CLAIMS

What is claimed is:

1. An apparatus for thawing frozen biological material, the apparatus comprising:

a vessel having an interior space for receiving the biological material, the vessel having an upper portion extending around an upper portion of the interior space, a middle portion extending around a middle portion of the interior space, and a lower portion extending around a lower portion of the interior space;

a plurality of thermal transfer devices operatively associated with the vessel for transferring heat between the vessel and the thermal transfer device, comprising at least:

a first thermal transfer device operatively associated with the upper portion of the vessel for transferring heat between the upper portion of the vessel and the first thermal transfer device;

a second thermal transfer device operatively associated with the upper middle portion of the vessel for transferring heat between the upper middle portion of the vessel and the second thermal transfer device;

a third thermal transfer device operatively associated with the lower middle portion of the vessel for transferring heat between the lower middle portion of the vessel and the third thermal transfer device; and

a fourth thermal transfer device operatively associated with the lower portion of the vessel for transferring heat between the lower portion of the vessel and the fourth thermal transfer device; and

at least one controller operatively associated with the first, second, third, and fourth thermal transfer devices for controlling the first, second, third, and fourth thermal transfer devices independently from one another, comprising the at least one controller being adapted for

controlling the first thermal transfer device to control thermal transfer between the first thermal transfer device and the upper portion of the vessel;

controlling the second thermal transfer device to control thermal transfer between the second thermal transfer device and the upper middle portion of the vessel;

controlling the third thermal transfer device to control thermal transfer between the third thermal transfer device and the lower middle portion of the vessel; and

controlling the fourth thermal transfer device to control thermal transfer between the fourth thermal transfer device and the lower portion of the vessel.

2. The apparatus of claim 1, further comprising at least one stirring apparatus and thermocouples extending into the interior space of the vessel, wherein:

the thermocouples are arranged in an upwardly extending series;

the thermocouples are operatively associated with the at least one controller; and

the at least one controller is operative for controlling the first, second, third, and fourth thermal transfer devices at least partially in response to signals from the thermocouples.

3. The apparatus of claim 1, wherein the at least one controller comprises at least one processor and at least one memory including computer program code, and the at least one memory and the computer program code are configured to, with the processor, provide signals for:

controlling the first, second, third, and fourth thermal transfer devices independently from one another; and

controlling the first thermal transfer device to control thermal transfer between the first thermal transfer device and the upper portion of the vessel;

controlling the second thermal transfer device to control thermal transfer between the second thermal transfer device and the upper middle portion of the vessel;

controlling the third thermal transfer device to control thermal transfer between the third thermal transfer device and the lower middle portion of the vessel; and

controlling the fourth thermal transfer device to control thermal transfer between the fourth thermal transfer device and the lower portion of the vessel.

4. The apparatus of claim 1, wherein each of the first, second, third, and fourth thermal transfer devices comprises a jacket mounted to an exterior of the vessel for providing at least conductive thermal transfer between the jacket and the vessel.

5. The apparatus of claim 4, wherein the jacket extends around the vessel.

6. The apparatus of claim 4, wherein the jacket comprises at least one passageway for having a thermal transfer medium flow therethrough.

7. The apparatus of claim 6, wherein the thermal transfer medium comprises a thermal transfer liquid.

8. The apparatus of claim 6, comprising a system in fluid communication with the at least one passageway for circulating the thermal transfer medium through the passageway.

9. A method for thawing frozen biological material, comprising:

introducing the frozen biological material into a vessel;

causing thermal transfer between an upper portion of the vessel and medium exterior to the upper portion of the vessel, comprising heating the upper portion of the vessel;

causing thermal transfer between an upper middle portion of the vessel and medium exterior to the upper middle portion of the vessel;

causing thermal transfer between a lower middle portion of the vessel and medium exterior to the lower middle portion of the vessel;

causing thermal transfer between a lower portion of the vessel and medium exterior to the lower portion of the vessel;

monitoring temperature of the biological material at different levels in the vessel;

adjusting the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel;

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel at least partially in response to the monitoring of the temperature of the biological material ;

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of

the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel; and

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

the adjusting of the thermal transfer between the lower portion of the adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

vessel and the medium exterior to the lower portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel; and

the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel being performed independently of the adjusting of the thermal

the causing of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises heating the lower portion of the vessel; and

thereafter, the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises cooling the lower portion of the vessel.

14. The method of claim 9, wherein:

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel comprises automatically adjusting the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel comprises automatically adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel;

the adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel comprises automatically adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and

the adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises automatically adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel.

15. The method of claim 9, wherein:

21. The apparatus of claim 19, wherein the internal temperature of the vessel is measured using the plurality of vertically arranged thermocouples.

22. The apparatus of claim 16, wherein the temperature of thermal transfer means is modulated by thermoelectric, Peltier, or liquid media.

23. The apparatus of claim 22, wherein the temperature of thermal transfer means is modulated by liquid media.

24. The apparatus of claim 23, wherein the liquid media comprises ethylene glycol.

25. The apparatus of claim 19, wherein there are at least four thermal transfer means and at least four thermocouples; and wherein the thermal transfer means and thermocouples are vertically positioned within the thawing vessel.

26. The apparatus of claim 21, wherein the temperatures of the plurality of thermal transfer means are raised to not more than about 10 °C above the melting point for the biological product until melting is completed, and wherein the temperature is maintained at about 2 °C after melting is completed.

27. The apparatus of claim 21, wherein the temperatures of the plurality of thermal transfer means are raised to not more than about 8 °C when a temperature of less than about 2 °C is measured; and wherein the temperatures of the plurality of thermal transfer means are lowered to about 4 °C when a temperature greater than about 10 °C is measured.

28. A process for thawing a frozen biological product comprising:

(a) introducing the frozen biological products into a vessel comprising one or more stirring means, a plurality of thermal transfer means; a plurality of thermocouples; and a means for temperature control;

(b) continuously measuring the temperature at a plurality of levels within the vessel using the plurality of thermocouples;

(c) heating the thermal transfer means adjacent to the frozen biological products at the same time mixing the contents of the vessel;

(d) cooling the thermal transfer means adjacent to the thawed biological products at the same time mixing the contents of the vessel;

(e) heating and/or cooling the thermal transfer means to compensate for the addition of additional frozen biological product and the thawing of the biological product.

Claims

1. An apparatus for thawing frozen biological material, the apparatus comprising:

a vessel having an interior space for receiving the biological material, the vessel having an upper portion extending around an upper portion of the interior space, a middle portion extending around a middle portion of the interior space, and a lower portion extending around a lower portion of the interior space; a plurality of thermal transfer devices operatively associated with the vessel for transferring heat between the vessel and the thermal transfer device, comprising at least:

a first thermal transfer device operatively associated with the upper portion of the vessel for transferring heat between the upper portion of the vessel and the first thermal transfer device;
a second thermal transfer device operatively associated with the upper middle portion of the vessel for transferring heat between the upper middle portion of the vessel and the second thermal transfer device;
a third thermal transfer device operatively associated with the lower middle portion of the vessel for transferring heat between the lower middle portion of the vessel and the third thermal transfer device; and
a fourth thermal transfer device operatively associated with the lower portion of the vessel for transferring heat between the lower portion of the vessel and the fourth thermal transfer device; and

at least one controller operatively associated with the first, second, third, and fourth thermal transfer devices for controlling the first, second, third, and fourth thermal transfer devices independently from one another, comprising the least one controller being adapted for controlling the first thermal transfer device to control thermal transfer between the first thermal transfer device and the upper portion of the vessel;

controlling the second thermal transfer device to control thermal transfer between the second thermal transfer device and the upper middle portion of the vessel;
controlling the third thermal transfer device to control thermal transfer between the third thermal transfer device and the lower middle portion of the vessel; and
controlling the fourth thermal transfer device to control thermal transfer between the fourth thermal transfer device and the lower portion of the vessel.

2. The apparatus of claim 1, further comprising at least one stirring apparatus and thermocouples extending into the interior space of the vessel, wherein:

the thermocouples are arranged in an upwardly extending series;
the thermocouples are operatively associated with the at least one controller; and
the at least one controller is operative for controlling the first, second, third, and fourth thermal transfer devices at least partially in response to signals from the thermocouples.

3. The apparatus of claim 1, wherein the at least one controller comprises at least one processor and at least one memory including computer program code, and the at least one memory and the computer program code are configured to, with the processor, provide signals for:

controlling the first, second, third, and fourth thermal transfer devices independently from one another; and
controlling the first thermal transfer device to control thermal transfer between the first thermal transfer device and the upper portion of the
vessel;
controlling the second thermal transfer device to control thermal transfer between second thermal transfer device and the upper middle portion of the vessel;
controlling the third thermal transfer device to control thermal transfer between the third thermal transfer device and the lower middle portion of the vessel; and
controlling the fourth thermal transfer device to control thermal transfer between the fourth thermal transfer device and the lower portion of the vessel.

4. The apparatus of claim 1, wherein each of the first, second, third, and fourth thermal transfer devices comprises a jacket mounted to an exterior of the vessel for providing at least conductive thermal transfer between the jacket and the vessel.

5. The apparatus of claim 4, wherein the jacket extends around the vessel.

6. The apparatus of claim 4, wherein the jacket comprises at least one passageway for having a thermal transfer medium flow therethrough.

7. The apparatus of claim 6, wherein the thermal transfer medium comprised a thermal transfer liquid.

8. The apparatus of claim 6, comprising a system in fluid communication with the at least one passageway for circulating the thermal transfer medium through the passageway.

9. A method for thawing frozen biological material, comprising:

introducing the frozen biological material into a vessel;
causing thermal transfer between an upper portion of the vessel and medium exterior to the upper portion of the vessel, comprising heating the upper portion of the vessel;
causing thermal transfer between an upper middle portion of the vessel and medium exterior to the upper middle portion of the vessel;
causing thermal transfer between a lower middle portion of the vessel and medium exterior to the lower middle portion of the vessel;
causing thermal transfer between a lower portion of the vessel and medium exterior to the lower portion of the vessel;
monitoring temperature of the biological material at different levels in the vessel;
adjusting the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;
the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel;
the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and

the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel; and

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel being performed independently of the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel; and

adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel at least partially in response to the monitoring of the temperature of the biological material;

the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;

the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel being performed independently of the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel; and

the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel being performed independently of

the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel.

10. The method of claim 9, wherein:

the causing of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel comprises heating the upper portion of the vessel; and thereafter, the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel comprises at least reducing the heating of the upper portion of the vessel.

11. The method of claim 9, wherein:

the causing of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel comprises heating the upper middle portion of the vessel; and thereafter, the adjusting of the thermal transfer between the middle portion of the vessel and the medium exterior to the upper middle portion of the vessel comprises cooling the upper middle portion of the vessel.

12. The method of claim 9, wherein:

the causing of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel comprises heating the lower middle portion of the vessel; and
thereafter, the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel comprises cooling the lower middle portion of the vessel.

13. The method of claim 9, wherein:

the causing of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises heating the lower portion of the vessel; and thereafter, the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises cooling the lower portion of the vessel.

14. The method of claim 9, wherein:

the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel comprises automatically adjusting the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel;
the adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel comprises automatically adjusting the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel;

the adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel comprises automatically adjusting the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel; and
the adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel comprises automatically adjusting the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel.

15. The method of claim 9, wherein:

at least the adjusting of the thermal transfer between the upper portion of the vessel and the medium exterior to the upper portion of the vessel is computer-implemented;
at least the adjusting of the thermal transfer between the upper middle portion of the vessel and the medium exterior to the upper middle portion of the vessel is computer-implemented;
at least the adjusting of the thermal transfer between the lower middle portion of the vessel and the medium exterior to the lower middle portion of the vessel is computer-implemented; and
at least the adjusting of the thermal transfer between the lower portion of the vessel and the medium exterior to the lower portion of the vessel is computer-implemented.

16. An apparatus for thawing frozen biological products comprising:

at least one vessel;
one or more stirring means;
a plurality of thermal transfer means surrounding the vessel; and
at least one means for temperature control.

17. The apparatus of claim 16, wherein the plurality of thermal transfer means are vertically positioned from the bottom to the top of the vessel.

18. The apparatus of claim 16, wherein the temperatures of the plurality of thermal transfer means are independently controlled.

19. The apparatus of claim 1, further comprising a plurality of thermocouples.

20. The apparatus of claim 19, wherein the plurality of thermocouples are vertically positioned from the bottom to the top of the vessel.
21. The apparatus of claim 20, wherein the internal temperature of the vessel is measured using the plurality of vertically arranged thermocouples.

22. The apparatus of claim 16, wherein the temperature of thermal transfer means is modulated by thermoelectric, Peltier, or liquid media.

23. The apparatus of claim 22, wherein the temperature of thermal transfer means is modulated by liquid media.

24. The apparatus of claim 23, wherein the liquid media comprises ethylene glycol.

25. The apparatus of claim 19, wherein there are at least four thermal transfer means and at least four thermocouples; and wherein the thermal transfer means and thermocouples are vertically positioned within thethawing vessel.

26. The apparatus of claim 21, wherein the temperatures of the plurality of thermal transfer means are raised to not more than about 10 °C above the melting point for the biological product until melting is completed, and wherein the temperature is maintained at about 2 °C after melting is completed.

27. The apparatus of claim 21, wherein the temperatures of the plurality of thermal transfer means are raised to not more than about 8 °C when a temperature of less than about 2 °C is measured; and wherein the temperatures of the plurality of thermal transfer means are lowered to about 4 °C when a temperature greater than about 10 °C is measured.

28. A process for thawing a frozen biological product comprising:

(a) introducing the frozen biological products into a vessel comprising one or more stirring means, a plurality of thermal transfer means; a plurality of thermocouples; and a means for temperature control;
(b) continuously measuring the temperature at a plurality of levels within the vessel using the plurality of thermocouples;
(c) heating the thermal transfer means adjacent to the frozen biological products at the same time mixing the contents of the vessel;
(d) cooling the thermal transfer means adjacent to the thawed biological products at the same time mixing the contents of the vessel;
(e) heating and/or cooling the thermal transfer means to compensate for the addition of additional frozen biological product and the thawing of the biological product.