SHAABAN, MONA, and RANDOLPH BEAUDRY*, Michigan State University, 1066 Bogue Street, East Lansing, MI 48824. **Modeling Temperature and Heat Flux in Field Piles of Sugarbeets in Michigan.**

ABSTRACT

Harvested sugar beet (*Beta vulgaris* L.) roots are stored in Michigan in large piles and exposed to ambient weather conditions during winter storage period, which generally lasts three to four months. During this time, the air temperature may range from as low as -23 °C to as high as 16 °C. Winter air temperatures are rising in association with long-term trends of increasing global temperatures. Higher air temperatures contribute to increasing respiration and storage decay due to increasing metabolic activities, and give decay organisms optimal conditions to increase their growth and aggressiveness.

Our study is focused on developing a model of heat transfer that occurs inside the sugar beet pile through the storage period with uncontrolled ambient conditions where cooling is by natural convection. Such simulation is intended to help storage managers estimate pile temperature and take the correct decision regarding the structure and management of beet piles and the design and installation of appropriate ventilation systems. Our rationale for this project is that its completion will not only identify improved storage cultivars, but point to the biological underpinnings of one of the major factors affecting losses.

To monitor the pile temperature, we installed a wiring harnesses of T type thermocouples encased in polypropylene tubing for protection in beet piles at the Gera road piling ground, Reese, Michigan. Harnesses were positioned in the pile (Fig. 1) at the time of pile construction at the beginning of November. Data were collected until the end of the storage period, optimally at the end of March. Each harness had from 1 to 10 thermocouples, depending upon their position in the pile. One harness ran vertically down the face of the pile at the midpoint, another harness ran diagonally across the face of the pile from its outer shoulder to the base at its midpoint, a third harness will ran along the base of the pile to its midpoint, a fourth harness (thermocouples only, no protective tubing used) was buried two inches in the soil surface along the base of the pile to its midpoint. In addition, one additional thermocouple was embedded in the pile between the vertical harness and the diagonal harness and another two thermocouples were embedded in the pile between the diagonal harness and the horizontal harness. A total of 36 locations in each pile were monitored. Data was collected by dataloggers every minute and the average for each hour was recorded. The experiment was conducted on Michigan Sugar Company piling area at Reese, MI, USA.

Gas exchange measurements indicated that there was no significant build-up of either CO_2 in the beet pile, even during the warmest days. The temperature of the pile typically increased from the outside to the inside of the pile. The warmest portion of the pile was at its center and typically ranged from 5 to 20 °F warmer than the surface of the pile. The portion of the pile near the ground surface was also quite warm relative to the upper portions of the pile. We found that the pile temperature was quite responsive to the air temperature and changed rapidly on a daily basis. During warm periods when the air temperature was in the mid-30s, large portions of the pile (>70%) had root temperatures above 45 ºF. During cooler periods when the air temperature was in the low 20s, about 30% of the pile still had temperatures in 40 ºF range. At these times, almost half of the pile had temperatures below freezing.

Input data (air temperature and velocity, and ground temperature) was used in a finite element analysis to calculate the rate of heat gain (from the ground and respiratory activity) and heat loss (to the environment). A model was developed using finite element simulation software (COMSOL Multiphysics 4.4). Important parameters include: air temperature (collected from MSU extension station), sugar beet thermal conductivity, heat capacity of sugar beets, and the heat generation of respiration (measured in previous studies in our lab). The model's accuracy was assessed by comparing the output results to experimental data.

The finite element model was able to predict pile temperatures using only air temperature and air velocity, and ground temperature. The environmental data are easily obtainable from weather stations. Using the data for pile temperature, we were able to estimate the respiration of the pile and, from that, predict the rate of sugar loss.

The heat build-up in sugar beet piles can be estimated with some degree of accuracy using a relatively simple model. Properly implemented, this model will help us assess the effect of pile architecture, air temperature and even storage duration on the rate of sugar loss in the pile. The model can also be adapted to predict the effectiveness of active and passive pile ventilation strategies. The model is currently configured as a steady-state model and needs to be translated into a dynamic model, which will more accurately depict day-by-day changes in respiratory activity and sugar loss.