CHAPTER 7

CONCLUSIONS

7.1 INTRODUCTION

In order to improve the sugar plant operating efficiency the drying characteristic of sugarcane bagasse is taken up for the study. Thin layer drying phenomenon for fibrous material like bagasse is found suitable using both air and low pressure steam as the drying medium. The various studies such as, thermo-gravimetric analysis study, thin layer drying experiments, energy exergy analysis, thin layer drying model and numerical simulation for air and steam as working medium, are performed. The TGA studies are performed for isothermal and heating rate conditions. The thin layer experiments are conducted for the varied operating conditions such as, product thickness: 20, 40 and 60 mm; air temperature: 80, 100 and 120°C; velocity: 0.5, 1.0, and 1.5 m/s and humidity: 9, 16 and 24 g/kg d.a. The results of these investigations are presented and discussed in the previous chapters. The following conclusions are drawn based on the present studies.

7.2 SUMMARY OF CONCLUSIONS

1. The derivative thermo-gram (DTG) curve from the TGA experiments reveals the absence of a constant-rate period during the moisture removal stage from bagasse.

2. Of the three zones of mass reductions during thermal analysis (TGA) of biomass, the first zone recorded an endothermic
period of 46.8% mass reduction in bagasse, which corresponds to the evaporation of the moisture content.

3. Thin layer drying of bagasse in the range of 20 to 60 mm, recorded the falling rate period of drying for all combinations of operating parameters.

4. From the thin layer experimental studies it is concluded, that the air velocity and humidity have a lesser effect on the drying rate compared to the product thickness and air temperature.

5. The diffusivity constant $D_0$ and the activation energy $E_a$ calculated based on Arrhenius-type relationship for bagasse using linear regression are $2.43 \times 10^{-7}$ m$^2$/s and 19.47 kJ/ mol K respectively.

6. The effective diffusivity of bagasse during drying in the temperature range of 80 to 120°C varied from $1.63 \times 10^{-10}$ to $3.2 \times 10^{-10}$ m$^2$/s.

7. The average Energy Utilization Ratio (EUR) for varied drying conditions of thin layer bagasse drying ranged between 9.19 and 34.78%. Varying the air velocity from 1.0 to 0.5 m/s for a bed thickness of 40 mm, results in 46.09% improvement in EUR while the reduction in the moisture removal process was 3.49%. Hence, with respect to the energy utilization parameter, the air velocity has to be optimized to the minimum level. The average exergetic efficiency for varied conditions of drying ranged between 39.84 and 95.66%.

8. Of the twelve thin-layer drying models, which were comparatively tested according to their coefficients of
correlation (r), reduced chi-square ($\chi^2$), RMSE and MBE values, the Page model best described the drying behavior of bagasse. The model and its incorporated relationships between the coefficients and the drying parameters are consistent with the experimental data, as evidenced by the good correlation values of $r = 0.99627$, $\chi^2 = 5.1352E-05$, RMSE = 0.007166034.

9. The two-dimensional numerical model developed for drying a rectangular moist bagasse layer was able to predict the experimental moisture content values closely with a deviation of up to 8%. This drying model permits simultaneous application of conduction and convection heat to the product. The developed model can be used to approximate and quantify the different heat and mass transfer phenomena for different conditions of drying. The model is able to provide reliable predictions of the drying rate and the temperature distribution in the product sample along the dryer.

10. The steam drying model which considers the reverse process, i.e., initial condensation of steam was developed. Due to the initial condensation phenomena the latent heat due to condensation is added to the material in addition to the convective heat from the drying medium. This phenomenon improves the rate of drying for the steam drying process. For the simulated conditions of steam at 130°C and bed thickness with 40 mm, the reverse point occurred at about 45s while the restoration process continued up to 195s. With regard to the change in mean moisture content of the material, the smaller the bed thickness and the larger the heat flux given to the material using elevated steam temperature, the shorter the
restoration time and the smaller the condensate evolved. Compared with the air drying process the drying rate of the steam-drying is distinctly ahead; hence, the duration of drying was noted to be considerably reduced while assuming the same activity coefficient obtained for air as the drying medium from the thin layer drying experiments.

The feasibility of using the thin layer approach for bagasse drying is established in this research. The Energy and exergy analysis, the evaluation of the thin layer model to represent the moisture removal process and the numerical model developed using both air and low pressure steam may be used for future studies on bagasse drying.

7.3 CONTRIBUTION OF RESEARCH TO INDUSTRY

The empirical modeling performed in this research, identified Page model to match the experimental results of bagasse drying closely within the specified conditions of drying. This model can be used by the sugar industry researchers or dryer manufacturers to estimate the amount of moisture reduction for a set of drying conditions without performing any expensive experimental procedures.

The detailed numerical model performed in the research, reasonably matches the experimental drying data. The results of this model give us the more in depth knowledge of moisture and temperature distribution during drying. Hence this model can be very well applied by the researchers or the dryer manufacturers, to predict the inside happenings during drying of bagasse.
7.4 SCOPE FOR FUTURE WORK

1. Detailed experimental and modeling study for steam drying of bagasse needs to be further investigated.

2. Multistage drying with drying medium recirculation has to be investigated for bagasse drying.

3. The design of a mathematical model to optimize the number of stages and fraction of recirculation has to be investigated.

4. The scope of pneumatic drying with respect to the present material handling system in a sugar plant needs to be investigated along with a model to represent the pneumatic drying of bagasse.