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The Effects of Magnetic Fields on Viscosity, Color and pH of Longan Honey

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Abstract

The magnetic fields were introduced in substitution of high temperature and prolonged heating during honey production with a promise of improved flowability and appearance of longan honey. The honey samples were exposed to magnetic fields of the permanent magnets for six hours at room temperature. The study was divided into two sets of magnetic fields depending on the maximum fields measured at the ends of the rod magnets. The lower magnetic fields were at 1400 G and 1600 G (samples F01 and F02), and the stronger magnetic fields at 4300 G (samples N01 and N02). The magnetically treated honey samples were then determined for any change of viscosity, color, pH, moisture content and total soluble solids (TSS) content. It was found that the honey samples subjected to the strong magnetic fields of 4300 G reduced their apparent viscosities from 6.7 Pa·s (control) to 6.1 Pa·s. The viscosity flow curves of all honey samples tested at the shear rates of 0.13 to 25 s^{-1} presented Newtonian behavior. The color space of all honey samples subjected to the magnetic fields showed increases in L^* (from 26.43 to 29.59) and a^* (from 3.12 to 5.22) values but decreases in b^* values (from 12.09 to 11.12). As the result, color of the treated honey became lighter, more red and slightly yellow. In addition, the positive potential of hydrogen ions (pH) analysis showed that the honey samples became more acidic with stronger magnetic fields, and their pH values decreased from 4.23 (control) to 4.14, 4.16, 3.82, and 3.84 for the samples subjected to magnetic fields of 1400 G and 1600 G (F01, F02) and 4300 G (N01, N02), respectively. Moisture and TSS contents of all samples were, however, unaffected by the magnetic fields.

Keywords: honey, magnetic fields, magnet, viscosity, longan

1. INTRODUCTION

Honey produced by honey bees is a natural health food product having a high nutritive value. Honey contains approximately 60-85% reducing sugars (mostly glucose and fructose), water, and minor components of organic acids, amino acids, vitamins, minerals, and bioactive substances [1]. Its color, taste, and aroma are mainly depended on floral nectar source, thermal processing, and storage of honey product.

Northern Thailand is the leading longan-growing region with areas of more than 600,000 acres [2]. Longan honey is, in general, yellowish brown in color and has strong fruity scent and sweet taste [3]. During Thailand's cold season, longan blossom becomes a good source of longan honey production. Unfortunately, agricultural watering and humidity could make honey unsatisfied as to be complied with the Polish Honey Standard (PN-88/A-77626) [4] for water content of not exceeding 20 g per 100 g of honey [5]. As every gram of water is removed from 100 g of honey, viscosity of honey increases. Besides, viscosity of honey can increase when cooled, as reported by Munro [6]. Heating the honey to evaporate excess water and decreasing viscosity of honey could improve honey flowability in honey processing but with a sacrificed drawback of browner appearance [7].

The magnetic fields have been generally used for cleaning the contamination of raw materials before entering in production process [8, 9] and being used to rearrange molecular structure of hydrogen containing molecules parallel to the magnetic fields, resulting in better flowability of liquids [10]. However, research on how applied magnetic fields affecting honey properties is lack. Aside from honey, the magnetic fields had been capable of treating precipitation formation in water processing [11-14]. It was reported that the magnetic fields affected magnetohydrodynamic interaction [15], interfacial tension and hydrated ionic structure of the cation in water [16], physicochemical characteristics, chemical inertness, turbidity of water, reduction of chemical oxygen demand [17], removal of Cr(VI) [18], and microbial activity [19]. Hosoda et al. [20] reported possible improved hydrogen bonding strength under the magnetic fields due to electron delocalization of a water dimer. Based on composition of honey, introduction of magnetic fields, which might interact with some water molecules and other ambiguous constituents [21] in honey, would potentially affect physical properties of honey and result in changes of honey flowability and appearance.

This research was, therefore, to focus on changes of viscosity of the honey by applying magnetic fields and to study how the magnetic fields would affect basic physical and chemical properties of honey, namely viscosity, moisture and TSS contents, color and pH.

2. MATERIALS AND METHODS

2.1 Materials

The honey samples were obtained from beehives cultivated in longan (*Dimocarpus longen* Lour.) plantation in the areas of Chiang Mai and Lamphun Provinces in Northern Thailand.

Permanent magnets used in the trials were ferrite rod magnets with the maximum fields of 1400 G and 1600

G and neodymium rod magnets with the maximum long and had 20 mm diameter, and the neodymium rod magnets were 50 mm long and had 10 mm diameter. All rod magnets were wrapped in commercially available food grade polyvinyl chloride film to prevent contamination and then measured for their magnetic fields. Therefore, the fields affected the honey samples were definitive.

2.2 Methods

Magnetic field measurement of all magnets was conducted by using AlphaLab High-Stability DC Gaussmeter, Model GM-2 with ST universal probe. Viscosity of all honey samples was measured at 27°C and given rotational speeds of 0.5, 1, 2, 2.5, 4, 5, 10, 20, 50 and 100 rpm by using Brookfield Viscometer with a TC-502P programmable refrigerated bath, small sample adapter, SC4-29 spindle and 13RPY sample chamber. Color measurement was conducted by using Konica Minolta Chroma Meters CR-400/CR-410. The positive potential of the hydrogen ions (pH) was measured by using Eutech Instruments Cyberscan pH 510 Meter.

Moisture contents in honey samples were analyzed using modified method of the Association of Official and Analytical Chemists [22] by following steps: (1) heating pre-weighed aluminum crucibles and lids at 105°C for 3 h and cooling them in a desiccator; (2) loading 5 g (W_1) of longan honey to the crucible and heated in vacuum oven at 70°C for 24 h until obtaining a constant weight; and (3) cooling in a desiccator and weigh the sample (W_2) after drying. The moisture content of the sample can be calculated by using equation (1).

$$\text{Moisture (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100 \qquad (1)$$

where W_1 is the weight before drying and W_2 is the weight after drying.

Total soluble solids (TSS) content was evaluated by means of Brix scale refractometer using ATAGO Master-3M (^{O}Brix 58.0-90.0%) refractometer.

3. EXPERIMENTATION

Two sets of samples of 50 g honey were assigned as C01 and C02 for control samples without subjection to magnetic fields, F01 and F02 for samples subjected to low magnetic fields at 1400 G and 1600 G, and N01 and N02 for samples subjected to strong magnetic fields at 4300 G. The samples were prepared in 50 ml Pyrex® beakers. Each rod magnet was placed vertically at the center of the beaker as shown in Figure 1. Inside the beaker, magnetic fields of each magnet were measured at every 5 mm distance vertically from both ends and circumferentially at top, center, and bottom positions.

All sample beakers were kept absence of interfering magnetic fields and stirring, and stored at 27°C for 6 h to ensure observable effects of magnetic fields on the honey samples. Immediately after storing, all honey samples were measured for viscosity, color coordinates (L^*, a^*, and b^*), pH, moisture content and total soluble solids (TSS) content. Triplicate measurements for color, pH, moisture content and TSS content of each honey sample were conducted. However, only one viscosity

fields of 4300 G. The ferrite rod magnets were 50 mm measurement was allowed due to the limited amount of each honey sample.

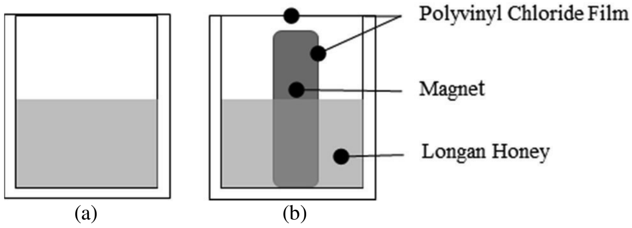

Figure 1 Schematic of the sample setups (a) without and (b) with a magnet placed vertically at the center inside the 50 ml beaker and 50 g honey

4. RESULTS AND DISCUSSIONS

4.1 Magnetic field profiles

All measurements of magnetic fields are shown in Figure 2. The maximum fields were located at the ends of the rod magnets. The magnetic fields decreased with increasing distance in vertical and radial directions away from the magnet's ends. This is due to greater densities of magnetic field lines at north and south poles of the magnet and the densities decrease with increasing distance away from the poles [23]. The measured magnetic fields at submerging ends of the 1400 G and 1600 G magnets were, respectively, 1419 G (sample F01) and 1641 G (sample F02), while those of 4300 G magnets were 4310 G (sample N01) and 4315 G (sample N02).

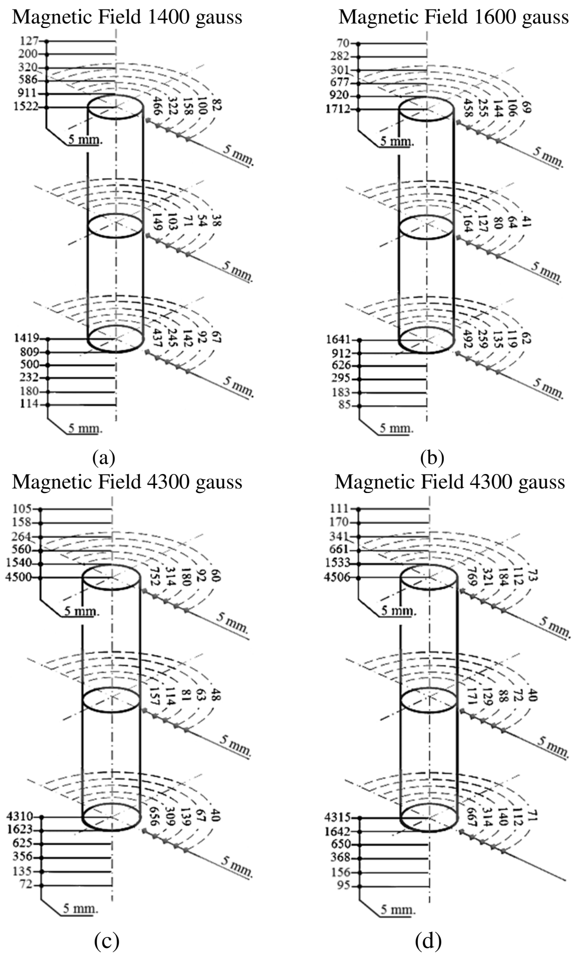

Figure 2 Magnetic field profiles about the magnets with the maximum fields of (a) 1400 G (b) 1600 G and (c, d) 4300 G at the ends of the magnets

4.2 Effect of magnetic field on viscosity of honey

Honey in the beakers was affected by the magnetic forces coming from each magnet differently, as shown in Figure 2. Despite ambiguity of magnetic field effect to honey, the viscosities of longan honey samples subjected to non-magnetic (C01 and C02) and magnetic (F01, F02, N01 and N02) fields at given rotational speeds of 0.5 to 100 rpm were measured in temperature-controlled environment right after being magnetized for 6 h and summarized in Table 1. As expected, viscosities of the samples decreased with increasing rotational speeds. However, the rates of decreasing viscosities of the samples subjected to magnetic fields were higher than those of the control ones. It was also apparent that in addition to increasing the rotational speeds, the magnetic fields applied to the samples reduced additional viscosities.

Table 1 Viscosity of longan honey samples

rpm	Viscosity (Pa·s)					
	C01	**C02**	**F01**	**F02**	**N01**	**N02**
0.5	12.000	12.000	10.000	10.000	10.000	10.000
1	9.000	9.000	9.000	9.000	8.000	8.000
2	8.000	8.000	8.000	8.000	7.500	7.500
2.5	8.000	8.000	7.600	7.600	7.200	7.200
4	7.500	7.500	7.250	7.250	7.000	7.000
5	7.400	7.400	7.200	7.200	7.000	7.000
10	7.200	7.200	7.200	6.800	6.600	6.600
20	6.950	7.100	6.790	6.650	6.450	6.400
50	6.800	6.800	6.640	6.460	6.260	6.160
100	6.716	6.716	6.500	6.340	6.140	6.060

As rotational speed increases, honeys could in general show Newtonian and non-Newtonian behaviors [1, 5, 24-25]. These behaviors can be determined from relationship between shear rate and shear stress. The relationships between shear rate and shear stress obtained from all longan honey samples are displayed in Figure 3. All longan honey samples subjected to non-magnetic (C01 and C02) and magnetic (F01, F02, N01 and N02) fields showed Newtonian behavior due to their near-constant proportionality between shear stress and shear rate. Similar Newtonian behavior of honeys had been reported elsewhere [1, 5]. The proportionalities between shear stress and shear rate of the control samples C01 and C02 showed viscosities of 6.7419 and 6.7327 Pa·s, respectively. The viscosities of the samples subjected to magnetic fields of 1400 G and 1600 G (samples F01 and F02) were, respectively, 6.5905 and 6.3863 Pa·s, and those of the samples subjected to magnetic fields of 4300 G (samples N01 and N02) were 6.1871 and 6.1021 Pa·s. It is also evident that the stronger magnetic fields cause greater reduction in viscosity. This finding shows similar effect of magnetic fields on viscosity of water compared with research reported by Xiao-Feng and Bo that viscosities of magnetized water at 3000 G and 4000 G were reduced from 6.6 mPa·s to 6.25 mPa·s and 6.15 mPa·s, respectively [21].

Water having hydrogen-bonded chains could change flow behavior because of distribution of molecules and electrons, displacements and polarization of molecules and atoms, dipole moment of transition, and vibrational states of molecules [21]. Longan honey in this experiment that contained about 16% moisture content would be affected by the applied magnetic fields. As a result, the magnetic fields could reduce viscosity of the longan honey. Moreover, it could be deduced that other constituents and molecular groups in longan honey such as sucrose, fructose, and glucose could also reduce honey's viscosity due to their solubility in water and concentration effects [7]. Accordingly, reduced viscosity of the longan honey is important to honey production. Despite raising temperature to lower honey's viscosity, this preliminary study of magnetic effect on the longan honey's viscosity could be put into practice to facilitate handling of honey including pumping honey through pipes and filling honey during packaging.

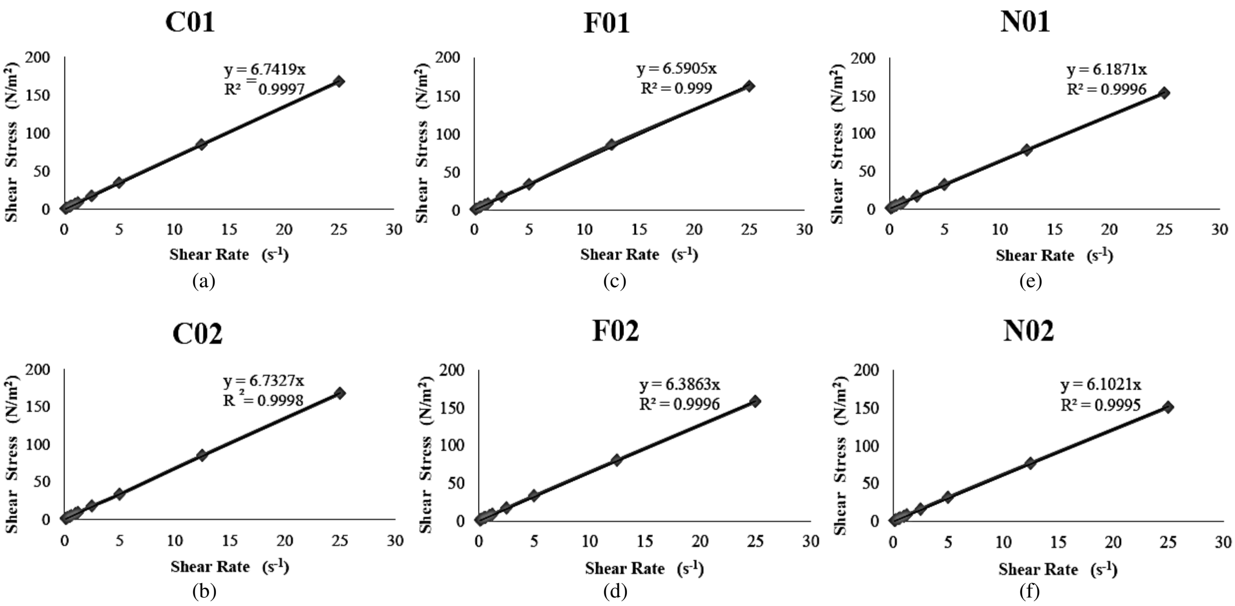

Figure 3 Relations between shear rate and shear stress of longan honey with and without subjection to magnetic fields (a), (b) Control samples without magnetic fields; (c), (d) Samples subjected to 1400 G, 1600 G; (e), (f) Samples subjected to 4300 G

4.3 Effect of magnetic field on color of honey

The color space of all honey samples subjected to the magnetic fields showed some increases in L^* and a^* but minor decreases in b^* values. The L^*, a^*, and b^* color space values are summarized in Table 2. The L^* values, representing lightness, increased from about 26.4 to about 29.6 for the honey subjected to the magnetic fields of 4300 G. The a^* values, representing additional degree of redness, also increased from 3.12 to about 5.2, while the b^* values slightly decreased from 12.09 to about 11.1, persisting primarily yellow appearance. Presence of particles in honey can influence optical properties. Decreasing particle size can increase L^* (lighter) and a^* (redder or less green) values, and it is most likely that the magnetic fields could deform pollen macroparticles into smaller particles and result in increased L^* and a^* values [26]. However, a study to confirm the result of microparticle deformation was not included.

Magnetic fields positively influence the appearance of the longan honey by causing the color of the honey to become lighter, redder (less green), and yellow appearances that could increase consumer acceptability. This effect is opposite to the thermal treatment of honey, which the color appears darker due to browning reaction [27]. Hence, applications of magnetic fields can be advantageous.

Table 2 Longan honey properties: Color L^*, a^*, and b^*, pH, moisture content, and TSS content

Sample	Color			pH	Moisture content (%)	TSS (%)
	L^*	a^*	b^*			
C01 Honey with No magnetic field	26.43±0.00	3.12±0.01	12.09±0.04	4.23±0.03	16.55±0.11	79.6±0.0
C02 Honey with No magnetic field	26.43±0.01	3.12±0.00	12.09±0.01	4.23±0.01	16.55±0.11	79.6±0.0
F01 Honey with Magnetic field of 1400 G	27.33±0.01	5.72±0.03	11.09±0.04	4.14±0.02	16.39±0.02	79.6±0.0
F02 Honey with Magnetic field of 1600 G	27.26±0.05	5.64±0.02	11.20±0.01	4.16±0.04	16.47±0.04	79.6±0.0
N01 Honey with Magnetic field of 4300 G	29.67±0.01	5.26±0.04	11.20±0.02	3.82±0.03	16.55±0.01	79.6±0.0
N02 Honey with Magnetic field of 4300 G	29.59±0.01	5.22±0.01	11.12±0.02	3.84±0.01	16.52±0.01	79.6±0.0

Note: The Values presented in the table are mean ± standard deviation. TSS is total soluble solids content.

4.4 Effect of magnetic field on pH of honey

In term of positive potential of hydrogen ions (pH), as shown in Table 2, the longan honey samples became more acidic with stronger magnetic fields. Their pH values decreased from 4.23 for the control samples to 4.14 and 4.16 for the samples subjected to magnetic fields of 1400 G and 1600 G, respectively, and to 3.82 and 3.84 for the samples subjected to 4300 G. Reduction in pH could result from increasing charge particles, such as H^+, under influence of the magnetic fields [21]. Lower pH values can positively influence quality of honey due to their contribution to inhibition of some microbial growth. However, the extent of pH reduction in this experiment is still in the common pH range of honey (3.4 to 6.1) [25] that should not affect processing parameters [7].

4.5 Effect of magnetic field on moisture and TSS content of honey

Moisture and TSS contents of all samples remained unaffected by magnetic fields. Covering the beakers with the food grade polyvinyl chloride film could prevent moisture exchange between honey and environment and result in preserving total sugars and other solids in honey.

5. Conclusions

Application of the magnetic fields reduced the viscosities of the longan honey and resulted in improved honey appearance, higher acidity and no change in moisture and TSS contents. The flow behavior suggested that the magnetic fields could improve flowability of honey by lowering its viscosity. Possible mechanisms of those changes are molecular orientation in parallel to magnetic fields, disintegration of macro-particles, and increased H^+ charge particles under subjection to the energy of magnetic fields. Since viscosity of the honey is reduced, as a result, lower temperatures and shorter heating times during honey production are expected.

Even though magnetic fields can influence the nature of molecules in fluids and consequently change the properties, those changes may be temporary. In-depth investigation about molecular relaxation and orientation after subjection to magnetic fields is necessary in order to gain better understanding.

6. Contribution

Application of magnetic fields is a non-thermal technique that can be beneficial to food industry. In this study, the magnetic fields reduced viscosity of longan honey, resulting in improved flowability and appearance without affecting the moisture and TSS contents of the longan honey. Moreover, food processing by this non-thermal method of using magnetic fields is expected to have no significant effect on nutrients and taste of liquid foods. Currently, research on application of the magnetic fields on liquid foods is limited. Mechanism of how magnetic fields influence food properties has not been clearly explained. Therefore, more research in this field is necessary.

7. ACKNOWLEDGEMENT

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9. BIOGRAPHIES

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