Should I insulate my hives in winter? When, how, why?

Lorenzo Pons

In winter, bees consume their stored resources for food and heat. Depending on the latitudes, the winter can be more or less mild, and the colonies can go through a variety of situations. What is the case where you should insulate your hives?

The month of January 2021 was particularly fresh. In the south-west of France days with 2 or 3°C maximum temperature had been usual. I was fearing my bees being stressed under those conditions. They already had to overcome the hornet season in autumn and now they are facing unexpectedly cold days.

To put this situation into perspective, during these last few years, I did not had any worries with the winter crossing, but this month of January, there are two things that make me wonder that some decisions should be taken.

The first is the low temperature alerts I received several days in a row. 4°C or less reached inside the hive, it's cold!

Events on January 5, 2021

Apiary	Hive	Past events	Date
Gelos	R6	Internal temperature below 4.0°C	Tue. 2021-01-05
Gelos	R7nw	Internal temperature below 4.0°C	Tue. 2021-01-05
Gelos	R8	Internal temperature below 4.0°C	Tue. 2021-01-05

low temperature alerts inside the hive

The second one, which definitely motivated me to act, is the observations after a snowfall this weekend. I realized an interesting difference on the roofs of the hives between the R6 which is empty and the others inhabited with bees that I could clearly hear "vibrating".

The snow completely covers the roof of the R6 hive, while it has melted all around the center stone of the other hives. Isn't this evidence that the bees are heating the inside of the hive and that some heat is being dissipated from above?

Hive without insulation.

Based on this observation, I wondered what the heat loss through the roof was. Clearly, if there is one side where the losses are important, it is the roof.

It was a long time I hadn't taken out my old heat transfer equations. I used them for many years in sizing helicopter turbines. Here comes the opportunity to dust them off and to use them for beekeeping.

Problem statement and assumptions

To state the problem, we start from a few principles:

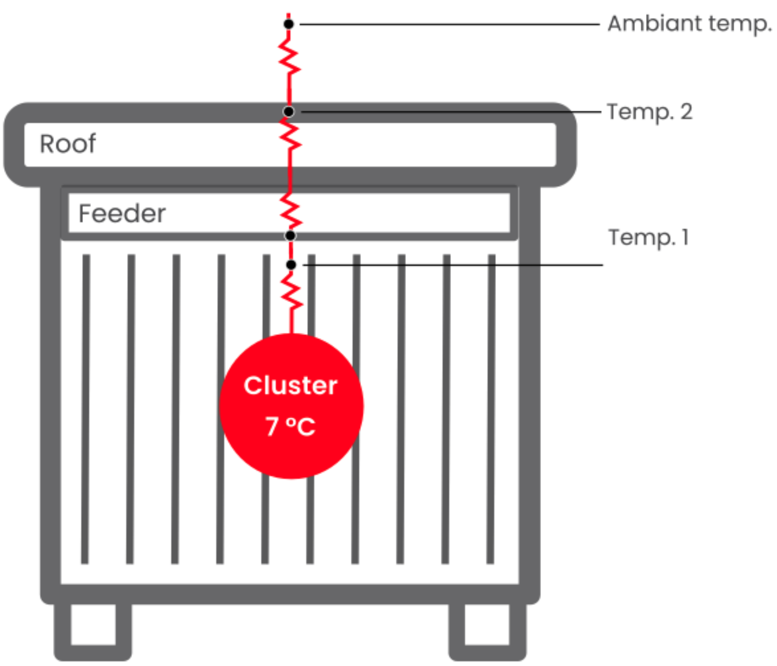
We know that bees aggregate in a cluster. The minimum external temperature of this cluster is 7°C. Below that threshold bees collapse. (read the excellent article by Janine KIEVITS).

«The cluster aggregates as soon as the outside temperature drops below 15°C; it is complete – i.e. all the bees in the colony have joined it – at 7°C; the individual rapidly collapses at lower temperatures. It is generally in the shape of a sphere or ellipsoid, sometimes flattened on one side when it is, for example, just under the frame cover. »

We can therefore conclude that the cluster can be modeled by a sphere and that the temperature of this boundary is 7°C in the worst case. This sphere being in a cooler environment, it loses heat by convection towards the roof. Warm air always rises, even within a hive!

Then there is the roof. In my case, feeder and roof, are all made of wood. The thicknesses are around 1.5 cm. The tray is made of 5mm plywood. The warm air that rises from the cluster heats the ceiling and is transmitted by conduction/convection through the roof.

There are some classic equations to calculate that kind of heat transfer configuration. It takes a bit of time, but it's quite straightforward. You can find the formulas here, or here for example.



The equivalent thermal network is displayed in the following diagram. In this model it is assumed that 100% of heat leaks from the top. This seems a bit of a strong approach – but (at our latitudes) wax frames avoid transverse losses quite well – and as mentioned before, the heat always rises. We will verify further on if this hypothesis holds (it even holds very well!).

The resolution of the system of equations provides the heat flux dissipated (in Watt) that varies between 0.04 and 2W depending on the outside temperature (+7 to -20°C). We are now fixed about the order of magnitude: The colony permanently dissipates 1/5th of a low-energy light bulb.

Now we would like to insulate the hives. What would be the effect of such an action?

Insulate the hives with 4cm polystyrene.

Consider adding a 4cm extruded polystyrene sheet under the hive roof (count an investment of 3.95€ per sheet for 3 hives at your preferred store). We add this constraint in our thermal model and recalculate the dissipated powers.

With the insulated hive, the dissipated powers are much lower: from 0.02 to 0.86 W for the same outside temperatures. The insulation of the roof – at these temperatures – therefore has a significant impact!

Ambiant Temp.(°C)	Dissipated power		
	Non-insulated	Insulated	gain
7	0,04	0,03	-41%
5	0,15	0,08	-47%
0	0,48	0,23	-52%
-1	0,55	0,26	-53%
-3	0,69	0,32	-54%
-10	1,23	0,54	-56%
-20	2,05	0,87	-58%

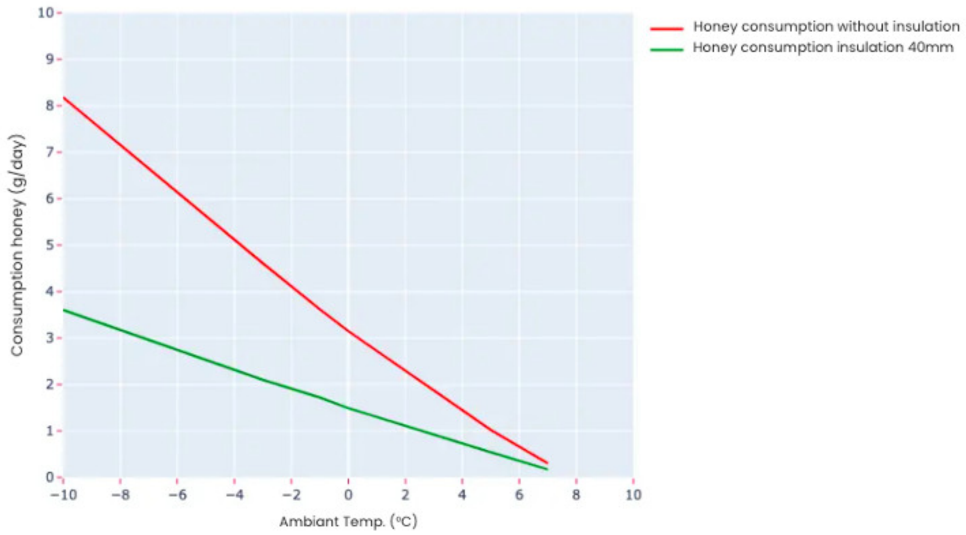
Dissipated power as a function of ambient temperature and expected gain with 40mm roof insulation

Quantity of honey consumed by bees

As said above, more heat means more honey consumed. We can therefore push this exercise a little further, by calculating the amount of honey consumed before and after insulating the hive. Be careful! Here we consider only the honey consumed for heating purposes, not for feeding. In other words, the real honey consumption by the bees must be higher than the values we will find.

Honey contains an energy of 13 kJ/gr. It is this energy that the bees dissipate in the middle of the cluster to warm all their fellow bees. It is by the movement of their muscles that they produce this heat, and since any exercise is a source of fatigue, a rotation is established between the bees of the cluster boundary and those at the core. They shift positions so that the bees in the center rest and those in the periphery come to work and warm up a little too!

Converting power needs into honey needs, here is what we find:



Honey consumption for heating as a function of ambient temperature, insulated (green) and without insulation (red).

The effect of the insulation of the hive has a very noticeable impact on the consumption of honey (for heating) which decreases considerably. At an external temperature of 0°C the consumption decreases from 3gr/day to 1.5gr/day. The saving is 50%!

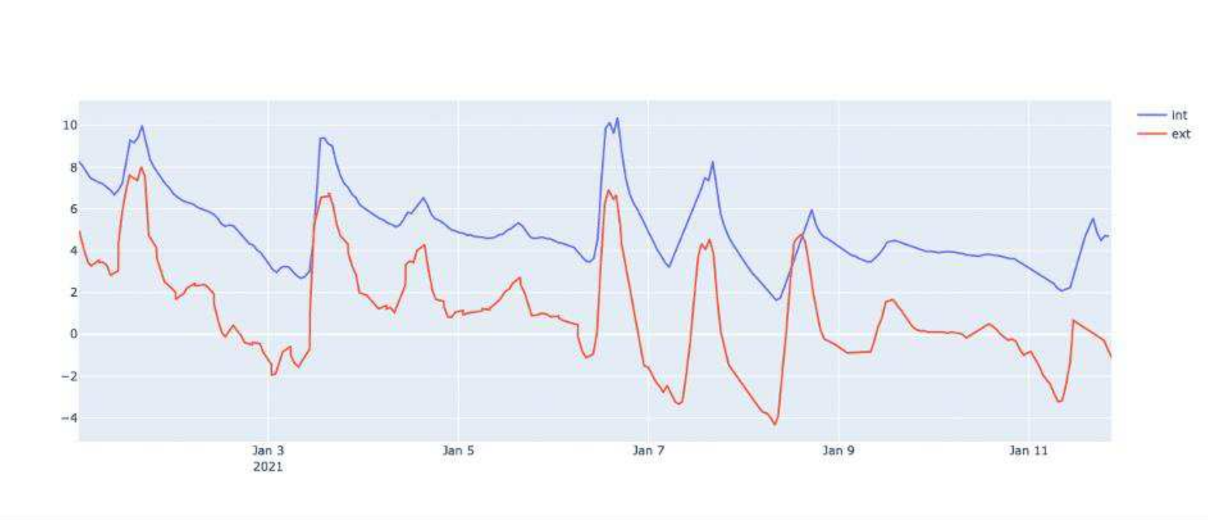
In view of these results, I folded the computer to go straight to the store! And here is the work, cut out to the pattern and installed in a blink of an eye 😃



Cutting of 40mm polystyrene boards and installation between the roof and the feeder.

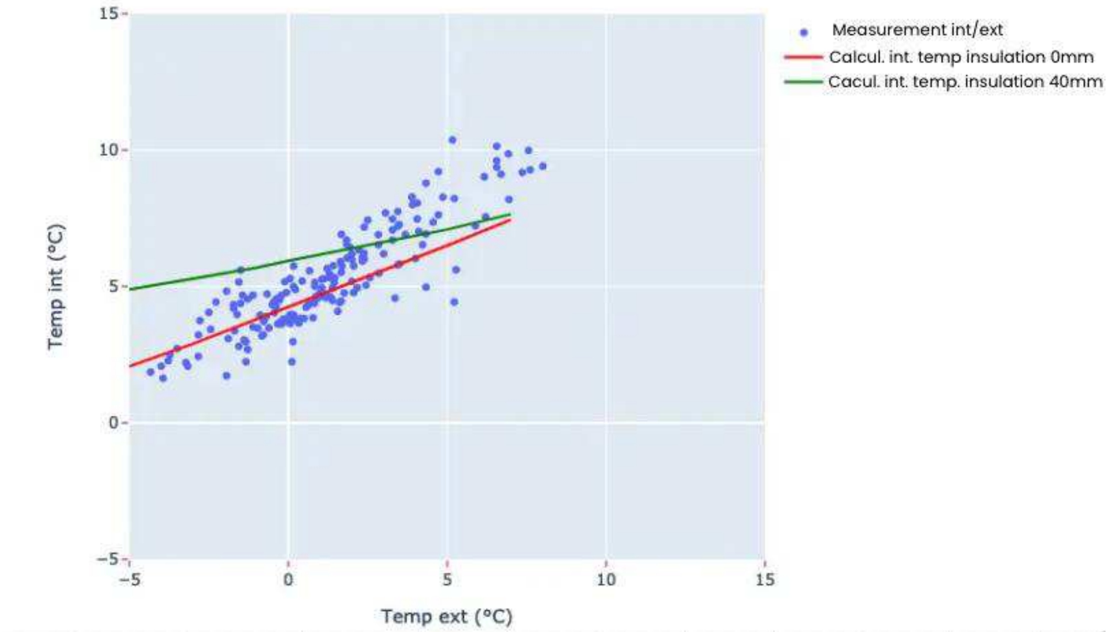
Some routine checks

To bring this scientific approach until its end, once the model is built, it is a good idea to validate it against actual measurements. As each hive is equipped with a temperature sensor and the outside temperature is also measured by the scales, I have retrieved some measurements over a period of about 10 days.



Sequence of internal/external temperatures measured over the period.

The graph below shows the correlation between internal and external temperatures. The blue dots represent the measurements and the lines correspond to the models described above with and without insulation.



Graphical representation of the two thermal models with and without insulation and correlation with the measurements (blue point cloud) before insulation. The model is representative of reality.

The model without insulation (red) correlates quite well with the measurements. I admit that it fits much better than expected!

There is also an intrinsic limit to the model for ambient temperatures above 7°C. This can be explained by the assumption of constant surface temperature of the cluster advanced at the beginning. Simply put, as soon as it gets warmer, the cluster has the “luxury” of warming up above this 7°C limit. From these levels, the equations should be taken up differently, but we also know that this case is less constraining for the bees.

In conclusion: when to insulate your hives?

Here is a nice model that allows to evaluate the effect of insulation on the dynamics of the bee colony. **We have learned and verified that: 1/ the roof of the hive is the main source of heat dissipation. 2/ the risk zone for bees starts for ambient temperatures below 5°C. 3/ insulation by a simple polystyrene panel brings a nice improvement of 50%.**

Therefore, in climatic zones where ambient temperatures fall below 5°C it is clearly useful to insulate your hives. For the more temperate zones the interest is less but certainly not negligible either. This would bring more comfort to the colony but maybe favours early queen rearing and varroa start. Which means there should be a choice to make.

Be careful to check the thermal resistance of your material (R = thickness / conductivity). Here are two examples:

- Apifoam of 20 mm: R = 0,020m/0,038W/m/K = 0,52
- 40mm extruded polystyrene: R = 0.040m/0.033W/m/K = 1.20

Polystyrene, which is two times thicker, has more than double the thermal resistance because it also has a slightly lower conductivity. Now that the insulation is in place, I hope that the bees will be able to get through this winter period better.

Lorenzo Pons