In this appendix, we derive expressions for the three resistances given in Equation (2). With measured values of the phloem flow speed U, this allows us to determine the hydrostatic pressure difference Δp required to drive the flow given in Eq. (1). Characteristic values of the parameters used in the calculations can be found in Table 1 while the calculated values of the hydrostatic pressure is given in Table 2.

Our starting point is the relation between the hydrostatic pressure drop Δp between source and sink and the volumetric flow rate Q given in Eq. (1):

$$\Delta p = RQ. \qquad \text{(A1)}$$

Here, the volumetric flux $Q = UA$ is the product of the flow velocity U and cross-section area A and R is the hydraulic resistance of the phloem translocation pathway. Assuming that the translocation pathway consists of N identical sieve tube elements, $M$of which contain a SEOR1 agglomeration, we write the resistance as

$$R = NR_{lumen} + (N-1)R_{plate} + MR_{plug}. \qquad \text{(A2)}$$

Here, we take into account three major components: a) the sieve tube lumen including organelles, R_{lumen}, b) the sieve plate, R_{plate}, and c) the SEOR1 agglomerations, R_{plug}. An expression for each of the terms in Equation (A2) is derived in the following sections, and numerical values are given in Table 2.

1. **Resistance of the sieve tube lumen**

Assuming that the cell lumen is well approximated by a cylindrical tube, we have for the resistance of the lumen R_{lumen} (Bruus, 2008)

$$R_{lumen} = \frac{8\eta L_t}{\pi a_e^4}. \qquad \text{(A3)}$$

Here, η is the viscosity, L_t is the length of the sieve tube element and a_e is the radius of the part of the tube which is open to flow. Due to the abundance of sieve tube constituents at the margins, we estimate that the effective radius a_e is between 80% and 100% of the total sieve tube element radius a_t.

2. **Resistance of the sieve plate**

For the resistance of the sieve plate we follow (Mullendore et al., 2010) and take into account the contribution to the resistance from each individual pore. The resistance of a sieve plate of thickness l consisting of N_p pores of (generally different) radii $a_{p,n}$ has two contributions. One due to the finite length of the pore and one due to the flow near the orifice (Weissberg, 1962; Dagan et al., 1982). We thus have for the plate resistance R_{plate} that

$$R_{plate} = \left(\sum_{n=1}^{N_p}\left(\frac{8\eta l}{\pi a_{p,n}^4} + \frac{3\eta}{a_{p,n}^3}\right)^{-1}\right)^{-1}, \qquad \text{(A4)}$$

where we have assumed that the sieve plates are unobstructed. Individual pore radii $a_{p,n}$ and average plate thickness from 22 sieve plates were determined as described in (Mullendore et al., 2010). The plate resistance R_{plate} was subsequently calculated from Eq. (A4). The value given in Table 2 is the average of the values obtained from 22 sieve plates. Average plate thickness, pore diameter, and number of pores are given in Table 1.

3. Resistance of the SEOR 1 agglomeration

As shown in Figures 6J, the SEOR1 agglomeration has a roughly circular opening of diameter $d_o \simeq 1$ µm. The fibrous part of the agglomeration can thus be thought of as acting in series with a cylindrical tube, such that the total resistance of the agglomeration is given by

$$R_{plug} = \left(R_{opening}^{-1} + R_{fibers}^{-1}\right)^{-1} \qquad \text{(A5)}$$

3.1 Resistance of the SEOR 1 agglomeration opening

The hydraulic resistance of the opening is completely analogous to that of a single sieve pore, Eq. (A4) (Weissberg, 1962; Dagan et al., 1982)

$$R_{opening} = \frac{8\eta L_p}{\pi a_o^4} + \frac{3\eta}{a_o^3}, \qquad \text{(A6)}$$

where $a_o = \frac{d_o}{2}$ is the radius of the opening and L_p is the length of the agglomeration.

3.2 Resistance of the SEOR 1 agglomeration fiber network

To calculate the resistance of the SEOR1 fiber agglomeration R_{fibers} we think of the fibers as a porous medium consisting of a large number of parallel solid cylindrical rods of uniform diameter d_f. Analogous to Eq. (A1), we write the hydraulic resistance of the fiber network as

$$R_{fibers} = \frac{\Delta p_{fibers}}{Q_{fibers}}, \qquad \text{(A7)}$$

where Δp_{fibers} is the pressure drop across the agglomeration and Q_{fibers} is the volume flux through the fibers. To determine R_{fibers} we follow Jackson and James (1986) and consider Darcy's law for the volumetric flow rate Q_{fibers}

$$\frac{Q_{fibers}}{A_{fibers}} = \frac{K}{\eta}\frac{\Delta p_{fibers}}{L_p}, \qquad \text{(A8)}$$

where $A_{fibers} = \pi(a_t^2 - a_o^2)$ is the cross-section area of the fiborous part of the agglomeration, L_p is the length of the agglomeration, and K is the permeability of the agglomeration. The non-dimensional permeability $\kappa = \frac{4K}{d_f^2}$ depends on the volume fraction of solid material ϕ and on the arrangement of the fibers. It has been determined experimentally and theoretically for several different classes of cylinder arrangements (Jackson and James, 1986). For flow parallel to an array of parallel cylindrical rods, the non-dimensional permeability κ is given by

$$\kappa = \frac{1}{4\phi}\left(2\phi - \log\phi - \alpha - \frac{1}{2}\phi^2\right), \qquad \text{(A9)}$$

where α depends on the arrangement of the cylinders. A comparison with experiments suggests that $\alpha = 1.5$ gives the best fit to a large collection of data, including flow through polymer gels, glass fibers and collagen, materials with dimensions similar to that of SEOR1 (Jackson and James, 1986).

The arrangement of cylinders is not know in detail. We therefore approximate the solid volume fraction by the mean value obtained in three simple geometries

$$\phi = \begin{cases} \frac{d_f^2}{4S^2} \simeq 0.46 & \text{Square array,} \\ \frac{d_f^2}{2\sqrt{3}S^2} \simeq 0.54 & \text{Staggered array,} \\ \frac{d_f^2}{3\sqrt{3}S^2} \simeq 0.36 & \text{Hexagonal array,} \end{cases} \quad \text{(A10)}$$

such that $\phi \simeq 0.45$ and where $S = b + d_f$ is the distance between adjacent fiber centers (Tamayol and Bahrami, 2011). From Equations (A7) and (A8) we finally have for the agglomeration resistance

$$R_{fibers} = \frac{\eta L_p}{\kappa a_f^2 A_{fibers}}. \quad \text{(A11)}$$

Supplemental References

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