ABSTRACT

Bagasse, the byproduct from the cane sugar industry, is a fuel used by the plant to meet its process steam and in-house power requirements. This mill-run bagasse has a high moisture content of around 50% with a gross heating value of 9456 kJ/kg compared to its bone-dried conditions at 19268 kJ/kg. Hence, if the mill-run bagasse is dried using the available waste heat, there is considerable scope for improving its calorific value. The increased calorific value of the fuel results in improved boiler efficiency, decrease in blower power consumptions, reduction in emission levels and savings in fuel. Hence, in this research, studies on bagasse drying using available waste heat have been focused on.

Considering minimum modification to the present material handling system in the plant, a thin layer tunnel type moving bed dryer with combined heating is considered. This study comprises both experimental and theoretical aspects. The thin layer drying experiments are conducted in a laboratory scale dryer for a wide range of air temperatures (80 to 120°C), velocities (0.5 to 2 m/s), humidity (9 to 24 g water/kg of d.a) and product thickness (20 to 60 mm) to determine the drying kinetics under varied operating conditions. The study revealed that the effect of bed thickness and temperature had more impact on drying studies than that of drying air flow rates and humidity. Even though the product has high initial moisture content, it is found that the drying of bagasse takes place only in the falling rate period.
The drying results are useful to describe the temperature dependence of the diffusivity coefficients for bagasse. The thermo-gravimetric study, an innovative approach to study the liquid-solid interfaces (drying kinetics) is carried out. The study reveals the absence of a constant rate drying period during the drying of bagasse.

The energy and exergy analysis are performed to estimate the Energy Utilization Ratio, the magnitude of exergy losses, exergy out-flow and the exergetic efficiency for the drying experiments conducted. For the chosen range of operating parameters during the experiments, the average Energy Utilization Ratio varied between 9.19 and 34.78%, while the exergetic efficiency varied between 39.84 and 95.66%. From the results it is observed that the variation of air velocities influences the Energy Utilization Ratio and exergetic efficiency significantly.

Twelve semi-theoretical / empirical thin layer drying models are comparatively tested to represent the bagasse drying phenomenon using non-linear regression analysis techniques. The drying data are fitted to the different models and compared based on their correlation coefficient (r), chi-square ($\chi^2$), root mean square error (RMSE) and mean bias error (MBE) values. The study revealed that the ‘Page Model’ predicts the drying behaviour of bagasse more closely than other models with a correlation coefficient of 0.99627.

A numerical two-dimensional model using the finite volume method is developed to provide reliable predictions on temperature and moisture profile distribution within the moist rectangular bagasse layer.
undergoing drying. The medium for the drying phenomenon is hot air and low pressure steam considered. The model was capable of predicting the experimental moisture removal rate with a maximum deviation of around 8\% while using air as the drying medium. The flow fields are numerically modeled using the Fluent CFD to analyze the heat and mass transfer coefficients at different time intervals. For the solid zone, a numerical procedure was developed using MATLAB codes to analyze the heat and mass transfer through diffusion inside the product. For the steam-drying model, the reverse process is considered with an initial condensation of steam. For the simulated conditions of steam at 130\(^\circ\)C and bed thickness of 40 mm, the reverse point occurred at about 45s while the restoration process continued up to 195s. As the bed thickness increases the reverse point extends, and hence, the moisture added increases. 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 outcome of the work is quite useful in understanding the thin layer drying kinetics of bagasse, which will go a long way in the design of bagasse drying systems.