that can cause human health issues upon inhalation; it is non-biodegradable and hence not environmentally friendly. Additionally, rock wool can lead to a high pH value of around 8 requiring a pre-soaking process in pH adjusted water before use. Sand is heavy and requires additional containers to preserve its shape. Furthermore, sand only retains water for a short time and needs to be watered frequently. Synthetic polymers such as polystyrene and polyethylene are not readily biodegradable, resulting in plastic pollution. Moreover, some of the above substrates are solids with limited porosities, which limit nutrient flow and fluid exchange. This can lead to stagnant water accumulation around plants' roots. Therefore, stagnant water is a main challenge in hydroponics culture that can cause chlorosis, pallor, retarded growth and eventual death.

There is therefore a need to develop support substrates that can overcome, or at least ameliorate, one or more of the disadvantages described above. There is also a need to develop substrates with improved properties or even the ideal substrates for plant growth and hydroponics applications.

Summary

The present disclosure refers to a substrate comprising:

(a) keratin derivative; and
(b) natural biopolymer,

wherein the keratin derivative and natural biopolymer are crosslinked.

In one aspect, the present disclosure refers to a substrate comprising:

(a) keratin derivative; and
(b) natural biopolymer,

wherein the natural biopolymer is selected from the group consisting of nanocellulose, modified nanocellulose, chitin, modified chitin, fibrinogen, modified fibrinogen, starch, modified starch, sericin, modified sericin, pullulan, modified pullulan, and combinations thereof, and

wherein the keratin derivative and natural biopolymer are crosslinked.

Advantageously, the substrate may comprise a keratin derivate derived from any keratin source. Keratins may be extracted from hair, nails, feather, horns, hooves, wool etc. Many of

these sources may come from farm waste. Thus, developing keratin-based substrates for agriculture and farm applications is a realistic strategy of recycling natural wastes, saving on cost and is in alignment with the concept of circular economy. Also, the keratin used is eco-friendly with good biocompatibility and biodegradability.

Also advantageously, with the incorporation of a natural biopolymer, the mechanical properties of the keratin-based substrate may be improved because of their crystalline domains and the potential for physical crosslinks with keratins through hydrogen bonds and electrostatic interactions. Further, the incorporation of natural biopolymers could enhance the water

Claims

1. A substrate comprising:
   (a) keratin derivative; and
   (b) natural biopolymer,
   wherein the natural biopolymer is selected from the group consisting of nanocellulose, modified nanocellulose, chitin, modified chitin, fibrinogen, modified fibrinogen, starch, modified starch, sericin, modified sericin, pullulan, modified pullulan, and combinations thereof, and
   wherein the keratin derivative and natural biopolymer are crosslinked.

2. The substrate of claim 1, wherein the keratin derivative is selected from the group consisting of keratin intermediate filament protein, kerateine, keratose, and combinations thereof.

3. The substrate of claim 1 or 2, wherein the keratin derivative is derived from any human and/or animal source selected from the group consisting of hair, nail, wool, fur, horn, hoof, feather, scales, and combinations thereof.

4. The substrate of any one of the preceding claims, wherein the natural biopolymer is a modified natural biopolymer.

5. The substrate of any one of the preceding claims, wherein the natural biopolymer or modified natural biopolymer comprises hydroxyl, amine, carboxyl, thiol, aldehyde, and/or methacrylate groups.

6. The substrate of any one of the preceding claims, wherein the nanocellulose is selected from the group consisting of cellulose nanocrystals, modified cellulose nanocrystals, cellulose nanofibrils, modified cellulose nanofibrils, bacterial nanocellulose, and modified bacterial nanocellulose.

7. The substrate of any one of the preceding claims, wherein the molecular weight of the keratin derivative is 40 kDa to 60 kDa.

8. The substrate of any one of the preceding claims, comprising 0.5 wt% to 2.0 wt% keratin derivative, based on the total weight of the substrate.

9. The substrate of any one of the preceding claims, comprising 0.25 wt% to 1.0 wt% natural biopolymer, based on the total weight of the substrate.

10. The substrate of any one of the preceding claims, wherein the weight percentage ratio of keratin derivative to natural biopolymer is 5:1 to 5:3.

11. The substrate of any one of the preceding claims, wherein the substrate further comprises:
    (c) micronutrients, macronutrients, pesticides and/or bioactives.

12. The substrate of claim 11, wherein the micronutrient is selected from the group consisting of metal oxides, metal salts, silica, carbon dots, and combinations thereof.

13. The substrate according to claim 11, wherein the bioactive is selected from the group consisting of biomolecules, antimicrobial agents, omega 3, folic acid, boron and calcium.

14. The substrate of claim 12, wherein the metal is selected from the group consisting of zinc, copper, iron, magnesium, manganese, titanium, molybdenum, cobalt, nickel, silver, gold and combinations thereof.

15. The substrate of any one of claims 11 to 13, wherein the micronutrients are particulates with an average diameter of 1 nm to 500 nm.

16. The substrate of any one of claims 11 to 14, wherein the concentration of the micronutrient, pesticide or bioactive, when present, in the substrate is independently 0.005 mg/ml to 1.0 mg/ml, and the concentration of the macronutrient, when present, in the substrate is 1 mg/ml to 50 mg/ml .

17. The substrate of any one of the preceding claims, wherein the substrate has a pore size of 100 µm to 200 µm.

18. The substrate according to any one of the preceding claims, wherein the substrate comprises:
    (i) keratin intermediate filament protein;
    (ii) cellulose nanofibrils; and
    (iii) particulate micronutrients selected from the group consisting of metal oxides, metal salts, silica, carbon dots, and combinations thereof,
        wherein the metal is selected from the group consisting of zinc, copper, iron, magnesium manganese, titanium, molybdenum, cobalt, nickel, silver, gold and combinations thereof.

19. A method of forming a substrate of any one of the preceding claims, wherein the method comprises:
    (i) mixing a solution of keratin derivative with a solution of natural biopolymer; and
    (ii) drying the resulting solution of step (i) to obtain the substrate.

20. The method of claim 19, further comprising step (i') dispersing micronutrients, macronutrients, pesticides, and/or bioactives, into the solution of keratin derivative, wherein step (i') occurs before step (i).

21. The method of claim 19 or 20, wherein step (ii) comprises drying the resulting solution for at least 24 hours.

22. The method of any one of claims 19 to 21, wherein step (ii) comprises freeze drying the solution of step (i) at a temperature of -10oC to -80oC.

23. Use of a substrate of any one of claims 1 to 18 as a plant growth medium or a hydroponic support medium.