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Rheology and botanical origin of Ethiopian monofloral honey

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ABSTRACT

Rheology and botanical origin of Ethiopian monofloral honeys were investigated using harmonized method of melissopalynology and HAAKE VT 500 over a temperature range of 25–45 °C, respectively. The percent dominance of monofloral honeys ranged from 59.8% (*Croton macrostachyus*) to 90.3% (*Schefflera abyssinica*). Botanical origin and geographical location of honeys were categorized on principal component analysis (PCA) of pollen data. The PCA graph showed that honeys were divided into two separate groups or three sub groups, based on their close appearance in the plot. The highest viscosity value was observed in *Eucalyptus globulus* honey and the lowest in *Vernonia amygdalina*. Shear stress versus shear rate linearity indicated that all the monofloral honeys exhibited Newtonian behavior. The effect of temperature on the viscosity of honey followed the Arrhenius relationship. The activation energy ranged from 60,042.05 (*Eucalyptus globulus*) to 9858.741 kJ/mol (*Vernonia amygdalina*). Viscosity of honey was found to be time independent.

1. Introduction

Honey is a viscous, sweet and aromatic product. It consists of pollen grains and has been used by humans without being processed since ancient times. Pollen grains are mostly carried from the honey plants during foraging, which is used to fulfill the amino acid, fatty acid and mineral requirement of honey bees' diet (Avni, Hendriksma, Dag, Uni, & Shafir, 2014; Yang et al., 2013). Pollen contribution can possibly guide to determine the honey floral origin (Molan, 1998; Ohe, Oddo, Piana, Morlot, & Martin, 2004). Consequently, the floral origin of honey helps to provide a specific sensorial, chemical and flowing behavior for honey (Bogdanov, 2012; Crane, 1983).

Ethiopia has the highest bee density in Africa; and the annual honey production reached to about 53,693 tons. This makes the country first in Africa and tenth in the world. The production of honey in Ethiopia plays a great role in economic, environment, social and cultural benefit of the citizens; and greatly benefits the forest dwellers (CSA, 2015). At present there is an increasing interest on science and commerce to investigate monofloral honeys. Certainly, many consumers prefer monofloral to polyfloral honeys. The production of monofloral honeys has a benefit to compete with low priced polyfloral honeys. Furthermore, the botanical designation of honey is allowed and can possibly use in the therapeutic and technological intervention of the product (Escriche, Kadar, Juan-Borrás, & Domenech, 2014).

Botanical origin is determined based on the relative frequencies of the pollen types of nectariferous species, using harmonized methods of melissopalynology (Ohe et al., 2004). Honey can be called monofloral honey, if it primarily originated from a dominant floral source and show the typical flowing property of the corresponding type of honey (Arrigoni, Kast, & Walther, 2014; Ohe et al., 2004). Hence; if the relative frequency of the pollen of that *taxon* exceeds 45%, honey is considered to be monofloral in its botanical origin.

Floral source and ripening processes are important factors that affect the composition and flowing capacity of honey. Ripening of

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nectar into honey is a combination of mainly two processes: conversion of sucrose into glucose and fructose, and evaporation of excess water. This is mostly occurring to saturate sugar and other solid compounds (Ball, 2007). Saturation of sugar and reduction of moisture are instrumental for flow resistant behavior. As a result honey becomes a viscous and aromatic product. This can be the intrinsic characteristics of honey that possibly distinguished one monofloral honey from the other (Bogdanov, 2012; Escriche et al., 2014; Nita, Murith, Chisholm, & Engmann, 2013).

Viscosity is a measure of its resistance to gradual deformation by shear stress (Eroglu et al., 2016). Knowledge of the rheology of honey is important and applicable in all firms of honey processing technology at different unit operations; staring from uncapping the honey comb up to consumption (Lazaridou, Biliaderis, Bacandritsos, & Sabatini, 2004).

Rheological property of honey was used to categorize honey into Newtonian and non-Newtonian fluids. This fluid behavior of honey is a factor of botanical origin that offer structural organization of food, and play an important role in fluid heat transfer (Ahmed, Prabhu, Raghavan, & Ngadi, 2007). In Newtonian fluid, the shear rate is directly proportional to the shear stress and the plot begins at the origin. The majority of monofloral honeys showed Newtonian behavior and their viscosity strongly depends on temperature (Gómez-Díaz, Navaza, & Quintáns-Riveiro, 2009). In non-Newtonian fluid, shear stress and shear rate plot is not linear and does not begin at the origin. Heather, manuka, buckwheat and some eucalyptus honeys are examples of non-Newtonian type of honey (Fauzi, Farid, & Silva, 2014; Witczak, Juszczak, & Gałkowska, 2011; Yanniotis, Skaltsi, Karaburnioti, 2006).

Viscosity of carbohydrate rich foods is affected by temperature. The effect of temperature can be described by Arrhenius relationship. Within the temperature range of 0–40 °C, honey is Newtonian and the viscosity over this temperature range can be predicted using Arrhenius model (Lazaridou et al., 2004; Mossel, Bhandari, D'Arcy, & Caffin, 2000).

Currently, description of honey using pollen analysis and rheological characteristics has received several attentions. The findings of Ahmed et al. (2007) showed that honey collected from the same environmental and geographical location significantly differ in rheological characteristics. Contrary to the majority of the findings, some honey samples showed non-Newtonian behavior. Oddo and Piro (2004) described the main European monofloral honeys based on botanical origin. A number of researchers studied the rheology of honey. Juszczak and Fortuna (2006) reported the rheology of polish honeys and found that honeys were Newtonian flow behavior; Yanniotis et al. (2006) studied the rheology of pine, fir, thymus, orange, helianthus and cotton honeys and found that viscosity is more sensitive to temperature changes at low moisture contents and the samples showed Newtonian behavior; Witczak et al. (2011) analyzed heather honey and found that the honey was non-Newtonian; and Kędzierska-Matysek, Florek, Wolanciuk, Skałecki, and Litwińczuk (2016) examined *Brassica napus* honey of Lublin region of Polish honey and found that honeys had temperature dependence of viscosity. So far, there is no report on the rheological property of Ethiopian honey, which is based on botanical origin. The purpose of this study was, therefore, to investigate the botanical origin using Melissopalynology; and explore the rheology of Ethiopian monofloral honeys at various operating temperatures.

2. Materials and methods

2.1. Study area

This study was conducted in Ethiopia, where monofloral honeys originate (Fig. 1). The selection of these areas was based on reconnaissance survey and questionnaire. Eighty individuals, who are actively participating in the honey sector, were selected to complete questionnaires. These include honey consumers, collectors, processors, exporters, experts and technicians.

2.2. Sample collection

Three hundred and twenty honey samples were collected from potentially honey producing areas (Fig. 1), based on their floral calendar from May 2014 to March 2015. Beekeepers, at the farm gate, were selected using randomized lottery sampling methods and oriented about the methodology of honey sample collection. Researchers were involved in the majority of sample collection activities. The materials used to collect honey samples were smoker, bee brush, brood free combs, rust free metallic honey containers, 250 g and 500 g food grade glass jar, dry and clean plastic honey containers, uncapping fork and honey extractor.

Late in the afternoon the traditional beekeeper mounts on the tree using a long rope (about 50 m). The traditional hive was tightened using rope and transferred to the ground. One or two beekeepers took the hive and set on stick bed, which has a length of 50–75 cm. The beekeeper puff smoke from the back (opposite to the entrance) and opens the hive. The vertically positioned fixed honey combs were clip from the top, brushed and put in dry plastic bucket. The honey combs were transported to temporarily arrange straining room; and honey combs were broken into pieces and strained using honey sieve, and allowed to settle in a 50 kg metallic honey container. These were done mostly in the South and South Western part of the country. Sample from Northern part of the country were from frame hives, which are extracted honey. To harvest honey from frame hive, a beekeeper puff smoke at the entrance and then the lid was opened and smoked at the top. Honey containing frame combs were clipped from the super box using hive tool, and bees were swept from the comb using brush. The honey was transported to temporary extraction places using empty super box. The sealed frame combs were decapitated using uncapping fork and inserted into the honey extractor. Through centrifugation, the honey was drained from the cell and taken from the outlet of the honey extractor. Both the comb and extracted honey was strained, settled, and later poured in 250 and 500 g food grade glass jar (Belay, Solomon, Bultossa, Adgaba, & Melaku, 2015).

2.3. Botanical origin identification

For identification of botanical origin of honey, a number of possible indicators such as floral calendar, dominance of honey plant and sensorial detection (mainly honey color, taste and flavor) were considered. For sensorial detection 3–4 beekeepers, which have a common knowhow and practice of identifying honey type were selected from the local community. The local panelists were screened using blind coded honey samples. Likewise, a sort of duo-trio test was used to select panelists. Assessors were served with three honey samples (30–40 g), two blind coded and one labeled as a 'reference', using 150 mL odorless food grade glass cup. The panelists were asked to choose one of the blind coded honey sample, which was most similar with the 'reference' (Belay et al., 2015). Accordingly, judges were selected. Honey samples were collected with the recommendation of these panelists and the researcher. Finally, pollen analysis was used to verify botanical origin of honey.

Pollen analysis was carried out to determine the major honey source. Honey (10 g) sample was weighed in a pointed glass centrifuge tube (capacity ca. 50 mL) and dissolved in 20 mL of distilled water (20–40 °C). Then the solution was centrifuged for