TROPICAL HONEY: PROPERTIES AND QUALITY
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1.introduction

In many parts of the tropical world honey from *Apis melifera* is harvested with export as the main goal, however in perhaps more countries honey is harvested for local use. This may be direct consumption, to brew alcoholic beverages like beer, for ceremonial purposes and as healing substance. Besides honey from *Apis melifera* also honey from other bee races like *A. dorsata, A. cerana* or from stingless bees are popular. Due to the price of the last mentioned product it is not common for mass consumption, however it has medicinal value.

Local honey harvesting
For harvesting honey it is not always is necessary to climb into a tree in the middle of the night armed with sticks and robes as was recently seen in a television program. But it is true that the traditional extraction of honey takes place in a more primitive way than we are used to.

In case of absence of a honey centrifuge honey is sometimes extracted above open fire, guaranteeing a good flow of the product, but causing serious damage to the product (too high HMF content and decomposition of enzymes); sometimes by pressing the combs, which procedure gives too many pollen as well as filth and insect fragments in honey.
Apart from the way of extracting also climatologic circumstances may have a negative effect on honey. Especially high tropical temperatures also harm the quality of the product (HMF, enzymes) and a high relative humidity of the environment may cause a higher water content in the honey with a high chance of fermentation.
In short, the circumstances in some tropical countries are not always optimal and – according to our insight – things can easily go wrong. In addition, any export to Europe is quite complex due to various legal hygiene regulations.

Support for beekeepers
Over the years, I had the privilege to meet many experts who out of idealism have tried to bring beekeeping in tropical countries to a higher level by helping local beekeepers providing them information about honey quality and about honey standards. Idealists sent by PUM, NECTAR, other organizations or just private. Part of their mission is to take samples of honey for chemical, physical and microscopic laboratory investigation on quality and botanical origin with the goal to get more exact details of the bee flora and to improve the honey yield. The research also focuses on the question whether the important quality criteria as stated in the somewhat more tolerant Codex (FAO / WHO) directive for honey (1) and the stricter European legislation (2) are met. Of particular interest is the pollen analysis: on which flowers do bees actually forage for nectar? Is this in line with field observations and claims. For many tropical areas this research is a challenge.

In the past, the NECTAR organization alone as well as together with the Agromisa organization has already issued some publications to help well-meaning idealists and local beekeepers in daily practice (4,5,6).

2. Properties

Composition
Has tropical honey a different in composition compared to honey from the temperate regions? The rough chemical composition is the same if we only consider, as nutrition experts do, the nutritional value: about 82% sugars and 18% water.

But honey is more than just sugar. Honey has – besides this huge amount of sugars - a whole range of specific ingredients such as enzymes, flavones, flavonoids (antioxidants), methylglyoxal and aromatic compounds that determine taste and color. Some honey types are locally important because of their taste or because of their assigned pharmacological properties like bitter honey, poisonous honey, healing honey and medicinal honey.
The taste and properties are linked to the specific botanical origin which is different in the tropics from that in Europe! Besides it seems from microscopic observations that in honey from tropical regions the total amount of pollen grains is higher than in the temperate regions, which may be due to climatologic circumstances.

Table 1. Properties of some honey types

Honey type	Property	Specific substance	Origin
Ilex surinamensis	bitter	?	Surinam
Arbutus unedo	bitter	arbutin	Italy
Manihot esculente	bitter	?	Nigeria
Rhododendron spp	toxic	grayanotoxines	Turkey, Nepal
Euphorbia sp	toxic	?	Central Africa
Ziziphus spina-christi	medicinal	?	Nord Africa
Anzer honey	medicinal	?	Turkey
Azadirachta indica (Neem tree)	medicinal	various	India
Leptospermum scoparium (Manuka)	wound healing	methylglyoxal ('UMF' factor)	New Zealand
Honey with PO>25	wound healing	Peroxide production >25µg/g/hr 20°C	Chile

Pharmacological properties
In table 1 just for illustration 'side effects', character properties or alleged characteristic properties of a few types of honey are mentioned. The well-known British botanist Kingdom Ward contracted a Rhododendron honey poisoning in Nepal as he describes in his book 'A plant hunters paradise' (1937). Problems caused by Rhododendron honey (*R. ponticum*) are mainly known from Turkey, where it is found around the Eastern part of the Black Sea, with the following symptoms: tingling in fingers and toes, nausea, decrease of heart rate to 30 and finally unconsciousness. It is usually called the 'mad honey disease'.
It is remarkable that honey from *R. ferrugineum* or *R. hirsitum* (Alpine rose) is non-toxic and this type of Rhododendron honey is very popular honey in Switzerland. The British Missionary Robert Moffat describes in his book 'Missonary Labor and Scenes in Southern Africa' (1856) a confrontation with an Euphorbia honey which gave an sensation of a sharp stinging taste in the throat.

Sometimes special types of honey are valued for their bitter taste (*Arbutus unedo*, strawberry tree), sometimes for the healing power ('Sidr honey from Morocco' - about $ 70 / 500g – 'works more powerful than Manuka'). For example, Anzer honey, a honey from the Anzer plateau, a special area around the Black Sea, is still a panacea for many Turkish people, as illustrated by a Turkish Dutchman who appeared with a jar of honey (250 euro for 1 kg) for his sick daughter at our institute (Food Inspection Service) asking: 'How much should I give my daughter daily?' For his fear was that the honey was contaminated with toxic Rhododendron honey from the same area.
All this to illustrate that honey is more than just sugar and that every type of honey has its own properties; indeed it may also have a pharmacological effect: sometimes positive and sometimes

negative for humans. Positive findings are not so well investigated for worldwide research focuses more on the negative than on the positive effects.

Bee plants

Several times a specific type of honey, of specific botanical origin, has been mentioned. A method that has been used for more than 100 years to determine the botanical as well as the geographical origin is to identify the pollen species that occur in honey. This type of science is known under the name melissopalynology and has given us a lot of information on nectar preferences for bees.
In Figures 1 - 4 some examples are shown of pollen found in tropical honeys.
Table 2 gives a summary of some important bee plants in the tropics. This list stems from field observations and melissopalynological investigation.

Table 2. Some important bee plants in the Tropics

Central America	Africa	Asia
Cocos	*Elaeis*	*Cocos*
Palmea	*Palmeae*	*Palmeae*
Eucalyptus	*Eucalyptus*	*Eucalyptus*
Mimosa	*Mimosa*	*Mimosa*
Syzygium	*Syzygium*	*Syzygium*
Coffea	*Coffea*	*Coffea*
Acacia	*Acacia*	*Acacia*
Bidens/Helianthus		*Asteraceae*
Vernonia	*Vernonia*	*Vernonia*
Spondias	*Lannea*	*Mangifera*
Bursera	*Terminalia*	*Euphoria longan*
Borreria	*Borreria*	*Viguera*
Trema	*Trema*	*Citrus*
Pterocarpus	*Combretum*	*Pterocarpus*
Cecropia	*Bombax*	*Ceiba*
Dombeya	*Casuarina*	
Bravaisia	*Commellina*	
Persea	*Butyrospermum paradoxum*	
Piper		
Triplaris surinamensis	*Parkia*	
Avicienna germinans	*Ziziphus*	
Solanum spp	*Ceratonia*	
Ilex		
Haematoxylon		

Honey from stingless bees

Honey from stingless bees (Meliponids)) has some special properties; it is not used as sweet spread for sandwiches but as traditional medicine for example in cases of eye complaints. The honey has a higher moisture content, up to 35% and as explained under 3. does not crystallize and is not prone to fermentation. It turns out that stingless bee honey contains *Lactobacillus* spp (lactic acid bacteria), which have a bacterial growth-inhibiting effect due to the production of hydrogen peroxide. On the other hand, some *L.* species produce the enzyme catalase that decomposes hydrogen peroxide.

Hence the hydrogen peroxide production in meliponids honey is sometimes low and sometimes very high. This cannot be said of the level of the enzyme diastase (added by the bees) which is in general very low. On the contrary the prices paid for this honey are rather high. Incidentally, the product may not be called honey because of these deviating properties. Although an international commitment has been made to adjust the international regulations, this has still not happened.

3. Problems/defects in tropical locally produced honey

Storage and crystallization of honey
In case of storing honey often problems may arise due to crystallization of glucose (dextrose) after some time. If this happens the upper liquid layer automatically gets a higher moisture content - up to a few percent - which makes honey liable to fermentation. Crystallization mainly depends on the temperature and on the glucose/water ratio and occurs sooner or later if this value is higher than 1.58; below this value glucose does not crystallize at room temperature. That is the reason that honey from stingless bees, due to the high moisture content, does not crystallize for the value of 1.58 is never reached (for example 35/25 = 1.4).

Temperature and quality damage
Longtime storage of honey in tropical areas influences the HMF (Hydroxy Methyl Furfural) content as well as the diastase activity, parameters which are used in international regulations as quality criteria. HMF is formed during heating or storage of honey. At 20 °C it takes two years to reach the legal limit of 40 mg/kg, however at 40 °C only 30 days! The enzyme diastase, nowadays called amylase, is introduced by the bees during processing of honey; during heating or storage the amount decreases. The 'half live' is the **time** taken for half of the activity of the enzyme to disappear, which is about 4 years at 20 °C and 90 days at 40 °C.

Indeed heat damage may be a problem in the tropics. In the 1970's, when there were no clear rules for honey quality in European countries, it appeared that two storage systems existed in a tropical export country: one in which the barrels of extracted honey were shielded from sunlight - which honey was destined for Germany and storage of barrels in the outside air - destined for the rest of the world. In later years, uniform EU requirements for honey have been issued and nowadays, for export purposes, controlled storage of honey in tropical countries is necessary.

Adulteration
From economic perspectives, it is sometimes rewarding to adulterate honey with sugar or invert sugar and sell it on local markets as pure honey. Production of invert sugar, the same sugar that also forms the main ingredient of honey, is rather easy and can be done by treating cane sugar according to an old recipe with (citric) acid. During this process HMF is formed, which is now easily detectable as explained under 4. A modern way to prepare invert sugar industrially is through an enzymatic route which produces no HMF and makes detection in honey extremely difficult. However, this technology is only industrially applicable and not suitable for domestic use.

Deviating sensory properties
From time to time deviating properties in traditionally produced honey are encountered; a few noteworthy defects are the following.

--Black honey: due to excessive heating, caramelization or heating over open fire. In Nigeria dark honey is locally considered as 'richer' and more 'powerful' (M. Mutsaers in (3))

-- Smoky taste: due to overuse of tobacco and other herbs and to heating over an open fire.

-- Sour taste: due to fermentation which is caused by a too high moisture content and/or high relative humidity or by harvesting unsealed honey.

--Alcohol taste: due to fermentation as above. See Figure 7.

--Deviating taste or burned smell: due to pressing of the combs causing a large amount of pollen in the honey. A deviating taste or smell may also originate from adulteration or strong heating.

--Grainy, granular feeling in the mouth: due to a large amount of pollen with a somewhat larger diameter causing the observation of individual particles on the tongue. Examples from Africa: *Julbernardia* and *Brachystegia* pollen.

4. Legal regulations and control

FAO/WHO and EU regulations

Important guidelines for international trade and honey quality are:

The Codex (FAO/WHO) directive for honey (1) and the EU Regulation for honey (2): the latter sets stricter requirements for honey, the Codex has partially released the diastase and HMF requirements.

In addition individual countries may impose additional quality requirements for special varieties for their own honey, e.g. 'honey rich in enzymes' or a special labelling according to the botanical or geographical origin as done in Italy for instance and in Turkey for their Anzer honey, which is honey from the Anzer plateau in the Black Sea region.

Some important paragraphs from the FAO/WHO guideline are:

- Honey should have a normal color, smell and taste.

  This can easily be verified on the spot by inspection of the method of extraction: preferably honey extraction by centrifuging instead of pressing, no open fire and no excessive amounts of smoke.

- Moisture not more than 20% [honey from *Calluna vulgaris (*Heather) 23%]

  This can be reached by collecting as far as possible sealed honey. The moisture content can easily be measured with a refractometer. For stingless bees honey, most honey refractometers are not suitable because the water content is outside the usual range. Possible present yeasts which may spoil the honey can be identified by microscopic analysis as illustrated in Figure 6.

- Enzyme diastase for EU: at least 8 units, for a few honey types and *Apis cerana* honey a minimum value of 3 is allowed

--HMF for the EU: maximum value 40 mg/kg; some honey types, poor in enzyme content, should have a maximum amount of 15 mg/kg , for tropical honeys the upper limit is 80 mg/kg.

- Correct labeling and nutrition declaration

- Declaration of a geographical and/or botanical origin is allowed, provided the honey is mainly derived from the mentioned plant origin and/or entirely from the claimed geographical origin.

  The preferred method of analysis is microscopic identification of the type of pollen grains

Besides there are other regulations on residues of pesticides and antibiotics.

Some simple control procedures on quality and adulteration

In order to get an impression on the quality of honey or to detect adulteration there are some simple methods available which give a quick impression on the type of fraud. The following methods have been proved to be useful and some of them can be carried out on-side.

--Microscopic examination to determine the pollen types, to determine yeasts, filth and detect addition of cane sugar and cane sugar syrups (6). See Figures 1-7.

--HMF screening to detect over heating or too long storage or adulteration by invert sugar prepared by old-fashioned acid hydrolysis of beet and cane sugar. A few years ago a special test with test strips has been developed by Merck (7).

--In the case of not too dark types of (liquid) honey: determination of the angle of optical rotation with polarization slides: left rotating honeys are not suspected, a turning of the plane of polarization to the right is highly suspected because dextrose (glucose) or sucrose (sacharose) may have been added.

This so-called rotation refers to the rotation of the polarization plane of polarized light through a honey or sugar solution. Normal honey, glucose, (added) sucrose as well as almost all other types of sugar are turning the plane to the right; however fructose (levulose) is turning this plane to the left and more strongly to the left than glucose is turning to the right. As a result, normal flower honey is turning left. Due to a different sugar composition honeydew honey has slight turning to the right.

--Hydrogen peroxide production for indication of presence of enzymes

This test is carried out with hydrogen peroxide test strips (for instance Merck); it gives an indication of the presence of the enzyme glucose oxidase, added by bees, and may give information on possible too strong heating of honey, which destroys enzymes; one should however be careful with this test for a value of zero does not always mean that honey is heated (8)!

NB: Besides the test also gives an indication of the wound healing properties of honey as far as attributed to the presence of hydrogen peroxide. It is interesting to know that for the processing of (tropical) honey in honey wound dressings a hydrogen peroxide activity of more than 25 micrograms/gram/hour at 20 ° C is used.

5. Summary and conclusions

The Tropics are always considered as an area with a large honey potential. Through cooperation and by providing the right information we can improve the honey yields and with some simple analyses the honey quality. In this way we can contribute to increase the economic perspectives for the local population.

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Figure 1.

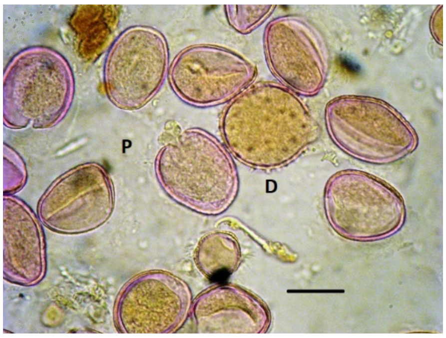

Figure 2

Figure 3

Figure 4

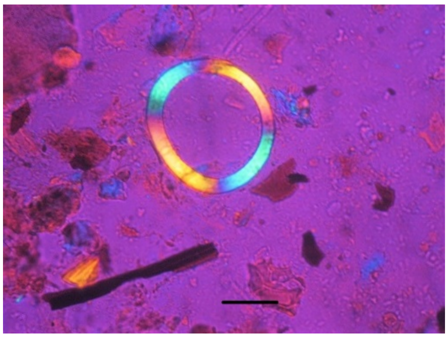

Figure 5

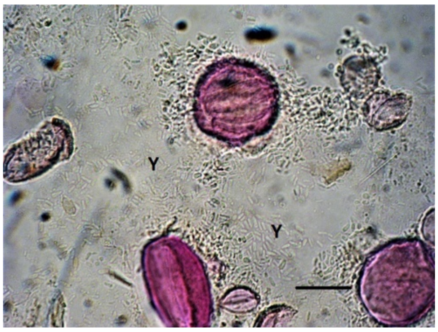

Figure 6

Figure 7

Figure 8

Text photographs:

Figure 1. Honey from Central America with pollen from Acacia (A) and Burseraceae (B)
Microscopic image, bar = 25 µm

Figure 2. Honey from Trinidad with pollen from Palm trees (P) and *Dombeya* (D)
Microscopic image, bar = 25 µm

Figure 3. Mixed European African honey with pollen from *Fagopyrum esculentum* (F), *Julbernardia* (J), *Brachystegia* (B) and *Vernonia* (V)
Microscopic image, bar = 25 µm

Figure 4. Honey from Burkina Fasso with pollen from *Acacia* (A), *Combretum* (C) and *Elaeis guineensis* (E)
Microscopic image, bar = 25 µm

Figure 5. Honey from South America with loose ring of sugar cane ring vessel, indicating adulteration with cane sugar.
Microscopic image, polarization microscopy, bar = 25 µm

Figure 6. Honey from Central America with many yeast cells (Y)
Microscopic image, bar = 25 µm

Figure 7. Tropical honey with many filth particles
Microscopic image, bar = 25 µm

Figure 8. Laboratory for testing honey quality in the neighborhood of Kathmandu, Nepal