The Pharma Innovation Journal 2022; SP-11(7): 337-348

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 337-348

www.thepharmajournal.com
Received: 24-04-2022
Accepted: 29-05-2022

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Variations in physicochemical characteristics of honey: A review

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Abstract
Honey is a natural sweet substance produced by honeybees using nectar. It is known to be an easily digestible food stuff containing a range of nutritionally important elements *viz.*, saccharides, organic acids, amino acids, minerals, vitamins, aromatic substances, colour etc. From the ancient times, honey has been used as a natural sweetener as well as a healing agent. Presently, the demand of honey has also been increasing from years to years. With the increasing demand, the focus of beekeepers are towards the production of more and more honey of \good quality. In India, Bureau of Indian Standards (BIS) and Food Safety and Standards Authority of India (FSSAI) have specified the standards for quality parameters of honey. The quality of honey is mostly related to its physico-chemical characteristics *viz*., colour, moisture content, sugars, fructose, glucose and acidity, pH, enzymes activities, hydroxyl methyl furfural (HMF) content and electrical conductivity. These physicochemical properties of honey are mainly dependent on the geographical region, honeybee species, flower type, weather conditions, processing conditions, packaging and storage period. This review summarizes the literature about variations in physico-chemical characteristics of honey as influenced by external parameters.

Keywords: Honey, honeybees, quality, physico-chemical characteristics, external parameters

1. Introduction
Since, time immemorial, the hive product honey is considered as a symbol of prosperity and sanctity. It is an easily digestible food stuff containing a range of nutritionally important elements *viz.*, saccharides, organic acids, amino acids, minerals, vitamins, aromatic substances, colour etc. (Alqarni *et al.*, 2012; Kulkarni *et al.*, 2012) [10, 59]. Owing to its medicinal value in Ayurveda, daily consumption of honey is encouraged keeping in view its good health promoting attributes. It is used as a popular sweetener in many commercially manufactured products (processed foods, cake mixes, jam, jellies and cereals), in cosmetics and medicines (Crane, 1979) [28]. Presently, there is an increasing demand for high quality honey and honey products (Pasias *et al.*, 2017) [78]. With substantial efforts and dedicated programme like Honey Mission (HM), honey production in India has recorded 200 per cent increase in the last 12 years. In India, the annual total honey production in 2018 was 4 thousand metric tons, which was greater than the total production of 3.7 thousand metric tons in 2017 (Anonymous, 2019) [12]. In India, Bureau of Indian Standards (BIS) and Food Safety and Standards Authority of India (FSSAI) have specified the standards for quality parameters of honey. The major quality criteria for honey are the physical and chemical components of honey *viz*., moisture content, sucrose content, reducing sugars, pH value, EC, ash content, free acidity, diastase activity, HMF content etc. The physicochemical properties of honey (Fig.1.) are mainly dependent on the geographical region, honeybee species, flower type, weather conditions, processing conditions, packaging and storage period (Tornuk *et al*., 2013; Esuredo *et al*., 2014) [99, 32]. In the present review, the work of various researchers on honey quality, influence of various parameters (geographical region, honeybee species, flower type, weather conditions, processing conditions, packaging and storage period etc.) on the honey quality from the world is reviewed.

The desirable levels of different physical and chemical characteristics of honey are given by different organizations *viz*., Colour Designations standards of quality honey (White, 1975) [106], FSSAI Standards for Quality Honey (FSSAI, 2018) [35] and Codex Alimentarius Commission and EU are described in Table 1 and Table 2 (Bogdanov *et al.*, 2015) [20].

Table 1: Colour designations standards of quality honey (White, 1975) [106]

USDA Colour Standard Designation	Range (Absorbance at 560nm)
Water White	0 - 0.094
Extra White	0.094 - 0.189
White	0.189 - 0.378
Extra Light Amber	0.378 - 0.595
Light Amber	0.595 - 1.389
Amber	1.389 - 3.008
Dark Amber	>3.008

Table 2: Quality standards of honey (FSSAI, 2018; Bogdanov *et al.*, 2015) [35, 20]

Quality attributes of honey	Types of honey	Codex standards	EU standards	FSSAI Limits
Moisture content	Heather, Clover honey	<23g/100g	<23g/100g	20.00%
	Industrial or baked honey	<25g/100g	<25g/100g	
	Other types of honey i.e., general honey	<21g/100g	<21g/100g	
Apparent reducing sugar content (Fructose and glucose content)	Honey not listed below	>65g/100g	> 65g/100g	> 60% (F:G
	Honeydew honey or blends of honeydew honey and blossom	>45g/100g	> 45g/100g	ratio: 0.95 1.50)
	Honey *Xanthorrhoea preissii*	>53g/100g	> 53g/100g	
Sucrose content	Honey not listed below *Robinia pseudoacacia, Lavandula, Hedysarum, Trifolium, Citrus, Medicago, Eucalyptus camaldulensis, Eucryphia lucida, Banksia menziesii, Rosemarinus* *Calothamnus sanguineus, Eucalyptus, Banksia grandis, Xanthorrhoea preissii* Honeydew honey and blends of blossom with honeydew honey	< 5g/100g < 10g/100g < 15g/100g	< 5g/100g < 10g/100g -	5%
Water insoluble solid content	General honey	<0.1g/100g	<0.1g/100g	-
Mineral content (ash)	Pressed honey	<0.5g/100g	<0.5g/100g	
	Honeydew or blends of honeydew and blossom honey or chestnut honey	1.2g/100g	1.2g/100g	-
Diastase activity (DN)	General honey	8	8	3
	Honey with natural low enzyme activity	3	3	
HMF content	-	60 mg/kg	40 mg/kg	80.00mg/kg
Acidity milliequivalent/1000g	-	-	-	50.00
Pollen Count	-	-	-	>25000
Proline	-	-	-	180 mg/kg

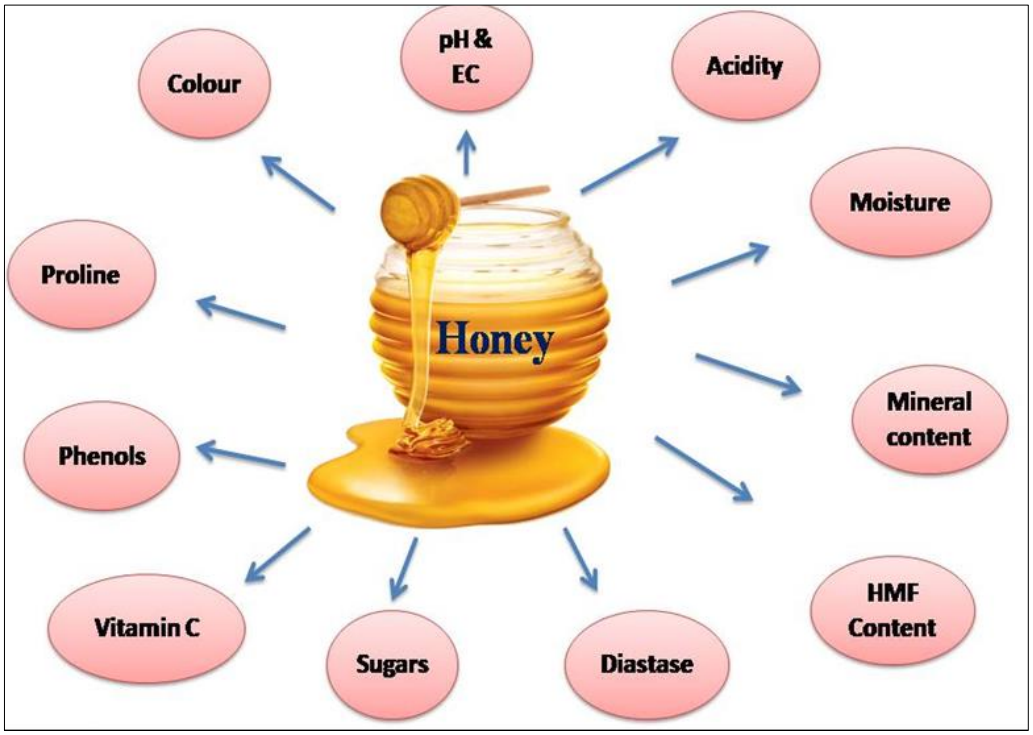

Fig 1: Physico-chemical properties of honey

2. Physico-chemical properties of honey

2.1 Colour

Colour an optical property of honey, may vary from virtually colourless to deep red in colour through shades of yellow, amber and brown with greenish to reddish tinge. It is the most important characteristic which contributes to the appearance of honey and thus improves the market value of honey. The variations in honey colours (Table 1) could be due to effects of plant sources (White, 1975) [106], processing, storage, severity of methods, rapidity of nectar secretion (Leightori, 1957; Milum, 1957) [61,68] and Millard reaction (Petrov, 1971) [79]. The optical density of honey was recorded which vary from 0.27 - 0.62 OD from different agroclimatic zones of Himachal Pradesh (Gupta, 2019) [42]. Variations in colour of honey of different honeybee species *viz*., *Apis mellifera*, extra white (0.14 OD), *A. cerana*, white (0.27 OD) *A. florea*, extra light amber (0.54 OD) and *A. dorsata*, dark amber (0.95 OD) was also observed under similar conditions of Himachal Pradesh by Yadav (1995) [108]. Different honey colours *viz*., light amber yellowish colour of natural honeys produced in different areas of Al-Qassim region, Saudi Arabia (Osman *et al.*, 2007) [76], light-dark brown (market honey), golden yellow (raw honey) and light-dark brown (industrial honey) from Kerala, India (Kavapurayil *et al*., 2013) [52].

2.2 Moisture

Moisture an important physico-chemical parameter of honey quality is influenced by climatic conditions (Sharma, 1998) [91], hive temperature, extraction techniques, degree of storage (Molan, 2002; Cherian *et al*., 2011; Gariola *et al.*, 2013; Finola *et al*., 2007; Townsend, 1970) [69,27,36,34,100] and degree of maturity (Molan, 2002; Cherian *et al.*, 2011; Townsend, 1970; Acquarone *et al*., 2007; Baroni *et al.*, 2009; Moniruzzaman *et al.*, 2013) [69,27,100,3,17,71]. It is important for shelf life of honey during storage as high moisture content (exceeding 22 per cent) leads to undesirable honey fermentation by microorganisms and enzymatic factors (Akharaiyi and Lowal, 2016) [6] during storage (Pryce-Jones, 1950; Bogdanov *et al.*, 1997; Gomes *et al.*, 2010; Saxena *et al.*, 2010) [82,21,40,89], therefore lowering of moisture content by partial drying or by mixing the samples with lower moisture content before preservation is required (Marvin, 1933) [66].

2.2.1 Method of harvesting

The traditional honey harvesting and processing methods had no significant effect on the moisture content which was in the range of 16.00-21.20 per cent (Muli *et al.*, 2007) [73]. Moisture varying from 18.00-28.80 per cent in hand extracted *A. cerana* (traditional hives) honey and 17.07-17.20 per cent in machine extracted *A. mellifera* (modern hives) honey from private and government apiaries (Attri, 2011) [14], 18.28 g/100g in traditional hives and 17.50 g/100g in honey of frame hives (Belay *et al.*, 2013) [18] is reported.

2.2.2 Different species

High moisture content in the range of 18.00-28.80 per cent for *A. cerana* (traditional hives), 17.07 - 17.50 per cent for *A. mellifera* (modern hives) and raw honey directly from the combs of *A. cerana*, *A. dorsata*, *A. florea* and *A. mellifera* colonies from different areas of Pakistan contained 20.06, 22.06, 20.80, 17.68 g/100g moisture, respectively (Attri, 2011; Belay *et al.*, 2013; Iftikhar *et al.*, 2011) [14, 18, 44] while from Himachal Pradesh, respectively contained 16.22, 21.80, 15.40, 16.92 per cent moisture (Yadav, 1995) [108]. Similarly, *A. dorsata*, *A. cerana* and *A. mellifera* honey from the floristic region of Chitwan district, central Nepal recorded 21.50, 20.10, 17.10 g/100g moisture (Joshi *et al.*, 1999) [47].16.60 per cent moisture in raw unprocessed honey of *A. cerana* from Kerala, India (Krishnasree and Ukkuru, 2015) [57], 19.00 - 25.00 per cent Uttarkashi district Uttarakhand, India (Gariola *et al.*, 2013) [36], 19.10 - 23.10 per cent from Nagpur, Maharashtra, India (Cherian *et al*., 2011) [27] is documented. Moisture content varying from 22.87- 26.70 per cent for fresh honey of *A. dorsata* from agro-climatically and geographically different areas of Pakistan (Akram *et al*., 2014) [8] and 20.50 - 26.00 per cent for multifloral honey of *A. dorsata* from Nepal (Qamer *et al*., 2008) [84]. 13.38 - 14.40 per cent *A. dorsata* from different locations of Varanasi, India (Sahney and Kumar, 2017) [88].

2.2.3 Regional variations

As per studies, the moisture content varies accordingly with respect to region. The moisture content documented for honey of different regions such as Al-Qassim region of Saudi Arabia, Telangana (India), Lower Chubut River Valley, Plains of Senguerr River, Andean region Sundarbon (Khulna, Bangladesh), Nigeria and Iran was 14.45 - 15.95 per cent (Osman *et al.*, 2007) [76], 1.79 - 2.72 per cent (Shobham *et al*., 2017) [92], 14.16, 14.30, 15.95 per cent (Aloisi, 2010) [9], 15.42 g/100g (Asaduzzaman *et al.*, 2015) [13], 16.60 per cent (Akharaiyi and Lowal, 2016) [6], 15.40 - 18.40 per cent (Khaledi *et al.*, 2016) [54], respectively.

Fresh honeys of *A. dorsata* from agro-climatically and geographically different areas of Pakistan *viz*., Changamanga (Central Punjab), Multan (Southern Punjab), Mansehra (Upper Khyber Pakhtunkhwa, KPK) and Islamabad (Federal Area) contained 26.70, 25.93, 24.50, 22.87 per cent moisture content, respectively (Akram *et al*., 2014) [8], while Nigerian honey from different sub-regions reported to contain 15.83 mg/100g (Adamawa); 15.83 mg/100g (Bauchi); 16.67 mg/100g (Borno); 17.33 mg/100g (Gombe); 15.00 mg/100g (Taraba) and 15.33 mg/100g (Yobe) moisture content (Buba *et al.*, 2013) [25]. *A. cerana* honey collected from different geographical regions *viz*., Nagpur (Maharashtra) and Uttarakhand contain 19.10 - 23.10 per cent (Cherian *et al*., 2011) [27], 19.00 - 25.00 per cent (Uttarakhand) moisture content. The honey samples from plains of Tamil Nadu, Jammu Kashmir, Sundarbon (Khulna, Bangladesh) were analysed and reported 21.97 per cent, 20.55 per cent, 15.42g/100g moisture content, respectively (Asaduzzaman *et al*., 2015; Manzoor *et al.*, 2013) [13,65]. Moisture content reported in honey from different origins of Egypt *viz*., Egyptian, Yemeni, Saudi and Kashmiri was 18.32, 16.28, 15.64, 14.73 per cent moisture, respectively (Sohaimy *et al*., 2015) [93].

2.2.4 Floral variations

Local honey collected from different flora *viz*., herbal, acacia and berry of Gilgit-Baltistan, Pakistan contained 18.20, 18.60, 16.40 per cent moisture content (Shahnawaz *et al*., 2013) [90]. The unifloral and multifloral honeys of *A. cerana*, respectively contained 15.85 and 14.98 per cent moisture content (Gaur *et al*., 2014) [37]. Moisture content of unifloral honeys was higher than the multifloral. The different floral honey *viz*., meadow, acacia, linden, multifloral, sunflower and forest, Algerian floral honey, respectively contained 17.10, 16.30, 16.50, 17.20, 17.20, 14.60, 15.30 per cent moisture content (Rebiai and Lanez, 2014) [85].

Raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey from beekeepers of different regions of Kashmir valley (Pulwama, Srinagar, and Budgam) (India) were analysed and had 18.60, 18.20, 19.11 per cent moisture content (Nayik and Nanda, 2015) [74]. The multifloral honey samples from beekeepers of four geographic regions *viz*., North West Plains, Jordan Valley, the Central Mountains and the Southern Semi-arid region of Palestine were reported to contain 16.53 per cent moisture content (Abdulkhaliq and Swaileh, 2016) [1]. Honey from different geographical and floral origins of Iran contained 15.40 - 18.40 per cent moisture and lowest moisture content (<16 per cent) was found for multifloral honey (Khaledi *et al.*, 2016) [54]. The jujube, multifloral, citrus, eucalyptus, thyme, carob, lavender and rosemary honey, from different regions of eastern Morroco, respectively contained 15.39, 17.17, 17.76, 19.37, 16.85, 15.59, 18.22, 17.92 per cent moisture content (Abselami *et al.*, 2017) [2]. The honeydew honey, floral honey and fir honey contained 15.20, 17.12 g/100g moisture content (Jafar *et al.*, 2017) [45]. During the year 2010–13, fir honey collected from local beekeepers from four different regions in Greece was analysed and reported to contain 15.40 - 18.59 g/100g moisture content (Karabagias *et al.*, 2017) [49]. Later during 2018, honey of different flora *viz*., *Robinia*, *Lavandula*, *Salvia*, *Rosmarinus*, *Medicago*, *Calluna* and *Citrus* collected from different regions of Southwest of Kef, Tunisia reported to contain 16.00 - 21.80 per cent moisture content (Jilani *et al.*, 2018) [46].

2.3 pH

pH of honey which is of great importance during honey extraction and storage, affects the texture, stability, and shelf life of honey (Terrab *et al.*, 2002; 2004; Terrab and Die, 2003; Mahmoudi *et al.*, 2012) [96,97,95,64] and is influenced by floral and geographic origins (Wang *et al*., 2014; Gomes *et al.*, 2010) [104,40]. The acidic pH of honey is basically due to the presence of some acids, mainly gluconic acid, which is formed as a result of glucose degradation by glucose oxidase (Oddo and Piro, 2004) [75]. The pH values of 3.88-4.58 was reported in natural honeys produced in different areas of Al-Qassim region, Saudi Arabia (Osman *et al*., 2007) [76], 3.80 - 4.40 in marketed samples of honey from Lahore, Pakistan (Khan *et al*., 2009) [55], 4.17 for raw honeys of different botanical sources from Algeria (Ahmed *et al*., 2014) [5], 3.72 - 3.97 for honey of Telangana, India (Shobham *et al.*, 2017) [92], 3.22 - 5.00 in honey of bee farmers and local markets of different locations of Nigeria (Lullah-Deh *et al*., 2018) [62].

2.3.1 Methods of harvesting

The pH value did not vary with respect to the method of harvesting (Belay *et al*., 2013) [18].

2.3.2 Regional variations

Honeys collected from different geographical regions may also differ in their pH values i.e., the pH values for honey samples collected from Telangana (India), Nigeria, Lower Chubut River valley, Plains of Senguerr River, Andean region and Sundarbon (Khulna, Bangladesh) recorded 3.72 - 3.97 (Shobham *et al.*, 2017) [92], 3.22 - 5.00 (Lullah-Deh *et al*., 2018) [62], 3.88 - 4.56 (Aloisi, 2010) [9] and 4.58 (Asaduzzaman *et al.*, 2015) [13], respectively. Fresh honey of *A. dorsata* from agro-climatically and geographically different areas of Pakistan *viz*., Changamanga (Central Punjab), Multan (Southern Punjab), Mansehra (Upper Khyber Pakhtunkhwa, KPK) and Islamabad (Federal Area), respectively had 3.09, 3.61, 3.28, 3.33 pH values (Akram *et al.*, 2014) [8]. Natural honeys produced in different areas of Al-Qassim region (Saudi Arabia) had pH in the range of 3.88 - 4.58 (Osman *et al*., 2007) [76]. On the other hand, the pH range of marketed honey samples (Lahore, Pakistan) was 3.80 - 4.40 (Khan *et al*., 2009) [55]. Raw honey harvested directly from the combs of *A. cerana*, *A. dorsata*, *A. florea* and *A. mellifera* colonies reported to had pH values of 3.59, 5.60, 6.45, 3.84, respectively (Iftikhar *et al.*, 2011) [44].

2.3.3 Floral variations

Multifloral honey samples collected from Shahabgunj (Dhakeri, Narayanpur) and Perari forest (Nepal), had pH value in the range of 3.80 - 4.68 (Qamer *et al*., 2008) [84]. Similarly, multifloral honey samples from beekeepers of four geographic regions *viz*., North West Plains, Jordan Valley, the Central Mountains and the Southern Semi-arid region of Palestine contained 3.44 pH (Abdulkhaliq and Swaileh, 2016) [1]. Raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey from beekeepers of different regions of Kashmir valley (Pulwama, Srinagar, and Budgam) of India, respectively had 3.55, 3.78, 3.52 pH (Nayik and Nanda, 2015) [74]. The herb, herbal and creamed honeys, respectively had 4.04, 3.91, 3.61 pH (Dzugan *et al*., 2016) [31]. It was reported that fir honey which was traditionally available, contained pH in the range of 4.80 - 4.97 (Jafar *et al.*, 2017) [45]. The Tunisian honey *viz*., mint, rosemary, thyme, orange, eucalyptus, horehound was analysed and pH values were observed as 4.11, 4.02, 3.87, 3.82, 3.68 and 3.67, respectively (Boiussaid *et al*., 2018) [24].

2.4 Acidity

Acidity contributes to honey flavour, stability against microorganisms, enhancement of chemical reactions, antibacterial and antioxidant activities (Gheldof and Engeseth, 2002) [39] and is indicative of fermentation of sugars into organic acids. Gluconic acid (2, 3, 4, 5, 6-pentahydroxyhexanoic acid) is the most abundant acid found in honey which is produced from enzymatic breakdown of glucose by glucose oxidase (a naturally found enzyme in honey (Oddo and Piro, 2004) [75]. Fresh honeys are less acidic than stored honey (Balasubramanyam, 2011) [16]. Generally, Indian honeys possess higher acidity as compared to foreign samples due to tropical climatic conditions.

2.4.1 Method of harvesting

The traditional honey harvesting contained 18.00-71.85 mg/kg acidity (Muli *et al.*, 2007) [73], 35.80 meq/1000g acidity while frame hives contained 33.33 meq/1000g acidity (Belay *et al.*, 2013) [18].

2.4.2 Regional variations

Natural honeys produced in different areas of Al-Qassim region, (Saudi Arabia) was known to contain 10.90-21.84 meq/kg total acidity (Osman *et al.*, 2007) [76]. However, the acidity content in marketed samples of honey was in range of 26.51-33.00 meq/kg (Khan *et al.*, 2009) [55] and 7.00-25.00 meq/kg (Iftikhar *et al*., 2014) [43]. The acidity in the market, raw and industrial honey varied from 0.11-0.17%, 0.07-0.20%, 0.15-0.16%, respectively (Kavapurayil *et al*., 2013) [52]. Another study on honey quality revealed that raw honey contained 17.22 meq/kg (Ahmed *et al.*, 2014) [5] and 0.16g/100g acidity (Krishnasree and Ukkuru, 2015) [57].

Honey from different geographical regions *viz*., Telangana (India), Lower Chubut River Valley, Plains of Senguerr River, Andean region, Tamil Nadu and Jammu Kashmir contained 9.2- 41.40 meq/kg (Shobham *et al.*, 2017) [92], 23.40, 19.70, 24.23 meq/kg (Aloisi, 2010), 24.35% and 23.19% acidity (Manzoor *et al*., 2013) [63]. Fresh honey samples of *A. dorsata* from agro-climatically and geographically different areas of Pakistan *viz*., Changamanga (Central Punjab), Multan (Southern Punjab), Mansehra (Upper Khyber Pakhtunkhwa, KPK) and Islamabad (Federal Area) had acidity as 43.00, 23.67, 34.67, 31.33 meq/kg, respectively (Akram *et al.*, 2014) [8]. Acidity of honey samples from different regions of Tepi town (Ethopia) and Iran, respectively varied from 17.00-29.00 meq/kg (Yadata, 2014) [107] and 21.36 – 66.31 meq/kg (Khaledi *et al.*, 2016) [54].

2.4.3 Floral variations

Acidity for nectar honey samples of different floral origin *viz*., *Citrus aurantius, Medicago sativa, Malus communis, Vitis vinifera* and *Helianthus annus*was 49.80, 40.80, 34.40, 65.10 and 29.30 meq/kg, respectively (Acquarone *et al*., 2007) [3]. Multifloral honey of indigenous honeybee species collected from three diverse zones of Western Ghats of Karnataka (India) had 0.52 per cent acidity (Balasubramanyam, 2011) [16]. The value of acidity content found in summer honey (*A. florea*) varied from 16.00-110.00 meq/kg (Shobham *et al.*, 2017) [92]. Different floral honey *viz*., meadow, acacia, linden, multifloral, sunflower and forest honey, respectively contained 20.39, 12.08, 18.26, 21.12, 14.25, 21.00 mmol of acid/100g (Prica *et al*., 2014) [81]. Following this, raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey were analyzed and reported 0.17, 0.39, 0.14% acidity, respectively (Nayik and Nanda, 2015) [74]. The herb, herbal and creamed honey, respectively contain 18.00, 26.00, 35.00 meq/kg acidity (Dzugan *et al*., 2016) [31]. Acidity content in acacia, blossom and honeydew honey, varied in the range of 8.23 - 10.87, 14.65 - 17.44, 18.53 - 26.03 meq/kg, respectively (Vranic *et al.*, 2017) [103]. The Tunisian honeys *viz*., horehound, mint, eucalyptus, thyme, orange and rosemary were known to contain 27.20 meq/kg, 27.03 meq/kg, 26.60 meq/kg, 26.20 meq/kg, 21.41 meq/kg and 7.11 meq/kg acidity, respectively (Boiussaid *et al*., 2018) [24].

2.5 Electrical conductivity (EC)

The EC of honey depends on the content of inorganic salts, organic acids, proteins, complex sugars, and mineral contents in the sample and may affect other honey quality parameters (Lullah-Deh *et al.*, 2018) [62]. Higher the content of ions and organic acids, higher will be the EC (Rebiai and Lanez, 2014) [85]. EC values are used for discriminating between honeydew and blossom honey and also for characterization of unifloral honeys (Chefrour *et al.*, 2009) [26]. Honey with EC > 0.8mS/cm is considered as honeydew honeys and < 0.8mS/cm as blossom honey (Bogdanov *et al*., 2007) [19].

2.5.1 Method of harvesting

The method of harvesting influences the EC of honey. EC of 0.71 mS/cm and 0.68 mS/cm was reported for honey harvested from traditional and modern frame hives, respectively (Belay *et al.*, 2013) [18].

2.5.2 Different species

Higher EC values in *A. cerana* honey (0.03 - 0.31 mS/cm), in comparison to *A. mellifera* honey (0.24 - 0.37 mS/cm EC) was reported (Attri, 2011) [14]. Raw honey of different *Apis* species *viz*., *A. cerana, A. dorsata, A. florea* and *A. mellifera* colonies was analysed and the values of EC was recorded as 0.59, 0.58, 0.76, 0.23 mS/cm,respectively (Iftikhar *et al*., 2011) [44]. EC in *A. dorsata* honey was in the range of 0.08-0.16 mS/cm (Qamer *et al.*, 2008) [84].

2.5.3 Regional variations

EC values vary accordingly with respect to their geographical regions. In order to study their variations, honey samples were collected from different regions *viz*., Telangana (India) and reported to contain EC values in the range of 0.45-0.55 mS/cm (Shobham *et al*., 2017) [92]. Similarly, honey samples collected from Lower Chubut River Valley, plains of Senguerr River and Andean region, respectively contained 0.28, 0.29, 0.46 mS/cm EC (Aloisi, 2010) [9]. The four local honey samples from beekeepers in Bihar (Monoflora-MF), South Delhi (Polyflora-PF), Sirsi (Polyflora forest-PFf) and Bangalore (Processed-Pro), India were analysed and observed EC values in the range of 152.33-371.66 µS/cm. Polyflora forest (PFf) honey was best with 371.60 µS/cm EC (Kumar *et al.*, 2013) [60]. The conductivity of darker honey was slightly greater than lighter honey, which indicated that the darker honey had more mineral content.

2.5.4 Floral variations

EC values were observed in the range of 0.09-0.34 mS/cm and 0.10-0.25 mS/cm, respectively for the samples collected during summer and winter season depending on the flora (Yadata, 2014) [107]. Multifloral honey of *A. dorsata* in Nepal contained electrical conductivity in the range of 0.22-0.63 mS/cm (Qamer *et al*., 2008) [84]. The EC values for multifloral, acacia, rape, honeydew, forest and mixed honey were 0.46, 0.29, 0.52, 1.12, 0.97, 0.69 mS/cm, respectively (Kasperova *et al.*, 2012) [50]. Previous reports showed that EC in unifloral, honeydew and floral honey was 0.31 mS/cm (Abselami *et al.*, 2017) [2], 1.32 mS/cm and 0.54 mS/cm (Jafar *et al.*, 2017) [45], respectively. Raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey from beekeepers of different regions of Kashmir valley (Pulwama, Srinagar, and Budgam) (India) had 0.26, 0.79, 0.25 mS/cm EC (Nayik and Nanda, 2015) [74]. Similarly, honey samples of multifloral, citrus, eucalyptus, thyme, carob, lavender and rosemary from beekeepers of different regions of eastern Morocco were evaluated and found that the jujube, multifloral, citrus, eucalyptus, thyme, carob, lavender and rosemary honey, respectively contain 578, 669, 338, 629, 566, 626, 328, 108 mS/cm EC (Abselami *et al*., 2017) [2]. During 2018, honey samples of different flora *viz*., *Robinia, Lavandula, Salvia, Rosmarinus, Medicago, Calluna* and *Citrus* were evaluated and found EC values in the range of 314.00-618.00 uS/cm (Jilani *et al.*, 2018) [46].

2.6 Hydroxymethylfurfural (HMF) content

Several factors *viz*., temperature and time of heating, storage conditions, pH and floral source, influence the level of HMF (a break down product of certain sugars), thus it provides an indication of overheating or improper heating, long storage in poor conditions or adulteration of honey with invert sugars (Fallico *et al.*, 2006; White and Doner, 1980) [33,105]. The higher the value of HMF content, lower will be the quality of honey (Saxena *et al.*, 2010) [89]. HMF content varied in the range of 55.90-70.20 mg/kg which was within the permissible

level (Table 1) for honey from different agroclimatic zones of Himachal Pradesh (Parihar *et al.*, 2020) [77]. Negative HMF was reported for honey of all the four species collected from honey producing areas, beekeepers, research centers, markets of Himachal Pradesh and adjoining areas of Haryana and Punjab (Yadav, 1995) [108]. In other studies, Hydroxy methyl furfural (HMF) upto 95.00 mg/kg i.e. higher than the recommended ranges for local and imported brands of honey of Pakistan markets has been documented indicating low quality of honey (Iftikhar *et al*., 2011) [44].

2.6.1 Different bee species

Honey of different *Apis* species *viz*., *A. cerana, A. dorsata, A. florea* and *A. mellifera* was analysed and observed that HMF values for these samples was 23.62, 23.18, 25.68, 27.37 mg/kg, respectively (Iftikhar *et al*., 2011) [44].

2.6.2 Regional variations

Studies conducted in the previous year's reported that honey samples collected from Algeria contain HMF content as 11.65 mg/kg (Ahmed *et al.*, 2014) [5]. It was observed that HMF content for the four local honey samples collected from beekeepers in Bihar (Monoflora-MF), South Delhi (Polyflora-PF), Sirsi (Polyflora forest-PFf) and Bangalore (Processed-Pro), India was in the range of 1.75-27.87 mg/kg. Polyflora forest (PFf) honey was best with 1.75 mg/kg HMF content (Kumar *et al.*, 2013) [60].

2.6.3 Floral variations

52 honey samples of different regions of central, southern and eastern Slovakia were characterised in different floral sources *viz*., multifloral, acacia, rape, honeydew, forest and mixed honey and reported to contain 14.97, 11.08, 13.70, 11.42, 26.02, 22.27 mg/kg HMF content, respectively (Kasperova *et al*., 2012) [50]. *Euphorbia resinifera* honey from the Azilal and Beni MellalProvines, Spain had HMF value within a range of 0.40-16.48 mg/kg (Moujanni *et al*., 2017) [72]. Also, HMF value of honeydew and blossom honey was reported as 2.40 and 7.60 mg/kg (Pasias *et al.*, 2017) [78].

2.7 Diastase

Diastase (alpha and beta amylases) are enzymes naturally present in honey, which are sensitive to heat (thermo labile) and indicate overheating and degree of preservation (Ahmed *et al.*, 2013) [4]. Thus, these are indicators of honey freshness (Bogdanov, 2009) [23]. Diastase content of 21.56 DN for honey from *A. mellifera* colonies at university apiary Nauni, Solan (Kaushik, 1988) [51] is previously reported. Effect of bee flora on the Diastase content is reported throughout the world by different workers (Akram *et al.*, 2014; Jilani *et al.*, 2018) [8, 46].

2.7.1 Methods of harvesting

Honey harvested using modern methods had better diastase activity (21.50-21.80 Schades unit) whereas, honey harvested using traditional methods had diastase activity in the range of 19.10 - 20.00 Schades unit (Babarinde *et al.*, 2011) [15].

2.7.2 Regional variations

Honey harvested from different regions *viz*., Algeria, Lower Chubut River Valley, Plains of Senguerr river, Andean regions, Tamil Nadu and Jammu Kashmir, respectively had 17.44 DN (Ahmed *et al.*, 2014) [5], 13.77, 8.84, 16.53 Gothe unit (Aloisi, 2010), 16.39% and 14.54% (Manzoor *et al*., 2013) [65]. Fresh honey samples of *A. dorsata* from agro-climatically and geographically different areas of Pakistan *viz*., Changamanga (Central Punjab), Multan (Southern Punjab), Mansehra (Upper Khyber Pakhtunkhwa, KPK) and Islamabad (Federal Area), respectively had diastase content varying from 29.00, 25.67, 22.33, 18.33DN (Akram *et al*., 2014) [8].

2.7.3 Floral variations

Multifloral honey of *A. dorsata* contained diastase in the range of 5.10-29.00 DN (Qamer *et al.*, 2008) [84]. The raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey had 15.51, 25.99, 14.93 diastase number, respectively (Nayik and Nanda, 2015) [74]. Similarly, jujube, multifloral, citrus, eucalyptus, thyme, carob, lavender and rosemary reported to had 21.17, 17.82, 12.71, 11.96, 18.72, 15.28, 12.97, 6.98 Gothe diastase activity (Abselami *et al.*, 2017) [2]. The range of DN found in acacia, blossom and honeydew honey was 8.86-13.05, 11.86-16.95, 15.63-23.50, respectively (Vranic *et al.*, 2017) [103]. It was also reported that honey dew and blossom honey, respectively contained 11.90, 13.60 diastase number (Pasias *et al.*, 2017) [78].

2.8 Sugars

Fructose and glucose are the primary and major sugars present in honey (Bogdanov *et al*., 2004) [23]. The sum of fructose, glucose, fructose/glucose ratio and glucose/water ratio are the important factors related to honey quality. Fructose/Glucose ratio indicates the ability of honey to crystallize (Buba *et al*., 2013; White and Doner, 1980) [25,105] and in good quality honey, the fructose content should exceed that of glucose. There are great variations in the sugar composition of honey due to botanical origin, geographical origin, climate, processing and storage. Sugars are known to change during storage.

The sucrose and fructose content was in the range of 4.91-6.94 per cent and 30.94-36.62 per cent, respectively for honey from different climatic zones of Himachal Pradesh (Thakur, 2020) [98]. These values meet the standards and corresponds to the levels observed in other studies (Rodriguez *et al*., 2004; Kucuk *et al*., 2007; Kakade and Deokule, 2011) [84,58,48]. The fructose glucose ratio indicates crystallization tendency of honey, higher ratio indicates its liquid form. As per literature, higher values of fructose are more in squeezed honey. Previously, sucrose, fructose, glucose and F:G ratio was documented in the range of 3.17 - 5.14 per cent, 29.71 - 33.28 per cent, 29.20 - 32.93 per cent and 0.97 - 1.41, respectively for *A. mellifera* honey from Chamba district of Himachal Pradesh (Yadav, 1995) [108]. Similarly, high values of 80.70 per cent total sugars, 32.43 per cent glucose and 35.90 per cent fructose content for fresh Himachal honey was documented (Kaushik, 1988) [51]. Sugar composition has been used to discriminate honey samples by botanical origin (Puusepp and Koff, 2014) [83] or geographical origin (Gomez *et al.*, 2000) [41].

2.8.1 Method of harvesting

Honey samples harvested from traditional and modern methods reported to vary in a specific range with respect to sucrose content i.e. found to be 0.80 - 0.83% and 0.54 - 0.58%, respectively (Babarinde *et al.*, 2011) [15].

2.8.2 Sugars in raw, market and natural honey

Varied range of sucrose content was found in natural, market, raw and industrial honey i.e. 58.98 - 80.60% (Osman *et al*., 2007) [76], 7.00 - 31.83%, 14.50 - 28.05% and 12.87 - 13.77% (Kavapurayil *et al*., 2013) [52]. Similarly, glucose and fructose content was evaluated using raw honey samples and it was observed that analysed honey contained 21.45 - 28.26 g/100g glucose and 25.20 - 37.64 fructose (Ahmed *et al.,* 2014) [5]. Honey samples collected from Rawalpindi and Islamabad markets reported to contain 7.60 - 8.70 per cent sucrose (Iftikhar *et al.,* 2014) [43].

2.8.3 Different bee species

Apis mellifera, *A. cerana*, *A. florea* and *A. dorsata* honey samples were reported to contain 5.57, 6.50, 8.42, 5.01% sucrose content, respectively (Yadav, 1995) [108]. The fructose content was found significantly higher in *A. cerana* (48.25 g/100g) and *A. dorsata* (48.01 g/100g) as compared to *A. mellifera* (45.93 g/100g). Comparatively, sucrose content was significantly low in *A. dorsata* (0.33 g/100g) honey followed by *A. cerana* (1.39 g/100g) and *A. mellifera* (1.96 g/100g) honeys (Joshi *et al.,* 1999) [47].

2.8.4 Regional variations

The fructose and sucrose content in *A. cerana* honey samples of Uttarkashi district of Uttarakhand (India) was recorded as 37.27 - 40.51 per cent and 35.21 - 38.04 per cent, respectively (Gairola *et al.,* 2013) [36]. The sugar content in honey samples of Sundarbon (Khulna, Bangladesh) were reported as 60.32g/100g (Asaduzzaman *et al.,* 2015) [13]. Honey samples from different origins of Egypt *viz*., Egyptian, Yemeni, Saudi and Kashmiri were evaluated and reported that these samples contained 26.54, 25.45, 21.58, 10.63 g/100g glucose, 43.30, 38.76, 50.78, 4.48 g/100g fructose, 1.63, 1.52, 2.35, 0.42% sucrose and 1.63, 1.52, 2.35, 0.42 F:G ratio, respectively (Sohaimy *et al.,* 2015) [93]. Similarly, four local honey samples from beekeepers in Bihar (Monoflora-MF), South Delhi (Polyflora-PF), Sirsi (Polyflora forest-PFf) and Banglore (Processed-Pro), India were analysed and found total sugar, reducing sugar and sucrose content in the range of 64.88 - 73.08%, 62.24 - 70.24% and 1.76 - 2.58%, respectively (Kumar *et al.,* 2013) [60]. Polyflora forest (PFf) honey was found best with 65.03% total sugar, 62.24% reducing sugar and 2.25% sucrose. Fructose, glucose and sucrose content in honey collected from Bitlis-Mutki was 317.00 - 357.38 mg/10g, 237.99 - 263.04 mg/10g and 10.57 - 25.75 mg/10g, respectively (Kierecci and Kierecci, 2018) [56].

2.8.5 Floral variations

Multifloral honey samples of *A. dorsata* were reported to contain 12.07 - 20.38% sucrose content (Qamer *et al.,* 2008) [84]. The unifloral and multifloral honey contained 58.58% and 58.68% reducing sugars, respectively which was near to similar (Gaur *et al.,* 2014) [37]. Also, honey samples collected from different flora *viz*., herbal, acacia and berry contained 73.06, 79.10, 73.60% total sugars, respectively (Shahnawaz *et al.,* 2013) [93]. The quality of honey derived from different sources *viz*., commercial herb honeys produced by bees fed with syrup having herbal extract of nettle, hawthorn, pine, chokeberry, aloe, natural herbal honey produced by bees from the nectar of herbs *viz*., nettle, blackberry, chokeberry and creamed multifloral honey of lavender, lemon balm, nettle, peppermint and ginger with added dried herbs was studied. The herb, herbal and creamed honeys, respectively contained 80.50, 77.57, 79.88 per cent sugar extract (Dzugan *et al*., 2016) [31]. Honeydew and blossom honey samples contained 2.90 and 1.50% sucrose content (Pasias *et al*., 2017) [78].

2.9 Vitamin C

Honey contains ascorbic acid because most flowers on which the bees forage contain vitamin C which serves as sources of polyphenol and dietary antioxidant (Gheldof and Engeseth, 2002) [39]. The antioxidant activity of honey, which depends on its botanical origin, is related to Vitamin C content (Kesio *et al.,* 2009) [53]. Low acidity value indicates the freshness of honey sample while high acidity indicates the fermentation of sugars into organic acids (Shobham *et al.*, 2017) [92].

2.9.1 Regional variations

Vitamin C content varying from 20.79-25.04 mg/100g for different zones of Himachal Pradesh is reported (Thakur, 2020) [98]. Similarly, Vitamin C content in honey samples of Bangladesh (Sundarbon, Khulna) was 21.68 mg/100g (Buba *et al.,* 2013) [25]. While, in honey samples collected from farmers in urban areas of Western States of Nigeria was reported as 2.61 mg/100g (Akharaiyi and Lawal, 2016) [6].

2.9.2 Floral variations

Variations in Vitamin C content due to various botanical sources is reported (Asaduzzaman *et al*., 2015; Dobrinas *et al.,* 2006) [13,30]. Honey of different flora *viz*., *Helianthus*, conifers, multifloral, mountain flowers, pine tree forest, Acacia and linden tree from beekeeper and local market of fourteen different regions of Romania had 0.79, 1.08, 0.96, 0.87, 0.89, 0.99 and 2.90 mg/g vitamin C content, respectively. Highest concentration of vitamin C content was obtained in linden tree (2.90 mg/g) followed by conifers (1.08 mg/g), whereas, lowest vitamin C content was reported in *Helianthus* honey (0.79 mg/g) (Dobrinas *et al.*, 2006) [30].

2.10 Phenols

Raw honey contains copious amounts of compounds such as flavonoids and phenols which may function as antioxidants and originate from nectar, pollen or propolis and vary according to the floral source (Mahawi *et al.*, 2009) [63].

2.10.1 Different flora

The total phenolic content of 145.00 mg/100g and flavonoid content of 59.30 mg/100g was reported for multifloral honey purchased from a local market of Ankara (Turkey) (Akkol *et al.,* 2009) [7]. Variable ranges of phenolic and flavonoid content in multifloral honeys was found as 250.00 - 548.00 mg/kg and 9.00 - 48.60 mg/kg, respectively (Pontis *et al*., 2014) [80]. The quality of honey derived from different sources *viz*., commercial herb honeys produced by bees fed with syrup having herbal extract of nettle, hawthorn, pine, chokeberry, aloe, natural herbal honey produced by bees from the nectar of herbs *viz*., nettle, blackberry, chokeberry and creamed multifloral honey of lavender, lemon balm, nettle, peppermint and ginger with added dried herbs was determined. Multifloral honey was used as a control and reported in comparison to multifloral nectar honeys, the highest phenolic content (66.97 mg/100g) was exhibited by creamed honey with herb additives which was superior to the herb honeys (Dzugan *et al*., 2016) [31]. Similar to this, phenol content for the honey of *Thymus*, *Mentha*, *Eucalyptus*, *Rosmarinus* and *Marrubium* was found in the range of 32.17-119.42 mg/100g (Boiussaid *et al*., 2018) [24]. The total phenolic content was

145.00 mg/100g for multifloral honey purchased from a local market of Turkey (Akkol *et al.*, 2009) [7]. Natural honey was known to contain phenolic compounds in a wide range of 113.33 - 169.67 mg/100g whereas phenolic compounds in manuka honey were 161.00 mg/100g (Venugopal and Devarajan, 2010) [102]. Comparatively, phenol content in the market, raw and industrial honey varied from 360 - 580 mg/100g, 360 - 502 mg/100g and 356 - 500 mg/100g, respectively (Kavapurayil *et al.*, 2013) [53].

2.10.2 Regional variations

The phenol content of honey from Himachal Pradesh varied from 65.02 - 77.39 mg/100g (Gupta, 2019) [42]. Among the four zones, highest phenol content was recorded in Zone 2 (77.39 mg/100g) which was statistically at par with Zone 1 (76.77 mg/100g) and Zone 4 (74.73 mg/100g), whereas, lowest was recorded in Zone 3 (65.02 mg/100g). High phenolic content of 113.33-169.67 mg/100g and content in the range of 59.86 mg/100g to 72.41 g/100g for honey samples from different sub-regions of Nigeria is documented (Buba *et al.*, 2013; Venugopal and Devarajan, 2010) [25,102]. However, the phenol and flavonoid content in honey of Sundarbon (Khulna, Bangladesh) was 19.47 mg/100g and 63.23 mg/100, respectively (Asaduzzaman *et al.*, 2015) [15]. Similarly, honey from Bitlis-Mutki, Turkey was reported to contain phenol content in the range of 17.82 - 51.55 µg/100g (Kierecci and Kierecci, 2018) [56]. Four local honey samples from beekeepers in Bihar (Monoflora-MF), South Delhi (Polyflora-PF), Sirsi (Polyflora forest-PFf) and Banglore (Processed-Pro) were analysed. In Polyflora forest (PFf) 2119.28 ± 0.34 mg/kg polyphenol, 975.50 ± 0.24 mg/kg flavonoids, 588.30 ± 0.33 mg/kg flavonols and 387.26 ± 0.22 mg/kg flavones were found to be more than monoflora, polyflora and processed honey. Thus, the honey of Polyflora forest variety was found best (Kumar *et al*., 2013) [60].

2.11 Proline content (Amino acid)

The amino acid content in honey is important from the nutritional point of view and influences the tendency of honey to caramelize on heating and to darken during processing and storage. Proline content is a criterion of honey ripeness and in some cases, also of sugar adulteration (Cherian *et al*., 2011) [27]. Very high proline content of upto 423.40 and 570.95 mg/kg was reported for honey from different apiaries and different floral sources of India (Cherian *et al*., 2011; Nayik and Nanda, 2015) [27, 74] and other countries (Czipa *et al.*, 2011) [29].

2.11.1 Different species

Honey samples of *A. dorsata*, *A. cerana* and *A. mellifera* honey from the floristic region of Chitwan district (central Nepal) were analysed and reported that *A. dorsata*, *A. cerana*and *A. mellifera* honey had 875.80, 323.00, 610.20 mg/kg proline, respectively (Joshi *et al*., 1999) [47].

2.11.2 Regions

The amino acid (proline) content varied from 79.53 - 103.83 mg/100g (Table 1). Zone 2 honey (Mid hills, sub-humid zone, Himachal Pradesh) had highest amino acid content (103.83 mg/100g) though not differing statistically from Zone 4 (95.16 mg/100g). High proline content for Zone 2 honey 651-1800 m amsl (Gupta, 2019) [42]. Similarly, amino acid content was found little higher i.e. 0.87 - 1.61 mg/g as reported for Turkey honey at an altitude of 1500 m amsl though within the European Union standards as well as the Turkish Food Codex Honey Notification (Kierecci and Kierecci, 2011) [56]. Amino acid content of 127.66 mg/100g was reported for fresh honey of *A. mellifera* colonies at university apiary Nauni, Solan (Kaushik, 1988) [51].

2.11.3 Floral variations in proline content of honey

Commercial heterofloral honeys purchased from beekeeper and market of Argentina were examined and found that these honey samples had wide range of proline content i.e. 73-577 ppm, with an average of 356 ppm (Geronimo and Fritz, 2001) [38]. The proline content in traditional honey was found in the range of 20.83 - 300.60 mg/kg (Muli *et al*., 2007) [73]. The multifloral honey of *A. dorsata* had proline as 76.00-160.00 mg/kg (Qamer *et al*., 2008) [84]. The proline content in honey from Hungarian beekeepers and commercial market with different flower origin *viz*., acacia, linden, rape, floral, fruit, sunflower, milkweed, chestnut, coriander, wild garlic, lavender and honeydew had proline ranging from 252-2283 mg/kg. Highest proline content was found in coriander honey (2283 mg/kg) followed by honeydew honey (1089 mg/kg), whereas, lowest in acacia honey (252 mg/kg). The rape and wild garlic honeys contained 377 mg/kg and 485 mg/kg proline content, respectively. In other samples the proline content was higher than 500 mg/kg (Czipa *et al*., 2011) [29]. Similarly, raw and fresh honey samples of different flora *viz*., acacia honey, pine honeydew and multifloral honey were analysed and reported to contain 292.02, 570.95, 168.05 mg/kg proline content, respectively (Nayik and Nanda, 2015) [74]. According to the previous study, honeydew honey and floral honey contained 758.69, 627.66 mg/kg proline content (Jafar *et al.*, 2017) [45]. Proline content in Tunisian honeys *viz*., rosemary, horehound, orange, thyme, eucalyptus, mint was 102.60 mg/kg (eucalyptus), 102.22 mg/kg (mint), 85.94 mg/kg (horehound), 68.70 mg/kg (thyme), 59.12 (orange) and 39.62 mg/kg (rosemary) proline content (Boiussaid *et al*., 2018) [24].

2.12 Mineral content in honey

Minerals detected from honey originate from both natural sources (soil and plants) and anthropogenic sources (Kumar *et al.*, 2013) [60]. In most of the reports, K was the highest mineral content in honey (Alqarni *et al.*, 2012; Rehman *et al*., 2008; Mbiri *et al.*, 2011) [10, 86, 67]. Variations observed in the mineral content of honey could be due to the floral sources, different regions, method of extraction, processing and beekeeping. Ca, K and Na content varying from 48.98-86.59 mg/kg, 167.65-319.51 mg/kg and 140.40-167.08 mg/kg, respectively was recorded for honey from different agro-climatic zones of Himachal Pradesh (Gupta, 2019) [42], whereas, Ca, K and Na content was reported as 21-71 mg/kg,152-1576 mg/kg and 14-73 mg/kg, respectively for honey from Garhwal Himalayas, Uttarakhand (Gaur *et al*., 2014) [37]. The information on mineral content of honey is not available for the honey of Himachal Pradesh. The Ca (81.04 mg/kg) and K (354.17 mg/kg) content were highest for Zone 2 (Mid hills, subhumid zone) as compared to other zones whereas, highest P content (62.93 mg/kg) was recorded in Zone 1 (Sub-mountain and sub-tropical, low hills zone) of Himachal Pradesh (Gupta, 2019) [42].

2.12.1 Different regions

Ca content present in raw honey (*A. cerana*) collected from southern zone of Kerala was 3600 µg/100g (Krishnasree and

Ukkuru, 2016) [57]. The mineral composition for the honey from desert and hilly locations of Pakistan recorded K 891.30 mg/kg, Na 79.18 mg/kg, Ca 58.47 mg/kg, Mg 35.43 mg/kg, Fe 5.74 mg/kg, Zn 2.44 mg/kg, Cu 1.75 mg/kg, Ni 1.26 mg/kg and Co 0.98 mg/kg. Honey samples of different locations of Kenya were analysed. The concentration of minerals varied depending on the botanical origin, climatic conditions, extraction and storage techniques. The K, Na, Ca and Mg content varied from 172.83-781.52 ppm, 98.04-269.10 ppm, 19.33-70.17 ppm and 12.64-41.88 ppm, respectively (Mbiri *et al.*, 2011) [67]. Most of the samples had high level of Zn (0.19 ppm) followed by Pb (0.16 ppm), Cu (0.02 ppm), Cd (0.02 ppm) and As (0.01 ppm). The concentration of Pb in most samples was above the WHO and Kenya Bureau of Standards (KEBS) limit of 0.1 ppm in food products. The studies on trace and essential elements in honey samples from different locations of Southern Region, Ethiopia recorded 0.03-0.07 mg/kg Cu, 0.07-0.82 mg/kg Mn and 0.06-0.34 mg/kg Zn, whereas, Co was not detected in any of the honey samples. The order of mineral concentration in the samples was Mn>Zn>Cu (Teka, 2018) [94].

Honey samples of Nigeria contained 29.64 mg/kg P, 55.93 mg/kg Ca, 481.30 mg/kg K, 25.57 mg/kg Mg and 25.42 mg/kg Na (Akharaiyi and Lawal, 2016) [6]. *A. dorsata* honey from different locations of Varanasi district (India) was analysed. Among the mineral content, K (1.80-47.67 ppm) was the most abundant followed by Na (4.77-7.71 ppm), Ca (2.87-7.71 ppm) and Mg (0.69-1.78 ppm) (Sahney and Kumar, 2017) [88]. Four local honey samples collected from beekeepers in Bihar (Monoflora-MF), South Delhi (Polyflora-PF), Sirsi (Polyflora forest-PFf) and Banglore (Processed-Pro), India were analysed. In Polyflora forest (PFf) the minerals viz., 300.40 mg/l Ca, 92.54 mg/l Mg, 293.36 mg/l Na, 1266.66 mg/l K, 2119.28±0.34 mg/kg were found to be more followed by monoflora, polyflora and processed honey (Kumar *et al.*, 2013) [60].

2.12.2 Floral variations

Unifloral and multifloral honeys, respectively contained 0.03, 0.035% N, 41.27, 52.73 mg/kg Na, 465.93, 933.64 mg/kg K and 48.20, 44.00 mg/kg Ca. N, Na and K content of multifloral honeys was slightly higher than unifloral, while calcium content of unifloral honey was higher than the multifloral (Gaur *et al.*, 2014) [37]. Studies on honey of different botanical sources *viz.*, acacia, pineapple, gelam, longan, borneo, tualang, rubber tree, sourwood, rainforest, bitter gourd and trigona types from different regions of Malaysia, recorded highest concentration of Na (732.16 mg/kg) while rubber tree honey contained the lowest amount (83.17 mg/kg). Rainforest honey showed the second highest concentration of Ca (567.27 mg/kg) followed by bitter gourd honey (358.27 mg/kg), gelam honey (275.77 mg/kg) and trigona honey (202.60 mg/kg). Sourwood honey contained the highest concentration of Mg (199.33 mg/kg), while borneo (21.83 mg/kg) and acacia honeys (23.27 mg/kg) contained the lowest concentration among all the analysed honey samples (Moniruzzaman *et al.*, 2014) [71]. The most abundant minerals were K (1.18-268.00 ppm), Na (0.57-13.10 ppm) and Ca (0.77-4.50 ppm) in honey from different regions of Turkey (Altun *et al.*, 2017) [11]. *Euphorbia resinifera* honey from the Azilal and Beni MellalProvines of Spain contained 536 mg/kg K, 99.57 mg/kg Ca, 54.20 mg/kg Na, 30.02 mg/kg Mg and 62.36 mg/kg P contents (MoujannI *et al.*, 2017) [72]. Acacia honey from East, Northwest Croatia and Istria had 111.24 mg/kg Ca, 325.54 mg/kg K, 95.85 mg/kg Na, 22.01 mg/kg Mg and 1.23 mg/kg Fe (Trstenjak *et al.*, 2017) [101].

3. Conclusions

The quality of honey is the most predetermining issue in price determination of honey. It is also a centre of attention that consumers value in marketing. The present review was focused on parameters for honey quality: moisture content, reducing sugars (glucose and fructose), sucrose, hydroxymethylfurfural (HMF) content, diastase (amylase) activity, pH, acidity, proline content minerals and factors affecting these parameters. To maintain the requirement of honey quality, consecutive training should be given for beekeepers, honey processors and traders on honey harvesting, handling, processing, storing and marketing so that honey quality with respect to standards are achieved for users at the end.

4. Acknowledgements: The authors are grateful to All India Coordinated Research Project on Honey bees and Pollinators, ICAR, New Delhi, India and Central Potato research Institute, Plant Protection Division, Shimla for generous help and support in the accomplishment of the study.

5. Conflict of interest: The authors hereby declare no conflict of interest.

6. References

1. Abdulkhaliq A, Swaileh KM. Physico-chemical properties of multifloral honey from the West Bank, Palestine. International Journal of Food Properties, 2016;20:447-454.
2. Abselami A, Tahani A, Sindic M, Fauconnier ML, Bruneau E, Elbachiri A. Physicochemical properties of some honeys produced from different flora of Eastern Morocco. Journal of Materials and Environmental Science. 2017;9:879-886.
3. Acquarone C, Buera P, Elizalde B. Pattern of pH and electrical conductivity upon honey dilution as a complementary tool for discriminating geographical origin of honeys. Food Chemistry. 2007;101:695-703.
4. Ahmed M, Djebli N, Aissat S, Khiati B, Meslem A, Bacha S. *In vitro* activity of natural honey alone and in combination with curcuma starch against *Rhodotorula mucilaginosa* in correlation with bioactive compounds and diastase activity. Asian Pacific Journal of Tropical Biomedicine. 2013;3:816-821.
5. Ahmed M, Khiati B, Meslem A, Aissat S, Djebli N. Evaluation of physicochemical and antioxidant properties of raw honey from Algeria. Journal of Microbiology and Biochemical Technology. 2014;4:1-6.
6. Akharaiyi FC, Lawal HA. Physicochemical analysis and mineral contents of honey from farmers in western states of Nigeria. Journal of Natural Sciences Research. 2016;6:78-84.
7. Akkol EK, Orhan DD, Gurbuz I, Yesilada E. *In vivo* activity assessment of a honey-bee pollen mix formulation. Pharmaceutical Biology 2009, 1-7.
8. Akram A, Sohail A, Masud T, Latif A, Tariq S, Butt SJ. Physico-chemical and antimicrobial assessment of honey of *Apis dorsata* from different geographical regions of Pakistan. International Journal of Agricultural Science Research. 2014;3:25-30.
9. Aloisi PV. Determination of quality chemical parameters

of honey from Chubut (Argentinean Patagonia). Chilean Journal of Agricultural Research. 2010;4:640-645.
10. Alqarni AS, Owayss AA, Mahmoud AA, Hannan MA. Mineral content and physical properties of local and imported honeys in Saudi Arabia. Journal of Saudi Chemical Society. 2012;18:618-625.
11. Altun SK, Dinc H, Paksoy N, Temamogullari FK, Savrunlu M. Analysis of mineral content and heavy metal of honey samples from South and East region of Turkey by using ICP-MS. International Journal of Analytical Chemistry. 2017;99:1-6.
12. Anonymous. Food and Nutrition. https://www.statista.com. 2019.
13. Asaduzzaman A, Rahman MS, Munira S, Rahman MM, Islam M, *et al*. Analysis of biochemical composition of honey and its anti-oxidant, phytochemical and anti-bacterial properties. Journal of Biomedical and Pharmaceutical Research. 2015;4:69-81.
14. Attri PK. Physico-chemical investigation of honey samples of *Apis cerana indica* F. (Traditional beekeeping) and *Apis mellifera* (Morden apiculture) from Chamba District, Himachal Pradesh. Biological Forum. 2011;3:67-73.
15. Babarinde GO, Babarinde SA, Adegbola DO, Ajayeoba SL. Effects of harvesting methods on physicochemical and microbial qualities of honey. Journal of Food Science and Technology. 2011;48:628-634.
16. Balasubramanyam MV. Chemical characteristics of multifloral wild and apiary honey from western ghats of Karnataka. The Bioscan. 2011;6:467-469.
17. Baroni MV, Arrua C, Nores ML, Fayec P, Diazd MDP. Composition of honey from Cordoba Argentina: Assessment of North/South provenance by chemometrics. Food Chemistry. 2009;114:727-733.
18. Belay A, Solomon WK, Bultossa G, Adgaba N, Melaku S. Physicochemical properties of the Harenna forest honey, Bale, Ethiopia. Food Chemistry. 2013;141:3386-3392.
19. Bogdanov S, Haldimann M, Luginbuhl W, Gallmann P. Minerals in honey: Environmental, geographical and botanical aspects. Journal of Apicultural Research. 2007;46:269-275.
20. Bogdanov S, Lullman C, Martin P, Ohe WVD, Russmann H, *et al*. Honey quality and international standards: Review by the international honey commission. 2015;80:1-69.
21. Bogdanov S, Martin P, Lullman C. Harmonised methods of the European honey commission. Apidologie. 1997, 1-59.
22. Bogdanov S, Ruoff K, Oddo LP. Physico-chemical methods for the characterization of unifloral honeys: A review. Apidologie. 2004;35:4-17.
23. Bogdanov S. Determination of pyrrolizidime alkaloids in honey from selected sites by solid phase extraction and HPLC-MS. Food Additives and Contaminants. 2009;14:419-428.
24. Boiussaid A, Chouaibi M, Rezig L, Hellal R, Donsi F, Ferrari G, Hamdi S. Physicochemical and bioactive properties of six honey samples from various floral origins from Tunisia. Arabian Journal of Chemistry. 2018;11:265-274.
25. Buba F, Gidado A, Shugaba A. Analysis of biochemical composition of honey samples from North-East Nigeria. Biochemistry and Analytical Biochemistry. 2013;2:1-7.
26. Chefrour C, Draiaia R, Tahar A, Kaki YA, Bennadja S. Battesti MJ. Physicochemical characteristics and pollen spectrum of some north-east Algerian honeys. African Journal of Food, Agriculture, Nutrition and Development. 2009;9:5.
27. Cherian KJ, Bhowal M, Godghate SD. Pollen and physicochemical analysis of honey produced by *Apis cerana indica* of Nagpur, Maharashtra (India). Journal of Environmental Research and Development. 2011;5:542-550.
28. Crane E. From honey- A comprehensive survey. London: Heinemann, 1979.
29. Czipa N, Borbely M, Gyori Z. Proline content of different honey types. Acta Alimentarius. 2011;41:26-32.
30. Dobrinas S, Matei N, Soceanu A, Birghila S, Popescu V. Estimation of vitamin C and Cd, Cu, Pb content in honey and propolis. Science Research. 2006;7:729-734.
31. Dzugan M, Sowa P, Kwasniewska M, Wesolowska M. Physicochemical parameters and antioxidant activity of bee honey enriched with herbs. Plant Foods for Human Nutrition. 2016;72:74-81.
32. Escuredo O, Dobre I, Fernandez-Gonalez M, Sejio MC. Contribution of botanical origin and sugar consumption of honeys on the crystallization phenomenon. Food Chemistry. 2014;149:84-90.
33. Fallico B, Arena E, Verzera A, Zappala M. The European Food Legislation and its impact on honey sector. Accreditation and Quality Assurance. 2006;11:49-54.
34. Finola MS, Lasagno MC, Marioli JM. Microbiological and chemical characterization of honeys from Central Argentina. Food Chemistry. 2007;100:1649-1653.
35. FSSAI. Food Safety and Standard Authority of India, 2018. https://foodsafetyhelpline.com.
36. Gairola A, Tiwari P, Tiwari JK. Physico-chemical properties of *Apis cerana indica* F. honey from Uttarkashi district of Uttarakhand, India. Journal of Global Biosciences. 2013;2:20-25.
37. Gaur RD, Tiwari P, Tiwari JK, Rawat DS. Physico-chemical properties of some unifloral and multifloral honeys from Garhwal Himalaya, Uttarakhand, India. International Journal of Basic and Applied Sciences. 2014;3:142-148.
38. Geronimo JD, Fritz R. Proline in Argentine honeys. International Apicultural Congress. 2001;37:377-382.
39. Gheldof N, Engeseth NJ. Antioxidant capacity of honeys from various floral sources based on the determination of oxygen radical absorbance capacity and inhibition of *in vitro* lipoprotein oxidation in human serum samples. Journal of Agriculture and Food Chemistry. 2002;50:3050-3055.
40. Gomes S, Dias GL, Moreira LL, Rodrigues P, Estevinho L. Physicochemical, microbiological and antimicrobial properties of commercial honeys from Portugal. Food Chemistry and Toxicology. 2010;48:544-548.
41. Gomez JAB, Garcia-Villanova, RJ, Elvira GS, Rivas P, Gonzalez AMP. Geographical discrimination of honeys through the employment of sugar patterns and common chemical quality parameters. European Food Research Technology. 2000;210:437-444.
42. Gupta N. Physico-chemical variations in honey from different agroclimatic zones of Himachal Pradesh. M.Sc. Thesis. Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Solan, 2019.
43. Iftikhar F, Mahmood R, Islam N, Sarwar G, Masood MA,

Shafiq H. Physicochemical analysis of honey samples collected from local markets of Rawalpindi and Islamabad, Pakistan. American Journal of Biochemistry 2014;4:35-40.
44. Iftikhar F, Masood MA, Waghchoure ES. Comparison of Apis cerana, *Apis dorsata*, *Apis florea* and *Apis mellifera*: Honey from different areas of Pakistan. Asian Journal of Experimental Biological Sciences. 2011;2:399-403.
45. Jafar K, Haidar J, Kuraydiyyah S, Ghaddar T, Knio K, Ismail B. Physicochemical, melissopalynological and antioxidant properties of artisanal honeys from Lebanon. Journal of Food Science and Technology. 2017;54:2296-2305.
46. Jilani IB, Schweitzer P, Khouja ML, Zouaghi M, Ghrabi Z. Physicochemical properties and pollen spectra of honeys produced in Tunisia (Southwest of Kef). Apiacta, 2018;3:8-48.
47. Joshi SR, Pechhacker H, Willam A, Ohe WV. Physico-chemical characteristics of *Apis dorsata*, *A. cerana* and *A. mellifera* honey from Chitwan district, Central Nepal. Apidologie. 1999;31:367-375.
48. Kakade PS, Deokule SS. Quality analysis of commercial honeys in Indian market. International Journal of Current Research. 2011;3:33-36.
49. Karabagias IK, Halatsi EZ, Karabournioti S, Kontakos S and Kontominas MG. Impact of physicochemical parameters, pollen grains, and phenolic compounds on the correct geographical differentiation of fir honeys produced in Greece as assessed by multivariate analyses. International Journal of Food Properties. 2017;20:520-533.
50. Kasperova J, Nagy J, Popelka P, Dicakova Z, Nagyova A, Mala P. Physico-chemical indicators and identification of selected Sloval honeys based on colour measurement. Acta Veterinary Brno. 2012;81:57-61.
51. Kaushik R. Effect of storage conditions on the quality of honey. M.Sc. Thesis. Department of Entomology, Dr. Y S Parmar University of Horticulture and Forestry, Solan, 1988.
52. Kavapurayil JB, Karalam S, Chandran RP. Analysis of physicochemical, biochemical and antibacterial properties of Indian honey samples with special reference to their non-conformity. Acta Alimentarius. 2013;43:9-18.
53. Kesio A, Mazalovic M, Crnkic A, Catovic B, Hadzidedic S. The influence of L-Ascorbic acid content and total antioxidant activity of bee honey. European Journal of Scientific Research. 2009;32:95-101.
54. Khaledi EM, Sanchez JL, Bakhouche A, Rezaei MH, Sadeghian I, Carretero AS. Physicochemical properties and biological activities of honeys from different geographical and botanical origins in Iran. European Food Research and Technology. 2016;243:1019-1030.
55. Khan SJ, Shafique M, Kausar S, Nawaz S, Salariya AM, Ejaz N. Study of physiochemical ntgcharacteristics and pollen spectrum of honey available in Lahore. Pakistan Journal of Biochemistry and Molecular Biology, 2009;42:58-62.
56. Kierecci AD, Kierecci OA. Examination of some biochemical properties of honeys in Mutki (Bitlis-Turkey). Journal of Agriculture and Natural Resources. 2018;21:936-943.
57. Krishnasree V, Ukkuru M. Quality evaluation of Indian bee (*Apis cerana indica* F.) honey in perception to enhance market potentiality. Asian Journal of Dairy and Food Research. 2015;34:243-246.
58. Kucuk M, Kolayli S, Karaoglu S, Ulusoy E, Baltac C, Canadan F. Biological activities and chemical composition of three honeys of different types from Anatolia. Food Chemistry. 2007;100:526-534.
59. Kulkarni S, Mahakalkar A, Godghate S. Qualitative analysis of summer honey of *Apis florea* from Nagpur region. Indian Streams Research Journal. 2012;2:1-5.
60. Kumar HM, Ananda AP, Vishwanathan D, Siddadangaiah. Study of physicochemical parameters and antioxidant in honey collected from different locations of India. International Journal of Pharmaceutical and Life Sciences. 2013;4:3159-3165.
61. Leightori AE. Honey: Color deterioration; influence of processing and other factors. Gleanings in Bee Culture. 1957;85:406-407.
62. Lullah-Deh JA, Khan ME, Eneji IS. Physicochemical characteristics of honey samples from Mambilla Plateau, Nigeria. Journal of Biomaterials. 2018;2:7-11.
63. Mahawi SZA, Gadkariem EA, Ayoub SMH. Determination of C vitamin and some essential trace elements (Ni, Mn, Fe, Cr) in bee products. Acta Chimica Slovenica. 2009;51:169-175.
64. Mahmoudi R, Zare P, Tajik H, Shadfarb S, Nyiazpour F. Biochemical properties and microbial analysis of honey from North-Western regions of Iran: Seasonal effects on physicochemical properties of honey. African Journal of Biotechnology. 2012;11:10227-10231.
65. Manzoor M, Shah GHN, Mathivanan V, Mir GM, Visabhanayakayam S. Chemical analysis of honey of *Apis cerana* F. and *Apis mellifera* from plains of Jammu and Kashmir and Tamil Nadu. International Journal of Agricultural Science Research. 2013;3:139-146.
66. Marvin GE. Methods for determining the weight per gallon of honey. American Bee Journal. 1933;73:426-428.
67. Mbiri A, Onditi A, Oyaro N, Murago E. Determination of essential and heavy metals in Kenyan honey by atomic absorption and emission spectroscopy. Journal of Agricultural Science Technology. 2011;13:1-10.
68. Milum VG. Honey: Color, flavor and aroma. Gleanings in Bee Culture 1957; 84:598-601.
69. Molan PC. Reintroducing honey in the management of wounds and ulcers-theory and practice. Ostomy Wound Management. 2002;48:28-40.
70. Moniruzzaman M, Chowdhury MA, Rahman MA, Sulaiman SA, Gan SH. Determination of mineral, trace element, and pesticide levels in honey samples originating from different regions of Malaysia compared to Manuka honey. BioMed Research International, 2014, 1-11.
71. Moniruzzaman M, Khalil MI, Sulaiman SA, Gan SH. Physicochemical and antioxidant properties of Malaysian honeys produced by *Apis cerana*, *Apis dorsata* and *Apis mellifera*. BMC Complementary and Alternative Medicine. 2013;13:43.
72. Moujanni A, Terrab A, Eddoha R, Nasser B, Benbachir M, Chaouqy NE, Bouzid T, Essamadi AK. Microbiological quality of morroccan labelled *Euphorbia resinifera* honey. Journal of Microbiology, Biotechnology and Food Sciences. 2017;6:1188-1194.
73. Muli E, Munguti A, Raina SK. Quality of honey harvested and processed using traditional methods in

rural areas of Kenya. Acta Veterinaria Brno. 2007;76:315-320.
74. Nayik GA, Nanda V. Physico-chemical, enzymatic, mineral and colour characterization of three different varieties of honeys from Kashmir valley of India with a multivariate approach polish. Journal of Food and Nutrition Sciences. 2015;65:101-108.
75. Oddo LP, Piro R. Main European unifloral honeys: Descriptive sheets. Apidologie. 2004;35:38-81.
76. Osman KA, Al-Doghairi MA, Al-Rehiayani S, Helal MID. Mineral contents and physicochemical properties of natural honey produced in Al-Qassim region, Saudi Arabia. Journal of Food, Agriculture and Environment. 2007;5:142-146.
77. Parihar A, Thakur M, Rana K, Devi S. Quality analysis of *Apis cerana* and *Apis mellifera* honey from Himachal Pradesh, India. Journal of Entomology and Zoological Studies. 2020;8:46-54.
78. Pasias IN, Kiriakou IK, Proestos C. HMF and diastase activity in honeys: A fully validated approach and a chemometric analysis for identification of honey freshness and adulteration. Food Chemistry 2017;229:425-431.
79. Petrov V. Qualitative determination of amino acids in some Australian honeys, using paper chromatogrphy. Journal of Apicultural Research. 1971;10:153-157.
80. Pontis JA, Costa LM, Silva SR, Flach A. Color, phenolics and flavonoid content, and antioxidant activity of honey from Roraima, Brazil. Food Science and Technology. 2014;34:69-73.
81. Prica N, Balos MZ, Jaksic S, Mihaljev Z, Kartalovic B, Babic J. Moisture and acidity as indicators of the quality of honey originating from Vojvodina region. Archives of Veterinary Science and Medicine. 2014;7:99-109.
82. Pryce-Jones J. The composition and properties of honey. Bee World. 1950;3:2-6.
83. Puusepp L, Koff T. Pollen analysis of honey from the Baltic region, Estonia. Grana. 2014;53:54-61.
84. Qamer S, Ahmad F, Latif F, Ali SS, Shakoori AR. Physicochemical analysis of *Apis dorsata* honey from Terai forests, Nepal. Pakistan. Journal of Zoology. 2008;40:53-58.
85. Rebiai A, Lanez T. Comparative study of honey collected from different flora of Algeria. Journal of Fundamental and Applied Sciences. 2014;6:48-55.
86. Rehman S, Khan ZF, Maqbool T. Physical and spectroscopic characterization of Pakistani honey. Ciencia e Investigacion Agraria. 2008;35:199-204.
87. Rodriguez GOD, Ferrer BSD, Ferrer A and Rodriguez B. Characterization of honey produced in Venezula. Food Chemistry. 2004;84:499-502.
88. Sahney M, Kumar A. Physiochemical and mineral analysis of honey samples from Varanasi district. International Journal of Pharma and Bio Sciences. 2017;8:160-166.
89. Saxena S, Gautam S, Sharma A. Physical, biochemical and antioxidant properties of some Indian honeys. Food Chemistry. 2010;118:391-397.
90. Shahnawaz M, Sheikh SA, Hussain M, Razaq A, Khan SS. A study on the determination of physicochemical properties of honey from different valleys of Gilgit-Baltistan. International Journal of Agricultural Science Research. 2013;2:49-53.
91. Sharma A. Physico-chemical analysis of some honeys from North-west Himalayas. Ph.D. Thesis. Himachal Pradesh University, Shimla, India, 1998.
92. Shobham, Chitluri KK, Nayar J. Physico-chemical analysis of some commercial honey samples from Telangana. Indian Journal of Nutrition. 2017;4:1-4.
93. Sohaimy SA, Masry SHD, Shehata MG. Physico-chemical characteristics of honey from different origins. Annals of Agricultural Sciences. 2015;60:279-287.
94. Teka AE. Levels of some selected trace and essential elements in honey from selected wore as of sidama zone, southern region, Ethiopia. Journal of Agricultural Science and Botany. 2018;2:12-18.
95. Terrab A, Die MJ. Palynological, physicochemical and colour characterization of Moroccan honeys: I. Rever redgum (*Eucalyptus camaldulensis* Dehnh) honey. International Journal of Agricultural Science Research. 2003;38:379-380.
96. Terrab A, Diez MJ, Heredia FJ. Characterisation of Moroccan unifloral honeys by their physico-chemical characteristics. Food Chemistry. 2002;79:373-379.
97. Terrab A, Escudero ML, Gonzalez-Miret ML, Heredia FJ. Colour characteristics of honeys as influenced by pollen grain content: a multivariate study. Journal of the Science of Food and Agriculture. 2004;84:380-386.
98. Thakur B. Physico-chemical and microbial status of honey of *Apis dorsata* F. and *Apis florea* F. M.Sc. Thesis. Department of Entomology, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan, 2020.
99. Tornuk F, Karaman S, Ozturk I, Toker OS, Tastemur B, Sagdic O. Quality characterisation of artisanal and retail Turkish blossom honeys: Determination of physicochemical, microbiological, bioactive properties and aroma profile. Industrial Crops and Products. 2013;46:124-131.
100. Townsend GF. Preparation of honey for market. Ontario Department of Agriculture and Food, 1970, 544.
101. Trstenjak NU, Puntaric D, Levanic D, Gvozdic V, Pavlek Z, *et al*. Pollen, physicochemical, and mineral analysis of *Croatian acacia* honey samples: Applicability for identification of botanical and geographical origin. Journal of Food Quality, 2017, 1-11.
102. Venugopal S, Devarajan S. Estimation of total flavonoids, phenols and antioxidant activity of local and New Zealand manuka honey. Journal of Pharmaceutical Research. 2010;4:464-466.
103. Vranic D, Petronijevic R, Stojanovic JD, Koricanac V, Milijasevic JB, Milijasevic M. Physicochemical properties of honey from Serbia in the period 2014-2016. Earth and Environmental Sciences. 2017;85:1-6.
104. Wang CW, Chen WT, Chang HT. Quantification of saccharides in honey samples through surface-assisted laser desorption/ionization mass spectrometry using HgTe nanostructures. Journal of the American Society for Mass Spectrometry. 2014;25:1247-1252.
105. White JW, Doner LW. Honey composition and properties. Beekeeping in the United States Agriculture Handbook. 1980;335:82-91.
106. White JW. Honey. In: The hive and the honey bee (Grout RA ed.). Hamilton, IL: Dadant and Sons. 1975, 625-646.
107. Yadata D. Detection of the electrical conductivity and acidity of honey from different areas of Tepi. Food Science and Technology. 2014;2:59-63.