Moisture In Honey[1]

Malcolm T. Sanford[2]

Using The Honey Refractometer

There continues to be confusion surrounding use of honey refractometers. The beekeeper should be aware that, as with most technologies, the major variable is the human using it. How many of us have heard the statement, "the computer made an error." More likely the human operator of the computer made the error. The same is true with the honey refractometer.

Those using a honey refractometer become comfortable with it only through a good deal of practice. This technology is also changing and what works on one instrument at a certain point in time can quickly become obsolete. Frequent refractometer calibration is also necessary. However, a hard and fast rule does not exist, although it is safe to say the more the better. Two instruments being calibrated at the same time give far more reliable readings than if calibrated at different times or places. Thus, beekeepers not taking backup readings at the warehouse or other point of purchase when delivering their honey are risking a great deal. In addition, because of the number of potential inherent technical and human operator variables in measuring moisture content, a number of samples should be taken from different parts of a honey lot. If all readings are averaged, the margin of error will be much less.

Managing Honey Moisture

Mr. Bert Kelley, Ex-President of The Florida State Beekeepers Association, has designed an inexpensive honey drier. It consists of a piece of plastic pipe about 2 inches in diameter with another piece inserted at a right angle. A small copper tube is affixed to and run down the outside of the pipe; its end is bent and inserted at the bottom. Thus, air is directed downward and then bubbles upward. The whole mixture of air bubbles and honey inside the pipe is lighter than the honey itself and so rises over the level of the honey on the outside of the pipe and flows into the section joined at a right angle. This air-honey mixture is directed to spread out over a flat surface before dripping back into the barrel. The system effectively recirculates the honey in a container and provides surface area for a dehumidifier to reduce its moisture. The air pump required is small. An aquarium pump can be used with success.

Although honey in a barrel can be effectively dried using Mr. Kelley's method, it is often easier to dry it in the comb. Capped comb is permeable to moisture, but it is much more efficient to have uncapped honey. The concept of taking honey off a colony before it is capped and then drying it in hot rooms was pioneered in Saskatchewan, Canada. Ontario Provincial Apiarist, Douglas McRory, provided the following information. The purpose of this publication is to present some methods of drying high moisture honey to an acceptable water content before extraction. Much of this also may have application for Florida where honey can be high in moisture content.

The practice of removing honey from colonies several times during the summer nectar flow has been adopted by most prairie commercial beekeepers. This practice allows the

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beekeeper to keep up with the incoming flow of nectar, and even to increase the size of the crop, by continually presenting each colony with an abundance of empty comb, and thus stimulating the bees to collect more nectar. In addition, in regions where honey granulates rapidly, removal of honey during the flow helps to avoid granulation problems during extraction.

Honey supers removed throughout the flow are generally not completely capped. Lack of cappings allows faster rotation of supers, faster extraction of honey and the decreased use or the elimination of the automatic uncapper. The disadvantage of pulling uncapped honey is that some of it will not be fully ripened and will have a high moisture content. This honey will need to be dried to an acceptable level before packaging it for sale.

Honey Moisture Content

Honey is hygroscopic; that is, it has excellent water absorbing properties. Thus honey will change in moisture content according to the surrounding atmosphere. This characteristic is important in storing honey because it will absorb water when exposed to high relative humidity (RH) and will give off water when exposed to low RH, until an equilibrium point is reached.

High moisture honey will ferment. This is caused by the presence of several yeast species which, as they multiply in the absence of air, produce alcohol. The alcohol may break down to acetic acid (vinegar) and water, giving the honey a distinctly sour or "off" taste and a runny texture with small bubbles, surface heaving or foaming.

Canadian Honey Regulations state that No. 1 honey will have a moisture content of not more than17.8%. While this level is not a guarantee against fermentation, it is a level at which fermentation is unlikely to occur.

Figure 1 illustrates the equilibrium moisture content of honey. Honey stored at 59% RH will equilibrate at 17.8% moisture. Optimum drying and storage conditions will therefore be at or below 58% RH.

Figure 1 also illustrates that wet honey is easier to dry than dry honey. A drop in RH from 70% to 60% corresponds to a change in honey moisture content of 5.9% (24.2% - 18.3%), while a drop from 60% to 50% RH corresponds to a honey moisture content change of only 2.4% (18.3% - 15.9%).

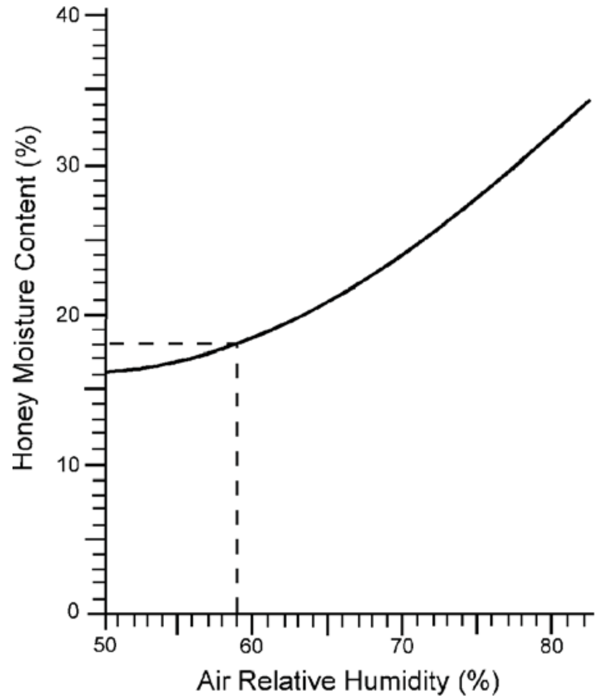

Figure 1. Equilibrium moisture content of honey.

Ventilation

Bees use ventilation to dry honey in the hive prior to capping. Ventilation with air at 27°C or warmer and a RH of less than 59% can be effectively used to remove moisture from honey. A honey house hot room kept at 27°C is a suitable facility in which to dry honey.

DAYTIME VENTILATION

For efficient drying, the incoming air should be at as low an RH as possible, while the outgoing air should be at 58% RH. Table 1 shows average July daytime air conditions for three locations in Saskatchewan. For all locations, the July daytime temperature is warmer than 27°C and the RH is below 59%. This air can therefore be used to dry honey.

Table 1. July daytime* air conditions.

Location	Temp.	RH
Prince Albert	29°C	50%
Saskatoon	30°C	44%
Regina	31°C	41%
* from 10 a.m. to 6 p.m.		

Figure 2 shows how summer daytime outdoor air can be used to dry honey situated in a hot room at Prince Albert. As the air enters the hot room it is at 29°C and 50% RH. Under these conditions each 1000 cu. ft. of air holds 0.9 lb of water. The room itself is kept at a minimum of 27°C. Because the RH of the air entering the room is below 58%, the honey will lose some of its moisture to the air. If the air leaving the hot room is at 27°C and 58% RH, each 1000 cubic feet of air leaving the room holds 10 lb of water. Therefore, the amount of water that each 1000 cubic feet of air can remove from the hot room is 1.0 - 0.9 = 0.1 lb of water.

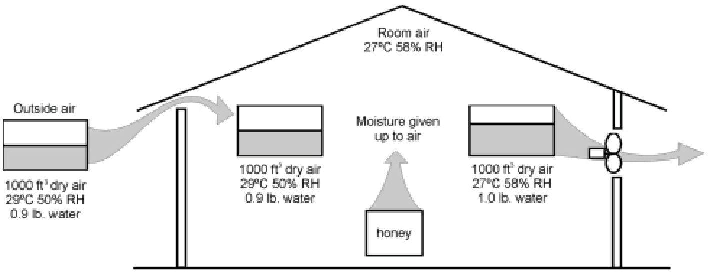

Figure 2. July daytime conditions for Prince Albert.

Table 2 shows the maximum amount of additional moisture that air from each location is capable of absorbing when exhausted at 58% RH and 27°C.

Table 2. Maximum water absorbed per 1000 ft^3 of daytime air.

Location	lb of water
Prince Albert	0.10
Saskatoon	0.15
Regina	0.20

To remove more water using ventilation two things can be done:

1. Add more heat to raise the room temperature so that the air leaving the building will carry more water.
2. Move more dry air through the building in order to move out more water.

Considering the above two options, it is cheaper to move more air than it is to add heat.

Figure 3 shows the ventilation rate required in cubic feet per minute (cfm) to remove from 0 to 25 lb of water per hour for three locations in Saskatchewan.

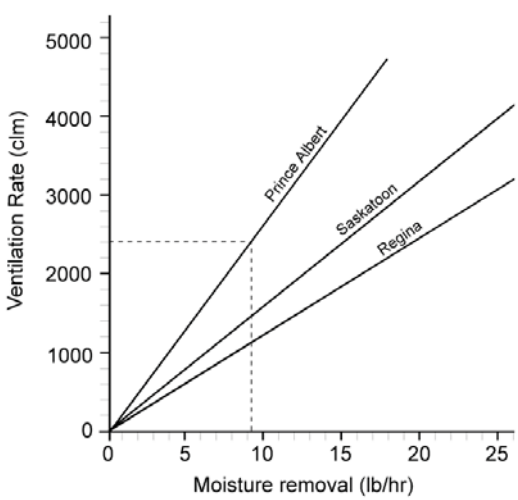

Figure 3. Moisture removal and ventilation rates for daytime conditions.

Example: A Prince Albert area beekeeper brings in 7500 lb of honey/day and wants to remove 2% moisture (by weight of honey) within two days. Water to be removed =

2/100 x 7500 lb = 150 lb in 2 days

or = 75 lb in 1 day

One day ventilation = 8 hrs

Water to be removed = 75 lb/8 hrs = 9.4 lb/hr

Ventilation rate = 2400 cfm (Figure 3)

NIGHTTIME VENTILATION

Night conditions present a different set of problems for moisture removal from honey. Table 3 shows the average evening air conditions for three locations in Saskatchewan for the month of July. There is essentially no difference among these locations at night.

Table 3. July nighttime* air conditions.

Location	**Temp.**	**RH**
Prince Albert	11°C	100%
Saskatoon	11°C	100%
Regina	10°C	95%
* from 6 p.m. to 10 a.m.		

Figure 4 shows that heat must be added to raise the air temperature and lower the RH so that drying of honey will occur.

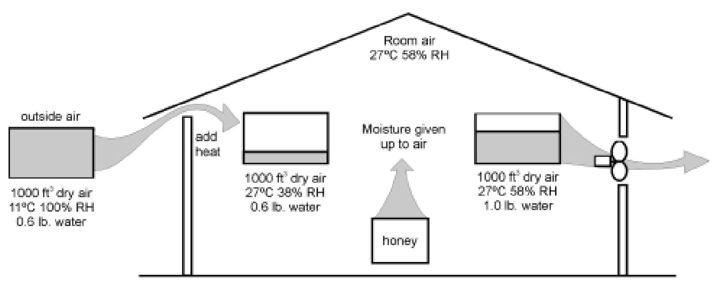

Figure 4. July nighttime conditions for Prince Albert.

The difference in moisture holding capacity between 1000 cubic feet of air at 11°C, 100% RH and 1000 cubic feet of air at 27°C, 58% RH is: 1.0 - 0.6 = 0.4 lb. However, air at 11°C, 100% RH will require the addition of about 770 Btu of heat for each 1000 cubic feet of air to obtain air at 27°C and 38% RH. Note that the heated nighttime air will hold almost four times as much water as will the daytime air (0.4 lb compared to 0.1 lb water per 1000 cubic feet of air). Consequently, the amount of ventilated air required to remove an equivalent amount of moisture is only 1/4 as much.

Figure 5 shows the ventilation rates required and the amount of heat that must be added for moisture removal for night conditions for any location in Saskatchewan.

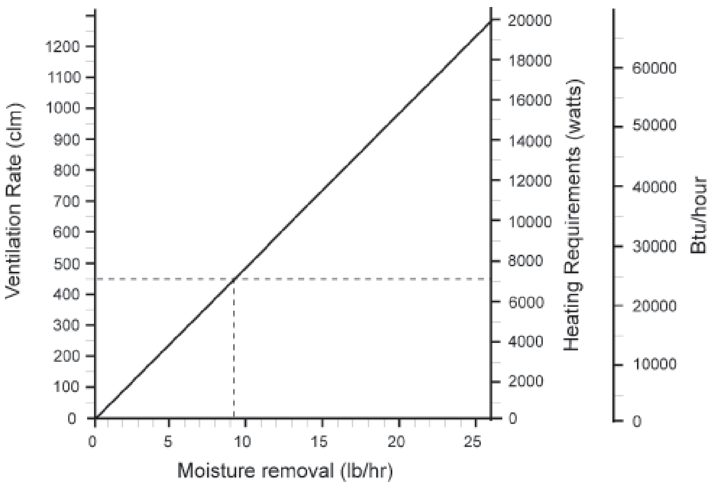

Figure 5. Ventilation rates required and the amount of heat that must be added for moisture removal for night conditions in Saskatchewan.

Water removal of 9.4 lb/hr, as in the previous example, during night conditions will require a ventilation rate of 450 cubic feet per minute with roughly 7200 watts of heat added. If the daytime rate of 2400 cubic feet per minute was used, the heating requirement would be over 40,000 watts. The operating cost for this amount of heating would be prohibitive.

Design Consideration for Ventilation

The selection of fans, controls and heat source is not complicated. First, determine the amount of ventilation required. Once the amount of ventilation is known, select a fan. Fan output in cubic feet per minute is provided for various static pressures. Be sure to select a fan that delivers the required amount of air at 0.125" static pressure.

The type of control required for the fan will depend on the fan selected. A single speed fan requires a single speed thermostat control, while a variable speed fan requires a variable speed control.

Heat may be provided by using either oil, electricity, propane or natural gas. An electric heater is simple to install and provides quick and clean heat. Because the heating requirements are small, electric heat is recommended. A thermostat set at hot room temperature is all that is required to control an electric heater.

As an example of selecting equipment, using information from previous examples (ventilation rates: daytime - 2400 cubic feed per minute, nighttime - 450 cubic feet per minute; heat required - 7200 watts): PAMI Report #490 shows that a Hurt model VSBF-16 variable speed fan will deliver 274 cubic feet per minute at low speed and up to 2640 cubic feet per minute at high speed, both at 0.125" static pressure. The fan can be controlled with a simple, manually adjusted rheostat controller such as Danor Model MC-5 controller. The controller would have to be set slightly higher than the low speed in order to deliver 450 cubic feet per minute. The heat required can be supplied with four 2000 watt baseboard heaters controlled by a single wall mounted thermostat.

Table 4 gives examples of day and night fan speeds and nighttime heat inputs required to dry honey at Prince Albert. This table assumes optimum drying conditions, which will not always occur; however, it will help to determine design requirements.

Dehumidification

Dehumidification may be used to dry honey in conjunction with or in place of ventilation. The capacity of household dehumidifiers varies from 10 to 30 lb of water per 24 hours, or 1/2 to 1 1/4 lb per hour (1 pint water = approximately 1 lb). Commercial dehumidifiers have higher capacities and are more expensive. Dehumidifiers are rated at 60% RH and 27°C, so they can be expected to operate at capacity in the hot room environment.

Dehumidifiers may be in the hot room or in a separate room. To be effective, the hot, dry air must circulate through each super stack and across each comb face (see Air Movement and Exposure of Comb faces).

If a combination of ventilation and dehumidification is used, the dehumidifiers will be most useful during the night or on cool and/or humid days.

An added advantage of using dehumidifiers is that they also provide heat to the hot room.

To minimize daily maintenance, dehumidifiers can be set up so that the water reservoirs drain to the outside rather than having to be manually emptied daily. Drainage lines should be checked regularly to ensure that they remain free of bees and other material which may slow or stop the drainage.

Example: If ventilation fans are used during the day and dehumidifiers are used at night, the moisture removed is:
daytime -- 9.4 lb/hr x 8 hr = 75 lb water removed

nighttime -- using dehumidifiers capable of removing 2.5 lb/hr for 16 hours L -- 2.5 lb/hr x 16 hr = 40 lb water removed

Note: Circulation fans are used continuously.

Air Movement and Exposure of Comb Faces

No matter how much air is exhausted, the honey will not dry evenly unless the fresh air is evenly mixed throughout the hot room, through the super stacks and across the comb faces. Moisture removal rates used in the examples, figures and tables assume that all honey is equally exposed to air movement. However, if air does not move through the stacks, differential drying will occur, with some honey becoming very dry and other honey remaining wet.

Overhead ceiling fans help air circulate. The general recommendation to reduce temperature stratification is use one 36" diameter fan per 1500 square feet of open area. However, a hot room stacked with supers is anything but open. In addition, air circulation is critical to the drying process. Based on beekeeper experience, it is therefore recommended to have one overhead fan for every 150-200 square feet.

Honey supers should be stacked on side-slotted pallets and some space left between rows to increase air circulation among the stacks. Supers are generally stacked five high; however, wet honey may be stacked four high or less to increase air movement through the stacks. Alternatively, supers can be staggered on the pallets. Wet honey supers can also be stacked on end on pallets. While this is time-consuming and labor-intensive, it is a very effective way to expose more surface area to air movement, and is useful for drying very high moisture honey. Frame spacers in the honey supers facilitate air circulation within stacks. Air circulation may be more closely directed through the super stacks by means of ventilation hoods which fit over several stacks, or by small fans mounted on inner covers and placed on individual stacks.

Final Notes

The design figures used are based on Saskatchewan weather data taken from 30 year averages. However, it is possible to get weather which is significantly different from these long-term averages. Consequently, if hot, humid weather or cool, wet weather occurs during honey extraction time, the drying of honey using ventilation only will be difficult and slow, and extra heat and/or dehumidifiers will be required for both daytime and nighttime conditions. Actual drying time will generally be longer than given in the examples because the exhausted air may not be at 58% RH and because dehumidifiers may not work to capacity.

Note that air has to be allowed into the hot room to replace the air that is being exhausted by the ventilation fan. To ensure that fresh air does enter the room without being unduly hindered, it is advisable to open a door slightly or use an open window to act as an air inlet. In this way the exhaust fan will be able to operate at its full capacity.

Incoming air may be brought into the hot room via an input fan from a passive solar collector. This collector may be as simple as an attic space under a black roof, or as complex as a specially-constructed south-facing wall designed to heat air. A heat exchanger is also effective for retaining heat, and may be especially useful at night.

A honey refractometer and good quality humidistat are necessary to monitor honey moisture content and ambient air conditions. It is important to maintain a low relative humidity in the hot room, by adjusting air flow, heat input and dehumidification.

Summary Checklist

1. Choose an exhaust fan or a combination of exhaust fans to cover both day and night ventilation needs.
2. Use dehumidifiers, if desired.
3. Connect heaters to thermostats set at desired hot room temperature.
4. Use overhead circulation fans.
5. Ensure that all comb faces are exposed to air movement.
6. Use a honey refractometer.
7. Keep the relative humidity as low as possible, to a maximum of 58% RH.
8. Use humidistats.

Table 4. Examples of moisture removal from honey using ventilation and heat for Prince Albert.

Honey in Hot Room (lb)[1]	Moisture Removal Desired (lb)[2,3]	Total Time Desired to Remove Moisture	Daytime[4] Airflow (cfm)	Daytime Moisture Removed (lb)	Nighttime[4] Airflow (cfm)	Nighttime Heat Input (watts)	Nighttime Moisture Removed (lb)
5000	100	day-night	2400	72	100	1500	32
(160 supers)	100	day only	3300	100	---	---	---
	100	night only	---	---	325	5000	100
10,000	200	day-night	3100	96	350	5500	112
(320 supers)	200	day-night	4000	120	250	4000	80
	200	day-night	5100	160	125	2000	40
20,000	400	day-night-day	4800	150	325	5000	100
(640 supers)	400	night-day-night	4800	150	400	6500	125
	400	day-night x 2	5100	160	125	2000	40

1. assuming honey supers @ 30 lb net weight and an average 20% moisture; hot room at 27°C
2. assuming a 2% drop in moisture required
3. assuming that all comb faces are equally exposed to circulating air
4. daytime = 8 hours, nighttime = 16 hours; daytime conditions 29°C, 50% RH; nighttime conditions 11°C, 100% RH