These methods are therefore not conducive to direct RNA collection from a sample (e.g., a biological sample) without significant sample processing.

[0006] Accordingly, compositions and methods that enable dry-state RNA extraction and stabilization from a biological sample under ambient conditions within a single process-step are needed. Moreover, the ability to store a dried biological sample for a substantial period at ambient temperature and recover intact RNA thereafter for further analysis is highly desirable.

BRIEF DESCRIPTION

[0007] There is provided a solid matrix comprising at least one protein denaturant, and at least one acid or acid-titrated buffer reagent impregnated therein in a dry state; wherein the matrix is configured to provide an acidic pH upon hydration, extract nucleic acids from a sample and preserve the nucleic acids in a substantially dry state at ambient temperature.

[0007a] In an aspect, there is provided a solid matrix, comprising:

at least one protein denaturant, and

at least one acid or acid-titrated buffer reagent impregnated therein in a dry state;

wherein the matrix is a non-dissolvable dry solid material and wherein the matrix is configured to provide an acidic pH upon hydration, extract nucleic acids from a sample, and preserve the nucleic acids in a substantially dry state at ambient temperature; and the acid-titrated buffer reagent generates a pH in a range from 3 to 6, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

[0008] There is provided an RNA extraction matrix comprising a protein denaturant comprising a chaotropic agent, a detergent or combination thereof; and an acid or acid-titrated buffer reagent impregnated therein in a dry state, wherein the matrix is a porous non-dissolvable dry material configured to provide a pH between 2 and 7 upon

hydration for extracting RNA and stabilizing the extracted RNA with an RNA Integrity Number (RIN) of at least 4.

[0008a] In another aspect, there is provided an RNA extraction matrix comprising:

a protein denaturant comprising a chaotropic agent, a detergent or combinations thereof; and

an acid or acid-titrated buffer reagent impregnated therein in a dry state,

wherein the matrix is a porous non-dissolvable dry material configured to provide a pH in a range from 3 to 6 upon hydration for extracting RNA and stabilizing the extracted RNA with a RIN of at least 4, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

[0009] There is provided an RNA extraction matrix comprising a protein denaturant comprising a chaotropic agent, a detergent or combination thereof; an acid or acid-titrated buffer reagent; and an RNase inhibitor comprising a triphosphate salt

or pyrophosphate salt, impregnated therein in a dry state, wherein the matrix comprises a porous non-dissolvable dry material configured to provide a pH between 2 and 7 upon hydration and stabilize RNA with an RNA Integrity Number (RIN) of at least 4.

[0009a] In another aspect, there is provided an RNA extraction matrix comprising:

a protein denaturant comprising a chaotropic agent, a detergent or combinations thereof;

an acid or acid-titrated buffer reagent; and

an RNase inhibitor comprising a triphosphate salt or pyrophosphate salt impregnated therein in a dry state, wherein the matrix comprises a porous non-dissolvable dry material configured to provide a pH between 3 to 6 upon hydration and stabilize RNA with a RIN value of at least 4, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

[0010] There is provided a method for extracting and storing nucleic acids from a sample comprising the steps of providing the sample to a dry solid matrix comprising a protein denaturant and an acid or acid titrated buffer reagent; generating an acidic pH upon hydration for extraction of nucleic acids from the sample; drying the matrix comprising the extracted nucleic acids; and storing the extracted nucleic acids on the matrix in a substantially dry state at ambient temperature.

[0010a] In another aspect, there is provided a method for extracting and storing nucleic acids from a sample, the method comprising:

providing the sample on a dry non-dissolvable solid matrix comprising a protein denaturant and an acid or acid-titrated buffer reagent;

generating an acidic pH upon hydration for extraction of nucleic acids from the sample, wherein the acidic pH in a range from 3 to 6;

drying the matrix comprising the extracted nucleic acids; and

storing the extracted nucleic acids on the matrix in a substantially dry state at ambient temperature, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

DRAWINGS

[0011] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0012] FIG. 1 is a P^{31} NMR profile showing the oxidation of Tris(2-carboxyethyl) phosphine (TCEP) and preparation of TCEP Oxide (TCEP-O).

[0013] FIG. 2 shows a bar graph derived from a 5,5'-Dithiobis-(2-Nitrobenzoic Acid) (DTNB) colorimetric assay for TCEP and TCEP-O reducing activity on cellulose samples.

[0014] FIG. 3 shows RNA Integrity Numbers (RIN) for dried blood spots collected on chemically-treated cellulose paper containing TCEP or TCEP-O.

Claims:

1. A solid matrix, comprising:

   at least one protein denaturant, and

   at least one acid or acid-titrated buffer reagent impregnated therein in a dry state;

   wherein the matrix is a non-dissolvable dry solid material and wherein the matrix is configured to provide an acidic pH upon hydration, extract nucleic acids from a sample, and preserve the nucleic acids in a substantially dry state at ambient temperature; and the acid-titrated buffer reagent generates a pH in a range from 3 to 6, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

2. The matrix of claim 1 is a solid phase extraction matrix.

3. The matrix of claim 1, wherein the extracted and preserved nucleic acids comprise ribonucleic acids (RNA), deoxy ribonucleic acids (DNA) or a combination thereof.

4. The matrix of claim 1, wherein the extracted and preserved nucleic acids comprise RNA.

5. The matrix of claim 4, wherein the extracted and preserved RNA has an RNA integrity number (RIN) of at least 4.

6. The matrix of claim 1, wherein the acid comprises acetic acid, citric acid, tartaric acid, phosphoric acid, hydrochloric acid, Tris(2-carboxyethyl) phosphine- hydrochloric acid (TCEP-HCl), oxidized Tris(2-carboxyethyl) phosphine- hydrochloric acid (TCEP-O-HCl), sulfuric acid, nitric acid, vanillic acid, 3-(N-morpholino)propanesulfonic acid or combinations thereof.

7. The matrix of claim 1 further comprising a UV protectant, a free-radical scavenger, a chelator or combinations thereof.

8. The matrix of claim 7, wherein the UV protectant or free-radical scavenger is selected from the group consisting of hydroquinone monomethyl ether (MEHQ), hydroquinone (HQ), toluhydroquinone (THQ), and ascorbic acid.

9. The matrix of claim 1 further comprising an RNase inhibitor.

10. The matrix of claim 9, wherein the RNase inhibitor comprises a triphosphate salt, pyrophosphate salt or combinations thereof.

11. The matrix of claim 9, wherein the RNase inhibitor comprises vanadyl ribonucleoside complex (VRC), sodium pyrophosphate, or a commercially available RNase inhibitor.

12. The matrix of claim 9, wherein the RNase inhibitor comprises sodium triphosphate.

13. The matrix of claim 1 further comprising at least one reducing agent.

14. The matrix of claim 13, wherein the reducing agent is selected from the group consisting of dithiothreitol (DTT), 2-mercaptoethanol (2-ME), tris(2-carboxyethyl)phosphine (TCEP), tris(2-carboxyethyl)phosphine hydrochloride (TCEP-HCl) and a combination thereof.

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15. The matrix of claim 1, wherein the matrix is porous.

16. The matrix of claim 1, wherein the protein denaturant is selected from a group consisting of guanidinium hydrochloride, guanidinium thiocyanate, sodium thiocyanate, potassium thiocyanate, arginine, sodium dodecyl sulfate (SDS), urea and combinations thereof.

17. The matrix of claim 1, wherein the sample is a biological sample.

18. An RNA extraction matrix comprising:

a protein denaturant comprising a chaotropic agent, a detergent or combinations thereof; and

an acid or acid-titrated buffer reagent impregnated therein in a dry state,

wherein the matrix is a porous non-dissolvable dry material configured to provide a pH in a range from 3 to 6 upon hydration for extracting RNA and stabilizing the extracted RNA with a RIN of at least 4, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

19. The matrix of claim 18 further comprising a UV protectant or free-radical scavenger selected from the group consisting of hydroquinone monomethyl ether (MEHQ), hydroquinone (HQ), toluhydroquinone (THQ), ascorbic acid and combinations thereof.

20. An RNA extraction matrix comprising:

a protein denaturant comprising a chaotropic agent, a detergent or combinations thereof;

an acid or acid-titrated buffer reagent; and

an RNase inhibitor comprising a triphosphate salt or pyrophosphate salt impregnated therein in a dry state, wherein the matrix comprises a porous non-dissolvable dry material configured to provide a pH between 3 to 6 upon hydration and stabilize RNA with a RIN value of at least 4, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

21. A method for extracting and storing nucleic acids from a sample, the method comprising:

providing the sample on a dry non-dissolvable solid matrix comprising a protein denaturant and an acid or acid-titrated buffer reagent;

generating an acidic pH upon hydration for extraction of nucleic acids from the sample, wherein the acidic pH in a range from 3 to 6;

drying the matrix comprising the extracted nucleic acids; and

storing the extracted nucleic acids on the matrix in a substantially dry state at ambient temperature, wherein the matrix comprises cellulose, cellulose acetate, glass fiber or combinations thereof.

22. The method of claim 21 further comprising recovering the nucleic acids from the matrix.

23. The method of claim 22, wherein the recovery of the nucleic acids from the matrix comprises rehydrating the matrix in an aqueous solution, a buffer or an organic solution.

24. The method of claim 22, wherein the recovery of the nucleic acids from the matrix comprises electroelution.

25. The method of claim 21, wherein the sample is a biological sample.

26. The method of claim 25, wherein the biological sample comprises blood, serum, tissue, saliva, or cells.

27. The method of claim 25, wherein the sample is a cell extract, a tissue culture cell preparation, an impure nucleic acid or a purified nucleic acid.

28. The method of claim 21, wherein the extracted nucleic acids comprise RNA, DNA or a combination thereof.

29. The method of claim 21, wherein the extracted nucleic acids comprise RNA.

30. The method of claim 29, wherein the extracted RNA has a RIN of at least 4.

31. The method of claim 21, wherein the matrix further comprises a UV protectant, a free-radical scavenger, a chelator or combinations thereof.

32. The method of claim 31, wherein the UV protectant or free-radical scavenger is selected from the group consisting of hydroquinone monomethyl ether (MEHQ), hydroquinone (HQ), toluhydroquinone (THQ), and ascorbic acid.

33. The method of claim 21, wherein the matrix further comprises an RNase inhibitor.

34. The method of claim 21, wherein the matrix comprises a porous cellulose paper.

35. The method of claim 21, wherein the protein denaturant is selected from the group consisting of guanidinium hydrochloride, guanidinium thiocyanate, sodium thiocyanate, potassium thiocyanate, arginine, sodium dodecyl sulfate (SDS), urea and combinations thereof.

36. The method of claim 21, wherein the matrix further comprises a reducing agent selected from the group consisting of dithiothreitol (DTT), 2-mercaptoethanol (2-ME), tris(2-carboxyethyl)phosphine (TCEP), tris(2-carboxyethyl)phosphine hydrochloride (TCEP-HCl) and a combination thereof.

37. The method of claim 21, wherein the acid comprises acetic acid, citric acid, tartaric acid, phosphoric acid, hydrochloric acid, tris(2-carboxyethyl) phosphine-hydrochloric acid (TCEP-HCl), oxidized Tris(2-carboxyethyl) phosphine-hydrochloric acid (TCEP-O-HCl),