Modeling of computer controlled bee wintering building profitability

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Abstract*. Model of determination of profitability of indoor wintering is made using program POWERSIM 2.51. The necessary heating or cooling power (N) to keep the target temperature in the wintering building is calculated from equation N=NB+NV1-NS-NG, where NB-metabolic power of bees, NV1-power of recirculation fan, NS-power lost through walls by heat transmission, NG-power to warm-up the incoming air. NB depends on the air temperature in the wintering building. Mean input variables are air temperature and humidity outdoors, size of wintering building (number of colonies), capacity of heating and cooling systems, electricity costs, coefficient of heat transfer (CHT) of wintering building.*

Output parameters are savings of consumed honey and bee resources compared to reference group of bee colonies wintered outside. It is assumed that each 600 mg of saved honey means additionally saving of physiological potential of one new-born bee.

As calculation samples efficiency of indoor wintering in Manitoba (Canada) and Riga (Latvia) for wintering buildings in different executions are compared.

Key words: bee, wintering, profitability, simulation.

Introduction

Wintering indoors is one of methods to improve the wintering results in regions with cold winter. Successful indoor wintering is described in different countries (Fingler and Small, 1982; The Prairies…, 1986; Furgala and McCutchenon, 1992). Practical tests in Latvia show, that under Latvian circumstances wintering building is not efficient (Argalis et.al., 1970). Theoretical calculations for rational bee wintering building in Latvia are done (Kristapsons et al., 1996).

Simulation model is created to investigate economical efficiency of wintering buildings under different climatical circumstances. The model is developed using software for dynamic modelling POWERSIM 2.51 (POWERSIM, Internet).

The goal is to compare efficiency of wintering buildings made for Canada (Fingler and Small, 1982) under Canadian (Manitoba, British Columbia) and Latvian (Riga) climatical circumstances depending on outside temperature, humidity and installed equipment of temperature control.

Methods of investigation

The calculations are based on the relationship between ambient temperature and warmth power of bees (Jeskov, 1983, 1990; Rybochkin, 2001). Economy of honey and energetical resource of bees are calculated. It is assumed that beehives in the wintering building are without additional insulation with sufficient amount of quality food and the bees are healthy. The number of bees per hive is about 20 000. It is assumed that bees do not start intensive brood rearing in spring in the wintering building.

The target of control algorithm of wintering building is to minimise use of bees and honey as energy source replacing them with electric energy. The effect of indoor wintering is compared with control group of equal companies wintered outdoors.

Calculations of warmth process are based on equation of necessary warming (cooling) power N to keep system in thermal balance (Kristapsons et al., 1996):

$$N=NB+NV1-NS-NG \quad (1)$$

where N_B- warmth power of bees (W);

NV1- capacity of recirculation fan (W);

NS- warmth losses through walls of the building (W);

NG – power for heating up of incoming air from outside (W).

Wintering simulation is done for wintering building built accordingly (Fingler and Small, 1982) described principles. The building is equipped as follows:

1) Constantly working air recirculation system with capacity 18 m^3/h per hive (at 30 Pa). This system homogenises the air inside building.
2) Cooling ventilation system controlling inside temperature consisting of four suction fans with capacities 0,9; 1,8; 3,6 and 11,7 m^3/h per hive (at 30 Pa). The fan with smallest capacity works constantly to deliver the necessary amount of air for breathing 0,9 m^3/h per hive. Thus the oxygen is delivered and the excess carbon dioxide and water is removed. The rest of suction fans ensure additional cooling if the temperature indoors exceed the target temperature set.

Following approximation is used to calculate the electrical capacity of all the fans. The data is based on information about electrical consumption of fans N_{nos} (W) (Kanalflakt, 1999):

$$N_{nos}=aV+15 \quad (2)$$

where a – 0,0052 (Wd/m3);

V – capacity of fan at pressure difference 30 Pa (m3/d).

3) Electrical heater system controlling the indoors temperature with maximal capacity 10W per hive.

Electrical heater is used for heating. Ventilation system is used for cooling. The control system has task to reach the nearest possible temperature to the target one if the capacity of control means is not sufficient.

Simulation program is created on the software for dynamic simulations POWERSIM 2.51 (POWERSIM, Internet).

Program has following variables (parameters, where a value in brackets is indicated does not change in all the described simulations):

1) Date of begin (16-th. November) and end (14-th. March) of indoors wintering (Kristapsons et al., 1996),
2) Number of colonies wintered indoors (100 pcs.),
3) Relative humidity in the wintering building (60%) (Fingler and Small, 1982),
4) Relative humidity outdoors (80%). It is possible to set the function of daily relative humidity during the winter like it is possible with outdoor temperature. Still the influence of this parameter is not significant. Changes of relative humidity outdoors within 80±20% influence parameters of economy less than 1%.
5) Coefficient of heat transmission C ($W/^oC$) (Kristapsons et al., 1996). This parameter in case of wintering building capacity of 100 hives in Manitoba is C=12.5 ($W/^oC$) (Fingler and Small, 1982),
6) Maximal power of heating system (10 W/hive) can be changed by means of coefficient,
7) Maximal capacity of cooling ventilation system (18 m^3/h hive) can be changed by means of coefficient,
8) Target temperature in wintering building (6 ^oC). The curve of warmth capacity of bee colony has minimum at outside temperature +8^oC (Jeskov, 1990). If the temperature increase from the minimum point for 1^oC the warmth power of bees increase about 5x compared to decrease of 1^oC. We use +6^oC as a target temperature, which is displaced from the minimal value to a lower temperature to avoid warming up over +8^oC even oscillations during transition process. In literature the target temperatures in wintering building are mentioned within interval 4-10 ^oC (Furgala and McCutchenon, 1992).
9) It is possible to change the way of definition of outside temperature. It is possible to use sinusoidal rule of change, sinusoidal rule with random oscillations, (Stalidzans et al, 2001), In case of use of sinusoidal rule its maximum and minimum are the long-therm average temperatures in July and January. It is possible to analyse the operation of wintering building in temperatures, which are given in form of MS Excel sheets.
10) Degree of thermoinsulation of control group of bee colonies wintered outdoors (in all simulations the control group of bee colonies is additionally thermally not insulated). It is assumed that the thermal processes in insulated hive is equal to the one of non-insulated hive in a higher outside air temperature. This temperature difference is assumed as the unit of measure of thermoinsulation. In the program the effect of thermoinsulation of hives is expressed as a temperature difference (oC). That is outside temperature difference between non-insulated and insulated hive to keep their microclimates equal.

The most important output parameters of program are:

1. Parameter ”Savings”: saved honey (kg) and saved energetical resource of wintering bees (%) compared to a control group of equal colonies wintered outdoors.

The honey is saved replacing the warmth energy of consumed honey by electrically driven control systems. Energetical value of 1 g of honey is 11 400 (J).

It is more difficult to estimate the savings of energetical resource of bees (Stalidzans et al, 2001). Savings are the difference between the resource of indoors (r_z) and outdoors (r_k)

wintered bee colonies in the day, when the indoors wintered colonies leave the building in the spring. r_z and r_k are calculated by the program. It is estimated, that energetical resource of single bee is 1,8±0,1 Wh, which is created after consumption of A_m=0,6 g of honey (Stalidzans et al, 1999, 2000, 2001). Thus every 0,6 g of saved honey correspond to an energetical resource of one newborn bee. The full (100%) resource R of colony with n=20 000 bees is R=nA_m=20000 x 0,6=12 000 (g)=12 (kg) of honey. Actual energetical resource of a colony can be calculated as follows:

$$r_i = \frac{R - m_i}{R} \times 100(\%) \qquad (3)$$

where m_i – honey spent by bees of the colony.

Economy of energetical resource of bees can be alternatively expressed in amount of wintered colonies of control group with 20 000 bees to calculate the value of money for saved energetical potential. Each R=12 kg of saved honey form imaginary colony of 20 000 new-born bees with full energetical potential. The value of saved colonies in spring after wintering can be compared with value of outdoors-wintered colonies from control group. The amount of imaginary colonies with newborn bees has to be corrected to the one of equal number outdoors-wintered colonies (energetical potential r_k).

Sample of calculation.

<u>Given data:</u>

Amount of saved honey in a wintering building of 100 hives M_i = 125 kg = 125 000 g.

Energetical resource of control colonies after wintering r_k = 38%.

Amount of consumed honey during life (energetical resource) A_m = 0,6 g/bee

<u>Calculation:</u>

$$S_i = \frac{M_i}{A_m n r_k} = \frac{125000}{0{,}6 \times 20000 \times 0{,}38} \approx 27(colonies) \qquad (4)$$

where S_i – number of saved outdoors wintered colonies.

Now it is possible to calculate savings in terms of money if costs of honey and wintered bee colony are known.

2. Parameter <u>“Costs”:</u> electric energy (kWh).

The running costs are the electrical energy spent by recirculation fan and heating and cooling control systems. Amortisation costs are not taken into account.

3. Parameter <u>“Profit”</u>: units of money.

This parameter can be calculated as difference between “Savings” and “Costs”, when they are expressed in units of money and show the profit of use of wintering building. At this stage to calculate the profitability of wintering building the amortisation costs can be considered. In this paper units of money are not used as prices of energy, honey and colonies in spring are different from country to country.

Results

Results of comparing the efficiency of wintering building (Fingler and Small, 1982) under Riga (Latvia) and Manitoba (British Columbia, Canada) climatical circumstances in the table 1 show the importance of heating and cooling systems using sinusoidal rule of annual temperature change.

Results indicate, that wintering building with heating and cooling systems will be ~2x more efficient in Manitoba than in Riga.

Wintering building without heating system in Manitoba means decrease of economy for ~25%. Under Latvian conditions building without heating system reduce economy for ~10%.

Table 1

Comparing of efficiency of 100 hives wintering building in Manitoba (Canada) and Riga (Latvia) with different control systems*.

Combination of control systems	Calculated parameters	Manitoba (Canada)	Riga (Latvia)
With cooling With heating	Savings Costs Resource r_z/r_k	454 kg honey+39% en. res. 1817 kWh electroenergy 67% / 28%	220 kg honey +19% en. res. 907 kWh electroenergy 61% / 42%
With cooling No heating	Savings Costs Resource r_z/r_k	325 kg honey +27% en. res. 742 kWh electroenergy 55% / 28%	203 kg honey +18% en. res. 772 kWh electroenergy 60% / 42%
No cooling With heating	Savings Costs Resource r_z/r_k	454 kg honey+38% en. res. 1818 kWh electroenergy 66% / 28%	48 kg honey +5% en. res. 857 kWh electroenergy 47% / 42%
No cooling No heating	Savings Costs Resource r_z/r_k	325 kg honey+27% en. res. 741 kWh electroenergy 55% / 28%	42 kg honey +3% en. res. 722 kWh electroenergy 45% / 42%

*Long-term average temperatures (^oC) in January and July in Manitoba and Riga are correspondingly (jan:-15; jūl:+15) and (jan:-5; jūl:+17). Coefficient of heat transmission C=12.5 (W/^oC). Standard deviation is 4.

Manitoba wintering results are not influenced if the cooling ventilation system is not used (constant suction fan and recirculating ventilation system is working constantly in any case). Under Latvian winter conditions the indoors wintered colonies would die because of high temperature if there would be no system able to equal the indoors temperature with the outside one.

In Manitoba good results can be reached even if the wintering building is not equipped with any of mentioned temperature control systems.

Investigating demands for a rational bee wintering building in Latvia further simulations were done for the a.m. wintering building. To get better idea about variety of Latvian climatic circumstances warmest (1991/92) and coldest (1995/96) winters in period of years 1991-2001 were used (Table 2). Data of average outside temperature each day was imported from MS excel sheet. During the indoors wintering period (16-th November-14-th March) the average outside temperatures in Riga district in winter 1991/92 was +1,4^{o}C, but in 1995/96 it was –7,1^{o}C. Simulations were done at C=12.5 (W/^{o}C), and C=50 (W/^{o}C).

Table 2

Efficiency of wintering building in cold and warm Latvian winter.

Type of winter	Calculated parameters	Riga (Latvia) C=12,5	Riga (Latvia) C=50
1991/92 warm winter	Savings Costs Resource r_z/r_k	114 kg honey+9% en. res. 888 kWh electroenergy 58% / 49%	114 kg honey+10% en.res. 1066 kWh electroenergy 59% / 49%
1995/96 cold winter	Savings Costs Resource r_z/r_k	326 kg honey+27% en.res. 1289 kWh electroenergy 63% / 36%	312 kg honey+26% en.res. 2395 kWh electroenergy 62% / 36%

Discussion

Comparing efficiency of the wintering building (Fingler and Small, 1982) in Manitoba (British Columbia, Canada) and Riga (Latvia) is found, that wintering building is more efficient in cold winters, when heating system works most of the time. The simulations are done using the average day and night temperature. Taking into account the momentan values of temperature the cooling ventilation system would be more important neutralising dangerous high temperature peaks while profit would stay about at the same level as the extreme values would stay for a short time. For the heating system the peaks of low temperature are not critical for bees and in the wintering building it will be anyway better than outside.

Conclusions

The bee wintering building projected in Manitoba (British Columbia, Canada) (Fingler and Small, 1982) for 100 bee hives assuming sinusoidal annual change of temperature in Manitoba (jan. -15^{o}C, jul. +15^{o}C) comparing to an outside wintered control group save is 454 kg honey and 39% of energetical resource using 1817 kWh electroenergy. Under Latvian circumstances in Riga with average temperatures (jan. -5^{o}C, jul. +17^{o}C) the economy is 220 kg honey and 19% energetical resource spending 907 kWh electroenergy.

Under Latvian conditions simulating “cold” winter (average temp. –7,1^{o}C) economy is 326 kg honey and 27% energetical resource spending 1289 kWh (C=12,5 W/^{o}C) or 312 kg honey and 26% of energetical resource spending 2395 kWh (C=50 W/^{o}C). In case of “warm” winter (average temp. +1,4^oC) economy is 114 kg honey and 9% energetical resource spending 888 kWh energy (C=12,5 W/^oC) or 114 kg honey and 10% energetical resource using 1066 kWh electroenergy (C=50 W/^oC). Amortisation costs of building and equipment are not taken into account.

Low coefficient of thermal transfer of wintering building is important in cold winters, when heating system is used. The heating system is not critical for bees survival, but it can significantly increase rentability of building, especially in cold winters. Thermoinsulation has no significant impact when the wintering building is cooled by ventilation system.

In wintering buildings especially in Latvia with relatively high temperatures the cooling ventilation system becomes critical. Capacity of cooling ventilation system has to be calculated taking into account the coefficient of heat transmission of building and estimated maximal momentan outside temperature during bee wintering.

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