The Performance Enhancement of the Agricultural Postharvest Cooling Systems by Using Heat Exchangers

Anchasa Pramuanjaroenkij[1 *], Phongsathon Janthasri[1], Sadık Kakaç[2]
[1] Faculty of Science and Engineering, Kasetsart University,
Chalermphrakiat Sakon Nakhon Province Campus, Thailand 47000
[2] Department of Mechanical Engineering, TOBB University of Economics and Technology,
Ankara, Turkey 06560
* Corresponding author: anchasa.p@ku.th; anchasa@gmail.com

Abstract

Refrigerating systems are important tools in agricultural postharvest; especially in hot, humid and fluctuating climate due to global climate change. There were numerous Computational Fluid Dynamics (CFD) works published and introduced their predictions on postharvest storage conditions, many of them experimentally investigated to validate the CFD results. Many agricultural products produce heat during their postharvest storages, their storages must manage temperature and relative humidity as their proper storage conditions; temperature and relative humidity relating to each product. For an example, the storage conditions for tomatoes, sweet potatoes, watermelon and pears are 18°C to 22°C and 85%RH to 90%RH. The product freshness directly affected the higher consumption rejection. Heat exchangers are equipment enhancing thermal performances of many thermal system, one of them is the refrigerating system. Chlorodifluoromethane or HCFC-22 has been phased out since 2010, environmentally friendly refrigerants were introduced such as Difluoromethane or HFC-32. Cooling systems in the postharvest applications normally use fixed speed compressors while the variable speed compressors are used in residential applications. This work focuses were on expressing air temperature, air relative humidity, and energy consumption profiles of two refrigerating storages using fixed and variable speed compressors. The profiles were obtained from before and after the double pipe heat exchanger (DPHEx) installations. The heaters, humidifiers, and hot water pots were used to generate heat and humidity inside both storages. The storage temperatures were investigated at 18°C and 22°C, a storage temperature range for many postharvest products. From all results, the air temperature and relative humidity profiles of the fixed-speed refrigerating room were more fluctuating than those of the variable-speed refrigerating room. As expected, the energy consumptions of the variable-speed refrigerating system were lower than those of the fixed-speed refrigerating system. The consumptions of the fixed and variable-speed refrigerating systems after the DPHEx installation, when the heaters were turned on, were lower than those of the systems without the DPHExs by 52.33% and 17.19% at 18°C, as well as 50.63% and 20.00% at 22°C, in average percentages respectively. The DPHEx enhanced the performance of the fixed speed system remarkably. Since the double pipe heat exchanger installations played important roles in both storages, the further investigations were carried on with the DPHEx installations. When the heaters were turned off and the humidity effects were experimentally studied, the energy consumptions of the fixed and variable-speed refrigerating systems working with humidifiers were lower than those of the systems without the humidifiers by 20.00% and 15.38% at 18°C, as well as 14.29% and 33.33% at 22°C, in average percentages respectively. The humidity showed their effects on the system energy consumptions in different ways; the higher effect on the fixed-speed system provided at 18°C while the higher effect on the variable-speed system occurred at 22°C.

Then, the heat loads were on, and the humidity was changed by turning on and off the humidifiers, the heat and humidity effects were observed. The consumptions of the fixed and variable-speed refrigerating systems dealing with high relative humidity were lower than those of the systems dealing with low relative humidity by 28.65% and 43.48% at 18°C, as well as 4.29% and 50.00% at 22°C, in average percentages respectively. The variable-speed system with the DPHEx consumed less energy outstandingly. Finally, the heat and humidity in the rooms were predominantly stimulated by boiling water to monitor the drastic conditions. The consumptions of the fixed and variable-speed refrigerating systems dealing with the drastic conditions were higher than those of the systems dealing with low relative humidity by 80.00% and 61.54% at 18°C, as well as 114.29% and 100.00% at 22°C, in average percentages respectively. These results implied that, when the drastic conditions were applied, the variable-speed system with the DPHEx performed better in both temperature levels. Additionally, the evaporating water amounts in the fixed-speed refrigerating storage at both storage temperatures were higher than those of another storage about 19.58% and 17.50%, respectively. This research information provides basic information for preliminary decisions in selecting the refrigerating systems targeting the fixed and variable speed compressors in different situations. The energy consumption information of each cooling system can be used to calculate the power demand and cost, the cost is one of central concerns in agricultural product storage. The postharvest storage conditions are critical to product freshness and abundant; the fluctuating conditions must be aware of. The variable-speed system coupled with the DPHEx demonstrated their enhancements on the energy consumption and storage conditions; temperature and relative humidity. Noticeably, the cost of the variable-speed systems is higher than that of the fixed-speed systems, cooling system users should estimate all expenses such as investment cost, annual energy consumption cost, routine maintenance cost, part and service cost, as well as operating cost, to choose the proper systems for their design conditions.

Keywords: Heat Transfer; Energy Efficiency Ratios; HFC-32; Air Conditioning; Relative Humidity.