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The removal of water from honey

EVA CRANE

Methods for reducing the water content of honey, especially in the humid tropics, were discussed at a Conference on the Asiatic Hive Bee held in Malaysia in 1988. The proceedings, published in 1995, include a chapter on the subject[10]. Large-scale beekeepers and honey packers in other parts of the world have also devised systems for reducing the water content of honey, or adapted systems developed for other foodstuffs. This article examines the reasons for removing water from honey, and assesses methods available for doing it.

Circumstances which necessitate the removal of water from honey

The usual custom in good beekeeping is to harvest honey combs from the hive after bees have reduced the water content of the honey sufficiently to prevent fermentation during future storage, and have capped (sealed) the cells*. The water content must also satisfy any applicable honey standards.

In certain circumstances the water content of the honey harvested is not low enough. A very high atmospheric humidity may prevent the bees evaporating sufficient water; this is a regular occurrence in parts of the humid tropics, and special problems with tropical honeys are considered elsewhere[9,10,11]. Similar problems occur under less extreme weather conditions in some other regions; for instance in parts of western Canada atmospheric humidity may be very high when late summer honey is harvested.

Table 1 shows the water content of a clover honey which were in equilibrium with air at different relative humidities (RH). For example, if the RH is higher than 60%, the bees can reduce the water content of their honey to about 18%; if the RH is 80%, the lowest water content they can achieve is 33%.

In most locations, however, the harvesting of honey with too high a water content is likely to result from the beekeeper's inappropriate management of the bees or their honey. He may use inappropriate hives which do not allow the bees sufficient ventilation, or he may site the hives inappropriately, without a clear air flow round them; these subjects are dealt with elsewhere[10]. He may remove the combs from the hive too soon, without allowing the bees time to finish the honey and seal the cells. Or, in advance of removing honey supers, he may place them above a bee escape and leave them there too long, so the honey reabsorbs water. Or combs of honey already removed may be exposed to a humid atmosphere, with a similar result. Even honey in sealed cells absorbs water from the air if the

*Freeze-drying honey to produce a hygroscopic powder (e.g. Shookhoff[32]) is not considered here.

TABLE 1. Approximate equilibrium between the relative humidity of air and the water content of a clover honey (from White[39], based on Martin[20]).

Relative humidity (%)	Water content (%)
50	15.9
55	16.8
60	18.3
65	20.9
70	24.2
75	28.3
80	33.1

relative humidity is too high; table 1 gives the equilibrium values for a clover honey.

The water content of honey can be reduced by a few per cent after it is taken off the hive. This may be done either before the honey is extracted from the combs, or afterwards when the honey to be treated is a bulk liquid. Figure 1 sets out options in more detail, and includes attention needed when the honey is still in the hive.

Removal of water from honey before extraction from the comb

It is better in every way to follow this option. The honey is still in cells of the comb whose depth is not much more than 1 cm; it presents a large surface area from which evaporation can take place. The operation is done in a 'warm room' where the supers are stacked. Air is dried with a dehumidifier, then heated, and blown through the stacks of supers. The colder the dried air is before it is heated, the less water it contains, and the more it can take up from the honey. Warm moist air leaving the supers carries off the excess water, and is pumped out by exhaust fans. In 1941 Stephen[33] made a detailed study of the process, and of ways of increasing its efficiency. Townsend[37] found that air at 38°C passed over uncapped combs reduced the water content of the honey 4 or 5 times as rapidly as air passed over capped combs.

Nass[24] described his operation in Wisconsin, Canada; the atmospheric humidity is high there when honey is harvested, and he removes supers when about a quarter of the cells are capped. In his warm room (3 × 2.5 m) he has eight pallets which support two rows of four stacks of supers, and these can accommodate up to 12 per stack, but he usually has 4 or 5 supers per stack, 32 to 40 in all. The temperature in the room is likely to be 29° to 34°C and the humidity 30 to 40%. Using one or two dehumidifiers, the water content of the honey, measured with a refractometer, is reduced in four days from 20% to about 18% in capped cells or to 16% in uncapped cells.

Murrell and Henley[23] give much quantitative information on the removal of water from combs of honey routinely taken from hives when incompletely capped. They emphasize the need to maintain the relative humidity in the warm room below 58%: the air flow is adjusted by using exhaust fans and circulation fans, a dehumidifier with a humidistat, and a heat supply connected to a thermostat set at the temperature desired. They include a table setting out nine programmes planned according to the amount of honey to be treated, the amount of water to be removed from it, and the period of operation. Different regimes are needed by day and by night because outside air temperature and humidity differ. Table 2 gives two examples of their programmes, in metric units.

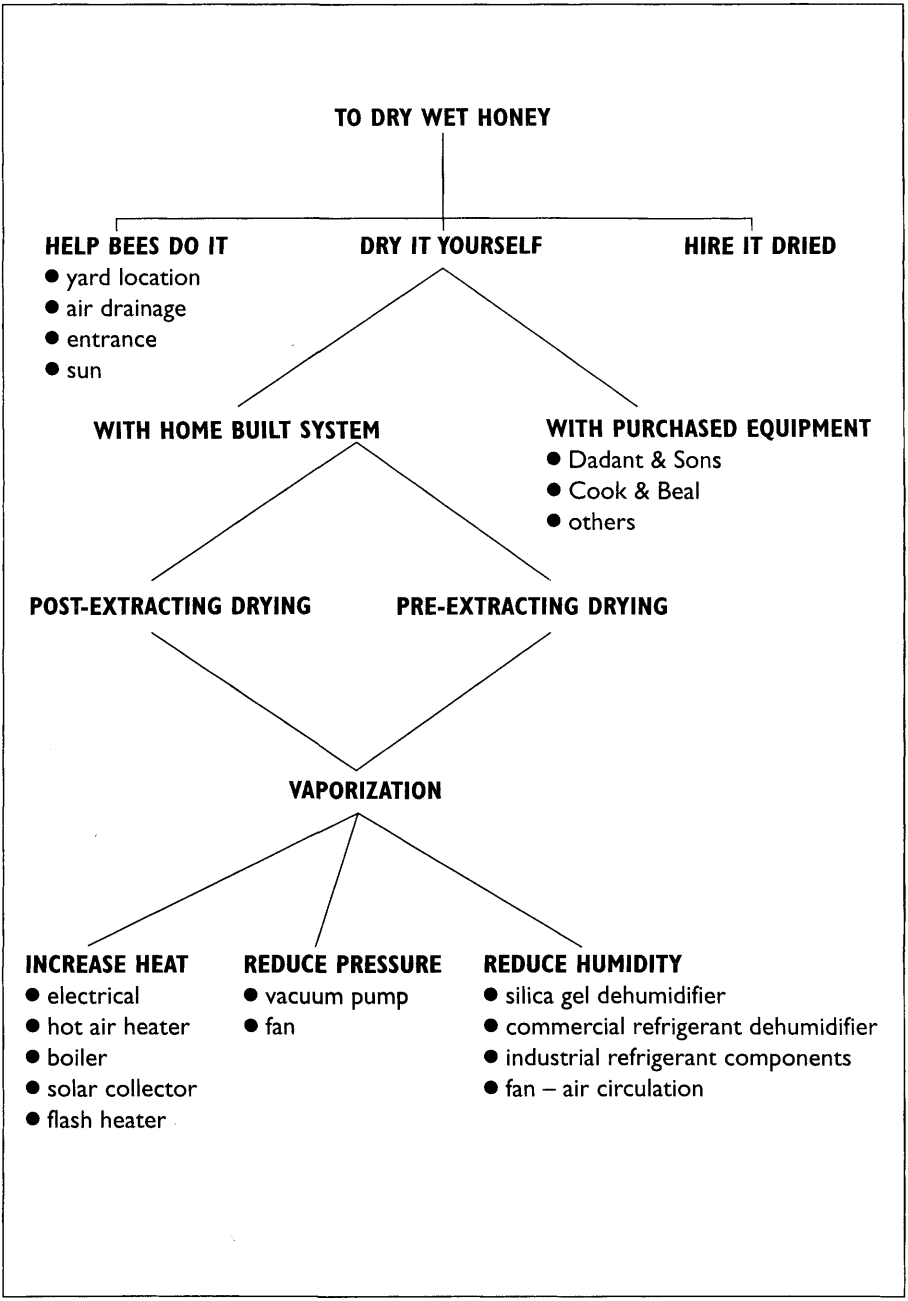

FIG. 1. Paysen's 1987 options for removing water from honey[28].

TABLE 2. Examples of the performance of operations to remove water from honey (based on Murrell and Henley's 1988 results[23]).

Weight of honey in warm room	2.3 t	9 t
Weight of water to be removed	45 kg	181 kg
One day only, no heating:		
air flow	93 m^3/min	
water removed	45 kg	
Two days and nights:		
day air flow, no heating		144 m^3/min
water removed per day		73 kg
night air flow, heating at 2 kW		3.5 m^3/min
water removed per night		18 kg

In Italy in 1976 Marletto and Piton[19] developed a system for removing water from combs of honey in 90 supers, arranged in nine stacks. More recently in France, Bois[7] published an account of a much smaller system which treated honey in a single stack of supers. In a region of Brazil where the water content of honey in sealed cells may be over 23%, Machado de Moraes *et al.*[16] used a system on similar principles.

Removal of water from honey after extraction from the comb

Water removal from an increased surface area of honey

Any water removed from bulk liquid honey must be evaporated into the air in contact with the honey surface. Under normal atmospheric pressure, the rate of evaporation of water can be increased by increasing the surface of the honey in contact with the air, as well as by increasing the temperature of the honey and by reducing the relative humidity of the air.

In some systems the humidity of the air is not reduced before it is passed over the honey. Maxwell[21] in the USA just heats the honey, in a simple home-made system, before blowing air at room temperature (13°C) over it. Honey from a 300-kg drum, heated by an immersed hot water pipe, is pumped to a warmed evaporating tray 0.6 × 1.2 m, which slopes down at 20° to a chute delivering the honey to another drum. Honey in the tray flows in a layer about 4 cm deep, and is kept at 32°–35°C; two fans blow air over its surface (fig. 2). The water content of the honey was reduced from above 19% to 18% in under 2 hours, after two or three passages through the system. Kuehl[15] uses a series of sloping trays made of expanded metal screen, with a fan heater.

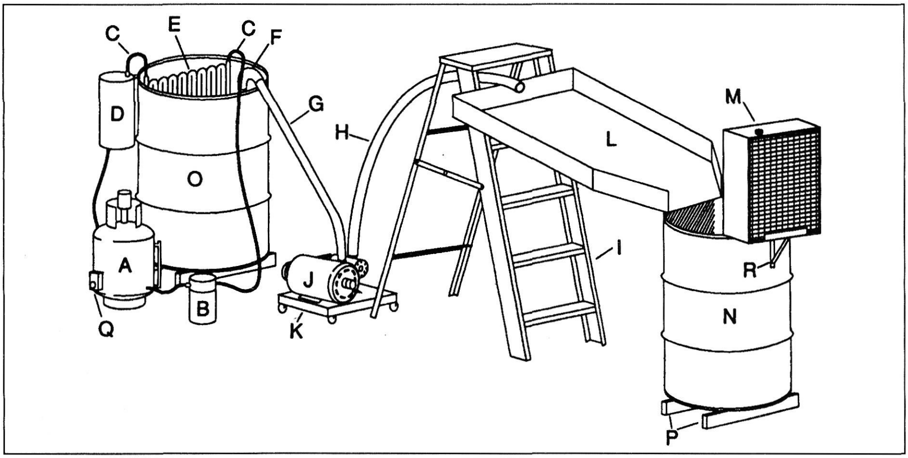

FIG. 2. Maxwell's simple batch-system for removing water from honey, used in the USA[21].

Especially in the humid tropics, with a RH above 80% and a high atmospheric temperature, air should be pre-dried by air conditioners, or by dehumidifiers which cool the air and thus condense water vapour from it. It is then preheated to increase its capacity to absorb water. As above, the colder the dry air is before it is warmed to pass over the honey, the more water it can remove from the honey.

Small-scale dehydration systems for honey were designed in humid regions of south-east Asia in the late 1980s[38]. An experimental system developed in Vietnam[22] increases the honey surface by allowing the honey to trickle down under gravity. A cabinet contains a stack of ten horizontal trays (35 × 65 cm), mounted 7 cm apart, each with 2-mm holes perforated all over it, 1 per cm^2. Heated air is blown into the cabinet by a fan. Honey is poured on to the top tray, and trickles down through all 10 trays into a honey container below the cabinet. After a series of eight trickling cycles, the water content of 20 kg honey was reduced from 26% to 21%; one cycle lasted a little more than 10 minutes. The RH of the outside air was 85%, and the temperature of the honey was kept below 40°C.

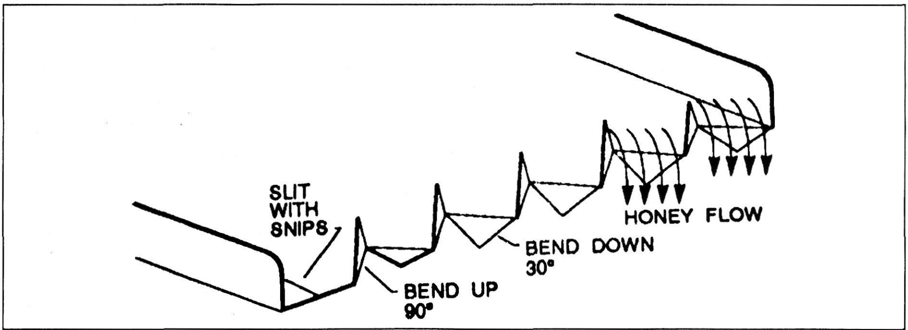

FIG. 3. Cutting and bending Paysen's tray edge[28] to ensure that the honey flows out in thin streams.

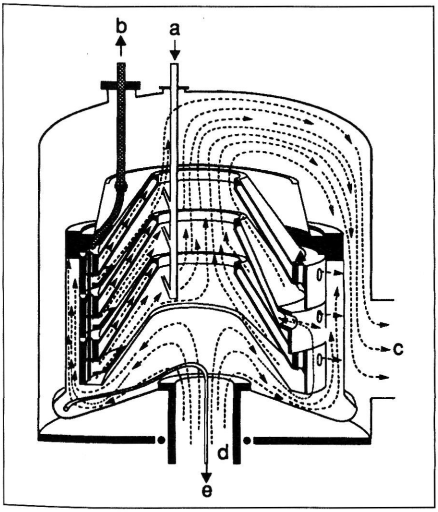

FIG. 4. Vertical section through the Centri-Therm Evaporator; see text[2]. (a) Process liquid in; (b) Concentrate out; (c) Vapour to condenser; (d) Steam in; (e) Steam condensate out.

In the USA Platt and Ellis[29] patented a system (and referred to earlier patents) in which water is evaporated from honey in a horizontal drum fitted with a rotating shaft along its axis. The shaft carries with it a series of discs or other surfaces having a large area. As the shaft rotates, honey is picked up from the bottom of the drum and spreads in a thin film over the surface. Air at 40° to 75°C is blown along the drum from a fan at one end, and carries the evaporated water through the air outlet at the other end. A research prototype, said to be expensive, was operated in Sumatra, Indonesia[30], during a project referred to by White et *al.*[40].

A much larger evaporator was built in the USA by Paysen[28], who obtained half the heat required for warming and drying the honey from solar panels. Honey cascades over a series of 24 large trays whose combined area is 360 m^2. The exit-edges of the trays are cut and bent so that the honey runs out in many thin streams (fig. 3). Paysen is very satisfied with the unit's performance: 57 tonnes of honey passing through it lost 0.6% of water (the required amount) in 30 hours.

Mannheim and Passy[18] published a useful general discussion on commercial continuous-flow methods for concentrating liquid food products by removing water from them. For liquids which are not heat-sensitive, evaporation temperatures of 70°–90°C may be applied. For those (like honey) which are heat sensitive, thin-film evaporators are used, either at or below atmospheric pressure. Such evaporators are manufactured with a tubular or conical evaporating surface, which may be stationary but usually rotates. One that is effective with viscous liquids such as honey (fig. 4) is the Centri-Therm made in Sweden[2], which can operate at atmospheric pressure or a reduced pressure (see below). Honey is led through tubes on to a steam-heated conical surface rotating at a high speed, where it spreads out into a film no more than 0.1 mm thick; centrifugal force spreads the film out and over the outer edge of the surface, whence the honey is pumped out of the centrifuge and immediately to a cooler.

Steam is admitted through the hollow spindle (d) to the jacket surrounding the cone stack, and thence to the insides of the cones where it is condensed by the liquid passing on the other side of the cone walls. As soon as condensate droplets form, they are flung by centrifugal force to the upper inside surface of the cone and travel down this surface, escaping back into the steam jacket through the same holes by which the primary steam entered. The condensate runs down the walls of the steam jacket to a paring channel at the bottom, from which it is removed by a stationary paring tube (e) mounted inside the hollow spindle.

The honey is in contact with the steam-heated surface for only about 1 second, but this is enough to evaporate water, the water vapour being drawn off through the central column under a partial vacuum, and condensed. Volatile substances evaporated from the honey can to some extent be condensed separately from the water and recombined with the honey output. The rate of evaporation of water can be controlled by the rate of honey flow, the air pressure, and the centrifuge speed.

Small-scale systems are described by Papoff *et al.*[25] who used *Arbutus unedo* honey in Italy, and by Krell working in Sri Lanka[14].

Water removal by reducing the air pressure

Vacuum (actually low-pressure) systems for evaporating water from honey are expensive, and so are their operating costs. They incorporate a vacuum pump connected to the air space of a container in which water is evaporated from the honey, and evaporation is accelerated by constant circulation of air at low pressure across the turbulent honey surface, and subsequently through a condenser. Such systems can operate even without enlarging the honey surface, although this is not efficient. They have the great advantage that they can function at low honey temperatures, but water is lost more rapidly if the temperature is higher.

Volatile substances give honey its aroma, and part of its flavour. There is a detrimental loss of these substances when water is evaporated from honey, according to the increase in temperature and decrease in pressure. Volatiles with low boiling points are lost more readily, and Girotti *et al.*[13] refer to their loss when honey is dehydrated at low pressure. Nevertheless, Tabouret[36] did not find any loss in flavour and aroma.

Experimental low-pressure systems were developed in New Zealand during the 1950s[26,27,31], and later in the USA, and the USSR[34]. In France, Tabouret[36] used a pressure of 680 mm of mercury (0.92 bar, 9.2×10^4 N/m^2) for 45 litres of honey heated on average to 63°C. This reduced the water content from 20.4% to 16.0% within 90 minutes. At 68°C, using atmospheric pressure (760 mm mercury), he could reduce the water content from 21.3% to 15.8% within 37 minutes. In Korea a system is used that evaporates 200 litres of water from honey at 50°C or higher, in 45 minutes[1].

Commercially, Dadant & Sons[12] in the USA market a batch system incorporating flash heating, evaporation at low pressure, and a cooling chute. They quote a reduction of water content of 300 kg of honey from 19.2% to 18.0% in 45 minutes; the honey was heated to 66°C and discoloration was slight. The Alfa-Laval continuous-flow Centri-Therm described above can incorporate a vacuum system, as well as an increased honey temperature and an enlarged honey surface. A Paravap vacuum system (fig. 5) is manufactured by APV in the UK for use with various food products, and trials have been made with honey for application in China[5]. The water content was reduced from 30% to 18%, during an operation that increased the HMF content only from 3 to 4 ppm and did not alter the diastase (amylase) number significantly: from 10.5 to 10.3.

Alfa-Laval[4] now recommend the use of their Convap scraped-surface evaporation plant in conjunction with a Contherm scraped-surface heat exchanger[3]. In the evaporator, rotating blades are used to scrape 'sticky, lumpy, or heat-sensitive products' from the heated inner wall of the vacuum cylinder where evaporation takes place. APV Crepaco[6] also make a scraped-surface heat exchanger.

At the 1994 meeting of the Asian Apicultural Association (AAA), Widjaja *et al.*[41] and Suwaryono *et al.*[35] from Indonesia described small-scale experiments on the removal of water from honey under low pressure, and

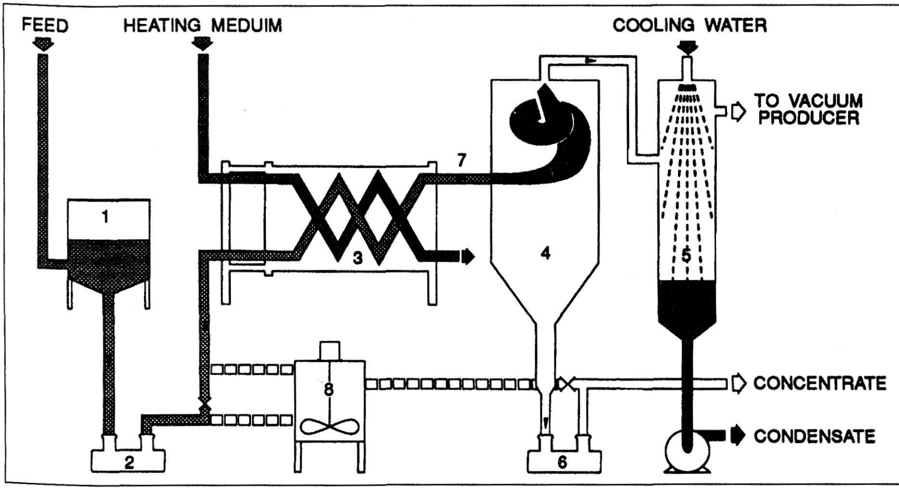

FIG. 5. Paravap Evaporator system[5]. (1) Balance tank; (2) Feed pump; (3) Heat exchanger; (4) Separator; (5) Condenser; (6) Product (honey) pump; (7) Orifice plate; (8) Pressurized recirculation vessel.

both stressed how little the honey was damaged by the process.

Water removal by a desiccant, or by reverse osmosis

The use of desiccants (drying agents) has not so far shown much promise as a method for removing water from honey.

A silica gel humidifier is included among the alternative methods shown in Paysen's 1987 diagram (fig. 1). Silica gel is a colloidal, highly absorbent form of silicon oxide, and is used for water removal in many chemical processes. At the 1994 AAA meeting mentioned above, Carmencita[8] presented a poster describing the use of two desiccants to remove water from 1.8 kg of honey. With silica gel — which was reusable — it took about 4, 7 and 11 days to reduce the water content of three different honeys from 21%, 20% and 24%, respectively, to 17%. With calcium oxide — which was not reusable — the times were a little shorter.

Reverse osmosis[17], or ultrafiltration, can reduce the water content of some solutions by forcing water under high pressure through a membrane within the liquid to be concentrated. However, the method does not seem to be practicable for honey, which has a very high sugar content.

Conclusion

In general, the first possibility to explore is Paysen's 'help bees do it', and my paper written in 1988[10] discusses at some length the problems that arose with honey harvested from single-box hives in parts of south-east Asia.

If the honey is treated after harvesting, it is better to do this before the honey is extracted from the combs. Bulk liquid honey can sometimes be blended with another batch whose water content is low. If not, then methods for removing water which involve reducing the air pressure are less likely to damage the honey than those which raise the temperature of the honey.

The best method for any one operator depends on the variety of factors.

- The available technology, expertise and capital
- The relative cost and feasibility of operations in bee management and honey handling
- The level required in the standard of honey sold to the consumer, especially with regard to preservation of 'biological' components of honey
- In some tropical countries, the tolerance of consumers to honey with a higher water content than that set in standards originating in temperate-zone countries

Most of the experience so far gained, worldwide, in the removal of water relates to honey from temperate-zone *Apis mellifera* in temperate zones. But most of the regions where bees are unable to reduce the water content are in the humid tropics, and the bees producing the honey may be *A. mellifera*, or another *Apis* species, or stingless bees (Meliponinae). Honeys produced by some of these bees can be stored without spoilage although they have a higher water content than is safe for temperate-zone *A. mellifera* honeys. More work is needed on the chemistry and biochemistry of these honeys to establish the reasons for the differences, and how honey standards should be adjusted.

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Dr Eva Crane

Honorary Life President and former Director of the
International Bee Research Association
Present address: Woodside House, Woodside Hill, Gerrards Cross, Bucks SL9 9TE, UK