CLAIMS

What is claimed is:

1. A perfusion filter element sheet comprising:

a microporous membrane having a mean pore size of at least 0.65 μm; and

a feed spacer comprising woven fibers and having an open area of at least 35%, the woven fibers having an average fiber diameter of at least 270 μm.

2. The perfusion filter element sheet of Claim 1, wherein the pore size is 0.8 μm to 10 μm.

3. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the pore size is 1.0 μm to 5 μm.

4. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the feed spacer has an open area of 35 % to 55%.

5. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the feed spacer has a fiber density of 6 fibers/cm to 13 fibers/cm.

6. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the feed spacer comprises fibers having an average fiber diameter of 300 μm to 500 μm.

7. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the feed spacer comprises fibers woven in a two-over-one twill pattern.

8. The perfusion filter element sheet of Claim 1 or Claim 2, wherein the feed spacer comprises fibers woven in a one-over-one weave pattern.

9. A perfusion filter element comprising at least one filter element sheet of Claim 1 or Claim 2.

10. The filter element of Claim 9, wherein the filter element is a spiral-wound filter element.

11. The filter element of Claim 9, wherein the filter element is a cassette filter element.

12. A perfusion system comprising:

at least one filter element of Claim 9; and

a pump configured to control flow of a liquid feed through the at least one filter element, the system configured to be operated in a tangential flow filtration (TFF) mode.

13. The perfusion system of Claim 12, wherein the pump is a magnetic levitation pump.

14. The perfusion system of Claim 12, wherein the pump is a peristaltic pump.

15. The perfusion system of Claim 12, wherein the pump is a diaphragm pump.

16. The perfusion system of Claim 12, wherein the system is configured to operate in a recirculation mode.

17. The perfusion system of Claim 12, wherein the system is configured to operate in an alternating flow mode.

18. A perfusion process, comprising:

passing a liquid feed through a feed channel of at least one filter element, the at least one filter element comprising a microfiltration membrane and a woven feed spacer located within the feed channel, the woven feed spacer comprising fibers having an average fiber diameter of at least 270 μm and having an open area of at least 35%; and

separating the liquid feed into permeate and retentate by tangential flow filtration (TFF) in the filter element.

19. The perfusion process of Claim 18, wherein the liquid feed comprises cells and a target protein.

20. The perfusion process of Claim 19, further comprising recovering the target protein in the permeate.

21. The perfusion process of Claim 19 or Claim 20, further comprising retaining the cells in the retentate.

22. The perfusion process of any one of Claims 18-20, further comprising recirculating at least a portion of the retentate through the at least one filter element.

23. The perfusion process of any one of Claims 18-20, further comprising alternating a flow of liquid through the at least one filter element.

24. The perfusion process of any one of Claims 18-20, wherein the microfiltration membrane is a microporous membrane having an average pore size of at least 0.65 µm.

25. The perfusion process of any one of Claims 18-20, further comprising:

supplying fresh media to the retentate; and

returning the retentate to a bioreactor upstream of the at least one filter element.

26. The perfusion process of Claim 25, wherein passing the liquid feed through the feed channel of the at least one filter element and returning the retentate to the bioreactor occurs on a continuous basis, the retentate being the liquid feed of a subsequent perfusion process.

27. A perfusion process for harvesting target proteins from a liquid feed containing host cells, comprising:

delivering a liquid feed containing target proteins and host cells to a feed channel of at least one filter element, the at least one filter element comprising a

microfiltration membrane and a woven feed spacer located within the feed channel, the woven feed spacer comprising fibers having an average fiber diameter of at least 270 μm and having an open area of at least 35%; and

separating the target proteins from the host cells in the at least one filter element.

28. The perfusion process of Claim 27, wherein the target proteins are monoclonal antibodies.

29. The perfusion process of Claim 27 or Claim 28, wherein the target proteins are separated from the host cells by tangential flow filtration (TFF).

30. The perfusion process of Claim 27 or Claim 28, further comprising recovering the target proteins from the at least one filter element.

31. The perfusion process of Claim 30, wherein at least 80% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 500 L/m^2 of the filter element.

32. The perfusion process of Claim 31, wherein at least 80% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 1000 L/m^2 of the filter element.

33. The perfusion process of Claim 31, wherein at least 90% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 500 L/m^2 of the filter element.

34. The perfusion process of Claim 33, wherein at least 90% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 1000 L/m2 of the filter element.

35. The perfusion process of Claim 31, wherein at least 95% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 500 L/m2 of the filter element.

36. The perfusion process of Claim 35, wherein at least 95% of the target proteins are recovered from the liquid feed at a harvest throughput of at least 1000 L/m^2 of the filter element.

37. The perfusion process of Claim 27 or Claim 28, further comprising:

recovering the host cells from the at least one filter element;

supplying fresh media to the recovered host cells; and

returning the recovered host cells to a bioreactor upstream of the at least one filter element.

38. The perfusion process of Claim 37, wherein delivering the liquid feed to the feed channel of the at least one filter element and returning the recovered host cells to the bioreactor occurs on a continuous basis, the recovered host cells being the liquid feed of a subsequent perfusion process.