MEASURES TO REDUCE ENERGY CONSUMPTION: A SIMULATION STUDY FOR MUSHROOM HOUSES

D.P. Martin[1, 2] and H. Loeffen[2]

[1]Kinsealy Research Centre, Teagasc, & Control Systems Group, DCU, Ireland.
[2]IMAG-DLO, Wageningen, The Netherlands.

ABSTRACT

The purpose of this study is to provide a model to facilitate the simulated evaluation of the energy consumption for different mushroom house and climate set point configurations. Climate management in this application is complex, including control of: oxygen, carbon dioxide, and water vapour, temperature, evaporation rate, air cleanliness, and indoor-outdoor pressure differential. Climate set points vary according to the stage of crop growth and need to be maintained regardless of weather conditions. Energy saving by set point alteration is part of the study as its effect on energy saving is currently indeterminate. Traditional solutions to satisfy the climate requirements have a number of drawbacks. Data is currently unavailable to quantify the effect of these drawbacks, hence the need for a simulation model. Use of a model facilitates comparative analysis of different house configurations that overcome these drawbacks and help determine minimum overall energy cost.

INTRODUCTION

If the application challenge for climate control is indicated by the number and range of climate variables that need to be controlled, then climate control in mushroom houses is at the complex end of the spectrum.

- Indoor pressure is normally positive with respect to ambient to limit the ingress of airborne disease carriers. When disease occurs in one house of a farm then it's desirable for the indoor pressure of that house to be negative, to prevent the spread of the disease.
- Mushrooms are prone to bacterial, fungal, and viral attack, so filtration of the air is essential to minimise damage potential from these airborne sources.
- The crop growth rate is governed by compost temperature, which is controlled by heat exchange with the house environment.
- The evaporation rate from the crop surface affects mushroom quality. Evaporation rate is controlled via the air's drying power, which is in turn dependent on air temperature, vapour pressure deficit, and airspeed.
- Mushroom metabolism requires oxygen as a process input. The partial pressure of oxygen in the mushroom house can be used as a 'damper' to regulate metabolic combustion.
- Carbon dioxide is a by-product of the metabolic process and its concentration affects mushroom morphology.

A qualitative analysis (quantitative data is unavailable) suggests that the typical mushroom house suffers from several ventilation related problems and that climate control is sub-optimal in terms of energy consumption. Qualitative synthesis suggests that these problems can be overcome and that energy consumption can be improved. The objective of the present study is to estimate via simulation, the design performance of current typical mushroom houses and set points, and other configurations/set points that use less energy.

METHODS

The qualitative analysis is based on a separation of energy use between kinetic and thermal energy consumption. A limited survey of mushroom farms identified some typical ventilation related problems. A combination of energy function and ventilation problem analysis was used to synthesise possible solutions. An energy consumption model under development in the Matlab/Simulink environment is for evaluation of the relative performance of different house configurations. The following problems and configurations are included in the study.

- The blowback of exhaust air during adverse wind conditions and the external re-circulation of exhausted air can both lead to undesirable air contamination levels in the mushroom house. Cowls can provide a natural ventilation supplement to the mechanical system to minimise this problem and reduce kinetic energy demand on the fan.
- The airflow pattern in a mushroom house varies, depending on the setting of the intake and re-circulation vents. Hence it's difficult to provide a homogenous air delivery to the crop surface. Re-design of the air circulation system can ensure a consistent airflow in the house and minimise the resistance to airflow in the air circulation path.
- High insulation levels facilitate low heating costs in winter. In general it is desirable to match insulation levels so that house heat loss matches crop heat production. A roofspace variable insulation system can provide a mechanism to match insulation levels to the prevailing weather conditions and thus reduce energy demand.
- Energy recuperation from exhaust air is not currently a common practice. The use of an energy recuperation wheel provides a means of selectively recuperating heat and/or water vapour from exhaust air.
- Variation of climate set points has resulted in significant energy savings in other applications. Current management practice matches climate set points to mushroom cultivar. If (as postulated) growth is an integral process it may be possible to match set points to weather conditions to take advantage of diurnal and seasonal variation and hence save energy without extending the crop growth cycle.

DISCUSSION

Each of the configurations listed is capable of delivering a reduction in energy consumption for mushroom growing and solving a problem resulting from the current sub-optimal design of the air conditioning unit and air circulation system. The model under development provides a mechanism to determine the relative gains of each of the proposed configurations in terms of energy saving. This will provide a means of determining implementation priorities based on a forecast cost/benefit analysis using the model.

Regulatory pressure to reduce energy consumption is a driving force to minimise carbon dioxide emissions and to migrate protected cultivation, of which mushroom growing is one element, to a position of sustainable agricultural production. The situation where natural means alone can be economically harnessed to provide the required air conditioning and circulation for mushroom growth is an unlikely occurrence in the near future. Steps, such as those listed above, can be taken to improve energy efficiency and thus facilitate increased production without increased energy consumption.

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