CONTINUOUS AND SCALABLE PROCESSING OF FAST PYROLYSIS OIL TO YIELD A HEAVY AROMATIC FRACTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Patent Application No. 63/521,060 filed on June 14, 2023, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This invention relates to fractionating fast pyrolysis oil (FPO) from lignocellulosic biomass quantitatively into energy dense streams (e.g., a heavy aromatic fraction and a water-soluble organic fraction), and a comprehensive upgrading approach for recovering value-added products (e.g., precursors for fuel range hydrocarbons, fuel oils, fuel additives, and fuel blends; concentrated fermentable sugars; industrial solvents, and chemicals).

BACKGROUND

[0003] Pyrolysis oil (FPO) is a liquid product produced from fast pyrolysis of biomass. In the fast pyrolysis process, biomass is rapidly heated to 450-550^{o}C in the absence of oxygen and with a short residence time, and rapidly quenched to produce FPO in the form of a condensate. Depending on the process conditions and the condensation train, FPO can either be a single phase mixture or a two-phase mixture with a heavy aromatic fraction (HAF) and a water-soluble organic fraction (WSOF).

SUMMARY

[0004] In a first general example, a system for separating a heavy aromatic fraction from fast pyrolysis oil includes a mixing system having a feedstock inlet and configured to accept recycled downstream water and solvent. A separator is coupled to the mixing system. A liquid-liquid extractor is coupled to the separator. A collector vessel is coupled to the separator and configured to accept an input stream from the liquid-liquid extractor. A solvent stripping column is coupled to the collector vessel. A distillation column is coupled to the solvent stripping column. An evaporator is configured to accept an aqueous raffinate from the liquid-liquid extractor. The distillation column is configured to accept an overhead from the solvent stripping column and from the evaporator. In some cases, the separator is configured to provide a heavy aromatic fraction and water-soluble organic fraction by

solvent-aided emulsion inversion. In certain cases, the collector is configured to accept an aqueous raffinate from the liquid-liquid extractor.

[0005] In a second general example, producing a heavy aromatic fraction from fast pyrolysis oil includes combining fast pyrolysis oil and a first solvent to yield an emulsion; heating the emulsion to yield an organic phase and an aqueous phase; vapor stripping the organic phase with a second solvent to yield the heavy aromatic fraction and a condensate comprising the first solvent, the second solvent, and water; concentrating the aqueous phase to yield a water-soluble organic fraction, water, and light ends comprising organic compounds having 1-6 carbon atoms; combining the condensate with the light ends to yield a mixture; distilling the mixture to yield a first stream comprising the first solvent and water and a second stream comprising the second solvent; combining the first stream with the fast pyrolysis oil to yield the emulsion; and combining the second stream with the organic phase to yield the heavy aromatic fraction and the condensate.

[0005a] In a first aspect of the present disclosure, there is provided a process for producing a heavy aromatic fraction from fast pyrolysis oil, the process comprising:

combining fast pyrolysis oil and a first solvent to yield an emulsion;

heating the emulsion to yield an organic phase and an aqueous phase;

vapor stripping the organic phase with a second solvent to yield the heavy aromatic fraction and a condensate comprising the first solvent, the second solvent, and water;

concentrating the aqueous phase to yield a water-soluble organic fraction, water, and light ends comprising organic compounds having 1-6 carbon atoms;

combining the condensate with the light ends to yield a mixture;

distilling the mixture to yield a first stream comprising the first solvent and water and a second stream comprising the second solvent;

combining the first stream with the fast pyrolysis oil to yield the emulsion; and

combining the second stream with the organic phase to yield the heavy aromatic fraction and the condensate.

[0006] The details of one or more examples of the subject matter of this disclosure are set forth in the accompanying drawings and the description. Other features, examples, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. 1 is a block flow diagram of a system and process for preparing a heavy aromatic fraction (HAF) and a water-soluble organic fraction (WSOF) from fast pyrolysis oil (FPO).

DETAILED DESCRIPTION

[0008] Fast pyrolysis oil (FPO) as a fuel has many environmental advantages when compared to fossil fuels. For example, combustion of FPO yields negligible quantities of SOx and half of the NOx of fossil fuel combustion, and is also CO_2 neutral. However, the large-scale use of FPO as a liquid fuel can be limited because of its high acidity and thermal instability. Furthermore, FPO has a high water content (e.g., 25-30%), high oxygen content (e.g., 40-50%), is immiscible with fossil fuels, and undergoes phase separation and an increase in viscosity during prolonged storage (aging).

[0009] FPO is a complex mixture containing various kinds of oxygenated organics (e.g., acids, aldehydes, alcohols, phenols, phenolic lignin-derivatives, anhydrosugars, and others with multiple functional groups). These oxygen containing organic compounds can make

WHAT IS CLAIMED IS:

1. A process for producing a heavy aromatic fraction from fast pyrolysis oil, the process comprising:

combining fast pyrolysis oil and a first solvent to yield an emulsion;

heating the emulsion to yield an organic phase and an aqueous phase;

vapor stripping the organic phase with a second solvent to yield the heavy aromatic fraction and a condensate comprising the first solvent, the second solvent, and water;

concentrating the aqueous phase to yield a water-soluble organic fraction, water, and light ends comprising organic compounds having 1-6 carbon atoms;

combining the condensate with the light ends to yield a mixture;

distilling the mixture to yield a first stream comprising the first solvent and water and a second stream comprising the second solvent;

combining the first stream with the fast pyrolysis oil to yield the emulsion; and

combining the second stream with the organic phase to yield the heavy aromatic fraction and the condensate.

2. The process of claim 1, wherein the fast pyrolysis oil is derived from lignocellulosic biomass comprising wood, straw, grasses, or any combination thereof.

3. The process of claim 1, wherein the first solvent comprises a C4-C8 alcohol, a C4-C8 alcohol-derived methyl or ethyl ester, a water-insoluble ketone, or a combination thereof.

4. The process of claim 3, wherein the water-insoluble ketone comprises methyl ethyl ketone, methyl isobutyl ketone, or a combination thereof.

5. The process of claim 1, wherein the second solvent comprises a C1-C4 alcohol.

6. The process of claim 5, wherein the second solvent comprises methanol, ethanol, n-propanol, isopropanol, butanol, or a combination thereof.

7. The process of claim 1, wherein the heavy aromatic fraction comprises polymeric, oligomeric, and monomeric aromatic derivatives of lignin.

8. The process of claim 1, wherein the aqueous phase comprises water-soluble organic compounds and water-soluble inorganic compounds from the fast pyrolysis oil.

9. The process of claim 1, wherein combining the fast pyrolysis oil and the first solvent occurs prior to combining water or an aqueous composition with the fast pyrolysis oil.

10. The process of claim 1, wherein combining the fast pyrolysis oil and the first solvent comprises stirring or static in-line mixing.

11. The process of claim 1, wherein combining the fast pyrolysis oil and the first solvent occurs at a pressure in a range of atmospheric pressure to about 100 psig.

12. The process of claim 1, wherein heating the emulsion occurs at a temperature in a range of 15°C to 65°C.

13. The process of claim 11, wherein heating the emulsion occurs at a temperature of about 40°C.

14. The process of claim 1, wherein the liquid flow regime of the emulsion provides a Reynolds Number between 5 and 1,000,000.

15. The process of claim 1, wherein the temperature, pressure, and flow conditions of combining the fast pyrolysis oil and the first solvent and heating the emulsion are selected such that a total amount of aromatic compounds in the organic phase is at least 80% mass fraction of the total amount of aromatic compounds of the fast pyrolysis oil.

16. The process of claim 1, wherein the water comprises 15% to 35% mass fraction of the emulsion.

17. The process of claim 1, wherein the first solvent comprises 1% to 25% mass fraction of the emulsion.

18. The process of claim 1, wherein the second organic phase comprises phenolic compounds and neutral compounds.

19. The process claim 1, wherein, in the vapor stripping, a mass fraction of the second solvent to a total amount of the heavy aromatic fraction and the first solvent is in a range of 5% to 20%.

20. The process of claim 1, wherein the distilling occurs at atmospheric pressure.

21. The process of claim 1, wherein the concentrating occurs at a pressure less than atmospheric pressure.

22. The process of claim 1, wherein a total amount of carbon in the heavy aromatic fraction and the water-soluble organic fraction comprises at least 90% or at least 95% of a total amount of carbon in the fast pyrolysis oil.

23. The process of claim 1, wherein a total amount of aromatic compounds in the heavy aromatic fraction is at least 95% mass fraction of an aromatic content of the fast pyrolysis oil.

24. The process of claim 1, wherein at least 95% mass fraction of pyrolytic sugars in the fast pyrolysis oil is transferred to the water-soluble organic fraction.

25. The process of claim 1, wherein at least 80% mass fraction of inorganic compounds in the fast pyrolysis oil is transferred to the water-soluble organic fraction.

26. The process of claim 1, further comprising combining water or an aqueous composition with the emulsion to yield a second emulsion.

27. The process of claim 26, wherein combining the water or the aqueous composition with the emulsion comprises stirring or static in-line mixing.

28. The process of claim 26, wherein combining the water or the aqueous composition with the emulsion occurs at a pressure in a range of atmospheric pressure to about 100 psig.

29. The process of claim 26, wherein the liquid flow regime of the second emulsion provides a Reynolds Number between 5 and 1,000,000.

30. The process of claim 26, wherein heating the emulsion comprises heating the second emulsion, and heating the second emulsion occurs at a temperature in a range of 15°C to 65°C.

31. The process of claim 30, wherein heating the second emulsion occurs at a temperature of about 40°C.

32. The process of claim 30, wherein the temperature, pressure, and flow conditions of combining the emulsion and the water or aqueous composition and heating the second emulsion are selected such that a total amount of aromatic compounds in the organic phase is at least 80% mass fraction of the total amount of aromatic compounds of the fast pyrolysis oil.

33. The process of claim 1, further comprising:

extracting the aqueous phase with an additional amount of the first solvent to yield an additional organic phase and an aqueous raffinate; and

combining the additional organic phase with the organic phase before vapor stripping the organic phase.

34. The process of claim 33, further comprising removing water from the aqueous raffinate to yield a first stream comprising residual pyrolysis oil and a second stream comprising water.

35. The process of claim 34, wherein the second stream is a clean water stream.

36. The process of claim 34, wherein the second stream comprises water-soluble organic compounds.

37. The process of claim 36, wherein the water-soluble organic compounds comprise acetic acid, acetol, glycoaldehyde, or any combination thereof.

38. The process of claim 37, wherein the second stream comprises about 2 wt% to about 7 wt% acetic acid.

39. The process of claim 37, wherein the second stream comprises about 1 wt% to about 3 wt% acetol.

40. The process of claim 37, wherein the second stream comprises about 0.1 wt% to about 1 wt% glycolaldehyde.

41. The process of claim 34, further comprising combining the second stream with the emulsion in a recycle loop.

42. The process of claim 41, wherein combining the second stream with the emulsion occurs before heating the emulsion.

43. The process of claim 34, wherein removing water from the aqueous raffinate comprises using a multiple-effect evaporator or a membrane filtration unit.