METHODS AND SYSTEMS FOR PREPARING LYSOLECITHIN

BACKGROUND

[0001] Lecithin is widely used in a number of industries, including the animal feed and food industries (see, e.g., List, G. R., Polar lipids, 2015: 1-33). Lysolecithin includes a hydrolyzed version of lecithin, and can have better emulsifying properties than lecithin. As a result, in the feed industry, lysolecithin can replace more fat in a feed formula (see, e.g., Brautigan, D. L. et al. Poultry Science, 2017, 96(8): 2889-2898). Lysolecithin can significantly improve the growth performance of animals, and increase the absorption and utilization of nutrients. In the food industry, lysolecithin may be used in dairy products and baked foods, likely due to its superior emulsification ability. Lysolecithin also may be used in a wide number of other fields, including, but not limited to, medicine, cosmetics, and bioengineering (see, e.g., Iwasaki, Y. et al. Lipid Biotechnology, 2002: 417-431). While phosphatidylcholine (PC) is the major component in lecithin, it can be converted to a hydrolyzed form, which is called lysophosphatidylcholine (LPC), in lysolecithin.

[0002] Typically, lysolecithin is synthesized by mixing lecithin, moisture, and phospholipase A1, A2, or B in a reactor with consistent stirring/mixing (see, e.g., Joshi, A. European Journal of Lipid Science and Technology, 2006, 108(4): 363-373). The reaction typically takes 6 hours to 48 hours in order to control the conversion rate. When the LPC content reaches a desired level, the reaction usually is deactivated by heating it to 95 °C, and then dried on a film evaporator to obtain the finished lysolecithin products. Typically, lysolecithin products for use in feed and food have an LPC content in the range of 3% to 8%.

[0003] Although continuous reactions are very common in the chemical synthesis industry, applying a continuous synthesis process to lecithin raw material has been a challenge for one or more reasons. For example, lecithin raw material usually has a high viscosity; therefore, lecithin raw material can be difficult to transport in components of a system, such as a pipeline, especially smoothly and/or at a consistent speed. As a further example, lecithin can become a non-Newtonian fluid when mixed with water (see, e.g., Zhang, K. et al. European Journal of Lipid Science and Technology, 2012, 114(11): 1254-1260), which may make its fluid characteristics difficult to predict. Also, the lecithin industry commonly processes hundreds of tons of lecithin on a daily basis; therefore, it can be difficult, if not impossible, to find an

appropriately-sized continuous reactor, especially if the reaction times are lengthy, such as about 6 hours to about 48 hours.

[0004] There remains a need for improved methods of producing lysolecithin, including continuous methods and/or methods that are more efficient, reduce the likelihood of over-reaction, occupy a smaller footprint, or a combination thereof.

BRIEF SUMMARY

[0005] Provided herein are embodiments of methods, including continuous methods, for producing lysolecithin, which, compared to known methods for producing lysolecithin, may be more efficient and/or less expensive. For example, embodiments of the methods described herein may require relatively shorter production cycle times, and/or occupy a relatively small footprint.

[0006] In one aspect, methods of producing a product are provided, wherein the methods may be continuous methods. In some embodiments, the methods include providing a first stream including lecithin and water, wherein the water may be present in the first stream at a concentration of about 10 wt% to about 300 wt%, based on the weight of the lecithin; contacting the first stream and a hydrolysis agent to form a second stream, wherein the hydrolysis agent may be effective to facilitate a hydrolysis reaction of the lecithin; subjecting the second stream to heating, mixing, or a combination thereof for a time effective to form a third stream including an emulsion; and subjecting the third stream to heating, mixing, or a combination thereof for a time effective to drive the hydrolysis reaction at a desired rate, to a desired extent, or a combination thereof to convert at least a portion of the lecithin to a product. The product may include lysolecithin.

[0007] In another aspect, systems for producing a product are provided. In some embodiments, the systems include a mixer and a reactor, wherein the mixer and the reactor are in fluid communication. The mixture may be a static mixer, or a dynamic mixer. The systems also may include one or more other components known in the art, such as a pump. The systems may be used to perform, in whole or in part, any of the methods disclosed herein.

[0008] Additional aspects will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the aspects described herein. The advantages described herein may be realized and attained by means of the elements

and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a schematic, which depicts elements of an embodiment of a continuous method and system for producing lysolecithin.

[0010] **FIG. 2A** depicts the effect of enzyme amount on the conversion rate of lysolecithin observed during the testing of an embodiment of the methods provided herein.

[0011] **FIG. 2B** depicts the effect of moisture on the conversion rate of lysolecithin observed during the testing of an embodiment of the methods provided herein.

[0012] **FIG. 2C** depicts the effect of reaction time on the conversion rate of lysolecithin observed during the testing of an embodiment of the methods provided herein.

[0013] **FIG. 2D** depicts the effect of reaction temperature on the conversion rate of lysolecithin observed during the testing of an embodiment of the methods provided herein.

[0014] **FIG. 2E** depicts the effect of emulsifying time on the conversion rate of lysolecithin observed during the testing of an embodiment of the methods provided herein.

[0015] **FIG. 3A** depicts the effect of enzyme amount on phosphatidylcholine (PC) and lysophosphatidylcholine (LPC) content observed during the testing of an embodiment of the methods provided herein.

[0016] **FIG. 3B** depicts the effect of moisture on the PC and LPC content observed during the testing of an embodiment of the methods provided herein.

[0017] **FIG. 3C** depicts the effect of reaction time on the PC and LPC content observed during the testing of an embodiment of the methods provided herein.

[0018] **FIG. 3D** depicts the effect of reaction temperature on the PC and LPC content observed during the testing of an embodiment of the methods provided herein.

[0019] **FIG. 3E** depicts the effect of emulsifying time on the PC and LPC content observed during the testing of an embodiment of the methods provided herein.

DETAILED DESCRIPTION

[0020] Provided herein are methods and systems for producing a product. The product, in some embodiments, includes lysolecithin.

[0021] In some embodiments, the methods provided herein are continuous methods. The methods may be performed in a continuous manner for one or more reasons, such as (i) the formation of an emulsion, which may be relatively easy to process, e.g., transport between components of a system, (ii) the relatively quick reaction times, or (iii) a combination thereof.

[0022] In some embodiments, the methods include providing a first stream that includes lecithin and water. Water may be present in the first stream at any amount, such as any amount that does not undesirably impact one or more embodiments of the methods provided herein. In some embodiments, water is present in the first stream at a concentration of about 10 wt% to about 300 wt%, about 10 wt% to about 250 wt%, about 10 wt% to about 200 wt%, about 10 wt% to about 150 wt%, about 10 wt% to about 100 wt%, about 10 wt% to about 50 wt%, about 20 wt% to about 40 wt%, about 25 wt% to about 35 wt%, about 50 wt% to about 300 wt%, about 100 wt% to about 300 wt%, about 150 wt% to about 300 wt%, about 200 wt% to about 300 wt%, or about 250 wt% to about 300 wt%, based on the weight of the lecithin. Any known technique may be used to modify (e.g., decrease) an amount of water in a first stream, and the modification of the amount of water may occur before or after the first stream and a hydrolysis agent are contacted.

[0023] In some embodiments, the methods provided herein include contacting a first stream and a hydrolysis agent to form a second stream. Any amount of hydrolysis agent may be used in the methods herein, such as any amount that does not undesirably impact one or more of the embodiments provided herein. In some embodiments, the hydrolysis agent is present in the second stream at a concentration of about 10 ppm to about 1,500 ppm, about 10 ppm to about 1,250 ppm, about 10 ppm to about 1,000 ppm, about 10 ppm to about 750 ppm, about 10 ppm to about 500 ppm, about 10 ppm to about 300 ppm, about 10 ppm to about 200 ppm, about 10 ppm to about 100 ppm, about 10 ppm to about 50 ppm, about 100 ppm to about 1,500 ppm, about 200 ppm to about 1,500 ppm, about 300 ppm to about 1,500 ppm, about 500 ppm to about 1,500 ppm, about 750 ppm to about 1,500 ppm, about 750 ppm to about 1,250 ppm, or about 750 ppm to about 1,000 ppm, relative to the lecithin. Other concentrations, however, may be used.

[0024] In some embodiments, the methods include subjecting the second stream to heating, mixing, or a combination thereof for a time effective to form a third stream that includes

an emulsion. The emulsion may be a uniform emulsion. The emulsion may be a Newtonian fluid. Not wishing to be bound by any particular theory, it is believed that the character of embodiments of the emulsions herein may allow the emulsions to be processed, e.g., transported, more easily than intermediate streams produced in prior processes. Therefore, the formation of embodiments of emulsions herein may allow embodiments of the methods provided herein to be effective and/or efficient continuous methods.

[0025] The time effective to form a third stream that includes an emulsion may be relatively short, which may facilitate and/or ease the ability to perform embodiments of the methods provided herein in a continuous manner. In some embodiments, the time effective to form the third stream that includes an emulsion is about 1 minute to about 10 minutes, about 1 minute to about 8 minutes, about 1 minute to about 5 minutes, about 2 minutes to about 4 minutes, about 2.5 minutes to about 3.5 minutes, about 3 minutes, or about 1 minute to about 3 minutes.

[0026] Generally, any two or more elements of the methods provided herein may be performed (i) in any order, (ii) completely or partially simultaneously, (iii) sequentially, or (iv) a combination thereof. For example, a hypothetical element "A" and a hypothetical element "B" may be performed in any of the following manners: (i) element "A" started and completed and then element "B" started and completed, (ii) element "B" started and completed and then element "A" started and completed, (iii) element "A" and "B" started and completed at the same times, (iv) element "A" started, element "B" started, element "A" completed, and then element "B" completed, (v) element "B" started, element "A" started, element "A completed, and then element "B" completed, etc. In some embodiments, the contacting of the first stream and the hydrolysis agent and the subjecting of the second stream to heating, mixing, or the combination thereof occurs simultaneously or sequentially.

[0027] Generally, any of the elements of the methods provided herein may be performed with and/or in any known apparatus. In some embodiments, the contacting of the first stream and the hydrolysis agent occurs, at least in part, in a first reservoir or a first mixing apparatus. In some embodiments, the contacting of the first stream and the hydrolysis agent includes transporting the first stream to the first reservoir or the first mixing apparatus, and transporting the hydrolysis agent to the first reservoir or the first mixing apparatus. The streams may be transported using any known apparatus, such as a pump. In some embodiments, the first stream

is transported with a screw pump. In some embodiments, the hydrolysis agent is transported with a peristaltic pump.

[0028] In some embodiments, the subjecting of the second stream to heating, mixing, or a combination thereof occurs, at least in part, in a first reservoir, a first mixing apparatus, or a combination thereof. In some embodiments, the contacting of the first stream and the hydrolysis agent to form the second stream occurs before the second stream is disposed in the first reservoir or the first mixing apparatus.

[0029] The first mixing apparatus may include any known mixing apparatus. In some embodiments, the first mixing apparatus includes a static mixer. The static mixer may be a static inline mixer. The first mixing apparatus may include an inlet and an outlet, which may be configured to permit one or more streams to enter and exit the static mixer, respectively.

[0030] In some embodiments, the second stream is present in the first reservoir, and the mixing of the second stream is achieved, at least in part, with a dynamic mixing apparatus. The dynamic mixing apparatus may include a stirring apparatus, a shaking apparatus, a rocking apparatus, etc. The first reservoir may include an inlet and an outlet, which may be configured to permit one or more streams to enter and exit the first reservoir, respectively. In some embodiments, the heating and/or the mixing of the second stream includes disposing the second stream in an inlet of the first reservoir or the first mixing apparatus.

[0031] Generally, the transporting of any one or more of the streams disclosed herein (e.g., the first stream, the second stream, the third stream, etc.) may be achieved with or assisted by any known apparatus, such as a pump. In some embodiments, the disposing of the second stream in the inlet of the first reservoir or the first mixing apparatus includes transporting the second stream or a component thereof with an apparatus, such as a pump, which may be a screw pump, peristaltic pump, etc.

[0032] Generally, the transporting of the hydrolysis agent and/or streams herein (e.g., the first stream, the second stream, the third stream, etc.) may be controlled, at least in part, with one or more flowmeters.

[0033] In some embodiments, the methods provided herein also include subjecting the third stream to heating, mixing, or a combination thereof for a time effective to drive a hydrolysis reaction at a desired rate, to a desired extent, or a combination thereof to convert at least a portion of the lecithin to a product, wherein the product includes lysolecithin.

[0034] In some embodiments, the methods include transporting a third stream from an outlet of a first reservoir or a first mixing apparatus to a second reservoir. The heating and/or the mixing of the third stream may occur, at least in part, in the second reservoir. The second reservoir may be a reactor.

[0035] In some embodiments, the time effective to convert at least a portion of the lecithin to the product is about 30 seconds to about 4 hours, about 30 seconds to about 3.5 hours, about 30 seconds to about 3 hours, about 30 seconds to about 2.5 hours, about 30 seconds to about 2 hours, about 30 seconds to about 1.5 hours, about 30 seconds to about 1 hour, about 30 seconds to about 40 minutes, about 30 seconds to about 30 minutes, about 30 seconds to about 25 minutes, about 30 seconds to about 20 minutes, about 30 seconds to about 15 minutes, about 30 seconds to about 10 minutes, about 1 minute to about 40 minutes, about 1 minute to about 30 minutes, about 1 minute to about 25 minutes, about 1 minute to about 20 minutes, about 1 minute to about 15 minutes, about 1 minute to about 10 minutes, about 2 minutes to about 40 minutes, about 2 minutes to about 30 minutes, about 2 minutes to about 25 minutes, about 2 minutes to about 20 minutes, about 2 minutes to about 15 minutes, about 2 minutes to about 10 minutes, about 5 minutes to about 40 minutes, about 5 minutes to about 30 minutes, about 5 minutes to about 25 minutes, about 5 minutes to about 20 minutes, about 5 minutes to about 15 minutes, about 5 minutes to about 10 minutes, about 10 minutes to about 40 minutes, about 10 minutes to about 20 minutes, about 12 minutes to about 18 minutes, about 14 minutes to about 16 minutes, about 15 minutes, about 15 minutes to about 40 minutes, about 20 minutes to about 40 minutes, or about 25 minutes to about 40 minutes.

[0036] In some embodiments, the heating of the third stream includes heating the third stream to a temperature at which the hydrolysis agent is effective to facilitate the hydrolysis reaction of the lecithin. In some embodiments, the heating of the third stream includes heating the third stream to a temperature of at least 40 ℃, at least 45 ℃, or at least 50 ℃. In some embodiments, the heating of the third stream includes heating the third stream to a temperature of about 50 ℃ to about 70 ℃, about 55 ℃ to about 65 ℃, or about 60 ℃.

[0037] In some embodiments, the methods also include heating the third stream at a temperature and for a time effective to inactivate the hydrolysis agent. A hydrolysis agent is "inactivated" when its ability to facilitate a hydrolysis reaction is reduced by at least 95 %, at least 99 %, or 100 %.

[0038] In some embodiments, the methods also include isolating a product from the third stream. The isolating of the product from the third stream may be achieved using any known technique. In some embodiments, the isolating of the product includes heating the second stream or the third stream at a temperature and for a time effective to remove at least 80 %, at least 85 %, at least 90 %, at least 95 %, at least 98 %, at least 99 %, or 100 %, by weight, of the water from the third stream.

[0039] *Product*

[0040] The product of embodiments of the methods provided herein may include lysolecithin. In some embodiments, after the isolating of the product, water is present in the product at a concentration that does not exceed 30 wt%, 25 wt%, 20 wt%, 15 wt%, 10 wt%, 5 wt%, or 1 wt%, based on the weight of the product.

[0041] In some embodiments, the product includes phosphatidylcholine (PC), lysophosphatidylcholine (LPC), or a combination thereof. In some embodiments, after the isolating of the product, PC is present in the product at a concentration of about 0.5 wt% to about 20 wt%, about 0.5 wt% to about 15 wt%, about 0.5 wt% to about 10 wt%, about 0.5 wt% to about 5 wt%, about 5 wt% to about 20 wt%, about 5 wt% to about 15 wt%, about 5 wt% to about 10 wt%, or about 5 wt% to about 8 wt%, based on the weight of the product. In some embodiments, after the isolating of the product, LPC is present in the product at a concentration of about 1 wt% to about 14 wt%, about 1 wt% to about 12 wt%, about 1 wt% to about 10 wt%, about 1 wt% to about 8 wt%, about 1 wt% to about 6 wt%, about 1 wt% to about 4 wt%, about 2 wt% to about 10 wt%, about 4 wt% to about 10 wt%, about 6 wt% to about 10 wt%, or about 8 wt% to about 10 wt%, based on the weight of the product.

[0042] In some embodiments, the conversation rate of the methods provided herein is about 10 wt% to about 75 wt%, about 20 wt% to about 75 wt%, about 30 wt% to about 75 wt%, about 40 wt% to about 75 wt%, about 50 wt% to about 75 wt%, about 60 wt% to about 75 wt%, about 10 wt % to about 70 wt%, about 10 wt% to about 60 wt%, about 10 wt% to about 50 wt%, about 10 wt% to about 40 wt%, about 10 wt% to about 30 wt%, or about 10 wt% to about 20 wt%, wherein the phrase “conversion rate” refers to the wt% of PC of the lecithin that is converted to LPC.

[0043] The product produced by embodiments of the methods provided herein may include lysolecithin. In some embodiments, the product also includes phosphatidylcholine (PC).

[0044] *Hydrolysis Agent*

[0045] Generally, any hydrolysis agent that is effective to facilitate a hydrolysis reaction of lecithin may be used in embodiments of the methods provided herein. The hydrolysis agent may include an enzyme. For example, the hydrolysis agent may include a phospholipase, such as phospholipase A1, phospholipase A2, phospholipase B, or a combination thereof.

[0046] All referenced publications are incorporated herein by reference in their entirety. Furthermore, where a definition or use of a term in a reference, which is incorporated by reference herein, is inconsistent or contrary to the definition of that term provided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply.

[0047] While certain aspects of conventional technologies have been discussed to facilitate disclosure of various embodiments, applicants in no way disclaim these technical aspects, and it is contemplated that the present disclosure may encompass one or more of the conventional technical aspects discussed herein.

[0048] The present disclosure may address one or more of the problems and deficiencies of known methods and processes. However, it is contemplated that various embodiments may prove useful in addressing other problems and deficiencies in a number of technical areas. Therefore, the present disclosure should not necessarily be construed as limited to addressing any of the particular problems or deficiencies discussed herein.

[0049] In this specification, where a document, act or item of knowledge is referred to or discussed, this reference or discussion is not an admission that the document, act or item of knowledge or any combination thereof was at the priority date, publicly available, known to the public, part of common general knowledge, or otherwise constitutes prior art under the applicable statutory provisions; or is known to be relevant to an attempt to solve any problem with which this specification is concerned.

[0050] In the descriptions provided herein, the terms "includes," "is," "containing," "having," and "comprises" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to." When methods or systems are claimed or described in terms of "comprising" various steps or components, the methods or systems can also "consist essentially of" or "consist of" the various steps or components, unless stated otherwise.

[0051] The terms "-a," "-an," and "-the" are intended to include plural alternatives, e.g., at least one. For instance, the disclosure of "a hydrolysis agent," "a stream", and the like, is meant to encompass one, or mixtures or combinations of more than one hydrolysis agent, stream, and the like, unless otherwise specified.

[0052] Various numerical ranges may be disclosed herein. When Applicant discloses or claims a range of any type, Applicant's intent is to disclose or claim individually each possible number that such a range could reasonably encompass, including end points of the range as well as any sub-ranges and combinations of sub-ranges encompassed therein, unless otherwise specified. Moreover, all numerical end points of ranges disclosed herein are approximate. As a representative example, Applicant discloses, in some embodiments, that water is present in the first stream at a concentration of about 25 wt% to about 35 wt%. This range should be interpreted as encompassing about 25 wt% and about 35 wt%, and further encompasses "about" each of 26 wt%, 27 wt%, 28 wt%, 29 wt%, 30 wt%, 31 wt%, 32 wt%, 33 wt%, and 34 wt%, including any ranges and sub-ranges between any of these values.

[0053] As used herein, the term "about" means plus or minus 10 % of the numerical value of the number with which it is being used.

[0054] EXAMPLES

[0055] The present invention is further illustrated by the following examples, which are not to be construed in any way as imposing limitations upon the scope thereof. On the contrary, it is to be clearly understood that resort may be had to various other aspects, embodiments, modifications, and equivalents thereof which, after reading the description herein, may suggest themselves to one of ordinary skill in the art without departing from the spirit of the present invention or the scope of the appended claims. Thus, other aspects of this invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein.

[0056] *Example 1 – Preparation of Lysolecithin*

[0057] In this example, the following materials were used: crude lecithin, phospholipase A1 (Novoenzymes A/S, Bagsvaerd, Denmark), and SUPELCOSIL™ LC-diol columns (250 x 4.6 mm, 5.0 μm) (Sigma-Aldrich, USA).

[0058] Laboratory Scale Continuous Enzymatic Hydrolysis Reactions

[0059] The following procedures were used in this example to conduct laboratory scale continuous enzymatic hydrolysis reactions at a 100 g scale.

[0060] The crude lecithin starting material contained about 10 wt% to about 300 wt% moisture, so an emulsifying step was carried out using mechanical stirring before the continuous hydrolysis reaction. Typically, 100 g crude lecithin was mixed with a phospholipase A1 solution (e.g., the enzyme was dissolved in the moisture first) in a 500 mL beaker. A homogenizer was used to emulsify the mixture at a temperature of about 50 ℃ to about 60 ℃ for about 1 minute to about 5 minutes. A uniform emulsion resulted.

[0061] Then, the emulsion was transferred into a continuous reactor by a pump to react for about 5 minutes to about 30 minutes in the continuous reactor.

[0062] After a desired reaction time, the mixture was heated to about 95 ℃ for 5 about minutes to inactivate the enzyme. The mixture was then dried at about 60 ℃ for about 4 hours to about 12 hours to remove the moisture from the product lysolecithin.

[0063] In this example, the conversion rate was calculated by molar ratio of LPC (in the product) / (PC+LPC) (in the starting material), and these numbers were obtained from high performance liquid chromatography performed with an evaporative light scattering detector (HPLC-ELSD) and phosphorus-31 nuclear magnetic resonance (NMR) spectroscopy.

[0064] A listing of the laboratory scale reactions performed in this example for the screening of continuous enzymatic hydrolysis reaction conditions is provided at **Table 1**. As shown at **Table 1**, enzyme amount, moisture, reaction time, temperature, and emulsification time were all screened as variables for this reaction.

[0065] **Table 1.** Lab-scale reactions conducted for the screening of continuous enzymatic hydrolysis reaction conditions for lysolecithin synthesis.

Entry	Enzyme amount (ppm, wt to lecithin wt)	Moisture (%)	Reaction time (min)	Reaction temperature (℃)	Emulsifying time (min)
1a	Blank	Blank	Blank	Blank	Blank
2a	50				
2b	100				
2c	200				
2d	300	30	15	60	3
2e	500				
2f	750				
2g	1000				

3a		10			
3b		30			
3c		50			
3d	200	80	15	60	3
3e		100			
3f		200			
3g		300			
4a			5		
4b			10		
4c	200	30	15	60	3
4d			20		
4e			25		
5a				50	
5b				55	
5c	200	30	15	60	3
5d				65	
5e				70	
6a					1
6b					2
6c	200	30	15	60	3
6d					4
6e					5

[0066] Pilot Scale Continuous Enzymatic Hydrolysis Reactions

[0067] The following procedures were used in this example to perform pilot scale lysolecithin synthesis using a continuous enzymatic hydrolysis reaction.

[0068] Two 100 L holding tanks, one peristaltic pump, one screw pump, one intensive inline mixer, and one 10 L stainless steel continuous reactor were used in this example.

[0069] A schematic of the system and method used in the embodiments of this example are depicted at **FIG. 1**. Briefly, in the system/process **100** of **FIG. 1**, crude lecithin **101** and the enzyme solution **102** of this example, i.e., phospholipase A1, were charged into an intensive inline mixer **130** via a screw pump **110** and peristaltic pump **120**, respectively. The enzyme solution **102** was delivered with the aid of a flow meter **121**. After emulsifying in the mixer **130**, the mixture **103** was directly transferred into the 10 L continuous reactor **140** for the subsequent reaction at about 60 °C. The final product lysolecithin **104** was then obtained after de-activation and drying **150**. The phospholipids in the product were also analyzed by HPLC-

ELSD and ^{31}P NMR. Reaction conditions for all batches of the pilot scale tests of this example are listed at **Table 2**.

[0070] **Table 2**. Continuous enzymatic hydrolysis reaction conditions for pilot scale batches of this example (other reaction parameters were the same if not mentioned in the following table).

Batch	Enzyme amount (ppm, wt to lecithin wt)	Moisture (%)	Reaction time (min)	Reaction temperature (°C)	Emulsifying time (min)
1	200				
2	200				
3	200	30	15	60	3
4	200				
5	200				

[0071] HPLC-ELSD Analysis of phospholipids

[0072] An HPLC-ELSD method was used in this example for the quantification of PC and LPC in the lecithin and lysolecithin, as explained in the literature (see, e.g., Sas B. et al. Journal of Chromatography A, 1999, 864(1): 179-182).

[0073] ^{31}P-NMR analysis

[0074] ^{31}P-NMR was run according to a method explained in the literature (see, e.g., Mayar, M. et al. Journal of agricultural and food chemistry, 2020, 68(17): 5009-50177). This analytical technique provided the molar ratio of PC and LPC molecules based on an internal standard, i.e., triphenyl phosphate (PPh_3). The weight percent of each molecule was calculated based on their molecular weight and molar ratio from the ^{31}P-NMR data.

[0075] Results – Effect of moisture, enzyme amount, emulsifying time, temperature, and reaction time on conversion rates of lysolecithin

[0076] All conversion rates of lysolecithin from the foregoing laboratory scale reactions are listed at Table 3.

[0077] **Table 3.** Conversion rate of lysolecithin as affected by enzyme amount, moisture, reaction time, reaction temperature and emulsifying time.

Entry	Enzyme amount (ppm, wt to lecithin wt)	Moisture (%)	Reaction time (min)	Reaction temperature (°C)	Emulsifying time (min)	PC content (%)	LPC content (%)	Conversion rate (%)

1a	Blank	Blank	Blank	Blank	Blank	16.8	0	0
2a	50					11.2	4.0	36%
2b	100					8.2	5.3	47%
2c	200					6.2	6.4	57%
2d	300	30	15	60	3	4.2	7.8	70%
2e	500					5.4	6.7	60%
2f	750					4.6	6.9	61%
2g	1000					2.2	6.2	56%
3a		10				13.6	2.7	24%
3b		30				6.2	6.4	57%
3c		50				4.8	7.5	67%
3d	200	80	15	60	3	1.6	6.7	60%
3e		100				1.3	5.6	50%
3f		200				1.0	3.4	30%
3g		300				0.8	1.8	16%
4a			5			12.0	3.0	27%
4b			10			8.8	4.8	43%
4c	200	30	15	60	3	6.2	6.4	57%
4d			20			5.3	6.7	60%
4e			25			4.8	6.9	61%
5a				50		8.0	4.6	41%
5b				55		6.6	5.6	50%
5c	200	30	15	60	3	6.2	6.4	57%
5d				65		7.2	5.6	50%
5e				70		8.5	4.6	41%
6a					1	8.8	4.6	41%
6b					2	7.2	5.6	50%
6c	200	30	15	60	3	6.2	6.4	57%
6d					4	5.4	6.4	57%
6e					5	6.2	6.1	54%

[0078] As summarized at **FIG. 2A—FIG. 2E**, enzyme amount, moisture, reaction time, reaction temperature and emulsifying time exhibited a significant effect on the conversion rate of lysolecithin. Specifically, **FIG. 2A—FIG. 2E** depict the effects of enzyme amount (**FIG. 2A**), moisture (**FIG. 2B**), reaction time (**FIG. 2C**), reaction temperature (**FIG. 2D**), and emulsifying time (**FIG. 2E**) on the conversion rates of lysolecithin.

[0079] When the reaction conditions included 30 wt% moisture (relative to lysolecithin), a 15 minute reaction time, a 60 °C reaction temperature, and 3 minutes of emulsifying time (Entry 1a, 2a-2g, Table 3), the conversion rate of lysolecithin (36%, 47%, 57%, 70%, 67%, 60%,

61%, and 56%) first increased along with the increasing enzyme amounts (50 ppm, 100 ppm, 200 ppm, 300 ppm), and then decreased slightly as the enzyme amount further increased (500 ppm, 750 ppm, 1000 ppm) (**FIG. 2A**).

[0080] When moisture content was screened (Entry 1a, 3a-3g, Table 3), the conversion rate of lysolecithin (24%, 57%, 67%, 60%, 50%, 30% and 16%) also increased at first, and then decreased along with the moisture content (10%, 30%, 50%, 80%, 100%, 200% and 300%) (**FIG. 2B**).

[0081] A similar trend was observed when the effects of reaction temperature (**FIG. 2D**) and emulsifying time (**FIG. 2E**) were screened.

[0082] However, the conversion rate of lysolecithin (27%, 43%, 57%, 60% and 61%) increased along with the reaction time (5 minutes, 10 minutes, 15 minutes, 20 minutes, and 25 minutes) (**FIG. 2C**). The increase became less pronounced after the reaction time was greater than 15 minutes.

[0083] *Example 2 – Optimization of Reaction Conditions*

[0084] In this example, reaction conditions were optimized for embodiments of producing lysolecithin using a continuous enzymatic hydrolysis reaction.

[0085] The effect of enzyme amount, moisture, reaction time, reaction temperature, and emulsifying time on the PC and LPC content are summarized at **FIG. 3A**—**FIG. 3E**. Specifically, these figures depict results showing the effects of enzyme amount (**FIG. 3A**), moisture (**FIG. 3B**), reaction time (**FIG. 3C**), reaction temperature (**FIG. 3D**), and emulsifying time (**FIG. 3E**) on the PC and LPC content after continuous enzymatic hydrolysis reactions.

[0086] Since PC was an important nutrient in the final product, the optimal reaction conditions of this example took into account not only the conversion rate of LPC, but also the residual amount of PC in the product, and the production cost.

[0087] As enzyme cost can be a significant production cost, it can be advantageous to control, reduce, or minimize the amount of enzyme used in the methods provided herein. Therefore, 200 ppm of enzyme was selected as an addition amount in the following experiments, due to its high PC and LPC content (6.2% and 6.4%, respectively) at a relatively low cost (**FIG. 3A**). As shown at **FIG. 3B**, PC content decreased sharply when moisture increased above 50 wt%, which devalued the final product and increased the drying cost.

[0088] The following experiments were all conducted with 30 wt% moisture. PC content decreased sharply as the reaction time increased, while LPC content increased as the reaction time increased (**FIG. 3C**). However, the increase was not plainly evident after 15 minutes of reaction time.

[0089] The reaction time was 15 minutes in the following experiments. The reaction temperature was screened near the optimum activity temperature for the embodiment of the enzyme used in this example (**FIG. 3D**). The LPC content was the highest (6.4%) at 60 °C, and a high PC content residue (6.2%) also was observed. An emulsifying time of 3 minutes produced the best result for the embodiments of this example (**FIG. 3E**).

[0090] Therefore, the favorable reaction conditions for producing lysolecithin using the embodiments of continuous enzymatic hydrolysis reaction of this example were 200 ppm enzyme, 30 wt% moisture, 15 minute reaction time, and a 3 minute emulsifying time at 60 °C, and these parameters resulted in a conversion rate of about 57%. These parameters were applied in the following pilot scale tests.

[0091] Pilot Scale Lysolecithin Synthesis

[0092] The PC, LPC content and conversion rates from the pilot scale synthesis of this example are listed at Table 4.

[0093] **Table 4.** Conversion rates and isolated yields of HMBI from pilot scale synthesis.

Batch	Enzyme amount (ppm, wt to lecithin wt)	Moisture (%)	Reaction time (min)	Reaction temperature (°C)	Emulsifying time (min)	PC content (%)	LPC content (%)	Conversion rate (%)
1	200					5.9	6.7	60%
2	200					6.1	6.6	58%
3	200	30	15	60	3	6.1	6.9	61%
4	200					5.6	6.9	61%
5	200					6.2	6.7	60%

[0094] The conversion rates were very close to those from the foregoing laboratory scale synthesis when the same reaction conditions were employed. These similarities indicated the scalability of the processes of this example.

[0095] For example, the conversion rate using 200 ppm enzyme, 30 wt% moisture, a 15 minute reaction time, and 3 minutes of emulsifying time at 60 °C (Entry 2c, Table 3) was 57% in

the 100 g laboratory scale synthesis, with 6.2 % PC remaining. The conversion rate increased to about 60% (average) when scaled up to a 20 kg pilot synthesis with 6.0% (average) PC remaining (Batch 1-5, Table 4).

[0096] Comparison of a traditional batchwise reaction process with a continuous enzymatic hydrolysis reaction process

[0097] The process using a continuous enzymatic hydrolysis reaction to make lysolecithin exhibited one or more advantages over a traditional batchwise process used for the commercial production of lysolecithin. For example, the continuous processes occupied less space, thereby eliminating or reducing the need to build a factory with many reactors. As a further example, the reaction time and cycle time were significantly reduced. As yet another example, the labor input was greatly reduced due to the continuous reaction process.

[0098] A full comparison of the processes is provided at Table 5.

[0099] **Table 5.** Comparison of the new continuous reaction with traditional batchwise reaction process.

	Traditional batchwise reaction process	**Newly continuous reaction process**
Reaction time (h)	> 6	0.3
Cycle time per batch (h)	> 8	0.5
Capacity	1-10 mt/batch	1-5 mt/hour
Labor cost (USD/kg product)	0.2-0.5	0

[0100] The screening of reaction conditions described in the foregoing examples revealed that the PC and LPC content both decreased as the variants changed (Entry 2f-2g, 3d-3g, Table 2). This likely was due to an excessive hydrolysis of lecithin by the excess addition of phospholipase A1, which, in all likelihood, produced another product, i.e., glycerylphosphorylcholine (GPC) (see, e.g., Zhang, K. et al. European Journal of Lipid Science and Technology, 2012, 114(11): 1254-1260).

[0101] Nevertheless, the continuous enzymatic hydrolysis reactions described herein can be precisely controlled—such as by controlling the reaction time—which may avoid or reduce the likelihood of "over" hydrolyzing the lecithin. The ability to control the continuous enzymatic hydrolysis reactions may ensure the stability of the lysolecithin products.

[0102] Compared to traditional batchwise reaction processes, the continuous reaction processes of the foregoing examples provided one or more advantages in addition to occupying smaller occupation spaces. For example, embodiments of the continuous reaction processes reduced reaction times and cycle times by at least 95% and 94%, respectively (Table 5), which reduced operational and energy costs. The cumbersome labor required for traditional batchwise reaction processes also was avoided or reduced, which can result in a significant reduction of manufacturing costs. In fact, the estimated total production cost savings were about $200 to about $400 per ton of lysolecithin product.

[0103] In the 20 kg pilot production test, the conversion rate (60%) was slightly greater than that of the corresponding laboratory scale (57%) test. A possible reason for this difference may have been the stronger emulsification effect of the intensive inline mixer used in the pilot experiment. These results, however, indicated the importance of emulsification for embodiments of the continuous reaction. An additional or alternative reason for this difference may have been that the pilot equipment used in the foregoing examples was more easily controlled.

[0104] ASPECTS

[0105] The following is a non-limiting listing of aspects of the disclosure.

[0106] Aspect 1. A method of producing a product, the method comprising, consisting essentially of, or consisting of providing a first stream comprising, consisting essentially of, or consisting of lecithin and water; and contacting the first stream and a hydrolysis agent to form a second stream, wherein the hydrolysis agent is effective to facilitate a hydrolysis reaction of the lecithin.

[0107] Aspect 2. The method of Aspect 1, further comprising, further consisting essentially of, or further consisting of subjecting the second stream to heating, mixing, or a combination thereof for a time effective to form a third stream comprising an emulsion.

[0108] Aspect 3. The method of Aspect 2, wherein the contacting of the first stream and the hydrolysis agent and the subjecting of the second stream to heating, mixing, or the combination thereof occurs simultaneously or sequentially.

[0109] Aspect 4. The method of any of Aspects 1 to 3, further comprising, further consisting essentially of, or further consisting of subjecting the second stream or the third stream to heating, mixing, or a combination thereof for a time effective to drive the hydrolysis reaction

at a desired rate, to a desired extent, or a combination thereof to convert at least a portion of the lecithin to a product, wherein the product comprises, consists essentially of, or consists of lysolecithin.

[0110] Aspect 5. The method of any of the preceding Aspects, further comprising, further consisting essentially of, or further consisting of heating the second stream or the third stream at a temperature and for a time effective to inactivate the hydrolysis agent.

[0111] Aspect 6. The method of any of the preceding Aspects, further comprising, further consisting essentially of, or further consisting of isolating the product from the second stream or the third stream.

[0112] *First Reservoir/First Mixing Apparatus*

[0113] Aspect 7. The method of any of the preceding Aspects, wherein the subjecting of the second stream to heating, mixing, or a combination thereof occurs, at least in part, in a first reservoir, a first mixing apparatus, or a combination thereof.

[0114] Aspect 8. The method of Aspect 7, wherein the first mixing apparatus comprises, consists essentially of, or consists of a static mixer.

[0115] Aspect 9. The method of Aspect 8, wherein the static mixer is a static inline mixer.

[0116] Aspect 10. The method of any of the preceding Aspects, wherein when the second stream is present in the first reservoir, the mixing of the second stream is achieved, at least in part, with a dynamic mixing apparatus.

[0117] Aspect 11. The method of any of the preceding Aspects, wherein the heating and/or the mixing of the second stream comprises, consists essentially of, or consists of disposing the second stream in an inlet of the first reservoir or the first mixing apparatus.

[0118] Aspect 12. The method of any of the preceding Aspects, wherein the disposing of the second stream in the inlet of the first reservoir or the first mixing apparatus comprises, consists essentially of, or consists of transporting the second stream or a component thereof with an apparatus, such as a pump, which may be a screw pump, peristaltic pump, etc.

[0119] Aspect 13. The method of any of the preceding Aspects, wherein the contacting of the first stream and the hydrolysis agent to form the second stream occurs, at least in part, in the first reservoir or the first mixing apparatus.

[0120] Aspect 14. The method of any of the preceding Aspects, wherein the contacting of the first stream and the hydrolysis agent to form the second stream occurs before the second stream is disposed in the inlet of the first reservoir or the first mixing apparatus.

[0121] Aspect 15. The method of any of the preceding Aspects, wherein the contacting of the first stream and the hydrolysis agent comprises, consists essentially of, or consists of transporting the first stream to the first reservoir or the first mixing apparatus, and transporting the hydrolysis agent to the first reservoir or the first mixing apparatus, wherein the transporting of the first stream and the hydrolysis agent is independently achieved with any known apparatus, such as a pump, e.g., a screw pump, peristaltic pump, etc.

[0122] Aspect 16. The method of Aspect 15, wherein the first stream is transported with a screw pump.

[0123] Aspect 17. The method of Aspect 15 or 16, wherein the hydrolysis agent is transported with a peristaltic pump.

[0124] Aspect 18. The method of any of the preceding Aspects, wherein the transporting of the first stream, the hydrolysis agent, the second stream, the third stream, or a combination thereof is controlled, at least in part, with one or more flowmeters.

[0125] *Second Reservoir*

[0126] Aspect 19. The method of any of the preceding Aspects, wherein the method further comprises transporting the third stream from an outlet of the first reservoir or the first mixing apparatus to a second reservoir.

[0127] Aspect 20. The method of Aspect 19, wherein the heating and/or the mixing of the third stream occurs, at least in part, in the second reservoir.

[0128] Aspect 21. The method of Aspect 19 or 20, wherein the second reservoir is a reactor.

[0129] *First Stream*

[0130] Aspect 22. The method of any of the preceding Aspects, wherein water is present in the first stream at a concentration of about 10 wt% to about 300 wt%, about 10 wt% to about 250 wt%, about 10 wt% to about 200 wt%, about 10 wt% to about 150 wt%, about 10 wtw% to about 100 t%, about 10 wt% to about 50 wt%, about 20 wt% to about 40 wt%, about 25 wt% to about 35 wt%, about 50 wt% to about 300 wt%, about 100 wt% to about 300 wt%, about 150

wt% to about 300 wt%, about 200 wt% to about 300 wt%, or about 250 wt% to about 300 wt%, based on the weight of the lecithin.

[0131] *Second Stream*

[0132] Aspect 23. The method of any of the preceding Aspects, wherein the hydrolysis agent is present in the second stream at a concentration of about 10 ppm to about 1,500 ppm, about 10 ppm to about 1,250 ppm, about 10 ppm to about 1,000 ppm, about 10 ppm to about 750 ppm, about 10 ppm to about 500 ppm, about 10 ppm to about 300 ppm, about 10 ppm to about 200 ppm, about 10 ppm to about 100 ppm, about 10 ppm to about 50 ppm, about 100 ppm to about 1,500 ppm, about 200 ppm to about 1,500 ppm, about 300 ppm to about 1,500 ppm, about 500 ppm to about 1,500 ppm, about 750 ppm to about 1,500 ppm, about 750 ppm to about 1,250 ppm, or about 750 ppm to about 1,000 ppm, relative to the lecithin.

[0133] *Third Stream*

[0134] Aspect 24. The method of any of the preceding Aspects, wherein the emulsion of the third stream is a uniform emulsion.

[0135] Aspect 25. The method of any of the preceding Aspects, wherein the emulsion is a Newtonian fluid, such as a Newtonian fluid that is transportable with known apparatuses, such as the pumps described herein.

[0136] *Reaction Times*

[0137] Aspect 26. The method of any of the preceding Aspects, wherein the time effective to form the third stream comprising, consisting essentially of, or consisting of the emulsion is about 1 minute to about 10 minutes, about 1 minute to about 8 minutes, about 1 minute to about 5 minutes, about 2 minutes to about 4 minutes, about 2.5 minutes to about 3.5 minutes, about 3 minutes, or about 1 minute to about 3 minutes.

[0138] Aspect 27. The method of any of the preceding Aspects, wherein the time effective to convert at least a portion of the lecithin to the product is about 30 seconds to about 4 hours, about 30 seconds to about 3.5 hours, about 30 seconds to about 3 hours, about 30 seconds to about 2.5 hours, about 30 seconds to about 2 hours, about 30 seconds to about 1.5 hours, about 30 seconds to about 1 hour, about 30 seconds to about 40 minutes, about 30 seconds to about 30 minutes, about 30 seconds to about 25 minutes, about 30 seconds to about 20 minutes, about 30 seconds to about 15 minutes, about 30 seconds to about 10 minutes, about 1 minute to about 40 minutes, about 1 minute to about 30 minutes, about 1 minute to about 25 minutes, about 1 minute

to about 20 minutes, about 1 minute to about 15 minutes, about 1 minute to about 10 minutes, about 2 minutes to about 40 minutes, about 2 minutes to about 30 minutes, about 2 minutes to about 25 minutes, about 2 minutes to about 20 minutes, about 2 minutes to about 15 minutes, about 2 minutes to about 10 minutes, about 5 minutes to about 40 minutes, about 5 minutes to about 30 minutes, about 5 minutes to about 25 minutes, about 5 minutes to about 20 minutes, about 5 minutes to about 15 minutes, about 5 minutes to about 10 minutes, about 10 minutes to about 40 minutes, about 10 minutes to about 20 minutes, about 12 minutes to about 18 minutes, about 14 minutes to about 16 minutes, about 15 minutes, about 15 minutes to about 40 minutes, about 20 minutes to about 40 minutes, or about 25 minutes to about 40 minutes.

[0139] *Reaction Temperatures*

[0140] Aspect 28. The method of any of the preceding Aspects, wherein the heating of the second stream or the third stream comprises heating the second stream or the third stream to (i) a temperature at which the hydrolysis agent is effective to facilitate the hydrolysis reaction of the lecithin, (ii) a temperature of at least 40 ℃, at least 45 ℃, or at least 50 ℃, or (iii) a temperature of about 50 ℃ to about 70 ℃, about 55 ℃ to about 65 ℃, or about 60 ℃.

[0141] *Hydrolysis Agent*

[0142] Aspect 29. The method of any of the preceding Aspects, wherein the hydrolysis agent comprises, consists essentially of, or consists of an enzyme.

[0143] Aspect 30. The method of any of the preceding Aspects, wherein the hydrolysis agent comprises, consists essentially of, or consists of a phospholipase.

[0144] Aspect 31. The method of any of the preceding Aspects, wherein the hydrolysis agent comprises, consists essentially of, or consists of phospholipase A1, phospholipase A2, phospholipase C, phospholipase D, or a combination thereof.

[0145] *Isolating the Product*

[0146] Aspect 32. The method of any of the preceding Aspects, wherein the isolating of the product comprises, consists essentially of, or consists of heating the second stream or the third stream at a temperature and for a time effective to remove at least 80 %, at least 85 %, at least 90 %, at least 95 %, at least 98 %, at least 99 %, or 100 %, by weight, of the water from the second stream or the third stream.

[0147] *Product*

[0148] Aspect 33. The method of any of the preceding Aspects, wherein, after the isolating of the product, water is present in the product at a concentration that does not exceed 30 wt%, 25 wt%, 20 wt%, 15 wt%, 10 wt%, 5 wt%, or 1 wt%, based on the weight of the product.

[0149] Aspect 34. The method of any of the preceding Aspects, wherein the product further comprises or further consists essentially of phosphatidylcholine (PC).

[0150] Aspect 35. The method of Aspect 34, wherein, after the isolating of the product, PC is present in the product at a concentration of about 0.5 wt% to about 20 wt%, about 0.5 wt% to about 15 wt%, about 0.5 wt% to about 10 wt%, about 0.5 wt% to about 5 wt%, about 5 wt% to about 20 wt%, about 5 wt% to about 15 wt%, about 5 wt% to about 10 wt%, or about 5 wt% to about 8 wt%, based on the weight of the product.

[0151] Aspect 36. The method of any of the preceding Aspects, wherein, after the isolating of the product, lysophosphatidylcholine (LPC) is present in the product at a concentration of about 1 wt% to about 14 wt%, about 1 wt% to about 12 wt%, about 1 wt% to about 10 wt%, about 1 wt% to about 8 wt%, about 1 wt% to about 6 wt%, about 1 wt% to about 4 wt%, about 2 wt% to about 10 wt%, about 4 wt% to about 10 wt%, about 6 wt% to about 10 wt%, or about 8 wt% to about 10 wt%, based on the weight of the product.

[0152] *Conversion Rates*

[0153] Aspect 37. The method of any of the preceding Aspects, wherein about 10 wt% to about 75 wt%, about 20 wt% to about 75 wt%, about 30 wt% to about 75 wt%, about 40 wt% to about 75 wt%, about 50 wt% to about 75 wt%, about 60 wt% to about 75 wt%, about 10 wt % to about 70 wt%, about 10 wt% to about 60 wt%, about 10 wt% to about 50 wt%, about 10 wt% to about 40 wt%, about 10 wt% to about 30 wt%, or about 10 wt% to about 20 wt% of the lecithin is converted to lysolecithin, wherein the phrase "conversion rate" refers to the wt% of PC converted to LPC.

[0154] *Provisos*

[0155] Aspect 38. The method of any of the preceding Aspects, wherein the first stream does not include a non-aqueous liquid, such as an organic liquid, and/or wherein (i) the contacting of the first stream and the hydrolysis agent, (ii) the subjecting of the second stream to heating, mixing, or a combination thereof, and/or (iii) the subjecting of the third stream to heating, mixing, or a combination thereof does not occur in the presence of a non-aqueous liquid, such as an organic liquid.

[0156] Aspect 39. The method of any of the preceding Aspects, wherein the first stream does not include a hydroxyl-containing acceptor, and/or wherein (i) the contacting of the first stream and the hydrolysis agent, (ii) the subjecting of the second stream to heating, mixing, or a combination thereof, and/or (iii) the subjecting of the third stream to heating, mixing, or a combination thereof does not occur in the presence of a hydroxyl-containing acceptor, such as any compound (e.g., serine, glycerol, L-ascorbic acid, gluclose, choline, etc.) that can receive or accept a phosphatidyl group in the presence of a phospholipase.

[0157] *Systems*

[0158] Aspect 40. A system, as depicted at **FIG. 1**.

[0159] Aspect 41. A system, such as a system for performing, in whole or in part, any of the methods of the preceding Aspects, wherein the system comprises, consists essentially of, or consists of (i) a first reservoir and/or a first mixing apparatus, and (ii) a reactor, wherein the reactor is in fluid communication with the first reservoir and/or the first mixing apparatus.

[0160] Aspect 42. The system of any of the preceding Aspects, further comprising, consisting essentially of, or consisting of a drying apparatus, wherein optionally the drying apparatus is in fluid communication with the reactor.

[0161] Aspect 43. The system of any of the preceding Aspects, further comprising, consisting essentially of, or consisting of one or more pumps, one or more flow meters, or a combination thereof.

[0162] Aspect 44. The system of any of the preceding Aspects, wherein the first mixing apparatus is a static mixing apparatus, such as an inline static mixing apparatus.

We claim -

1. A method of producing a product, such as a continuous method, the method comprising:

providing a first stream comprising lecithin and water, wherein the water is present in the first stream at a concentration of about 10 wt% to about 300 wt%, based on the weight of the lecithin;

contacting the first stream and a hydrolysis agent to form a second stream, wherein the hydrolysis agent is effective to facilitate a hydrolysis reaction of the lecithin;

subjecting the second stream to heating, mixing, or a combination thereof for a time effective to form a third stream comprising an emulsion; and

subjecting the third stream to heating, mixing, or a combination thereof for a time effective to drive the hydrolysis reaction at a desired rate, to a desired extent, or a combination thereof to convert at least a portion of the lecithin to a product;

wherein the product comprises lysolecithin; and

wherein optionally the time effective to convert at least a portion of the lecithin to the product is about 30 seconds to about 4 hours.

2. The method of claim 1, wherein the mixing of the second stream comprises disposing the second stream in an inlet of a mixing apparatus.

3. The method of claim 2, wherein the mixing apparatus is a static mixer.

4. The method of claim 2, further comprising transporting the third stream from an outlet of the mixing apparatus to a reservoir, wherein the heating and/or the mixing of the third stream occurs, at least in part, in the reservoir.

5. The method of claim 1, further comprising heating the third stream at a temperature and for a time effective to inactivate the hydrolysis agent.

6. The method of claim 1, further comprising isolating the product from the third stream.

7. The method of claim 6, wherein the isolating of the product comprises heating the third stream at a temperature and for a time effective to remove at least 95 %, by weight, of the water from the third stream.

8. The method of claim 1, wherein the hydrolysis agent comprises an enzyme.

9. The method of claim 8, wherein the enzyme comprises a phospholipase.

10. The method of claim 1, wherein the hydrolysis agent is present in the second stream at a concentration of about 10 ppm to about 1,500 ppm, relative to the lecithin.

11. The method of claim 1, wherein the water is present in the first stream at a concentration of about 20 wt% to about 40 wt%, based on the weight of the lecithin.

12. The method of claim 1, wherein the water is present in the first stream at a concentration of about 30 wt%, based on the weight of the lecithin.

13. The method of claim 1, wherein the time effective to form the third stream is about 2 minutes to about 4 minutes.

14. The method of claim 1, wherein the time effective to form the third stream is about 3 minutes.

15. The method of claim 1, wherein (i) the time effective to drive the hydrolysis reaction is about 10 minutes to about 20 minutes, (ii) the third stream is heated to a temperature of about 55 ℃ to about 60 ℃ to drive the hydrolysis reaction, or (iii) a combination thereof.

16. The method of claim 1, wherein the product further comprises phosphatidylcholine (PC).

17. The method of claim 16, wherein, after the isolating of the product, the phosphatidylcholine is present in the product at a concentration of about 5 wt% to about 10 wt%, based on the weight of the product.

18. The method of claim 1, wherein the lysolecithin comprises lysophosphatidylcholine, and wherein, after the isolating of the product, the lysophosphatidylcholine is present in the product at a concentration of about 2 wt% to about 14 wt%, based on the weight of the product.

19. The method of claim 1, wherein the lecithin comprises phosphatidylcholine, wherein the lysolecithin comprises lysophosphatidylcholine, and wherein about 50 wt% to about 75 wt%, of the phosphatidylcholine of the lecithin is converted to the lysophosphatidylcholine of the product.