accessed on March 6, 2007), all of which are herein incorporated by reference in their entirety.

Methods and compositions for delaying the fruit ripening process include, for example, the application of silver salts (e.g., silver thiosulfate), 2,5-norbornadiene, potassium permanganate, 1-methylcyclopropene (1-MCP), cyclopropene (CP) and derivatives thereof. These compounds have significant disadvantages, such as the presence of heavy metals, foul odors, and explosive properties when compressed, that make them unacceptable for or of limited applicability for use in the food industry. Transgenic approaches for controlling ethylene production to delay plant development processes (e.g., fruit ripening) by introducing nucleic acid sequences that limit ethylene production, particularly by reducing the expression of the enzymes ACC synthase or ACC oxidase, are also under investigation. The public's response to genetically modified agricultural products, however, has not been entirely favorable.

Accordingly, a significant need remains in the art for safe methods and apparatuses to delay plant development processes. Such methods and apparatuses could provide better control of fruit ripening, vegetable ripening, flower senescence, leaf abscission, and seed germination and extend the shelf-life of various agricultural products (e.g., fruit, vegetables, and cut flowers), thereby permitting longer distance transportation of these products without the need for refrigeration, increasing product desirability to consumers, and decreasing monetary costs associated with product loss due to untimely ripening and senescence.

BRIEF SUMMARY OF THE INVENTION

In one aspect, there is provided a method for delaying a plant development process comprising exposing a plant or plant part to one or more isolated enzymes, wherein the one or more isolated enzymes are selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, and wherein the one or more isolated enzymes are exposed to the plant or plant part in a quantity sufficient to delay the plant development process.

Methods for delaying a plant development process, including but not limited to fruit ripening, vegetable ripening, flower senescence, and leaf abscission, are provided. The methods of the present disclosure~~invention~~ generally comprise exposing a plant or plant part to one or more bacteria in a quantity sufficient to delay the plant development process of interest. In the present disclosure~~certain aspects of the invention~~, the bacteria are selected from the group consisting of *Rhodococcus spp.*, *Pseudomonas chloroaphis*, *Brevibacterium ketoglutamicum*, and mixtures thereof. The bacteria used in the practice of the present methods may be further treated with an inducing agent,

including for example asparagine, glutamine, cobalt, urea, and mixtures thereof, to induce the ability of the bacteria to delay a plant development process of interest.

In another aspect, there is provided an apparatus for delaying a plant development process comprising multiple layers, wherein at least one layer comprises a catalyst that comprises one or more isolated enzymes selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, wherein the catalyst is placed in, placed on, or affixed to a physical structure, and wherein the one or more isolated enzymes are provided in a quantity sufficient to delay the plant development process.

The present disclosure~~invention~~ further provides apparatuses for delaying a plant development process comprising a catalyst that comprises one or more of bacteria, particularly *Rhodococcus spp.*, *Pseudomonas chloroaphis*, *Brevibacterium ketoglutamicum*, or a mixture thereof. Any apparatus that permits exposure of a plant or plant part to the catalyst and delays the plant development process of interest is encompassed by the present invention. Exemplary apparatuses include those in which the catalyst is immobilized in a matrix and placed in, placed on, or otherwise affixed to any physical structure. Various configurations of the disclosed apparatuses are envisioned and described in greater detail herein below. The methods and apparatuses of the disclosure~~invention~~ for delaying a plant development process find particular use in increasing shelf-life and facilitating longer-distance transportation of plant products such as fruits, vegetables, and flowers, improving consumer product satisfaction, and reducing product loss resulting from untimely ripening or senescence.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 shows a non-limiting depiction of a three-layer apparatus for retarding fruit ripening. The outer layers (designated A and B) provide structural integrity to the apparatus. The catalyst layer, as defined herein below, comprises one or more of the enzymes of the invention and is located between the outer layers.

FIG. 2A-C provides non-limiting depictions of various apparatuses for retarding fruit ripening. These apparatuses comprise a catalyst layer, one or more layers intended to provide structural integrity, and one or more layers intended to be removed prior to use of the apparatus. Removal of one or more of these layers may, for example, expose an adhesive for attachment of the apparatus to another physical structure.

What is claimed:

1. An apparatus for delaying a plant development process comprising a catalyst that comprises one or more bacteria comprising *Pseudomonas chloroaphis*, wherein the one or more bacteria are provided in a quantity sufficient to delay the plant development process.

2. The apparatus of claim 1, wherein the one or more bacteria are induced by exposure to an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea, and mixtures thereof.

3. The apparatus of claim 1, wherein the plant development process is selected from the group consisting of fruit or vegetable ripening, flower senescence, wilting, petal closure, and leaf abscission.

4. The apparatus of claim 1, wherein the one or more bacteria are immobilized in a matrix comprising cross-linked DEAE-cellulose, a matrix comprising alginate, a matrix comprising carrageen, a matrix comprising cross-linked alginate, a matrix comprising cross-linked carrageen, a matrix comprising polyacrylamide, or calcium alginate beads.

5. The apparatus of claim 4, wherein the matrix comprises cross-linked DEAE-cellulose, wherein the DEAE-cellulose is cross-linked with glutaraldehyde.

6. The apparatus of claim 1, wherein the catalyst is present in a catalyst module that is placed in, placed on, or affixed to a physical structure.

7. The apparatus of claim 1, further comprising a control device to adjust exposure of the catalyst to a plant or plant part.

8. The apparatus of claim 1, further comprising a monitoring device for monitoring the efficacy of the catalyst in delaying the plant development process.

9. The apparatus of claim 6, wherein the physical structure is selected from the group consisting of a film, sheet, coating layer, a slotted chamber, a box, a pouch, and a bag.

10. The apparatus of claim 6, wherein the catalyst module can be removed and replaced with a second catalyst module.

11. The apparatus of claim 6, wherein more than one catalyst module is placed in, placed on, or affixed to the physical structure.

12. The apparatus of claim 6, wherein the physical structure permits air flow into the catalyst module.

13. The apparatus of claim 12, further comprising an element for controlling the air flow into the catalyst module.

14. The apparatus of claim 6, wherein the physical structure is provided as a refrigerated structure.

15. The apparatus of claim 6, further comprising an element for controlling the moisture level in the physical structure.

16. The apparatus of claim 6, further comprising an element for regulating the carbon dioxide level in the physical structure.

17. An air-permeable catalyst apparatus for delaying a plant development process comprising:

a first layer; and

a second layer that includes a catalyst comprising one or more bacteria comprising *Pseudomonas chloroaphis,* wherein the one or more bacteria are provided in a quantity sufficient to delay the plant development process;

wherein the first layer provides structural integrity to the apparatus.

18. The apparatus of claim 17, wherein the one or more bacteria are induced by exposure to an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea, and mixtures thereof.

19. The apparatus of claim 17, wherein the plant development process is selected from the group consisting of fruit or vegetable ripening, flower senescence, and leaf abscission.

20. The catalyst apparatus of claim 17, further comprising a third layer, wherein said third layer can be removed from said second layer to expose an adhesive layer that can be used to affix the catalyst apparatus to a separate structure.

21. The catalyst apparatus of claim 20, wherein said second layer is said adhesive layer.

22. The catalyst apparatus of claim 20, further comprising a fourth layer adjacent said third layer that can be removed from said third layer to expose an adhesive layer that can be used to affix the catalyst structure to a separate structure.

23. The catalyst apparatus of claim 22, wherein said third layer is said adhesive layer.

24. An air-permeable bag or pouch including the catalyst apparatus of claim 17.

25. A method for delaying a plant development process comprising exposing a plant or plant part to an enzymatic extract of one or more bacteria comprising *Pseudomonas chloroaphis,* said bacteria being induced by an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea, and mixtures thereof and said enzymatic extract being exposed to the plant or plant part in a quantity sufficient to delay the plant development process.

26. A method for delaying a plant development process comprising exposing a plant or plant part to one or more bacteria, wherein the one or more bacteria are *Pseudomonas chloroaphis* that have been induced by exposure to an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea and mixtures thereof, and wherein the one or more bacteria are exposed to the plant or plant part in a quantity sufficient to delay the plant development process.

27. The method of claim 26, wherein the one or more bacteria are induced by exposure to asparagine or asparagine, cobalt, and urea.

28. The method of claim 26, wherein the plant or plant part is directly or indirectly exposed to the one or more bacteria.

29. The method of claim 26, wherein the plant development process is fruit or vegetable ripening.

30. The method of claim 26, wherein the plant part is a fruit, a vegetable or a flower.

31. The method of claim 30, wherein the fruit is a nonclimacteric or climacteric fruit.

32. The method of claim 31, wherein the climacteric fruit is selected from the group consisting of bananas, pears, plums, nectarines, apples, tomatoes, peaches, and avocados.

33. The method of claim 26, wherein the plant part is a flower and the plant development process is flower senescence, wilting, abscission or petal closure.

34. The method of claim 33, wherein the flower is a carnation, rose, orchid, portulaca, malva, or begonia.

35. The method of claim 26, wherein the plant development process is leaf abscission.

36. The method of claim 26, wherein the plant part is a cut flower.

37. The method of claim 26, wherein delaying the plant development process results in increased shelf-life or facilitates longer-distance transportation of the plant or plant part.

38. The method of claim 26, wherein the one or more bacteria are immobilized and are placed in, placed on, or affixed to a physical structure suitable for transport or storage of the plant or plant part.

39. A method for delaying a plant development process comprising exposing a plant or plant part to one or more enzymes, wherein the one or more enzymes are selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, and wherein the one or more enzymes are exposed to the plant or plant part in a quantity sufficient to delay the plant development process.

40. The method of claim 39, wherein the one or more enzymes are provided by one or more bacteria.

41. The method of claim 40, wherein the one or more enzymes are isolated, purified, or semi-purified from the one or more bacteria.

42. The method of claim 39 or 40, wherein the one or more bacteria are selected from the group consisting of *Rhodococcus spp.*, *Brevibacterium ketoglutamicum*, *Pseudomonas chloroaphis*, genus *Nocardia*, genus *Pseudonocardia*, and mixtures thereof.

43. The method of claim 42, wherein the one or more bacteria include *Rhodococcus spp.*, optionally, wherein the *Rhodococcus spp.* includes *Rhodococcus rhodochrous* DAP 96253 strain, *Rhodococcus sp.* DAP 96622 strain, *Rhodococcus erythropolis*, or mixtures thereof.

44. The method of claim 39 or 40, wherein the one or more bacteria are induced by exposure to an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea, and mixtures thereof.

45. The method of claim 39, wherein the plant or plant part is indirectly or directly exposed to the one or more enzymes.

46. The method of claim 39, wherein the plant development process is fruit ripening, vegetable ripening or leaf abscission.

47. The method of claim 39, wherein the plant part is a fruit, a vegetable or a flower; optionally, wherein the fruit is a climacteric fruit, optionally wherein the climacteric fruit is selected from the group consisting of bananas, peaches, plums, nectarines, apples, tomatoes, pears, and avocados.

48. The method of claim 39, wherein the plant part is a flower and the plant development process is flower senescence, wilting, abscission or petal closure, optionally wherein the flower is a carnation, rose, orchid, portulaca, malva, or begonia.

49. The method of claim 39, wherein delaying the plant development process results in increased shelf-life or facilitates longer-distance transportation of the plant or plant part.

50. The method of claim 39, wherein the one or more enzymes are immobilized and are placed in, placed on, or affixed to a physical structure.

51. An apparatus for delaying a plant development process comprising multiple layers, wherein at least one layer comprises a catalyst that comprises one or more enzymes selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, wherein the catalyst is placed in, placed on, or affixed to a physical structure, such as a film, sheet, coating layer, box, pouch, bag or slotted chamber, and wherein the one or more enzymes are provided in a quantity sufficient to delay the plant development process.

52. The apparatus of claim 51, wherein the one or more enzymes are immobilized in a matrix comprising cross-linked DEAE-cellulose, a matrix comprising alginate, a matrix comprising carrageenan, a matrix comprising polyacrylamide, or calcium alginate beads.

53. The apparatus for delaying a plant development process of claim 51, wherein the apparatus is an air-permeable catalyst apparatus for delaying a plant development process and comprises:

a first layer; and

a second layer that includes a catalyst comprising one or more enzymes selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, wherein the one or more enzymes are provided in a quantity sufficient to delay the plant development process;

wherein the first layer provides a structural integrity to the apparatus.

What is claimed:

1. A method for delaying a plant development process comprising exposing a plant or plant part to one or more isolated enzymes, wherein the one or more isolated enzymes are selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, and wherein the one or more isolated enzymes are exposed to the plant or plant part in a quantity sufficient to delay the plant development process.

2. The method of claim 1, wherein the one or more isolated enzymes are provided by one or more bacteria.

3. The method of claim 2, wherein the one or more isolated enzymes are purified or semipurified from the one or more bacteria.

4. The method of claim 2 or 3, wherein the one or more bacteria are selected from the group consisting of *Rhodococcus spp.*, *Brevibacterium ketoglutamicum*, *Pseudomonas chloroaphis*, and mixtures thereof.

5. The method of claim 4, wherein the one or more bacteria include *Rhodococcus spp.*, optionally, wherein the *Rhodococcus spp.* includes *Rhodococcus rhodochrous* DAP 96253 strain, *Rhodococcus sp.* DAP 96622 strain, *Rhodococcus erythropolis*, or mixtures thereof.

6. The method of claim 2 or 3, wherein the one or more bacteria are induced by exposure to an inducing agent selected from the group consisting of asparagine, glutamine, cobalt, urea, and mixtures thereof.

7. The method of claim 1, wherein the plant or plant part is indirectly or directly exposed to the one or more isolated enzymes.

8. The method of claim 1, wherein the plant development process is fruit ripening, vegetable ripening or leaf abscission.

9. The method of claim 1, wherein the plant part is a fruit, a vegetable or a flower; optionally, wherein the fruit is a climacteric fruit, optionally wherein the climacteric fruit is selected from the group consisting of bananas, peaches, plums, nectarines, apples, tomatoes, pears, and avocados.

10. The method of claim 1, wherein the plant part is a flower and the plant development process is flower senescence, wilting, abscission or petal closure, optionally wherein the flower is a carnation, rose, orchid, portulaca, malva, or begonia.

11. The method of claim 1, wherein delaying the plant development process results in increased shelf-life or facilitates longer-distance transportation of the plant or plant part.

12. The method of claim 1, wherein the one or more isolated enzymes are immobilized and are placed in, placed on, or affixed to a physical structure.

13. An apparatus for delaying a plant development process comprising multiple layers, wherein at least one layer comprises a catalyst that comprises one or more isolated enzymes selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, wherein the catalyst is placed in, placed on, or affixed to a physical structure, and wherein the one or more isolated enzymes are provided in a quantity sufficient to delay the plant development process.

14. The apparatus of claim 13, wherein the one or more isolated enzymes are immobilized in a matrix comprising cross-linked DEAE-cellulose, a matrix comprising alginate, a matrix comprising carrageenan, a matrix comprising polyacrylamide, or calcium alginate beads.

15. The apparatus for delaying a plant development process of claim 13, wherein the apparatus is an air-permeable catalyst apparatus for delaying a plant development process and comprises:

a first layer; and

a second layer that includes a catalyst comprising one or more isolated enzymes selected from the group consisting of nitrile hydratases, amidases, asparaginases, and combinations thereof, wherein the one or more isolated enzymes are provided in a quantity sufficient to delay the plant development process;

wherein the first layer provides a structural integrity to the apparatus.

16. The apparatus of any of claims 13 to 15, wherein the physical structure is a film, sheet, coating layer, box, pouch, bag or slotted chamber.