Comparison Analysis of Honeydew Honey Production and Quality in Fujairah, U.A.E and Other Regions of the World: A Review

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Abstract:- The honey that is produced by the bees using excretions of plant-sucking insects (Hemiptera) is called honeydew honey. The main differentiating factors of blossom honey and honeydew honey are the sugar composition and electrical conductivity. The higher fructose contents and electrical conductivity makes honeydew honey better than other types of honey. Honeydew honey has a rich composition of nutrients in its content and can be a dietary supplement and has therapeutic uses, besides antioxidant and antimicrobial properties. Few countries in the world especially Turkey, Greece, Germany, Spain, and Bulgaria, have the necessary environmental conditions for producing this rare type of honey. In the United Arab Emirates, among ten honey samples harvested in different regions of the Emirate of Fujairah, all can be considered honeydew honey showing average electrical conductivity higher (1.4030 mS/cm) compared to foreign samples (1.0968 mS/cm). Furthermore, fructose, glucose, and inverted sugars are similar to the levels of monosaccharides found in honeydew honey samples studied in other countries.

Keywords:- *beekeeping in UAE; honeydew; honeydew honey in UAE; electrical conductivity in honeydew honey; honeydew honey composition.*

I. INTRODUCTION

Research on honey and its constituents has a long tradition. It has been an essential ingredient in Emirati households and hence one of the biggest user and producer of this miracle syrup(Afifi et al., 2021). Needless to say, honey produced in UAE is one of the best honey in the world based on previous studies, which raises the question, what makes it better than other few in the list. In our investigation led analysis, we reported in this paper that the honey produced in UAE, emirates of Fujairah, is the honeydew honey. This study also provides an in-depth review of dietary and therapeutic importance of honeydew honeyand its production in various other regions of the world.

Excretions of plant-sucking insects (Hemiptera) who feed on the secretions of plants, excluding nectar, are the main source of Honeydew honey (Thrasyvoulou, 2006). Honeydew honeyis considered a delight around the world because of its unique taste and composition and represents an economically important non-wood forest product.(Yilmaz et al., 2018).

II. THE HONEYDEW SECRETIONS AND HONEYDEW HONEY PRODUCTION

The honeydew honey can present a mix with various amounts of nectar honey (Victorita et al., 2008). It is differentiated honey from the complex result of the association between plants, sucking insects, and bees. Phloem sap, which transports nutrients to the tissues of a plant, is inaccessible to bees unless an injured surface occurs under pressure inside. Some plant-sucking insects have buccal parts that can penetrate plant surfaces.

The sap of the phloem is then forcibly pulled out through the bite by internal pressure, and it increases by the pumping of the insect itself. The fluid crosses from the buccal parts of the insect to the digestive tract, allowing the insect to have a large amount of well-diluted food every few hours, which may correspond many times to the weight of the insect itself. Surplus food is found in leaves, flower buds, and stems in tiny droplets, known as honeydew(Türkçe et al., 2009).

Honeydew droplets excreted by sucking pests are influenced by leaf nutrient composition, plant conditions, water stress, and temperature (Ahmed Zia et al., 2016). As a result, honeydew production varies considerably between aphid species or when feeding on different host plants (Fischer et al., 2005). In addition, the intensity of honeydew flows varies significantly from year to year according to the annual population growth of honeydew-producing insects, which is very sensitive to environmental factors (Crane & London, 1986).

Honeydew production by Hemiptera is an essential ecological function, have been the honeydew a food source for different animals, including the own aphids, birds, geckos, ants, bees, wasps, fruit flies, snails, cockroaches, moths, and hoverflies (Moir et al., 2018).

Phloem sap is a potentially super food for some animals because of its ‘pre-digested’ contents providing abundant carbon, amino acids and energy and higher concentrations of sugar(Douglas, 2006).For honeydew honey production, *Apis mellifera* bee foragers collect honeydew from plants, carry them using their honey sac, and bring it to their colony(Bogdanov, 2011).

III. PHYSICO-CHEMICAL PROPERTIES OF HONEYDEW HONEY

Higher fructose contents than glucose keeps it from crystallization (Bobis et al., 2008; Campos et al., 2003; Kaškoniene et al., 2010; Olga et al., 2012; Seraglio et al., 2019). According to the current EU honey standard, the F+G (fructose and glucose) minimum value for blossom honey should be 60g/100g, while for honeydew honey, it is 45g/100g (Barbattini et al., 2001; Bogdanov et al., 1999; Cavia et al., 2002; Manikis et al., 2011; Puścion-Jakubik et al., 2020a).Similarly, it represents higher values of electrical conductivity, polysaccharides (oligosaccharides, disaccharides, trisaccharides), pH, net absorbance, ashes percentage, and lower level of monosaccharides, moreover, darker colour and distinctivephysicalquality compared to blossom honey (Atanassova et al., 2016; Bacandritsos, 2004; Nešović et al., 2020; Olga et al., 2012; O. L. Persano & Piro, 2004; Primorac et al., 2009; Purcărea et al., 2014; Seraglio et al., 2019; Yurukova et al., 2008).

Electrical conductivity less than 0.8 mS/cm indicates blossom honey and more than 0.8 mS.cm indicates honeydew honey (Shaaban et al., 2021; Thrasyvoulou et al., 2018).

For decades, one of the most popular questions sought after are related to the therapeutic benefits of the honey. Phenols and phenolic acids define the antioxidant capacity of the honey. honeydew honeyhas the higher antioxidant capacities as compared to blossom honey to inhibit the development of colonies of different species of bacteria(Bogdanov, 1997, 2016; Živkov Baloš et al., 2019). In previous studies, honeydew honey has shown exceptional antibacterial activity against multi-drug resistant *S. maltophilia*, isolates from cancer patients(Majtan et al., 2011; Olga et al., 2012; Recklies et al., 2021; Urcan et al., 2021).

Based on the valuable characteristics, The First International Symposium on the development and production of honeydew honey was held in Tzarevo, Bulgaria, in 2008(Georgiev & Borisov Mirchev, 2008).

IV. THE HONEYDEW HONEY PRODUCER REGIONS AROUND THE WORLD AND INVOLVEDMAJOR PLANTS AND INSECTS

Following the complexity of factors involved in the secretion of honeydew and then honeydew honey production, only a few regions in the world have environmental conditions allowing to produce this kind of honey.

Turkey is the biggest producer of honeydew honey in the world specifically West Mediterranean and South Aegean regions. It is producing around 15,000 tons/year which represents the 30-50% of total honey produced in Turkey(Miguel et al., 2014; Yilmaz, 2016). Turkey produced 107.920 and 109.330 tons of natural honey in 2018 and 2019, respectively(Bradbear, 2009; Özkök et al., 2018; Unal et al., 2017).

The most significant production of honeydew honey is from forests as a result of the interaction between pines *(Pinus brutia* Ten., *Pinus halepensis* Miller, *Pinus nigra* J. F. Arnold.) and sap-sucking insects (*Marchalina hellenica* Gennadius)(Silici & Karaman, 2014). In the World, Turkey is the 2nd country for honey production after China and 3rd for bee colony after India and China.Turkey can increase its exportation of honey by improving the production of geographically identified pine honey (honeydew honey), protecting the pine area within Aegean Region, which is the foremost resource for beekeeping activity, and protecting *Marchalina hellenica* living within this area(Özkök et al., 2010; Seijo et al., 2019).

Greece is producing significant amount of honeydew honey which makes up 65% of its total honey production, which is on average 22.288 tons/year (FAOSTAT, 2021). This honeydew honey production comes from *Pinus* spp. (60 %) and *Abies* spp. (5 %). The insects which produce honeydew on Pinus are *M. hellenica*, *C. palaestinensis*, and *C. close pini*(Crane & London, 1986; A. Santas, 2017; L. A. Santas, 1983, 2017; Thrasyvoulou & Manikis, 1995; Thrasyvoulou Manikis, 1995; Tsigouri et al., 2004) .

In Bulgaria, honeydew honey is produced mainly in Strandzha Mountain. The forestry area of the Bulgarian part of Strandzha is 219 920 ha(Georgiev & Borisov Mirchev, 2008).

The honeydew honey produced in this region is received from the European Union, since 2019 the certificate of register of protected designations of origin and protected geographical indications(Marinova et al., 2015). The honeydew honey production is based on a relationship between five species of sap-sucking insects: Linnaeus (*Lachnus roboris)*, Hartig (*Lachnus pallipes and Tuberculatus annulatus)*(Hemiptera: Aphididae), Monell ex Riley & Monell (*Monelliopsis caryae)* and Kaltenbach (*Tuberculatus querceus)*andthe host plants: oaks (*Quercus* spp.) (Atanassova et al., 2016; Bankova et al., 2012; Gerginova et al., 2020; Ülgentürk et al., 2020).

The primary production of honeydew honey in Poland occurs in Podkarpacie Region and Świętokrzyskie Mountains, southern and south-eastern Poland. The relationship between the coniferous species plant Abies *alba* and the sap-sucking insect *Cinara pectinatae* (Nördl.) results in production of the primary type of honeydew honey every two years in Poland (Crane & London, 1986; Podgórska, 2019; Rybak-Chmielewska et al., 2013).

Typically, the high phloem pressure produces honeydew secretion in Spanish oak forests during the summer in the presence of moderate humidity. Different species of oaks secrete large amounts of sweetened phloem sap through their fruits used by bees and taken to hives and transformed into dark honeydew honey(Terrab et al., 2019). Honeydew honey is more frequently harvested by beekeepers in the northwest region of the Iberian, from the honeydew mainly produced by oaks: *Quercus ilex* , and *Quercus pyrenaica* (Nogueira et al., 2021; Seijo et al., 2019; Shantal & Flores, 2015).

In Brazil, commercial honeydew honey production takes place in the states of the southern region of Brazil(Lisboa, 2015; Wiese & Salomé, 2020).Honeydew honey is produced from the stem of "bracatinga" *(Mimosa scabrella* Benth) and 'ingá' (*Inga sp*) every two years from January to April, which is a time corresponds to the scale insect life cycle (Campos et al., 2003).

There is evidence of the association of *Stigmacoccus. paranaensis* and *Mimosa scabrella* Benth with the production of honeydew corroborated by the presence of nymphs in the cyst stage and adults of the insect, with an interval of about two years, where the bees collect the honeydew, transport to the hives, and produce the honeydew honey (Dortzbach et al., 2020; Fischer et al., 2005).

On the stem of the *Mimosa scabrella* tree, the insects, mainly ants, when collecting the honeydew, spread residues on the bark, forming a medium of culture for a fungus of the genus *Capnodiun*, popularly known as sooty mold, which blackens the stems of the most extended attacked trees(Tomo Homopteros, 1942).

Abies and metcalfa honeydew honey are two kinds of honeydew honey that have been characterized and studied in Italy(Grego et al., 2016). Abies honeydew honey production is limited to theApennines and alps of the Tuscany. The colour of this honey is particularly greenish(L. Persano et al., 1995). The secretions of Metcalfa *pruinosa* are the main source of metcalfa honeydew honey. Metcalfa *pruinosa*was introduced in Europe in the 1970s which later spread to France, Slovenia, and Italy. Its attacks on plants particularly in summertime, gives rise to significant quantities of uniflora honey. As a result, the colour of honeydew honey is significantly dark(Barbattini et al., 2001).

Spruce (*Picea abies*) and fire tree (*Abies alba*) are the main plant species in France to produce honeydew. Metcalfa honeydew honey is being harvested since 1985 from the valley of Rhône. France is ranked as fourth amongst European countries to produce honeydew honey with a forest surface of 155 000 km². The French forests cover 28.2% of the total country: oaks represent 25% of this surface, pruce 8%, beech 11%, fir tree 7%, maritime pine 8%and Scots pine 6%. The honeydew honey producing regions are Massif Central, Alsace, Vosges, Jura, Southeast, Alsace, the Alps, Haute Loire,the Pyrenees and Corsica (O. L. Persano et al., 2004; O. L. Persano & Piro, 2004).

The most abundant honeydew honey production in Romania is in the mountain and hills regions under the Carpathians chain (Purcarea et al., 2016). According to basic physical-chemical and biochemical parameters, the honeydew honey from Romania is considered authentic honeydew honey, rich in antioxidant components such as total phenols, flavonoids, and ascorbic acid(Bobis et al., 2008; Purcărea et al., 2014).

From 2006, Slovenia registered protection of geographical indications and designations of origin for honeydew honey produced in the country. The identification of forest honey or honeydew honey is for honey produced with characteristicssuch as aroma, which is medium duration to long-lasting, and its taste is long-lasting(Kačániová et al., 2011; Tomczyk et al., 2019). In addition, this honeydew honey has physicochemical properties with sucrose content < 5g/100g, pH: 4,3-5,6, and electrical conductivity ≥ 0,8 mS/cm (Bogdanov, 2006; Saitanis, 2006; Vorlova et al., 2006).

V. COMPARISON OF PHYSICO-CHEMICAL PROPERTIES OF HONEYDEW HONEY OF EMIRATE OF FUJAIRAH, UAE ORIGIN WITH OTHER COUNTRIES

Honey produced in the years 2018, 2019, 2020, and 2021 in different regions of the Emirate of Fujairah – UAE (Dibba, Fujairah, Ohala, Tawiyan) were sent to "German Laboratories" in Germany to check mainly fructose, glucose, invert sugar contentsand electrical conductivity. The fructose content in 10 samples produced in UAE (samples 31-40; Table 1, Figure 1) presents the average value of 36.4900 g/100g ± 1.7866. The averagevalue of the 13 samples (samples 1; 11-12; 16; 18-21; 23; 25-28; Table 1) studied in different countries around the world calculated as 34.7485 g/100g ± 3.6222. Both the values indicate similar fructose contents statistically, presenting a P0.05-value: 0,0823.

Similarly, the analysis of glucose contents in samples from Fujairah-UAE and other countries indicated similar average values calculated as 27.2100 g/100g ± 4.5160 and 26.6562 g/100g ± 3.0861, respectively with P0.05-value: 0,3669.

Fructose and glucose were the major monosaccharides in all honeydew honey evaluated, with content ranging between 28.2 and 48.3 g /100 g and 21.7 to 37.7 g /100 g, respectively (Seraglio et al., 2019).

Among the ten samples of honeydew honey from UAE, the amplitude observed in terms of fructose content was 32,6 g/100g, between the maximum 38.5 g/100g in the sample (sample 32 - Table 1, Figure 1) produced in the region of Dibba - 2021 and the minimum 32.6 g/100g in the sample (35- Table 1) produced in Ohala - 2018. On the other hand, the glucose content presented an amplitude of 17,6 g/100g between the maximum 31.8 g/110g in the sample (sample 33 – Table 1) produced in Fujairah – 2020 and the minimum 17.6 g/100g in the sample (sample 35- Table 1, Figure 1) produced in Ohala – 2018.

In 13 samples searched in literature, the amplitude of fructose content was 16.20 g/100g between the maximum level (43.8 g/100g – sample 20, Table 1) and the minimum level (27.6 g/100g – sample 16, Table 1). On the other hand, the amplitude of glucose level was 11.40 g/100g, being the maximum 30.7 g/100g in sample 11 and the minimum 19.3 g/100g in sample 16 (Table 1).

The invert sugar content (fructose + glucose) shows a higher content of fructose than glucose in all samples evaluated. Fructose predominates the glucose in nearly all honey samples, except few, such as such as rape honey, which appear to contain more glucose than fructose. The permissible value of the concentration of the invert sugar shouldn't be < 45 g /100 g (Kivrak et al., 2017; Palacios et al., 2019; Srećković et al., 2019).

By comparing results from previous studies, the invert sugar contents present the similar values between UAE samples and the samples from other countries with P0.05-value=0.1038. Further analysis indicates the average value for invert sugar content for Fujairah, UAE samples and other countries, as 63.70 g/100g ± 6.2082 and 61.27 g/100g ± 6.5050, respectively. Honey contains organic acids and minerals, an aqueous solution that can dissociate into ions or conduct electric power (Živkov Baloš et al., 2018). This property of honey is considered an excellent criterion for assessing honey's botanical origin and purity.

Table 1: Values of sugar content (F; G; F+G (g/100g)) and electrical conductivity (mS/cm) in honeydew honey samples produced from different geographical origins.

Number	Geographical Origin	Sample Collection (year)	Fructose (F) Content (g/100g)	Glucose (G) Content (g/100g)	Invert Sugar Content (g/100g)	Electrical Conductivity (mS/cm)	Reference
1	Brazil	2018	36,5	23,3	59,9	1,40	Bergamo et al, 2019
2	Bulgaria	2008-13				0,97	Balkanska & Ignatova, 2014
3	Bulgaria	2000-04				0,86	Dinkov, 2007
4	Bulgaria	2005-06				0,94	Dinkov, 2007
5	Bulgaria	2007				1,04	Yurukova et al, 2008
6	Bulgaria	2007				0,85	Yurukova et al, 2008
7	Bulgaria	2009-15				0,99	Marinova et al, 2015
8	Bulgaria	2009-15				0,96	Marinova et al, 2015
9	Bulgaria	2016				1,05	Atanassova et al, 2016
10	Bulgaria	2007				1,44	Yurukova et al, 2008
11	Croatia	2009	32,7	30,7	63,4	0,98	Primorac et al, 2009
12	[1]Europe	1990-2002	[2]32,5	[2]26,2	[2]58,7	[2]1,20	Persano Oddo & Piro, 2004
13	Germany	2021				1,21	Recklies et al, 2021
14	Greece	2004				1,15	Dimou et al, 2006
15	Greece	2004				1,40	Dimou et al, 2006
16	Greece	2000	27,6	19,3	46,9	1,31	Bacandritsos et al, 2006
17	Greece	2004			48,5	1,30	Bacandritsos et al, 2004
18	Montenegro	2017	36,35	29,48	65,8	1,03	Nesovic et al, 2020
19	Poland	2006-07	34,2	27,8	62,0	1,14	Rybak-Chmielewska et al, 2013
20	Poland	2012-13	43,8	25,5	69,4	1,02	Purcarea et al, 2014
21	Poland	2015	34,67	29,10	63,7	0,82	Tomczyk et al, 2019
22	Romania	2008				0,84	Marghitas et al, 2008
23	Romania	2012-13	36,3	28,4	66,0	0,94	Purcarea et al, 2014
24	Serbia	2017				1,12	Balos et al, 2018
25	Serbia	2019	35,41	29,35	64,7	1,22	Balos et al, 2019
26	Spain	2014	32,5	24,7	67,2	1,00	Jara-Palacios et al, 2019
27	Spain	2019	35,4	27,2	62,4	1,00	Seijo et al, 2019
28	Swiss	2006	33,8	25,5	59,3	1,04	Bogdanov & Gfeller, 2006
29	Turkey	2018				1,41	Ozkok et al, 2018
30	Turkey	2014				1,31	Kivrak et al, 2017
31	UAE/Dibba	2020	36,0	29,2	65,2	0,90	*"German Laboratories", 2021a
32	UAE/Dib	2021	38,5	30,0	68,5	1,50	*"German

	ba						Laboratories", 2021b
33	UAE/Fujairah	2020	37,3	31,8	69,1	0,91	*"German Laboratories", 2021c
34	UAE/Fujairah	2021	37,8	29,9	67,7	1,62	*"German Laboratories", 2021d
35	UAE/Ohala	2018	32,6	17,6	50,2	1,20	*"German Laboratories", 2021e
36	UAE/Ohala	2019	35,8	24,7	60,5	1,97	*"German Laboratories", 2021f
37	UAE/Ohala	2020	36,5	25,8	62,3	1,75	*"German Laboratories", 2021g
38	UAE/Ohala	2021	37,5	30,4	67,9	1,62	*"German Laboratories", 2021h
39	UAE/Tawiyan	2018	34,8	22,4	57,2	1,22	*"German Laboratories", 2021i
40	UAE/Tawiyan	2021	38,1	30,3	68,4	1,34	*"German Laboratories", 2021j
41	Uruguay	2018				1,06	*"German Laboratories", 2021

[1]21Countries; [2]Mean. * "German Laboratories"- Name given to the laboratory in Germany responsible for carrying out physico-chemical analyzes on honey samples produced in UAE.

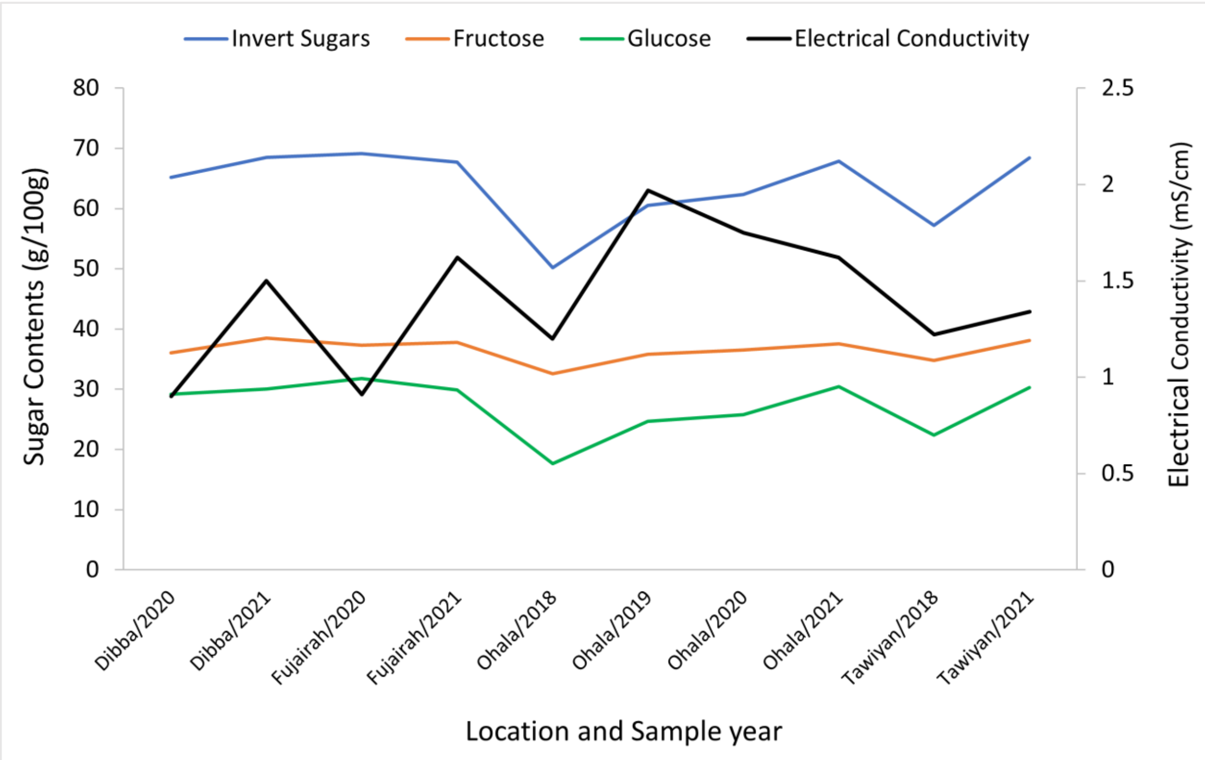

Fig. 1: The comparison of Sugar contents (y-axis left) and Electrical conductivity (y-axis right) for the different sample collected at different years and locations from emirates of Fujairah, UAE. The comparison indicates the quality of the honey can significantly change based on environmental factors (we suppose) even in a single region

Electrical conductivity is the widely used parameter to distinguish between blossom or honeydew honey and in honey quality control (Bogdanov, 2006; Sancho et al., 1991). According to the EU honey standard, the electrical conductivity of blossom honey should lie below 0,8 mS/cm while that of honeydew honey should exceed that value(Nešović et al., 2020; Puścion-Jakubik et al., 2020b; Shaaban et al., 2021; Subbiah et al., 2015).

The electrical conductivity of samples from UAE showed the average value of 1.4030 mS/cm ± 0,3528.This indicates significantly better results as compared to the samples of other regions which shows the average value of 1.0968 mS/cm ± 0.1811 with P0.05-value=0,0001, with the difference of 0.3062mS/cm. The whole population of samples shows the variance as 9.61 (Table 1, Figure 1).

The investigations showed the higher electrical conductivity reported for the honeydew honeysample produced in Ohala desert - UAE with value 1.97 mS/cm. According to the analysis report (report nº 2106220585;

supplementary materials) of "German Laboratories" based on the interpretation of the result of electrical conductivity for the sample 2 -2019 (sample 36 – Table 1), the given samples can be called as "Honeydew Honey".

It is worth discussing that the UAE samples itself showed varied level of electrical conductivity based on production year and region. For example, the honeydew honey produced in Ohala (samples 36-38), in the years of 2019, 2020, and 2021 showed higher levels of electrical conductivity than the samples taken from same region in 2018, and rest of the samples taken from other regions. Similarly, the samples taken in Fujairah in the year 2021 (sample 34) showed significant higher EC of 1.62 than the sample taken in same regions in the year 2020 (sample 33) with EC of 0.91 (Table 1, Figure 1).

VI. CONCLUSION

Sufficient evidence exists mentioning the significant therapeutic benefits and importance in daily use of honeydew honey. Despite the limitations and complexity of factors involved in the production of honeydew honey, it represents major part of total honey production in various regions around the world, including Turkey, Greece, and Bulgaria to name the few.The fructose, glucose contents and electrical conductivity are the essential factors to determine the difference between blossom honey and honeydew honey. Upon our investigation, the ten honey samples produced in different regions of Emirate of Fujairah – UAE can be considered honeydew honey, mainly by similar invert sugar values and significantly higherlevels of electrical conductivitythan the samples studied in traditional producer countries such as Turkey, Greece, Poland, Bulgaria, Germany. However, none of the studies had been done so far specifically regarding the production of this differentiated and valuable type of honey in the Emirate of Fujairah – UAE. We are intending to extend our spectrum of study covering rest of the emirates in UAE and findings can be published as separate research paper.The future investigations are necessary to validate the sources of this honeydew in which the bees are collecting the secretion to take the hives and produce this honey and design and develop future studies on the relationship of host plants and possible sap-sucking insects.

Conflicts of interest: The authors declare that they have no conflict of interests.

Authors' Contributions: JAR designed the project, carried out the practical/ analytical part and defined the first draft of the manuscript. FRL contributed to designing of the project. SBM contributed in the graphical illustration, calculation and editing the final version of the manuscript.

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