## CHAPTER VIII

## CONCLUSIONS

### 8.1 Conclusions

From the modeling, validation, and test of the general applicability and the application of the present comprehensive model, the following conclusions have been obtained:

1. A comprehensive generic model, which can describe both the surface evaporation and internal moisture diffusion controlled periods, has successfully been developed.

1.1 The fourth-order Runge-Kutta method used to numerically integrate the model equations requires an integration step size of $1*10^{-4}$ m in the drying length. A step size of $5*10^{-5}$ m in the drying length is also used to check and control the relative errors.

1.2 The criteria for the model selection is as follows:

- If $R_{ds} > R_{dd}$ at $Z = 0$, then the surface evaporation period does not exist and the actual drying rate is controlled by the rate of internal moisture diffusion from the beginning.
- If $R_{ds} < R_{dd}$ at $Z = 0$, then the surface evaporation rate determines the actual drying rate in the vicinity of the dryer inlet.
- As the drying material proceeds step by step along the dryer length ($\Delta Z = 1*10^{-4}$ m being a typical stepsize), the local value of $R_{ds}$ tends to decrease

at a slower pace than that of $R_{dd}$. If $R_{ds} < R_{dd}$ throughout the entire dryer length, then only surface evaporation controls the actual drying rate.

- If $R_{ds} > R_{dd}$ at some point in the dryer length, then a switching to another dominant model occurs and the actual drying rate is determined thereafter by the rate of internal moisture diffusion ($R_{dd}$).

2. Validation of the model with experimental results obtained from a full-scale industrial pneumatic conveying drying of cassava flour has been successful.

2.1 Between the three unknown key parameters, the intrinsic equilibrium moisture content have the most significant effect on the simulation results. By varying the initial equilibrium moisture content, the most suitable value for cassava flour is 13 % dry basis.

2.2 The outlet moisture content, humidity and air temperature predicted by present model are more accurate than those predicted by the previous model. The present simulated flour temperatures are slightly high than the experimental values but the relative errors are less than 7 %.

3. The general applicability of the present model has been shown by comparing the simulated results with published results of ilmenite, Glauber's salt, calcium carbonate, ammonium sulfate and PVC resins obtained in industrial dryers.

3.1 When some of the three key parameters of certain materials are unknown, they have to be estimated from known drying results. Estimated values of the internal moisture diffusion coefficient and initial equilibrium moisture content are as follows:

- Internal moisture diffusion coefficient of ilmenite, Glauber's salt and ammonium sulfate are $4*10^{-12}$ $m^2/s$, $1.5*10^{-12}$ $m^2/s$ and $4*10^{-12}$ $m^2/s$, respectively.
- Intrinsic equilibrium moisture content of carbon and PVC are 5.3 and 1.5, respectively.
- In all of the above cases, the slope of the equilibrium moisture content curve may be taken to be 0.4.

3.2 The model predicts the outlet moisture content and air humidity of all the additional materials reasonably well. Because of the assumption of negligible heat loss, the predicted solid and air temperatures cannot avoid showing some discrepancies from the reported values as long as there is an error in the overall energy balance in terms of the reported operating conditions.

4. Further applications of the present model on the industrial scale pneumatic conveying dryer of cassava flour yield the following results.

4.1 At the same existing drying capacity of 5759 kg/hr, the most economical operating condition among the studied range are 493 K and 20 m/s of inlet air temperature and velocity, respectively. At this suggested condition, it is possible to reduce 45 % in the mass flow rate of air and 35 % of the operating costs while maintaining the specified product quality.

4.2 To increase the drying capacity by 20 % to 6910 kg/hr, the model suggests 493 K and 25 m/s of inlet air temperature and velocity. Thus the mass flow rate of dry air is decreased 30 % from the original value at the existing drying capacity. This is accompanied by an decrease of 20 % in the operating costs.