MALAYSIAN JOURNAL OF APPLIED SCIENCES 2021, VOL 6 (1): 99-110
E-ISSN:0127-9246 (ONLINE)
http://dx.doi.org/10.37231/myjas.2021.6.1.280
https://journal.unisza.edu.my/myjas

PENERBIT Universiti Sultan Zainal Abidin

MALAYSIAN JOURNAL OF APPLIED SCIENCES
eISSN:0127-9246

REVIEW ARTICLE

The Impact of Processing Methods on the Quality of Honey: A Review

Nur Syahidah Ramly[1], Izzati Shahira Rosidi Sujanto[1], Asmaliza Abd Ghani[1], John Tang Yew Huat[1], Nadiawati Alias[1], *Norhayati Ngah[1]

[1]Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia

*Corresponding author: norhayatingah@unisza.edu.my

Received: 27/03/2021, Accepted: 28/04/2021, Published: 30/04/2021

Abstract

The quality of honey are naturally differs depending on its geographical origin and the botanical source of honeydew collected by the bees. These characteristics influence the physical appearance of honey such as its colour lightness and liquid thickness; which then may influence the honey attractiveness to the consumers. The thickness of honey is correlate with its moisture content. The higher the moisture content of honey, the higher the risk of fermentation, thus honey is commonly process before marketed. However, the processing methods may change the nutritional content, original taste and physical characteristics of the honey. This paper reviews the effect of five types of processing methods on the quality of honey; which are the spray-drying process, thermal treatment technique, thermosonication technique, high-pressure processing technique and microwave processing method. Overall, it can be concluded that all processing methods reviewed in this article altered the nutritional quality and physicochemical characteristics of honey. However, the different processing methods may alter the quality of honey differently. This information is very important for consumer to understand the reasons on the variability of honey quality in the market. It also will help the honey industry players to choose the best method in processing their honey and ensuring the best quality of honey can be produce to fulfil the consumers need and satisfaction.

Keywords: Honey, nutrient content, physicochemical characteristics, processing method

Introduction

Honey had been defined as a natural sweet substance produced by the bees from the nectar of plants or secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants; which the bees collect, transform by combining with specific substances of their own deposit, dehydrate, store and leave in the honeycomb to ripen and mature (FAO, 2019). Honey is basically a liquid solution of supersaturated in sugars that composed of at least 181 components; where the fructose and glucose are the most important element (Gheldof et al., 2002). Honey gets its sweetness from the monosaccharides, fructose, and glucose; where its relative sweetness is approximately the same as granulated sugar. The main components of honey are sugar which covers about 70 to 75% (Sahu and Devi, 2013), and water (Machado De-Melo et al., 2018). The minor constituents are protein, amino acids, phenolic compounds, flavonoids, ascorbic acid, carotenoids, organic acids, vitamins, and enzymes such as glucose oxidase and catalase (Jaganathan and Mandal, 2009), as well as pollen grains (De Almeida-Muradian et al., 2013).

The quality of honey is relate to its sensorial characteristics as well as physical, chemical, and microbiological standards. According to the international honey trade, the quality of honey is referred to its organoleptic characteristics (flavour, consistency and colour) and chemical composition (moisture and HMF content, the diastase index, pH, acidity as well as the content and proportion of the carbohydrates) (Muli et al., 2007). Many has agreed that the quality of honey is depend on the nectar and honeydew sources collected by the bees, climate at the honey botanical origin, and conditions during storage and processing methods (Alvarez-Suarez et al., 2010; Ajlouni and Sujirapinyokul, 2010; Manzanares et al., 2011; Gheldof et al., 2002; Azeredo et al., 2003; Aljadi and Kamaruddin, 2004; Akhmazillah et al., 2013; Shafiq et al., 2014; Al et al., 2009).

There are two characteristics that commonly evaluated by the consumers before purchasing; the colour lightness and the sweetness of honey. The colour of honey can be ranges from straw yellow to amber and from dark amber to almost black with a hint of red. The colour of honey is influence by the mineral content, pollen and phenolic compounds presence in the honey. This characteristics is reflected to the geographical origin and botanical sources visited by the bee. However, the original colour of honey changes upon storage due to the temperature and duration applied which cause browning due to Maillard reaction, caramelisation of fructose and polyphonic reaction (Bertoncelj et al., 2007).

Most honey are acidic, with pH lower than seven (Heredia et al., 2003). The acidity of honey improves the antioxidant activity of honey, thus contributes to development of honey flavour and decrease microorganism development (Cavia et al., 2007). Organic acids are naturally presence in honey that raise its acidity. However, high acidity in honey indicates that fermentation occurs due to the excessive water content in honey; which then resulting the conversion of alcohols to organic acid. Water content in honey depends on factors such as season, maturity, climate (Finola et al., 2007), and conditions during collection and processing, thus water content varies from season to season and from year to year (Acquarone et al., 2007). Excessive water content can lead to undesirable fermentation during storage. According to FAO (2019), honeys with 18–20% moisture content are considered mature and stable. Reduction of moisture content below 17% is considered as safe level to retard the yeast activity. In addition, moisture content also influences granulation and the flavour of honey (Subramanian et al., 2007). On the contrary, decrease in moisture content of honey increase the chances of granulation.

Hydroxymethylfurfuraldehyde (HMF) in one of the important element in classifying the quality of honey. The lower the HMF, the better the honey. Hydroxymethylfurfuraldehyde is a decomposition product of fructose in honey. The freshly harvested honey has almost zero amount of HMF. However, the value of HMF is increase over time of storage and upon processing. Thus, HMF value has become as the parameter to determine the freshness of honey or fault during processing (Bogadonov et al. 1999; White, 2015). Findings by Tanzi and Gabay (2002) shows that the development of HMF in high acidic blossom honey is rapid compared to high acidic darker honey.

Result and Discussion

Types of Processing Method and its Effect on the Quality of Honey

In commercial processing plant, honey is usually heated in order to purify, filter, and reduce the moisture content at the standard level. This process is important to inhibit microorganism growth, delay crystallization process and to prolong the shelf life of honey. As the honey is highly saturated with sugar solution, the spontaneous crystallization is common to occur. Crystallization lead to the undesirable appearance where two distinct phase can be visually observed; liquid phase at the top and crystallized phase at the bottom. This unwanted appearance will deter consumer from purchasing the honey. In addition, the higher amount of water content in honey is favourable for naturally present osmophilic yeasts in honey to multiply. According to Gleite et al (2006), high moisture content in honey leads to fermentation which degrades the quality of honey by altering its taste. Thus, honey need to be process to fulfil the customer satisfaction. Currently, there are five common methods of honey processing which are spray drying process, thermal treatment, thermosonication, high-pressure processing and microwave processing.

Spray Drying Process

Some foods are dried into powder by using spray drying technique in order to prolong its shelf-life and retain the activity of specific bioactive compound (Schutyser et al., 2012). Spray drying is a convective drying method that widely applied to convert liquid foods into powders. This method is cost-effective, reproducible and easy to scale up (Bansal et al., 2014; Schutyser et al., 2012). The concept of spray drying process is the removal of almost all liquid from a solution of a non-volatile solid through vaporisation process (Santivarangkna et al., 2007). Generally, an atmosphere in the spray drying machine is heated, and liquid is sprays into the heated atmosphere; which then promotes evaporation. The liquid is sprayed in small droplets size, which are dried very rapidly when contacted with the hot air blown at high velocity and at short residence time (Santivarangkna et al., 2007).

Spray drying is a method used for preservation of heat-sensitive materials such as enzymes (Belghith et al., 2001; Samborska et al., 2005) and lactic acid bacteria (Riveros et al., 2009; Peighambardoust et al., 2011). This is due to short drying time, cooling effect of fast evaporation and relatively the low temperature to which the product being exposed. However, freezing or freeze-drying method are more preferred industrially. This is because in spray-drying method, the drying conditions need to be optimized and the matrix formulations need to be tailored to avoid severe heat damage leading to loss in enzyme activity or reduced survival of bacteria (Schutyser et al., 2012). The drying condition should be such that the heat-sensitive materials are retained maximally.

The parameters of spray-drying for honey drying is almost the same as for other materials as such inlet air temperature in a range from 150 to 200 °C, while outlet from 70 to 106 °C (Samborska, 2019). Decreasing outlet temperatures and lower residence times are found to increase retention of enzyme activity and probiotic viability (Silva et al., 2011). Too low outlet temperatures may result in higher residual moisture contents, especially leading to loss of probiotic viability during subsequent storage of the powder. Damaging to bioactive compounds may occur if residence times increased. The other factors that affect the drying process are the specific spray dryer configuration, such as nozzle type, positioning of air flow and injection of feed, and chamber design (Santivarangkna et al., 2007).

The chemical composition of honey, mainly related to high content of low molecular weight sugar (glucose, fructose) and organic acids (citric, malic and tartaric acid) have become a challenge for spray drying process (Muzaffar et al., 2015). The processing of liquid honey into powder honey is difficult, which cause stickiness of dried honey. These substances are characterized by low glass transition temperature, $T_{g,}$ high hygroscopicity and low melting point of amorphous material containing high amount of sugars.

During spray drying of honey, its temperature in the drying chamber is usually higher than the glass transition temperature. As a result, the material exists in the visco-elastic rubbery state, namely in the form of syrup or sticky particles adhering to the walls of the chamber (Samborska et al., 2015). To enable the drying of honey, it is necessary to modify the parameters of drying or to prepare the honey in such a way that glass transition temperature is higher than honey temperature. This can be achieved by adding carrier substances such as starch, maltodextrin or gum Arabic (Truong et al., 2005; Gabas et al., 2007;Jittanit et al., 2010).

Thermal Treatment

Conventionally, honey will go through thermal treatment before storage. Similar to the modern techniques, honey is treated with thermal treatment in order to ease packaging by lowering the viscosity of honey (Anklam, 1998), reduces the water content in honey to prevent fermentation (Subramanian et al., 2007), homogenizes the colour of honey for the consumer sastisfaction (Abu-Jdayil et al., 2002), dissolves the sugar crystal nuclei to retard granulation and destroys the sugar tolerant osmophilic yeasts to prolong the shelf life of honey (Escriche et al., 2009). In thermal treatment, honey undergoes preheating at 40°C, straining, filtering, exposed to indirect heating at 60–65°C for 25–30 min and followed by rapid cooling (Subramanian et al., 2007).

The temperature use to heat the honey is varies from mild to high temperature. Industrial practices commonly use thermal processing to liquefy and pasteurize honey at 45℃ and 80℃, respectively (Escriche et al., 2009). Based on previous studies, heating honey at 63, 65, and 68°C for 35, 25, and 7.5 minutes, respectively can destroy the yeast cells completely (Subramanian et al., 2007). However, this heating process will cause disadvantages to the honey such as loss of aromatic substances, reduce its diastase activity (Tosi et al., 2008; Sahinler and Gul, 2005) and increases its hydroxymethylfulfural (HMF) content (Subramanian et al., 2007; Samborska and Czelejewska, 2014).

The adverse effect of heating on honey is proportional to the temperature and duration of heat applied; the higher the temperature and the longer duration applied on the honey, the higher the disadvantages on the honey. Flavonoid, amino acid and phenolic are among main antioxidant compounds in honey that are unstable over time and thermolabile. As thermolabile, antioxidative activities of honey reduce due to decomposition of vitamins and also denaturation of the enzymes, particularly at higher temperature (Nagai et al., 2001). According to Chaikham and Prangthip (2015), the levels of antioxidant extensively diminished with increasing of processing time while honey heated at 100 ℃ for 5 min showed the significantly lowest levels of total phenolic contents and antioxidant capacity than the others.

This is in accordance as Kowalski (2013), who reported that after heating at 90℃ up to 60 min, total phenolic compounds and antioxidant activity of honeydew honey markedly decreased compared to the untreated honey. Although thermal processing is a convenient way to change the consistency of honey and protect it from fermentation (since an increase of water activity during crystallization tends to ferment), high temperature can be detrimental to the quality of honey and its biological properties.

Thermosonication

Integration of ultrasound and heat is known as thermosonication and products treated by this technology have better results with minimal impact on quality parameters (Chong et al., 2017), in comparison to ultrasound alone (Aadil et al., 2015). Ultrasonication is a technology with minimal processing with the potential to inactivate microorganisms and promote dehydration in foods (Musielak et al., 2016), also can preserve and improve nutritional values and sensorial properties of food (Chemat et al., 2011; Abid et al., 2013; Chaikham & Prangthip, 2015).

The transmission of ultrasound through honey liquid medium cause cavitation through which bubbles or cavities formed increase rapidly in size and collapse under the influence of the acoustic field. The collapse of bubbles leads to intense local heating or hot spots, and this rapidly changes temperature and pressure in its surrounding medium. As ultrasound waves alone may not be very effective in destroying microorganisms unless very high intensities are used, thermosonication is a potential alternative processing method to enhance destruction of microorganisms. It has been reported that ultrasound is often more effective when combined with other preservation methods, such as heat (temperature 30-50 ºC) to increase the enzymatic and microbial inactivation.

Thermosonication reduced the water activity and moisture content by 7.9% and 16.6%, respectively, compared to 3.5% and 6.9% for conventional heating (Chong et al., 2017). However, to date there has been little research on the effects of high pressure, ultrasonic and thermal treatments on bioactive components and antioxidant properties present in honey (Chaikham and Prangthip, 2015). Chaikham and Prangthip (2015) also found that total phenolic compounds, total flavonoids and antioxidant capacity in ultra-sonic treated honeys at 20kHz and 20–60% amplitudes for 5–20 min were slightly increased ($Pr \leq 0.05$) when compared to the untreated sample. Escalating treatment time had improved the availability of antioxidant compounds and properties of honey (Chaikham and Prangthip, 2015).

The increase in bioactive compounds of ultra-sonic treated samples is primarily accredited to the breakdown of plant cells. The cell membranes and organelles are disrupted and enzymes are released through vacuoles, which then affect the phenols and antioxidant activity in the samples (Akhmazillah et al.,2013). In view of the fact that there are no intact cells in honey, one possible explanation for the observed increase in phenol levels and antioxidant activity in honey due to ultra-sonic stimulation is the disintegration of pollen (Chaikham and Prangthip, 2015).

High-Pressure Processing

In the recent years, high hydrostatic pressure has been successfully used to produce various foods with high quality. This method inactivates microorganisms in food matrices for shelf-life extension (Cao et al., 2012; Chaikham and Apichartsrangkoon, 2012; Keenan et al., 2012)**.** High pressure processing could be an alternative technique to preserve the qualities of food products more effectively than thermal treatments (Cao et al., 2012; Carbonell-Capella et al., 2013; Kaushik et al., 2013).

At all pressure levels, the amounts of these components and properties in the sample were positively correlated with the treatment time, in particular, honey treated at pressure 500 MPa for 20 min displayed the highest levels in phenols and antioxidant capacity (Chaikham and Prangthip, 2015). It was interesting to note that a significant increase in antioxidative compounds and capacity was obtained by processing. Akhmazillah et al. (2013) and Fauzi et al., (2014) found that total phenolic content and antioxidant activity of honey could be enhanced using high pressure processing, especially, honey pressurized at 600 MPa for 10 min which showed the highest amounts of total phenolic content and DPPH radical scavenging activity with the increment of 47% and 30% respectively when compared to untreated samples. The increase of these properties in honey after pressurization might be due to the disintegration of pollen leading to antioxidant compound enhancement. Pollen was reported to contain various levels of different antioxidant constituents including 2–5 g/100g phenolic compounds, 7–56 mg/100g ascorbicacid, 1–20 mg/ 100 g β-carotene, and 4–32 mg/100g tocopherol (Campos et al., 2003; Campos et al., 2008).

Microwave processing

In recent years, microwave heating has become common for heat treatment of food. It has broad range of application not only in household for domestic usage, but also being used in industry. Microwave heating has advantages more than conventional one in term of shorter intervals of heating, which helps save energy, and space-saving compactness of the microwave equipment with ease and comfort to use. Microwaves are electromagnetic waves whose frequency are between 300 MHz to 300 GHz and it is non-ionizing electromagnetic wave radiation. Through this wave, the conversion of the energy into heat throughout the food product is more efficient (Bartákova et al., 2011). According to Dimiņš et al., (2019), honey that is treated thermally with microwaves, even only for 10 s, affects the quality of honey. Decrease in invertase activity and increase of HMF content reduces the quality of honey.

Due to the contents of a substantial amount of water (20%), as well as large amounts of dissolved saccharides (70–80%) in honey, the heating of honey by using microwave radiation could be more effective (Hebbar et al., 2003), as microwave heating is greatly affected by the presence of water. Materials containing polar molecules such as water are rapidly heated when exposed to microwave radiation due to molecular friction generated by dipolar rotation in the presence of an alternating electric field. The number of photons in commercial microwaves oven is too small to cause multiphoton dissociation or ionization. Thus, this concludes that the honey can't be altered chemically when heated in microwave oven. The only effect of the molecules from the microwaves heating is the increase in kinetic energy (Aguilar-Reynosa et al., 2017).

Enzymes are the indicators for the quality of honey and its biological activity as it catalyse reaction within cell. Small amount of enzymes that naturally preserved in honey such as amylase, glucose oxidase, catalase and invertase. Honey composition, pH level and antibacterial properties are determined by the function of the enzymes and catalysed reactions (Dimiņš et al., 2019). Invertase enzyme is one of the indicator for honey thermal treatment (Belitz et al., 2009). Invertase is more sensitive to heat than amylases and loses activity during storage faster compared to amylases. Another honey thermal treatment indicator is hydroxymethylfurfural (HMF) which is one of the most important quality parameters of the quality and health safety of honey. HMF content in fresh honey is very low or non-existent, its concentration increases in the course of storing (in relation to pH, the length of storing) and also in the course of the honey heating (Contreras et al., 2017). The usage of microwave has gaining popularity over conventional heating as its advantage of rapidity. Microwave penetrates into food product and do not act only on the surface, thus making the conversion of energy into heat throughout the product more efficient.

Effects of Processing Methods on the Quality of Honey

Honey treated with thermal processing has lower viscosity than the untreated one as crystals that naturally occur in the honey melted with high temperature. The quality of honey decrease as it goes through thermal processing such as cause alteration of flavor, color and granulation of honey, also degrade bioactive compounds and antioxidants. This degradation occurs due to unstable and thermolabile components in honey (Nagai et al., 2001). Uncontrolled heating influences the quality parameters such as hydroxymethylfurfural (HMF) content and enzymatic activity (Subramanian et al., 2007).

In microwave processing, short time taken to reach the required processing temperature ensured little change in chemical properties. Heated honey is more resistant to spoilage than the untreated one as the spoilage attributed by the yeast count in honey (Subramanian et al., 2007). Upon storage of treated honey, no remarkable variation in yeast observed. However, the colour does change into darker as time passed. Moreover, the colour is darker in heated honey compared to unheated honey ignored the storage temperature. Moisture content of honey is not much affected, in addition, no noticeable change in ash, nitrogen contents, pH, and acidity. On the contrary, heat effect of the honey led to a 37.5% loss in diastase activity (Subramanian et al., 2007). The level up of microwave power and heating duration lead to higher formation of HMF and browning effect.

The spray dried powders have longer shelf life and resemble the quality of the original liquid feed. High intensity of temperature affects the quality parameters of hydroxymethylfurfural (HMF) content and enzymatic activity which further affects the quality of honey. Water content in honey powder after the processing ranges from 2.3 to 8.6% (Nurhadi et al., 2012; Samborska et al., 2015; Suhag and Nanda, 2016). Phenolics compounds are easily degraded during high-temperature processing as it is responsive to harsh environmental conditions, that including spray drying (Suhag and Nanda, 2016). High heat transfer during traditional spray drying leads to loss of honey bioactivity while lower heat transfer during spray drying provides the energy necessary for advantageous phenolic alterations.

Highest increment of antioxidant activity observed in high pressure processing honey (HPP) when compared to combined HPP–thermal and thermal processes (Fauzi et al., 2014), which is in accordance with (Akhmazillah et al., 2013) as measurements of the total phenolic content where HPP treatment at ambient temperature gave a significant increase. Through HPP treatment, antioxidant activities are retained and improved to up to 30% than untreated honey. As non-thermal process, HPP treatment retain the original colour of honey after treatment.

During thermosonication process, reduction of water is high which attributed by the mechanical effects of collapsing microbubbles that cause increase in mass transfer (Chong et al., 2017). Both thermosonication and thermal processing reduced moisture content to less than 30% with note of higher efficiency in the thermo- sonication method. Thermosonication at 45℃ and 55℃ produce light colour of honey due to its mild heat. During thermosonication, less evaporation takes place as low temperature applied in high water content condition, thus viscosity changes is small. Radical scavenging activity increases as being stimulated by the treatment. According to Chong et al. (2017), when the honey treated at 90℃ for 120 minutes, the DPPH inhibition for thermosonication and thermal treatment are increased by 63.0% and 72.5%, respectively.

When considering the storage period, residual phenols and antioxidant capacity in pressure and ultra-sonic treated honeys were still higher than that heated sample in the entire storage study (Chaikham & Prangthip, 2015). Through assessment of nutritional values, both high pressure and ultra-sonic processing could be an alternative technique to preserve the antioxidative qualities of longan flower-honey better than thermal treatment (Chaikham & Prangthip, 2015).

Conclusion

Honey processing is important in producing the high quality and prolong the shelf life of honey. The processing methods either spray drying process, thermal treatment, thermosonication, high-pressure processing and microwave processing makes honey more presentable for marketing. The quality of honey is a key factor for both local and international markets to enable attainment of competitive premium prices and ensure human health. It can be concluded that the thermal treatment ultimately essential in honey industry.

This method can be used in reducing the water content in honey to prevent fermentation, homogenize honey for the consumer preferences and destroys sugar tolerant osmophilic yeast, thus increase shelf life of honey. Alternative method to the conventional thermal processing give great advantages upon the disadvantages of thermal treatment in producing high quality of honey. For further suggestion, it is necessary to conduct research on other commercial honey processing method with the combination of conventional thermal method so that the best processing method can be determine.

Acknowledgments

This work was funded by the Malaysia Government through the Ministry of Education Malaysia (FRGS/1/2019/WAB13/UNISZA/02/1).

References

Aadil, R. M., Zeng, X. A., Zhang, Z. H., Wang, M. S., Han, Z., Jing, H., & Jabbar, S. (2015). Thermosonication: A potential technique that influences the quality of grapefruit juice. *International Journal of Food Science and Technology*, *50*(5), 1275–1282.

Abid, M., Jabbar, S., Wu, T., Hashim, M.M., Hu, B., Lei, S., Zhang, X. and Zeng, X. (2013). Effect of ultrasound on different quality parameters of apple juice. *Ultrasonics Sonochemistry*, *20*(5), 1182–1187.

Abu-Jdayil, B., Al-Majeed Ghzawi, A., Al-Malah, K. I. M., & Zaitoun, S. (2002). Heat effect on rheology of light- and dark-colored honey. *Journal of Food Engineering*, *51*(1), 33–38.

Acquarone, C., Buera, P., & Elizalde, B. (2007). Pattern of pH and electrical conductivity upon honey dilution as a complementary tool for discriminating geographical origin of honeys. *Food Chemistry*, *101*(2), 695–703.

Aguilar-Reynosa, A., Romaní, A., Ma. Rodríguez-Jasso, R., Aguilar, C. N., Garrote, G., & Ruiz, H. A. (2017). Microwave heating processing as alternative of pretreatment in second-generation biorefinery: An overview. *Energy Conversion and Management*, *136*, 50–65.

Ajlouni, S., & Sujirapinyokul, P. (2010). Hydroxymethylfurfuraldehyde and amylase contents in Australian honey. *Food Chemistry*, *119*(3), 1000–1005.

Akhmazillah, M. F. N., Farid, M. M., & Silva, F. V. M. (2013). High pressure processing (HPP) of honey for the improvement of nutritional value. *Innovative Food Science and Emerging Technologies*, *20*, 59–63.

Al, M. L., Daniel, D., Moise, A., Bobis, O., Laslo, L., & Bogdanov, S. (2009). Physico-chemical and bioactive properties of different floral origin honeys from Romania. *Food Chemistry*, *112*(4), 863–867.

Food and Agriculture Organization (FAO) (2019). Codex Alimentarius: Standard for honey. Retrieved at http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252F workspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXS%2B12-1981%252FCXS_012e.pdf on 27 March 2021.

Aljadi, A. M., & Kamaruddin, M. Y. (2004). Evaluation of the phenolic contents and antioxidant capacities of two Malaysian floral honeys. *Food Chemistry*, *85*(4), 513–518.

Alvarez-Suarez, J.M., Tulipani, S., Díaz, D., Estevez, Y., Romandini, S., Giampieri, F., Damiani, E., Astolfi, P., Bompadre, S. and Battino, M (2010). Antioxidant and antimicrobial capacity of several monofloral Cuban honeys and their correlation with color, polyphenol content and other chemical compounds. *Food and Chemical Toxicology*, *48*(8–9), 2490–2499.

Anklam, E. (1998). A review of the analytical methods to determine the geographical and botanical origin of honey. *Food Chemistry*, *63*, 549–562.

Azeredo, L. D. C., Azeredo, M. A. A., De Souza, S. R., & Dutra, V. M. L. (2003). Protein contents and physicochemical properties in honey samples of *Apis mellifera* of different floral origins. *Food Chemistry*, *80*(2), 249–254.

Bansal, V., Sharma, H. K., & Nanda, V. (2014). Optimisation of spray drying process parameters for low-fat honey-based milk powder with antioxidant activity. *International Journal of Food Science & Technology*, 49(4), 1196-1202.

Bartákova, K., Dračková, M., Borkovcová, I., & Vorlova, L. (2011). Impact of microwave heating on hydroxymethylfurfural content in Czech honeys. *Czech Journal of Food Sciences*, *29*(4), 328–336.

Belghith, H., Ellouz Chaabouni, S., & Gargouri, A. (2001). Stabilization of *Penicillium occitanis* cellulases by spray drying in presence of Maltodextrin. *Enzyme and Microbial Technology*, *28*(2–3), 253–258.

Belitz, H.-D., Grosch, W., & Schieberle, P. (2009). Wine. In Food Chemistry. *Springer-Verlag Berlin Heidelberg* (4th ed.).

Manzanares, A.B , García, Z. H., Galdón, B. R., Rodríguez, E. R., & Romero, C. D. (2011). Differentiation of blossom and honeydew honeys using multivariate analysis on the physicochemical parameters and sugar composition. *Food Chemistry*, *126*(2), 664–672.

Bertoncelj, J., Doberšek, U., Jamnik, M., & Golob, T. (2007). Evaluation of the phenolic content, antioxidant activity and colour of Slovenian honey. *Food Chemistry*, *105*(2), 822–828.

Campos, M. G. R., Bogdanov, S., de Almeida-Muradian, L. B., Szczesna, T., Mancebo, Y., Frigerio, C., & Ferreira, F. (2008). Pollen composition and standardisation of analytical methods. *Journal of Apicultural Research*, *47*(2), 154–161.

Campos, M. G., Webby, R. F., Markham, K. R., Mitchell, K. A., & Da Cunha, A. P. (2003). Age-induced diminution of free radical scavenging capacity in bee pollens and the contribution of constituent flavonoids. *Journal of Agricultural and Food Chemistry*, *51*(3), 742–745.

Cao, X., Bi, X., Huang, W., Wu, J., Hu, X., & Liao, X. (2012). Changes of quality of high hydrostatic pressure processed cloudy and clear strawberry juices during storage. *Innovative Food Science & Emerging Technologies.*, *16*, 181—190.

Carbonell-Capella, J., Barba, F., Esteve, M. J., & Frigola, A. (2013). High pressure processing of fruit juice mixture sweetened with Stevia rebaudiana Bertoni: Optimal retention of physical and nutritional quality. *Innovative Food Science & Emerging Technologies*, *18*, 48–56.

Cavia, M. M., Fernández-Muiño, M. A., Alonso-Torre, S. R., Huidobro, J. F., & Sancho, M. T. (2007). Evolution of acidity of honeys from continental climates: Influence of induced granulation. *Food Chemistry*, *100*(4), 1728–1733.

Chaikham, P., & Apichartsrangkoon, A. (2012). Comparison of dynamic viscoelastic and physicochemical properties of pressurised and pasteurised longan juices with xanthan addition. *Food Chemistry*, *134*(4), 2194–2200.

Chaikham, P., & Prangthip, P. (2015). Alteration of antioxidative properties of longan flower-honey after high pressure, ultra-sonic and thermal processing. *Food Bioscience*, *10*, 1–7.

Chemat, F., Zill-E-Huma, & Khan, M. K. (2011). Applications of ultrasound in food technology: Processing, preservation and extraction. *Ultrasonics Sonochemistry*, *18*(4), 813–835.

Chong, K. Y., Chin, N. L., & Yusof, Y. A. (2017). Thermosonication and optimization of stingless bee honey processing. *Food Science and Technology International*, *23*(7), 608–622.

Contreras, C., Benlloch-Tinoco, M., Rodrigo, D., & Martínez-Navarrete, N. (2017). Impact of microwave processing on nutritional, sensory, and other quality attributes. In *The Microwave Processing of Foods: Second Edition*. Woodhead Publishing Series in Food Science, Technology and Nutrition, 65-99

De Almeida-Muradian, L. B., Stramm, K. M., Horita, A., Barth, O. M., Da Silva de Freitas, A., & Estevinho, L. M. (2013). Comparative study of the physicochemical and palynological characteristics of honey from *Melipona subnitida* and *Apis mellifera*. *International Journal of Food Science and Technology*, *48*(8), 1698–1706.

Dimiņš, F., Miķelsone, V., Augšpole, I., & Niklāvs, A. (2019). Microwave facilities for thermal treatment of honey. *Key Engineering Materials*, *800 KEM*, 103–107.

Escriche, I., Visquert, M., Juan-Borrás, M., & Fito, P. (2009). Influence of simulated industrial thermal treatments on the volatile fractions of different varieties of honey. *Food Chemistry*, *112*(2), 329–338.

Fauzi, N. A., Farid, M. M., & Silva, F. V. M. (2014). High-pressure processing of Manuka honey: improvement of antioxidant activity, preservation of colour and flow behaviour. *Food and Bioprocess Technology*, *7*(8), 2299–2307.

Finola, M. S., Lasagno, M. C., & Marioli, J. M. (2007). Microbiological and chemical characterization of honeys from central Argentina. *Food Chemistry*, *100*(4), 1649–1653.

Gabas, A. L., Telis, V. R. N., Sobral, P. J. A., & Telis-Romero, J. (2007). Effect of maltodextrin and arabic gum in water vapor sorption thermodynamic properties of vacuum dried pineapple pulp powder. *Journal of Food Engineering*, *82*(2), 246–252.

Gheldof, N., Wang, X. H., & Engeseth, N. J. (2002). Identification and quantification of antioxidant components of honeys from various floral sources. *Journal of Agricultural and Food Chemistry*, *50*(21), 5870–5877.

Gleiter, R. A., Horn, H., & Isengard, H. D. (2006). Influence of type and state of crystallisation on the water activity of honey. *Food Chemistry*, *96*(3), 441–445.

Hebbar, H. U., Nandini, K. E., Lakshmi, M. C., & Subramanian, R. (2003). Microwave and infrared heat processing of honey and its quality. *Food Science and Technology Research*, *9*(1), 49–53.

Heredia, F. J., Terrab, A., & Dı, M. J. (2003). Palynological, physico-chemical and colour characterization of Moroccan honeys II Orange (*Citrus* sp.) honey. *International Journal of Food Science and Technology*, 387–394.

Jaganathan, S. K., & Mandal, M. (2009). Anti-proliferative effects of honey and of its polyphenols: A review. *Journal of Biomedicine and Biotechnology*, 830616.

Jittanit, W., Niti-Att, D., & Techanuntachaikul, O. (2010). Study of Spray Drying of Pineapple Juice Using Maltodextrin as an Adjunct. *Chiang Mai Journal of Science*, *37*, 498–506.

Kaushik Shandilya, N., Kaur, B., Rao, P., & Mishra, H. N. (2013). Effect of high pressure processing on color, biochemical and microbiological characteristics of mango pulp (*Mangifera indica* cv. Amrapali). *Innovative Food Science & Emerging Technologies*, 22, 40-50.

Keenan, D. F., Rossle, C., Gormley, R., Butler, F., & Brunton, N. P. (2012). Effect of high hydrostatic pressure and thermal processing on the nutritional quality and enzyme activity of fruit smoothies. *Food Science & Technology. 45*(1), 50—57.

Kowalski, S. (2013). Changes of antioxidant activity and formation of 5-hydroxymethylfurfural in honey during thermal and microwave processing. *Food Chemistry*, *141*(2), 1378–1382.

Machado De-Melo, A. A., Almeida-Muradian, L. B. de, Sancho, M. T., & Pascual-Maté, A. (2018). Composition and properties of *Apis mellifera* honey: A review. *Journal of Apicultural Research*, *57*(1), 5–37.

Muli, E., Munguti, A., & Raina, S. K. (2007). Quality of honey harvested and processed using traditional methods in rural areas of Kenya. *Acta Veterinaria Brno*, *76*(2), 315–320.

Musielak, G., Mierzwa, D., & Kroehnke, J. (2016). Food drying enhancement by ultrasound – A review. *Trends in Food Science and Technology*, *56*, 126–141.

Muzaffar, K., Nayik, G. A., & Kumar, P. (2015). Nutrition & food sciences stickiness problem associated with spray drying of sugar and acid rich foods. *Nutrition and Food Science*, *S12:003*, 11–13.

Nagai, T, Sakai, M., Inoue, R., Inoue, H., & Suzuki, N. (2001). Antioxidative activities of some commercially honeys, royal jelly, and propolis. *Food Chemistry*, *75*(2), 237—240.

Nurhadi, B., Andoyo, R., Mahani, & Indiarto, R. (2012). Study the properties of honey powder produced from spray drying and vacuum dry. *International Food Research Journal*, *19*(3), 907–912.

Peighambardoust, S. H., Golshan Tafti, A., & Hesari, J. (2011). Application of spray drying for preservation of lactic acid starter cultures: A review. *Trends in Food Science and Technology*, *22*(5), 215–224.

Riveros, B., Ferrer, J., & Bórquez, R. (2009). Spray drying of a vaginal probiotic strain of lactobacillus. *Drying Technology*, *27*(1), 123–132.

Sahinler, N., & Gul, A. (2005). Effect of heating and storage on honey hydroxy methylfurfural and diastase activity. *Journal of Food Technology*, 3, 152–157.

Sahu, J. K., & Devi, K. D. (2013). Modeling of vacuum puffing characteristics and color change of liquid honey. *Industrial Crops and Products*, *48*, 118–123.

Samborska, K. (2019). Powdered honey – drying methods and parameters, types of carriers and drying aids, physicochemical properties and storage stability. *Trends in Food Science and Technology*, *88*, 133–142.

Samborska, K., & Czelejewska, M. (2014). The Influence of thermal treatment and spray drying on the physicochemical properties of polish honeys. *Journal of Food Processing and Preservation*, *38*(1), 413–419.

Samborska, K., Gajek, P., & Kamińska-Dwórznicka, A. (2015). Spray drying of honey: The effect of drying agents on powder properties. *Polish Journal of Food and Nutrition Sciences*, *65*(2), 109–118.

Samborska, K., Witrowa-Rajchert, D., & Gonçalves, A. (2005). Spray-drying of α-amylase - The effect of process variables on the enzyme inactivation. *Drying Technology*, *23*(4), 941–953.

Santivarangkna, C., Kulozik, U., & Foerst, P. (2007). Alternative drying processes for the industrial preservation of lactic acid starter cultures. *Biotechnology Progress*, *23*(2), 302–315.

Schutyser, M. A. I., Perdana, J., & Boom, R. M. (2012). Single droplet drying for optimal spray drying of enzymes and probiotics. *Trends in Food Science and Technology*, *27*(2), 73–82.

Shafiq, H., Iftikhar, F., Ahmad, A., Kaleem, M., & Sair, A. T. (2014). Effect of crystallization on the water activity of honey. *International journal of food and nutritional sciences*, *3*(3), 1-6

Silva, J., Freixo, R., Gibbs, P., & Teixeira, P. (2011). Spray-drying for the production of dried cultures. *International Journal of Dairy Technology*, *64*(3), 321–335.

Subramanian, R., Hebbar, H. U., & Rastogi, N. K. (2007). Processing of honey: A review. *International Journal of Food Properties*, *10*(1), 127–143.

Suhag, Y., & Nanda, V. (2016). Evaluation of different carrier agents with respect to physico-chemical, functional and morphological characteristics of spray dried nutritionally rich honey powder. *Journal of Food Processing and Preservation*, *40*(6), 1429–1437.

Tanzi, M. G., & Gabay, M. P. (2002). Association between honey consumption and infant botulism. *Pharmacotherapy*, *22*(11), 1479–1483.

Tosi, E., Martinet, R., Ortega, M., Lucero, H., & Ré, E. (2008). Honey diastase activity modified by heating. *Food Chemistry*, *106*(3), 883–887.

Truong, V., Bhandari, B., & Howes, T. (2005). Optimization of co-current spray drying process of sugar-rich foods. Part I—Moisture and glass transition temperature profile during drying. *Journal of Food Engineering*, *71*, 55–65.

White, J. (2015). The Role of HMF and Diastase Assays in Honey Quality Evaluation. *Bee World*, *75*, 104–117.

How to cite this paper: Nur Syahidah Ramly, Izzati Shahira Rosidi Sujanto, Asmaliza Abd Ghani, John Tang Yew Huat, Nadiawati Alias, Norhayati Ngah (2021). The Impact of Processing Methods on the Quality of Honey: A Review. *Malaysian Journal of Applied Sciences, 6*(1), 99-110.