granulation are fluidization velocity of process air, ratio of granulation spray rate to drying capacity of fluidization air, inlet air temperature, bed depth, and droplet size of the sprayed binder [45,46]. It is recommended that one use the same inlet temperature, droplet size, and air velocity (airflow/area of screen size) and achieve the same fluidization level when transferring the process from smaller equipment to production scale. The spray rate for the larger unit may be calculated using the following equation [47]:

$$R = (B/b)r, \tag{5.3}$$

where R is the spray rate in the larger unit (g/min), B is the bowl screen area for the larger unit (ft^2), b is the bowl screen area for the smaller unit (ft^2), and r is the spray rate in the smaller unit (g/min). Small adjustments may need to be made to such theoretical calculations to account for differences in bed depth [47].

Roller Compaction

Roller compaction involves continuous compaction of drug–excipient blends into ribbon-like compacted material, which is subsequently milled, lubricated, and either compressed into tablets or encapsulated. Roller compaction, as a pharmaceutical unit process, has several advantages over other particle enlargement techniques such as wet granulation. For high-dose, water-soluble drugs, aqueous granulation is not the preferred method due to inadequate water distribution and formation of lumps. For drugs that are chemically unstable in the presence of water or the granulating solvent, roller compaction offers an effective alternative for granulation. Several equipment and process parameters have to be addressed when scaling up a roller compaction granulation [48]:

1. Roll configuration or design: smooth, corrugated, or concave-convex
2. Roll diameter, nip angle, and area
3. Screw feed rate
4. Roll speed
5. Compaction pressure
6. Feed screw orientation vertical or horizontal
7. Vacuum deaeration of the blend before compaction

Nip angle is the angle made by the powder being compacted by the rolls in the compaction (nip) region [49]. Highly compressible materials have large nip angles compared with incompressible materials. Corrugated rolls have a higher capacity to drag material between the rolls compared with smooth rolls and hence provide greater compaction forces. It is important to maintain these design similarities between compactors when scaling up from a laboratory or pilot unit to the production equipment. Sheskey et al. [50] studied the effect of several process parameters during scale-up of a hydroxypropylmethylcellulose containing controlled release matrix formulation of theophylline. They scaled up the roll speed by maintaining the same linear velocity as that obtained from the laboratory unit, thus providing similar dwell time for the material in the compaction zone. Keeping the parameter