the process, it does not interfere with the operation of the circulating oxygen system and requires no separate distillation. In other words, since pelargonic acid is one of the end products of the process, it is a suitable diluent.

[0012] The first residue of the mixed oxidation products, now stripped of a substantial portion of the available pelargonic acid, are next conveyed to an azelaic acid distillation unit 52 in which a portion of the first residue of the mixed oxidation products is distilled to form a second distillate, which includes azelaic acid, and a second residue of the mixed oxidation products. The second distillate is condensed by passage through an azelaic acid distillate condenser 55 to form a crude azelaic acid, which is transferred to a crude azelaic acid storage tank 58. The second residue of the mixed oxidation products or pitch that remains after

distilling away the second distillate is removed from the azelaic acid distillation unit 52 and transferred to residue storage 61. The second residue of the mixed oxidation products may still contain some amount of azelaic acid, so further processing, if desired, can occur to recover a portion thereof.

[0013] From the crude azelaic acid storage tank 58, the crude azelaic acid is transferred to extractor 64 where the crude azelaic acid is extracted with hot water (e.g., about 175°F, about 80°C to about 210°F, about 99°C) to form a hot aqueous solution of azelaic acid. The by-product acids (BPA) that do not dissolve in the hot aqueous azelaic acid solution are decanted from the extractor 64 to BPA storage 67. Meanwhile, the hot aqueous azelaic acid solution is transferred to an evaporator 70 in which water is removed therefrom. Next, azelaic acid in molten form is fed from the evaporator 70 to a flaker 73 where the temperature is reduced to below the melting point, and then solid flakes of azelaic acid are conveyed to an azelaic acid storage bin 76.

[0014] While the process and apparatus described above provide desirable products such as azelaic and pelargonic acids from oleic acid, deficiencies exist with respect to chemical purity of the product(s), personnel safety, system efficiencies and equipment longevity. One such deficiency of the prior art procedure and apparatus pertains to achieving high purity of the azelaic acid, without sacrificing its overall yield. For example, certain impurities in the crude azelaic acid, such as long chain (e.g. C14 to C18) monocarboxylic acids, are difficult to remove by distillation insofar as the boiling points can be very similar. Depending on the application for the azelaic acid, a monocarboxylic acid impurity may be problematic. For example, monocarboxylic acids can act as a "chain stopper" during the formation of long linear polymers (e.g. polyamides) from the dicarboxylic acid. As such, new procedures are needed to purify dicarboxylic acids such as azelaic acid.

SUMMARY OF THE INVENTION

[0015] According to embodiments of the present invention, a process for purifying a dicarboxylic acid is provided. The process includes ozonizing a mixture comprising an ethylenically unsaturated compound having between 6 to 24 carbons with an ozone-containing gas to form a plurality of ozonization products, cleaving the plurality of ozonization products under oxidative conditions in the presence of a suitable catalyst to form mixed oxidation products. The mixed oxidation products comprise a mixture of C2 to C22 monocarboxylic acids and C2 to C22 dicarboxylic acids. The process further includes distilling the mixed oxidation products to provide a first distillate and a first residue of the mixed oxidation products. The first distillate comprises a mixture of C2 to C16 monocarboxylic acids, and the first residue of the mixed oxidation products includes the dicarboxylic acid and a mixture of C9 to C22 monocarboxylic acids. The process further includes distilling the first residue of the mixed oxidation products to provide a second distillate and a second residue of the mixed oxidation products, wherein second distillate comprises the dicarboxylic acid and a fraction of the mixture of C9 to C22 monocarboxylic acids; partitioning the second distillate between water and an organic solvent, wherein the water is at a temperature within the range of about 175°F, 79°C to about 230°F, 110°C; wherein water and the organic solvent are substantially immiscible to thereby form an aqueous layer containing the dicarboxylic acid and an organic solvent layer containing at least a portion of the fraction of the mixture of C9 to C22 monocarboxylic acids; separating the organic solvent layer from the aqueous layer. The process further includes isolating the dicarboxylic acid from the aqueous layer to provide a purified dicarboxylic acid having a residual content of C9 to C22 monocarboxylic acids in an amount that is less than 0.5 percent by weight.

[0016] According to another embodiment of the present invention, a process for producing a monocarboxylic acid and a dicarboxylic acid from an unsaturated carboxylic acid is provided. The process comprises the steps of generating an ozone gas in an ozone generator; contacting the ozone gas with an unsaturated carboxylic acid feed comprising the unsaturated carboxylic acid in an absorber to obtain an ozonide; contacting the ozonide with an oxygen gas and at least one catalyst in a reactor to provide mixed oxidation products, and separating at least a portion of the mono carboxylic acid from the mixed oxidation products by distilling the mixed oxidation products to provide a first distillate and a first residue of the mixed oxidation products, wherein the first distillate comprises a fraction of the monocarboxylic acid, and wherein the first residue of the mixed oxidation products comprises a fraction of the dicarboxylic acid. The method further includes purifying the saturated dicarboxylic acid by extracting with an organic solvent in accordance with the processes described herein.

[0017] In accordance with another embodiment of the invention, a chemical derivative of a dicarboxylic acid afforded by the processes claimed herein is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the general description of the invention given above, and the detailed description given below, serve to describe the invention.

[0019] FIG. 1 is a schematic representing an oleic acid ozonolysis plant (under the prior art).

[0020] FIG. 2 is a schematic representing an organic extractant recovery system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] According to embodiments of the present invention, a process for purifying a dicarboxylic acid compound is provided. The dicarboxylic acid is derived from a chemical process where an unsaturated carboxylic acid is contacted with ozone to obtain an ozonide. The ozonide is treated with an oxygen-containing gas and at least one oxidation catalyst in a reactor to obtain mixed oxidation products containing a monocarboxylic acid and a dicarboxylic acid. The carboxylic acid mixture is purified by distilling at least a portion of the monocarboxylic acid in a first distillation fraction thereby leaving the dicarboxylic acid in a first residue of the mixed oxidation products. The residue of the mixed oxidation products is then distilled in a second distillation to form a second distillate and a second residue of the mixed oxidation products. The second distillate comprises the dicarboxylic acid and may contain monocarboxylic acid impurities at levels of between about 10% to about 30% by weight, where a significant portion of these impurities cannot be effectively removed from the dicarboxylic acid portion by distillation. As such, additional purification of the saturated dicarboxylic acid is effected by performing an extraction with an organic solvent. The second residue of the mixed oxidation products includes various tars and metal soaps derived from the at least one oxidation catalyst.

[0022] According to one embodiment, the ozonolysis may be performed on ethylenically unsaturated compounds. Suitable ethylenically unsaturated compounds are not particularly limited by their source and may include any number of carbon atoms, such as between 6 to 24 carbon atoms. For example, the ethylenically unsaturated compounds may include an ethylenically unsaturated compound having between 12 to 20 carbon atoms. Accordingly, an ethylenically unsaturated compound may have 18 carbon atoms. Further, the ethylenically unsaturated compounds may include additional functional groups, such as carboxylic acids. The ethylenically unsaturated compounds may be derived from animal or

plant sources. Accordingly, the ethylenically unsaturated compounds include fatty acids, including those obtained from palm oil or tallow. In one example, the ethylenically unsaturated compounds include oleic acid.

[0023] After reacting a C6 to C24 ethylenically unsaturated compound with an ozone-containing gas, a plurality of ozonization products are formed, which are cleaved under oxidative conditions in the presence of a suitable catalyst to form mixed oxidation products, which comprise a mixture of C2 to C22 monocarboxylic acids and C2 to C22 dicarboxylic acids. For example, the mixture of carboxylic acids may include C2 to C16, C5 to C9, or C6 to C18 monocarboxylic acids. The mixture of carboxylic acids may include C2 to C16, C5 to C9, or C6 to C18 dicarboxylic acids, for example. According to an exemplary embodiment, the ozonolysis may be performed on oleic acid to thereby produce pelargonic acid, which is a saturated C9 monocarboxylic acid, and azelaic acid, which is a saturated C9 dicarboxylic acid.

[0024] In order to isolate a desired dicarboxylic acid, such as azelaic acid, the mixed oxidation products, which may be oleic acid derived, are distilled under a first set of distillation conditions to provide a first distillate comprising a portion of the C2 to C22 monocarboxylic acids, which can include pelargonic acid, and a first residue of the mixed oxidation products. The first residue of the oxidation products comprises the desired dicarboxylic acid (e.g., azelaic acid), along with a plurality of impurity acids, which may include a mixture of C9 to C22 monocarboxylic acids, as well as other dicarboxylic acids.

[0025] The first residue of the mixed oxidation products is then subjected to a second distillation performed under a second set of distillation conditions to provide a second distillate and a second residue of the mixed oxidation products. The second distillate comprises the desired dicarboxylic acid and a first fraction of the plurality of impurity acids.

The impurity acids are by-product acids (BPA), which may include a mixture of C9 to C22 monocarboxylic acids.

[0026] In order to separate the azelaic acid from the bulk of the impurity acids, further processing includes an aqueous extraction using an organic solvent, as explained next. The aqueous extraction includes partitioning the second distillate in water and/or between water and an organic solvent that is substantially immiscible with water. Accordingly, the second distillate is combined with hot water to form a concentrated aqueous solution of the second distillate. If desired, a portion of the by-product acids (BPA) that do not dissolve in the concentrated aqueous azelaic acid solution can be decanted from the concentrated aqueous solution in a separate extractor or decanter prior to subsequently extracting the concentrated aqueous solution cut with an organic solvent or simply transferred to an extractor. In either case, the concentrated aqueous solution of second distillate is then mixed with the organic solvent, where the azelaic acid is retained in the water layer, i.e., the aqueous phase, along with a second fraction of the plurality of impurity acids, such as various water-soluble short chain (e.g., C4 to C8) dicarboxylic acids. The organic solvent soluble by-product acids (e.g., C9 to C22 monocarboxylic acids) are extracted into the organic solvent.

[0027] With reference to FIG. 2, the crude azelaic acid (i.e., the second distillate) from storage tank 58 may be combined with water in a hot water tank 80 to make a concentrated aqueous solution of crude azelaic acid, which may then be fed into decanter 81, where a portion of the by-product acids (BPA) that do not dissolve in the hot aqueous azelaic acid solution can be decanted from the concentrated aqueous solution, prior to transfer to the extractor 64, where the concentrated aqueous solution cut is then mixed with the organic solvent. According to one embodiment, the concentrated aqueous solution of crude azelaic acid may be directly fed into extractor 64. According to one embodiment, the azelaic extractor 64 may be a York-Scheibel extractor, which is a counter-current, multistage,

continuous liquid-liquid extractor. In one embodiment, the York-Scheibel extractor has about 10 to about 60 stages. For example, the York-Scheibel extractor may have 10, 20, 30, 40, 50, or 60 or more stages.

[0028] Azelaic acid is soluble in hot water. The extraction temperature of the water may be within the range of about 175°F, 79°C to about 230°F, 110°C. The extraction may be performed under ambient pressure or under elevated pressure conditions. The organic solvent is not particularly limited to any specific solvent, but should be substantially immiscible with water under the operating conditions. For example, the organic solvent may have water solubility of less than 0.5 grams per liter at 20°C. Further, suitable organic solvents have boiling points greater than the temperature of the extracting water under the extraction pressure.

[0029] Exemplary organic solvents that can be used in the process include, but are not limited to, an aliphatic or aromatic hydrocarbon solvent and/or mixtures thereof in which the impurities present in the crude dicarboxylic acid are soluble and in which the dicarboxylic acid is substantially insoluble. Examples of such aliphatic solvents include, but are not limited to, linear and branched, cyclic and acyclic alkanes such as pentane, hexane, heptane, octane, 2,2,4-trimethylpentane, cyclopentane, cyclohexane, methylcyclopentane, methylcyclohexane, alkenes such as pentene, hexene, heptene, cyclopentene, cyclohexene, methylcyclopentene, methylcyclohexene and the like and liquefied hydrocarbons that are normally gases at room temperature and pressure such as liquid propane and liquid butane. Examples of such aromatic solvents include, but are not limited to, benzene, toluene, and xylene. Solvent mixtures include, but are not limited to, petroleum distillates such as naphtha, heavy naphtha and petroleum ether. In one example, the organic solvent is octane. In another example, the organic solvent is a heavy naphtha, such as VM&P Naphtha.

[0030] The crude azelaic acid from storage tank 58 may be combined with water in a hot water tank 80, where the water is at a temperature within the range of about 175°F, 79°C to about 230°F, 110°C, to make a concentrated aqueous solution of crude azelaic acid, which according to one embodiment is then fed into the extractor 64 and mixed with the organic solvent. Over time, the immiscible organic solvent separates from the aqueous solution thereby forming an extracted aqueous solution of azelaic acid and an organic solvent layer containing the extracted by-product acids (BPA). On discharge from the extractor 64, the organic solvent content of the extracted aqueous solution of azelaic acid should be as low as possible to avoid introducing flammable organic solvents into other parts of the plant while transferring the extracted aqueous solution to a crystallizer 85. A flash tank may be used to remove the organic solvent from the extracted aqueous solution. According to an embodiment, the extracted aqueous solution comprises less than 1 percent by weight of the organic solvent portion prior to any subsequent processing step.

[0031] The organic phase comprising the organic solvent and extracted BPA (e.g., C9 to C22 monocarboxylic acids) can be transferred to the BPA storage vessel 67, if desired. However, according to an embodiment of the present invention, further processing can be performed to recycle the organic solvent by removing the BPA, as explained next.

[0032] In one embodiment, the organic solvent layer comprising the C9 to C22 monocarboxylic acids may be transferred to an organic solvent evaporator 90, wherein the organic solvent is separated from the C9 to C22 monocarboxylic acids by vaporizing the organic solvent to form an organic solvent vapor, thereby leaving the C9 to C22 monocarboxylic acids as a residue. Any suitable conditions may be used for the organic solvent distillation unit. For example, organic solvent evaporator may be run at about 250°F, 121°C to about 275°F, 135°C and atmospheric pressure. The residue containing the C9 to C22 monocarboxylic acids may be stored for later processing, if desired.

[0033] The organic solvent vapor, having been separated from the C9 to C22 monocarboxylic acids, is transported to a condenser 95, which condenses the organic solvent vapor to form the recycled organic solvent, which is then passed through a decanter 100 to remove entrained water, and may be collected in a recycled organic solvent tank 105. According to an embodiment of the invention, the recycled organic solvent includes less than 1 percent by weight of C9 to C22 monocarboxylic acids. For example, a residual content of C9 to C22 monocarboxylic acids in the recycled organic solvent may be less than 0.5 percent by weight, or less than 0.1 percent by weight, or less than 0.05 percent by weight.

[0034] The C9 to C22 monocarboxylic acids residue may be further processed by using an additional distillation unit to strip off any remaining organic solvent prior to discharging the residue. For example, the C9 to C22 monocarboxylic acids residue from the evaporator 90 may be sent to organic solvent stripper 110. The organic solvent stripper 110 uses a carrier vapor, such as steam, to strip out any remaining solvent. Any suitable conditions may be used for the organic solvent stripper 110. For example, stripper 110 may be run at approximately about 250°F, 121°C to about 275°F, 135°C and atmospheric pressure. The recovered organic solvent may be combined with the first distilled organic solvent prior to the condenser 95, or a standalone condenser may be used. The stripping steam is also condensed in the condenser 95, but is then separated from the solvent. For example, the water and organic solvent may be separated using the decanter 100.

[0035] The recycled organic solvent is thereby rendered sufficiently pure to then be reused to purify the azelaic acid of sufficient purity to use in preparing derivatives that may be used for a number of different purposes such as lubricants, plasticizers, lacquers, herbicides, and skin treatments. For example, azelaic acid having a residual content of C9 to C22 monocarboxylic acids that is less than 0.5 percent by weight can be achieved in accordance with the processes described herein. In another embodiment, azelaic acid having

a residual content of C9 to C22 monocarboxylic acids that is less than 0.1 percent by weight or 0.05 percent by weight can be achieved.

[0036] The apparatus and processes described herein may be useful to recycle organic solvents used in the purification of dicarboxylic acids derived from ethylenically unsaturated monocarboxylic acids, such as oleic acid. As mentioned above, the apparatus and processes are particularly suited for use with a ozonolysis system that breaks down oleic acid into pelargonic acid and azelaic acid. However, the apparatus and processes may be useful to purify other dicarboxylic acids which can be derived from ethylenically unsaturated monocarboxylic acids other than oleic acid via the described ozonolysis reaction. The unsaturated acids may generally have between 6 and 30 carbon atoms, for example between 8 and 24 carbon atoms, and one or more unsaturated carbon to carbon bonds. The monobasic and dibasic acid products that result from the ozonolysis reaction are determined by the location of the one or more unsaturated carbon to carbon bonds in the unsaturated acid. The unsaturated acids may be isolated from biological sources, such as plants, animals, or microorganisms. Alternatively, the unsaturated acids may be isolated from petroleum sources and synthetic sources. Exemplary unsaturated acids and their respective potential oxidation products are included in the Table below.

Table 1. Exemplary ethylenically unsaturated compounds and corresponding ozonization products.

Carbons	Exemplary Unsaturated Fatty Acid	Exemplary Monobasic Product	Exemplary Dibasic Product
10	Obtusilic acid	Caproic acid	Succinic acid
10	Caproleic acid	Formic acid	Azelaic acid
11	Undecenoic acid	Formic acid	Sebacic acid
12	Lauric acid	Propionic acid	Azelaic acid
14	Myristoleic acid	Valeric acid	Azelaic acid
16	Palmitoleic acid	Heptanoic acid	Azelaic acid
18	Petroselinic acid	Lauric acid	Adipic acid
18	Oleic acid	Pelargonic acid	Azelaic acid
18	Vaccenic acid	Heptanoic acid	Hendecanedioic acid
18	Octadecenoic acid	Caproic acid	Dodecanedioic acid
20	Gadoleic acid	Undecanoic acid	Azelaic acid
22	Cetoleic acid	Undecanoic acid	Hendecanedioic acid
22	Erucic acid	Pelargonic acid	Brassylic acid
24	Selacholeic acid	Pelargonic acid	Pentadecanedioic acid
26	Hexacosenoic acid	Pelargonic acid	Heptadecanedioic acid
30	Tricosenoic acid	Pelargonic acid	Heneicosanedioic acid

[0037] While the table above includes mono-unsaturated acids, it is understood that poly-unsaturated acids could be utilized as well. The resulting monobasic acids and dibasic acids, and their derivatives, may be used for a number of different purposes such as lubricants, plasticizers, lacquers, herbicides, and skin treatments.

[0038] While the present invention has been illustrated by the description of one or more embodiments thereof, and while the embodiments have been described in considerable detail, they are not intended to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative product and/or method and examples shown and described. The various features of exemplary embodiments described herein may be used in any combination. Accordingly, departures may be made from such details without departing from the scope of the general inventive concept.

What is claimed is:

1. A process for purifying a dicarboxylic acid comprising
 - a) ozonizing a mixture comprising an ethylenically unsaturated compound having between 6 to 24 carbons with an ozone-containing gas to form a plurality of ozonization products;
 - b) cleaving the plurality of ozonization products under oxidative conditions in the presence of a suitable catalyst to form mixed oxidation products, wherein the mixed oxidation products comprise a mixture of C2 to C22 monocarboxylic acids and C2 to C22 dicarboxylic acids;
 - c) distilling the mixed oxidation products to provide a first distillate comprising a mixture of C2 to C16 monocarboxylic acids, and a first residue of the mixed oxidation products, wherein the first residue of the mixed oxidation products includes the dicarboxylic acid and a mixture of C9 to C22 monocarboxylic acids;
 - d) distilling the first residue of the mixed oxidation products to provide a second distillate and a second residue of the mixed oxidation products, wherein the second distillate comprises the dicarboxylic acid and a fraction of the mixture of C9 to C22 monocarboxylic acids;
 - (e) partitioning the second distillate between water and an organic solvent comprising an organic solvent, wherein the water is at a temperature within the range of about 175°F, 79°C to about 230°F, 110°C; wherein water and the organic solvent are substantially immiscible to thereby form an aqueous layer containing the dicarboxylic acid and an organic solvent layer containing at least a portion of the fraction of the mixture of C9 to C22 monocarboxylic acids;
 - f) separating the organic solvent layer from the aqueous layer; and

g) isolating the dicarboxylic acid from the aqueous layer to provide a purified dicarboxylic acid having a residual content of C9 to C22 monocarboxylic acids that is less than 0.5 percent by weight.

2. The process according to claim 1, wherein the residual content of C9 to C22 monocarboxylic acids is less than 0.05 percent by weight.
3. The process according to claims 1 to 2, wherein the organic solvent comprises one or more C6 to C12 hydrocarbon compounds.
4. The process according to any of the claims 1 to 3, wherein the organic solvent comprises hexanes, heptanes, octanes, nonanes, decanes, undecanes, dodecanes, or combinations thereof.
5. The process according to any of the claims 1 to 4, wherein the organic solvent is heavy naphtha.
6. The process according to any of the claims 1 to 5, wherein the organic solvent has a water solubility of less than 0.5 grams per liter at 20°C.
7. The process according to any of the claims 1 to 6, wherein the organic solvent is a recycled organic solvent provided by a method comprising distilling the organic solvent layer containing the mixture of C9 to C22 monocarboxylic acids to provide a recycled organic solvent, wherein the recycled organic solvent has a content of C9 to C22 monocarboxylic acids in an amount that is less than 1 percent by weight.

8. The process according to claim 7, wherein the distilling the organic solvent layer comprises:

i) transferring the organic solvent layer comprising the organic solvent and the mixture of C9 to C22 monocarboxylic acids to a first distillation unit, wherein the organic solvent and the mixture of C9 to C22 monocarboxylic acids are separated by forming an organic solvent vapor;

ii) condensing the organic solvent vapor to form the recycled organic solvent, wherein the content of C9 to C22 monocarboxylic acids in the recycled organic solvent is less than 0.5 percent by weight.

9. The process according to claim 8, wherein the organic solvent vapor further comprises water, which is subsequently removed from the recycled organic solvent.

10. The process according to any of the claims 7 to 9, wherein the content of C9 to C22 monocarboxylic acids in the recycled organic solvent is less than 0.1 percent by weight.

11. The process according to any of the claims 7 to 10, wherein the content of C9 to C22 monocarboxylic acids in the recycled organic solvent is less than 0.05 percent by weight.

12. The process according to any of the claims 1 to 11, wherein the aqueous layer contains less than 1 percent by weight of the organic solvent prior to any subsequent processing step.

13. The process according to any of the claims 1 to 12, wherein the ethylenically unsaturated compound is derived from plant or animal sources.
14. The process according to any of the claims 1 to 13, wherein the ethylenically unsaturated compound is an unsaturated fatty acid.
15. The process according to any of the claims 1 to 14, wherein the ethylenically unsaturated compound is derived from palm oil or tallow.
16. The process according to any of the claims 1 to 15, wherein the ethylenically unsaturated compound is oleic acid.
17. The process according to any of the claims 1 to 16, wherein the dicarboxylic acid is azelaic acid.
18. A process for producing a monocarboxylic acid and a dicarboxylic acid from an unsaturated carboxylic acid, comprising the steps of:
 - a) generating an ozone gas in an ozone generator;
 - b) contacting the ozone gas with an unsaturated carboxylic acid feed comprising the unsaturated carboxylic acid in an absorber to obtain an ozonide; and
 - c) contacting the ozonide with an oxygen gas and at least one catalyst in a reactor to provide mixed oxidation products, and
 - d) separating at least a portion of the monocarboxylic acid from the mixed oxidation products by distilling the mixed oxidation products to provide a first distillate and a first

residue of the mixed oxidation products, wherein the first distillate comprises a fraction of the monocarboxylic acid, and wherein the first residue of the mixed oxidation products comprises a fraction of the dicarboxylic acid;

e.) isolating the monocarboxylic acid from the first distillate; and

e) isolating the dicarboxylic acid by any of the methods of claim 1-17.

19. A chemical derivative of a dicarboxylic acid produced by the process according to any of the claims 1 to 18.