CLAIMS

1. A method comprising:

(a) infiltrating a piece of natural fibrous plant material with one or more chemical solutions; and

(b) after (a), subjecting the piece of natural fibrous plant material with the one or more chemical solutions therein to a first temperature of at least 80 ºC for a first time so as to produce a softened piece of fibrous plant material,

wherein a content of modified lignin in the softened piece after (b) is at least 90% of a content of native lignin in the piece of natural fibrous plant material prior to (a),

the modified lignin retained in the softened piece after (b) has shorter macromolecular chains than that of the native lignin in the fibrous plant material prior to (a), and

after (b), the softened piece of fibrous plant material comprises a salt of the one or more chemical solutions.

2. The method of claim 1, wherein a content of modified hemicellulose in the softened piece after (b) is at least 90% of a content of native hemicellulose in the piece of natural fibrous plant material prior to (a).

3. The method of claim 1, wherein the salt is a substantially pH-neutral salt immobilized within the softened piece of fibrous plant material.

4. The method of claim 1, wherein the salt is formed by reaction of the one or more chemical solutions with an acidic degradation product of native hemicellulose in the piece of natural fibrous plant material produced by the one or more chemical solutions during (b).

5. The method of claim 1, wherein the first temperature is in a range of 80-180 ºC, inclusive.

6. The method of claim 1, wherein at least 90% of the one or more chemical solutions infiltrated in the piece of natural fibrous material is consumed during (b).

7. The method of claim 1, wherein the softened piece of fibrous plant material after (b) has a substantially neutral pH.

8. The method of claim 1, wherein:

the subjecting to the first temperature of (b) comprises using steam to heat the piece of natural fibrous plant material with the one or more chemical solutions therein; and

the heating using steam is performed with the piece of natural fibrous plant material, with the one or more chemical solutions therein, in a pressure reactor or in a flow-through steam reactor.

9. The method of claim 1, further comprising, after (b):

(c) compressing the softened piece of fibrous plant material to produce a densified piece of fibrous plant material,

wherein the densified piece of fibrous plant material after (c) has a first density greater than a second density of the piece of natural fibrous plant material prior to (a), the first density is at least 1.15 g/cm^3, and the second density is less than 1.0 g/cm^3.

10. The method of claim 9, wherein the compressing comprises:

pressing the softened piece of fibrous plant material at a first pressure for a second time, followed by further pressing at a second pressure for a third time,

wherein (i) the second pressure is greater than the first pressure, (ii) the third time is greater than the second time, or both (i) and (ii),

the pressing at the first pressure for the second time is performed while subjecting the softened piece to a first pressing temperature, and

the pressing at the second pressure for the third time is performed while subjecting the softened piece to a second pressing temperature greater than the first pressing temperature.

11. The method of claim 1, further comprising, after (b):

(c) compressing the softened piece of fibrous plant material to produce a densified piece of fibrous plant material,

wherein the densified piece of fibrous plant material after (c) has a first density greater than a second density of the piece of natural fibrous plant material prior to (a), and

a content of the modified lignin in the densified piece after (c) is at least 90% of the content of the native lignin in the piece of natural fibrous plant material prior to (a).

12. The method of claim 1, wherein the piece of natural fibrous plant material prior to (a) has a native microstructure of open lumina formed by cellulose-based cell walls, and the softened piece produced by (b) retains the open lumina formed by the cellulose-based cell walls.

13. The method of claim 1, wherein the natural fibrous plant material is wood, bamboo, reed, or grass.

14. The method of claim 1, wherein (a) and (b) are performed without producing black liquor or other waste liquid.

15. A structure comprising:

a densified piece of fibrous plant material having a density of at least 1.0 g/cm^3 and modified lignin therein,

wherein the modified lignin has shorter macromolecular chains than that of native lignin in natural fibrous plant material, and

the densified piece of fibrous plant material comprises a salt of an alkaline chemical immobilized within a microstructure of the fibrous plant material.

16. The structure of claim 15, wherein:

a content of modified lignin in the densified piece of fibrous plant material is at least 90% of a content of the native lignin in the natural fibrous plant material; and

a content of modified hemicellulose in the densified piece of fibrous plant material is at least 90% of a content of native hemicellulose in the natural fibrous plant material.

17. The structure of claim 15, wherein the salt is substantially pH-neutral.

18. The structure of claim 15, wherein the densified piece of fibrous plant material has been compressed in a direction substantially perpendicular to a longitudinal growth direction of the fibrous plant material, such that lumina formed by cellulose-based cell walls in a microstructure of the fibrous plant material have substantially collapsed.

19. The structure of claim 15, wherein:

a density of the densified piece of fibrous plant material is at least 1.15 g/cm^3; and

a density of the natural fibrous plant material is less than 1.0 g/cm^3.

20. The structure of claim 15, wherein the natural fibrous plant material is wood, bamboo, reed, or grass.