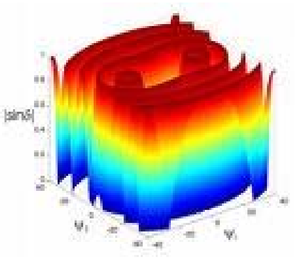


Physical Properties of Honey

Stefan Bogdanov

Knowledge of the physical characteristics of honey are important for the different aspects of honey technology: harvest, processing, storage, granulation and liquefaction [8, 47], see chapter 3.

WATER CONTENT AND WATER ACTIVITY

Water Content,	Refractive Index	Water Content	Refractive Index	Water Content	Refractive Index
g/100 g	20°C	g/100 g	20°C	g/100 g	20°C
13.0	1.5044	17.0	1.4940	21.0	1.4840
13.2	1.5038	17.2	1.4935	21.2	1.4835
13.4	1.5033	17.4	1.4930	21.4	1.4830
13.6	1.5028	17.6	1.4925	21.6	1.4825
13.8	1.5023	17.8	1.4920	21.8	1.4820
14.0	1.5018	18.0	1.4915	22.0	1.4815
14.2	1.5012	18.2	1.4910	22.2	1.4810
14.4	1.5007	18.4	1.4905	22.4	1.4805
14.6	1.5002	18.6	1.4900	22.6	1.4800
14.8	1.4997	18.8	1.4895	22.8	1.4795
15.0	1.4992	19.0	1.4890	23.0	1.4790
15.2	1.4987	19.2	1.4885	23.2	1.4785
15.4	1.4982	19.4	1.4880	23.4	1.4780
15.6	1.4976	19.6	1.4875	23.6	1.4775
15.8	1.4971	19.8	1.4870	23.8	1.4770
16.0	1.4966	20.0	1.4865	24.0	1.4765
16.2	1.4961	20.2	1.4860	24.2	1.4760
16.4	1.4956	20.4	1.4855	24.4	1.4755
16.6	1.4951	20.6	1.4850	24.6	1.4750
16.8	1.4946	20.8	1.4845	24.8	1.4745
				25.0	1.4740

after Chataway [10]

Relationship between water content of honey to refractive index.

Temperatures above 20^{o} C: add 0.00023 per ^{o}C.
Temperatures below 20^{o} C: substract 0.00023 per ^{o}C.

The table is derived from a formula developed by Wedmore[46] from the data of Chataway [10]

$$W = \frac{\bar{1}.73190 - \log(R.I.-1)}{0.002243}$$

W is the water content in g per 100 g honey and R.I. is the refractive index

The water content is a quality parameter, important above all for honey shelf life. Higher honey humidity will often cause fermentation. There is a relation between honey water content and the yeast count (see chapter on honey microbiology). At 17 % humidity. there is a very minimal fermentation danger due to the very low yeast content.

Abbe Refractometer

Digital Refractometer

The capacity of honey to break the light is used for the refractometric determination of humidity. Both Abbe and digital refractometers can be used. However, this measurement does not reflect the true water content. Indeed, measurements of water content by the Karl Fischer method showed, that the refractometric measurements overestimates the true water content by about 1 Brix unit [21, 51]. As the refractometric moisture determination has proved useful in routine control, there is no reason to replace this simple measurement by the more complicated and expensive Karl Fischer technique.

The water activity (a_w) is proportional to the free water content in food. In honey a part of the water is bound to sugars and is thus unavailable for microorganisms, thus the a_w value and not the overall water content is the criteria determining bacterial spoilage. The a_w values of honey vary between 0.55 und 0.75, honeys with an a_w value < 0,60 are microbiologically stable [7, 33, 35]. Actually, it is the better quality criteria for honey than the water content, because it will indicate the free water content, which is microbiologically active to eventually cause fermentation. However, the simple and fast measurement of the water content has proven sufficient for assaying the fermentation risk of honey.

Further Reading: [9, 11, 12, 16, 22, 25, 38, 40, 50]

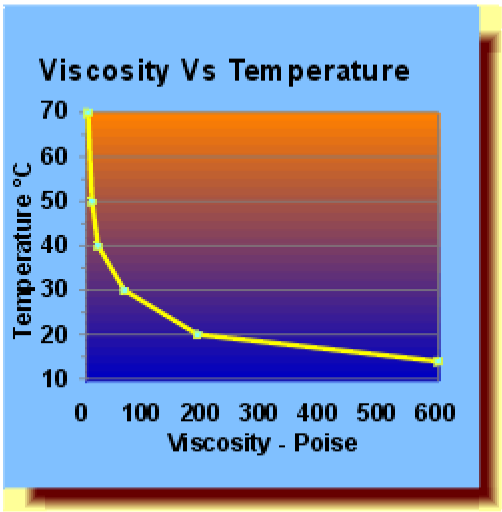
FLUIDITY AND VISCOSITY

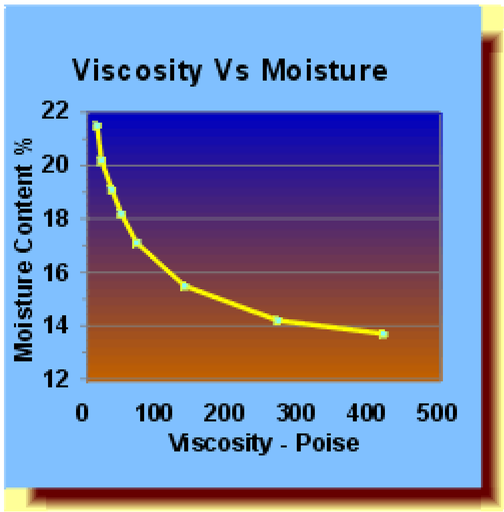
Honey is a viscous liquid. Honey viscosity depends on the water content and on temperature (table below). Honey with higher water content flows faster than that with lower one. Temperature influences also greatly honey viscosity. At room temperature (20^o C) the viscosity of most honeys is not high enough to allow a good fluidity and an easy harvesting. At 30^o C, where the viscosity values are mostly lower than 100 poise, the fluidity of most honeys is high enough for efficient handling. Honey granulation results in a dramatic increase of viscosity of a factor of 10, while the dependence of viscosity of granulated honey on the water content and on temperature is similar to that of liquid honey [19]. Higher temperatures are necessary to allow easy handling of granulated honey, at which liquefaction can take place. The composition of honey generally has a little effect on honey viscosity. However, there are honeys, which show different characteristics in regard to viscosity, e.g. heather (*Calluna vulgaris*) and manuka (*Leptospermum scoparium*) honeys are described as thyxotrophic which means they are gel-like (extremely viscous) when standing still, while they turn liquid when agitated or stirred. The viscosity of heather honey is so high, that centrifugation of honey from the combs is very difficult.

Dependence of the viscosity (in poise) on the water content and temperature of liquid honey after [28]

% humidity	15° C	20 ° C	25 ° C	30 ° C	35 ° C
14.2	> 800	540	250	120	80
15.5	650	250	130	80	30
17.1	293	115	75	30	20
18.	200	85	50	20	18

Dependence of the viscosity (in poise, p.) on temperature on the water content of liquid honey, after[3]





At 16% moisture :
14°C : 600 p. ; 20°C : 190 p.
30°C : 65 p. ; 40°C : 20 p.
50°C : 10 p. ; 70°C : 3 p.

At 25°C:
13.7% : 420 p ; 14.2% : 270 p; 15.5% : 138 p
17.1% : 70 p. ; 18.2% : 48 p. ; 19.1% : 35 p.
20.2% : 20 p. 14 p. : 14 p.

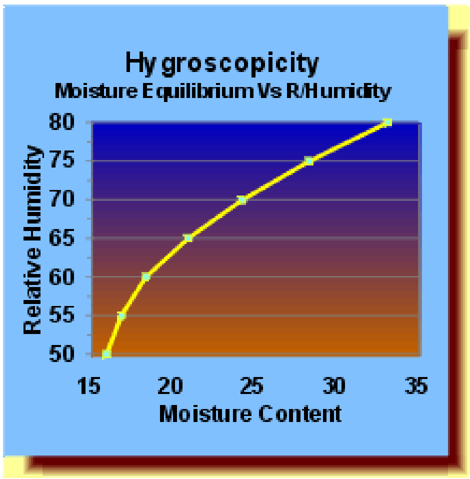
Further Reading: [1, 17, 23, 24, 27, 31, 42, 49]

DENSITY

Another physical characteristic of practical importance is density. Honey density, expressed as specific gravity, is greater than water density by about 50 %, and it also depends on the water content. Because of the variation in density it is sometimes possible to observe distinct stratification of honey in large storage tanks. The high water content (less dense) honey settles above the denser, drier honey. Such inconvenient separation can be avoided by more thorough mixing.

Specific gravity of honeys with different water content [47]

Water content (%)	Specific gravity at 20°C	Water content (%)	Specific gravity at 20°C	Water content (%)	Specific gravity at 20°C
13.0	1.4457	16.0	1.4295	19.0	1.4101
14.0	1.4404	17.0	1.4237	20.0	1.4027
15.0	1.4350	18.0	1.4171	21.0	1.3950



HYGROSCOPICITY

Honey is strongly hygroscopic, this characteristics being important in processing and storage. From the table below it can be seen that normal honey with a water content of 18.3 % or less will absorb moisture from the air at a relative humidity of above 60%. Thus it is important to keep honey well closed when it is stored in humid places. Also, under conditions of moist climate the bees have difficulties to keep the moisture down to safe levels, and undesirable fermentation might be the consequence.

Graph moisture content of honey versus relative humidity[3]

Approximate equilibrium between relative humidity (RH) of ambient air and water content of a clover honey [47]

Air (%RH)	50	55	60	65	70	75	80
% honey water content	15.9	16.8	18.3	20.9	24.2	28.3	33.1

THERMAL PROPERTIES

For the design of honey processing plants its thermal properties have to be taken into account. The heat absorbing capacity, i.e. specific heat, varies from *0.56* to 0.73 cal/g/^{0}C according to its composition and state of crystallisation. The thermal conductivity varies from 118 to 143 x 10^{-5} cal/cm^2/sec/^{0}C [47] Thus, the amount of heat for cooling and mixing which is necessary to treat honey, i.e. before and after filtration or pasteurisation, can be calculated. The relatively low heat conductivity, combined with high viscosity leads to rapid overheating from point-heat sources (see liquefaction in chapter 3).

Further Reading: [24, 25]

ELECTRICAL CONDUCTIVITY

Honey contains minerals and acids, serving as electrolytes, which can conduct the electrical current. The measurement of electrical conductivity (EC) was introduced in 1964 [45]. At present it is the most useful quality parameter for the classification of unifloral honeys, which can be determined by a relatively

inexpensive instrumentation. This parameter was included recently in the new international standards for honey of the Codex Alimentarius and the European Union, replacing the of ash content. Accordingly blossom honeys should have less, honeydew honeys more than 0.8 mS/cm. Exceptions are *Arbutus, Banksia, Erica, Leptospermum, Melaleuca, Eucalyptus and Tiglia* honeys and blends with them, see EU and Codex Alimentarius standards on this website.
There is a linear relationship between ash content and electrical conductivity [2]. Measurements of ash content can be concerted to electrical conductivity units by a simple calculation:

$$C = 0.14 + 1.74 \times A$$

Where C in the electrical conductivity in milli-Siemens per cm and the ash content in g/100 g.

Further Reading: [2, 36, 37, 39]

COLOUR

Colour in liquid honey varies from clear and colourless (like water) to dark amber or black The various honey colours are basically all nuances of yellow amber.
The most important aspect of honey colour lies in its value for marketing and determination of its end use. Darker honeys are more often for industrial use, while lighter honeys are marketed for direct consumption. While light honeys (e.g. acacia) achieve generally higher prices, there are also countries (Germany, Switzerland, Austria, Greece, Turkey) where consumers prefer dark honeydew honeys.

Honey colour expressed in different units
Honey colour is frequently given in millimetres Pfund scale, while an optical density reading is generally used in international honey trade [14] or according to the Lovibond Schale [4], used by the US Department of Agriculture, with following relation between both:

USDA colour standards	Lovibond scale disk	Pfund scale (mm)	USDA colour standards	Lovibond scaleII disk	Pfund scale (mm)
water white	30	11	light amber	150	71
extra white	40	18	light amber	200	83
white	50	27	amber	250	92
white	60	35	amber	300	99
extra light amber	70	41	amber	400	110
extra light amber	80	46	dark amber	500	119
extra light amber	90	51	dark amber	650	130
light amber	100	55	dark amber	800	140
light amber	120	62			

The values of these comparators give a measure of colour intensity, but only along the normal amber tone of honey. The Lovibond comparators are easier to handle than the Pfund graders, but honey is generally marketed according to the Pfund colour scale. That is why at present Lovibond graders with a Pfund scale are marketed. Other more objective methods have also been tested, as the determination of all colour parameters through the CIE L*a*b* *tristimulus* method [5, 30, 44], or reflectance spectroscopy [29, 43]

Further Reading: [4, 18, 20, 26, 41, 43, 48]

OPTICAL ROTATION

Honey has also the property to rotate the plane of polarisation of polarised light. This property is due to the individual sugars. As a sugar solution, honey has the property of rotating the plane of polarised light. Some sugars (e.g. fructose) exhibit a negative optical rotation, while others (e.g. glucose) a positive one. The overall optical rotation depends on the concentration of the various sugars in honey. Blossom honey have negative values and honeydew honeys have mostly positive values [32], but the values for the different unifloral honeys are not very typical. Thus, the determination of the electrical conductivity is the better tool for the prediction of the botanical origin of honey.

Further reading: [6, 13, 15, 34]

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