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Original research article

Capped Honey Moisture Content from Four Honey Bee Species; *Apis dorsata* F., *Apis florea* F., *Apis cerana* F, and *Apis mellifera* L. (Hymenoptera: Apidae) in Northern Thailand

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Abstract Honey moisture content from beneath capped honey storage cells was examined for four species of honey bees in northern Thailand. Three species, *Apis dorsata*, *A. florea*, and *A. cerana* are indigenous to SE Asia, the fourth species, *A. mellifera*, is a recently introduced species. It is assumed that capped honey will possess the lowest moisture content attainable under tropical conditions. Average honey moisture content was as follows: *A. dorsata* 22.7%, *A. florea* 20.1%, *A. cerana* 21.2% and *A. mellifera* 18.8%. Capped honey storage cells for the indigenous honey bee species frequently exceed the moisture content standard set by regulatory agencies for *A. mellifera* honey in Europe. The introduced, temperately adapted *A. mellifera* is capable of lowering honey moisture to regulatory standards even in the environmental restraints of high ambient temperature and relative humidity of northern Thailand.

Keywords Capped honey, moisture content, *Apis florea*, *Apis cerana*, *Apis mellifera*, *Apis dorsata*

INTRODUCTION

Water content is a crucial quality parameter for practically all food products and their ingredients. Water has a substantial, if not decisive, influence on the quality and especially the shelf life of practically all materials of biotic origin. Water content is an important aspect of overall "quality control" for food products and this also applies to honey. Excess honey moisture can be a problem for beekeeping in tropical areas. A potential problem for high moisture honey is fermentation as it has been shown that the probability of fermentation is highly linked to moisture content (White, 1975). Honey fermentation is activated by the presence of osmotolerant yeast species utilizing the primary honey sugars (fructose and glucose), producing ethyl alcohol and carbon dioxide. Most yeast species associated with honey fermentation are within the genus *Saccharomyces* but there are reports of other yeast genera as well (Snowdon and Cliver, 1996). Moisture content is also connected to additional honey quality issues *e.g.*, viscosity and crystallization.

There are five honey bee species in Thailand; the indigenous *Apis andreniformis* Smith, *A. florea* F., *A. cerana* F. and *A. dorsata* F. along with *A. mellifera* L. the western honey bee, an introduced exotic species. Honey from all indigenous species is sought after in traditional honey hunting scenarios. The Thai Ministry of Public Health found excessive honey moisture content in randomly examined retail honey products, moreover, yeast and some fungi infected wild honey which resulted in excess fermentation (MGR online, 2017). The authors have also observed indigenous "wild" honey at the retail level, frequently exhibits outward signs of

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fermentation. The Thai Ministry of Public Health has established a standard for moisture content in honey as 21 g/100 g (≤21%) (The Ministry of Public Health, 2000). CODEX (FAO, 2001) and the EU require that no honey should have a moisture content exceeding 20%, although these longstanding international standards apply to *A. mellifera* only (Bogdanov and Martin, 2013). Beekeeping organizations in various countries (*e.g.*, Germany, Belgium, Austria, Italy, and Switzerland) have set a maximum moisture content not to exceed 18~18.5% for *A. mellifera* honey (Swiss Bee Research Centre, 2000). Chirife *et al.* (2006) measured some essential features of the relationship between water activity and moisture content in honey. A noteworthy relationship was found between both parameters in the range examined (15~21% moisture).

Honey moisture content has been reported from numerous investigations for Asian *Apis* species (*i.e.*, Joshi *et al.*, 2000; Balasubramanyam, 2011; Iftikhar *et al.*, 2011). Traditional reports of honey moisture result from samples of centrifugally extracted honey and/or honey removed from storage cells *via* a crush and drain technique, both of which represent an aggregate honey taken from many hundreds to many thousands of honey storage cells. Often these extractions of honey from cells will include a combination of both capped honey cells and uncapped honey (nectar) cells. Our objective was to elucidate honey moisture values as found in capped honey storage cells for 4 *Apis* species as encountered in northern Thailand. We approached this by examining honey only from individual capped honey storage cells. It is assumed that honey beneath capped storage cells has been dehydrated by the worker bees to as low as ambient and colony conditions allow. This is opposed to uncapped honey storage cells which contain nectar in the process of being dehydrated. Concerning *A. mellifera* Maurizio (1975) states that honey storage cells are sealed when the moisture is below 20%.

Table 1. Average (±SD) and range of capped honey moisture content of four species of honey bees in Northern Thailand

Species	N	Average±SD	Range
Apis florea	384	20.1±1.7%	16.6~26.5%
Apis dorsata	297	22.7±1.2%	20.0~26.0%
Apis cerana	297	21.2±1.0%	18.5~24.5%
Apis mellifera	331	18.8±1.2%	15.9~26.2%

*N represents the number of honey comb cells where honey moisture was measured from

MATERIALS AND METHODS

Honey combs from seven *A. florea*, six *A. dorsata*, nine *A. cerana*, and seventeen *A. mellifera* colonies were collected from January to December 2016. All colonies were located within a 15 km radius of metropolitan Chiang Mai in northern Thailand (18°58′N). All honeycombs possessed both capped and uncapped storage cells. Individual capped honey cells were carefully decapped and the honey removed by micropipette. Honey moisture from individual capped cells was determined using a hand-held honey refractometer (Atago model N-3E).

RESULTS

Table 1 summarizes the findings. The data demonstrate that the average honey moisture from only one species (*A. mellifera*) falls below a "mandated" 20%, although *A. florea* honey averaged only slightly higher than 20% while *A. cerana* and *A. dorsata* exceed 20% at levels of 21.2 and 22.7% respectively. It should be noted that the average honey moistures results from a wide range of moisture with capped honey high moisture outliers found in all species sampled (≥24.5%). A comparative study by Iftikhar *et al.* (2011) provided similar results with the caveat that their honey sample collection methodology was by straining entire combs

Table 2. Comparative values of honey moisture reported from SE and Central Asia

Species	This study (Thailand)	Joshi *et al.* 2000 (Nepal)	Iftikhar *et al.* 2011 (Pakistan)	Balasubramanyam 2011 (India)
Apis florea	20.1%	NR	20.9%	20.9%
Apis dorsata	22.7%	21.5%	22.1%	23.6%
Apis cerana	21.2%	20.1%	20.1%	21.1%
Apis mellifera	18.8%	17.1%	17.7%	NR

as opposed to our examining individual capped cells. The Joshi *et al*. (2000) report examined honey from *A. mellifera*, *A. dorsata* and *A. cerana* and again our results are similar. They provide no explanation as to how the honey samples were obtained other than saying from cut honey comb, but we assume that both their samples, as well as those from the Iftikhar *et al*. (2011) study, represent honey moisture values from an aggregate of honey storage cells. Balasubramanyam (2011) states his *A. cerana* honey samples were obtained by centrifugal extraction of honey combs and that the *A. florea* and *A. dorsata* samples by crushing and draining honey combs, which again results in aggregate samples from hundreds to thousands of honey and nectar cells. Their results in a comparison to what we report, are summarized in Table 2.

DISCUSSION

Our observations support a hypothesis that moisture content in capped honey cells of indigenous honey bee species is most often higher than the international regulations which define honey derived for the western honey bee *A. mellifera*. Interestingly, the *A. mellifera* capped honey moisture from this report averaged 18.8 $\pm$1.2%, the lowest of all species examined. White *et al*. (1962) in a classic study of American honey, found an average moisture of 17.2$\pm$1.5% from a sampling of 490 unifloral *A. mellifera* honeys. In a survey of commercial *A. mellifera* honey from northern Thailand, the average honey moisture from unifloral honeys, ranged from 19.9 to 20.2% (Santhasup *et al*., 2009), which along with our results, demonstrate that even under the temperature and humidity constraints of northern Thailand, honey from the temperately evolved *A. mellifera* is produced with a moisture content within recognized international standards. As cogently stated by Ward (2000), in tropical regions with high relative humidity (RH) and high temperatures, honey bees must expend more energy to reduce moisture in ripening honey than in temperate regions where the RH and temperatures are lower, which suggests that the indigenous honey bees might ultimately cap honey at higher moisture levels than those traditionally shown for *A. mellifera* honey. Our finding support that supposition.

The Government of Thailand has noted that wild honey products taken from forest areas have a high moisture content. This has resulted in accusations of alleged production of fake honey or adulterated honey. Our data show that capped honey stores of indigenous species have moisture contents often exceeding 21%, with the exception of *A. florea*. While Maurizio (1975) states that *A. mellifera* capped honey possesses a moisture content $\leq$20%, such cannot be said for several Asian honey bee species, i.e., *A. cerana* and *A. dorsata*, which averaged 21.2% and 22.7% moisture respectively. In the future development of national and/or international honey standards, it needs to be taken into account that honey moisture from indigenous tropical species can frequently be in excess of 20%.

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