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THE INFLUENCE OF WEATHER ON THE QUALITY OF HONEY IN RASINA REGION FOR THE PERIOD OF 2019-2024

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Abstract

The paper monitored the influence of weather conditions (temperature, air humidity, sunshine and rainfall) on the quality of acacia honey, meadow honey and honeydew in the period 2019-2024. from the territory of the Rasin district in Serbia. Weather conditions were monitored both throughout the year and for 30 days during the acacia flowering. The parameters of honey quality were determined according to the methods of the Rulebook on the quality of honey and other bee products (2015). According to this rulebook, the following parameters of honey quality were determined: the amount of water, free acids, reducing sugars, sucrose, substances insoluble in water, hydroxymethylfurfural (HMF), diastase activity and electrical conductivity. When it comes to the weather in this period, two years stand out. One of these was 2024, dry and warm with high temperatures, low humidity and little precipitation. The other is 2023, which was warm and humid, when a high average temperature was measured, but also the highest amount of precipitation and the highest air humidity. After the weather conditions were followed 30 days since the flowering of acacia, we concluded that the year 2022 was the warmest, and that the other parameters were the highest in 2023. The weather conditions, in all three analyzed types of honey, had the greatest influence on the amount of water and the amount of free acids. In 2023, all three types of honey had the most water and the most free acids. Acacia honey had slightly more water in 2021 and less sucrose in 2023. Honeydew has an increased content of free acids and their presence in honey does not depend much on weather conditions.

Keywords: *acacia, meadow honey, honeydew, weather conditions, yield, honey quality.*

Introduction

Honey is a natural sweet liquid created by honeybees by collecting: nectar from flowering plants, exudates from plants (honeydew) or exudates from insects that feed on plants (honeydew). Honey is a complex mixture that contains nutritious compounds and bioactive substances. It mainly consists of carbohydrates (primarily glucose and fructose) and water, and also contains proteins, enzymes, organic acids, amino acids, vitamins, minerals. In addition, it also contains aromatic and fragrant substances, polyphenols, pigments, beeswax and pollen that affect its color, smell and taste. Honey contains over 200 different compounds (Ferreira *et al.*, 2009). Thanks to this composition, in addition to its nutritional properties, honey also has medicinal value, especially when it is used continuously. According to the EU standard (Codex Alimentarius), only the product of the *Apis mellifera* L. honey bee can be called honey (Bradbear, 2009; Buba *et al.*, 2013; Pavlova *et al.*, 2018). Honey division is based on: origin (floral or honeydew), number of plants from which it was collected (monofloral or polyfloral), methods of obtaining (squeezed, pressed, extracted, honeycomb honey, honey in pieces), processing (crystallized, granulated, creamy honey) and according to purpose (table honey and

industrial or bakery honey) (Bradbear, 2009; Alvarez-Suarez *et al.* 2014). Natural honey represents the most complete and highest-quality food for both honey bees and humans.
The chemical composition, physical properties, color, aroma and taste of honey depend primarily on the botanical and geographical origin of the plants from which it was collected. In addition, they also depend on climatic conditions, the types of bees that collect it, as well as on the way of preservation (Pascoal, 2013; Islam *et al.*, 2020), collection, treatment, manipulation, packaging and storage (Pavlova *et al.*, 2018). The quality of honey is also influenced by the altitude at which the apiary is located at the time of honey collection (Bouhala *et al.*, 2020; Turk and Sen 2021; Jevtić *et al.*, 2023). In addition to affecting the activity of plants in nectar secretion (Schweitzer *et al.*, 2013), the amount of honey collected by bees (Solovev, 2020), climatic conditions also affect the quality of the obtained honey (Escuredo *et al.*, 2013).
The goal of this research was to determine how weather conditions (temperature, humidity, sunshine and rainfall) affected the quality of acacia honey, meadow honey and honeydew in the Rasin region in Central Serbia for the period of 2019-2024.

Material and methods

The paper analyzed acacia, meadow and forest honey (honeydew) from the territory of the Rasin region for the period of 2019-2024. The honey was obtained from the area bordered on the east by the Mojsinj Mountains and Jastrebac, on the south and west by the Kopaonik and Goč, and on the north by the Resava Mountains. A total of 180 honey samples were analyzed, 30 per year. Table 1 shows the number of samples for each type of honey by year of research.

Table 1. Number of samples of acacia, meadow honey and honeydew in the period of 2019-2024.

Year	Acacia honey	Meadow honey	Honeydew
2019	11	15	4
2020	13	13	4
2021	23	4	3
2022	22	5	3
2023	18	9	3
2024	21	6	3
Total	108	52	20

Concerning the physico-chemical parameters of honey quality, the following were determined: amount of water, free acids, reducing sugars, sucrose, substances insoluble in water, HMF (hydroxymethyl-furfural) diastase activity, and electrical conductivity. All parameters were determined by appropriate methods according to the Rulebook on the quality of honey and other bee products (Official Gazette of RS, 2015). Each sample was run in three replications. Climatic parameters (temperature, air humidity, sunshine and rainfall) were monitored at the climatic station of the Institute for Forage Crops Kruševac at the Mačkovac-Globoder location. The measuring point of this climate station is located 140 cm above the ground, and readings were taken at every 60 minutes, a total of 24 times a day.
ANOVA was done using computer program Statistica 12.0 (StatSoft) in completely randomised design in three replications.

Results and discussion

Table 2 shows the average values of climatic parameters in the observed period. When it comes to air temperature, two years stand out: 2021, with the lowest average temperature and 2024, with the highest average temperature. Air humidity was very uniform in all of the years and ranged from 71-73% except in 2023. when it was significantly higher (Table 2). There was a similar situation with sunshine, with the note that the highest value was recorded in 2024. When looking at the amount of water sediment, the least amount of rainfall was in 2024 (481 mm). This was also the warmest year. It is interesting to point out that the second warmest year (2023) had the most precipitation. Of the two warmest years, one had the most (2023) and the other had the least precipitation (2024). A lot of precipitation was also recorded during 2020.

Table 1. Average temperature, air humidity, sunshine, total amount of rainfall and yield of honey in Rasin region for the period of 2019-2024.

Year	Temperature (^{0}C)	Air humidity (%)	Sunshine	Total amount of precipitation (mm)
2019	11,98	71,24	30,12	556
2020	11,35	73,64	30,99	788
2021	11,20	71,34	30,79	634
2022	11,52	72,77	30,63	636
2023	12,24	81,82	29,60	821
2024	13,29	71,27	35,41	481
Average	**11,93**	**73,68**	**31,26**	**652,67**

As much as the weather conditions during the year are important for the activity of bees and the yield of honey, they are even more important during the flowering period of acacia. This becomes especially important if it is known that acacia honey makes up 60-70% of the honey produced in Serbia. In some parts of Serbia, bees provide surplus honey exclusively on acacia pasture.

Climatic conditions at the time of acacia flowering were quite different from the annual climates. This is especially characteristic of 2024, the hottest and driest year. This year, due to the early flowering of acacia (already in mid-April), which has never happened until now (personal observation of the author), the lowest temperature and the least amount of sunlight during the period of acacia flowering were measured. But the precipitation was quite sufficient, so almost ¼ of the annual precipitation fell in these 30 days (Table 3).

Table 3. Average temperature, air humidity, sunshine and total amount of precipitation during acacia flowering in Rasin region in the period of 2019-2024.

Time of measuring	Temperature (^{0}C)	Air humidity (%)	Sunshine	Total amount of precipitation (mm)
1.-30.05.2019.	14,58	72,12	38,24	89,2
8.5.-7.6.2020.	15,94	75,48	38,07	125,6
15.5.-14.6.2021.	16,40	69,02	40,95	83,4
10.5-9.6.2022.	19,09	67,42	40,04	112,4
14.5-13.6.2023.	18,59	82,12	43,94	232,0
14.4-14.5.2024.	12,96	67,48	14,68	107,1
Average	**16,26**	**72,27**	**35,99**	**124,95**

In 2023, during the flowering of acacia, was recorded the highest rainfall amount even though the sunshine was the greatest, which is a bit illogical (apparently it rained during the night). In this year, it rained three times more than in 2021, with the least amount of rain during the flowering time of acacia. The acacia honey obtained during this period was of uniform

(excellent) quality (Table 4). All analyzed acacia honey samples met the requirements of both domestic and EU standards. Apart from the amount of reducing sugars, all other analyzed honey quality parameters differed statistically significantly ($p<0.05$) depending on the year they were obtained. The amount of water in acacia honey was the highest in 2023 (rainy) year, and the lowest in 2022 (highest temperature during acacia flowering). Similar to water amount, free acids were the highest in the rainy year (2023) and increased in 2021 (year with the least precipitation during acacia flowering). Other years did not differ significantly for this parameter. The amount of sucrose in acacia honey was the lowest in the rainy year (2023), and the highest in 2019 with little precipitation both during acacia flowering and throughout the year. Other observed parameters of honey quality differ statistically significantly depending on the year of observation. However, climatic factors do not have a decisive influence on the differences between them. Matters insoluble in water are exactly the same in both the rainy (2023) and dry (2024) years. HMF is the highest in the first two observed years (which do not stand out climatically), while it is uniform in the others.

Table 4. Quality parameters of acacia honey in Rasin region in the period of 2019-2024.

Year	Water (%)	Free acids (meq/kg)	Reducing sugars (%)	Sucrose (%)	Matters insoluble in water (%)	HMF	Diastase activity	Electrical conductivity (μS/cm)
2019	16,58±0,21^{bc}	10,19±0,36^{c}	69,51±0,23	3,76±0,22^{a}	0,024±0,002^{bc}	5,68±0,44^{a}	12,5±0,8^{d}	181±8,8^{ab}
2020	16,58±0,21^{bc}	10,29±0,61^{c}	69,73±0,25	3,70±0,10^{ab}	0,021±0,001^{c}	6,27±0,41^{a}	13,1±0,7^{cd}	165±5,0^{bc}
2021	17,29±0,17^{ab}	13,57±0,63^{b}	69,68±0,25	3,04±0,11^{cd}	0,027±0,001^{bc}	3,82±0,15^{cd}	15,1±0,4^{b}	139±2,6^{d}
2022	16,57±0,18^{c}	11,35±0,46^{c}	68,86±0,30	3,15±0,16^{c}	0,030±0,002^{ab}	3,58±0,06^{d}	18,5±0,6^{a}	182±5,3^{a}
2023	17,74±0,30^{a}	19,30±0,52^{a}	68,93±0,40	2,68±0,13^{d}	0,034±0,005^{a}	4,35±0,21^{bc}	16,0±0,6^{b}	181±6,4^{ab}
2024	16,77±0,20^{bc}	11,45±0,40^{c}	69,60±0,57	3,24±0,13^{bc}	0,036±0,004^{a}	4,95±0,24^{b}	14,7±0,5^{bc}	159±4,4^{c}
p value	0.004*	0.000*	0.519 ^{ns}	0.000*	0.003*	0.000*	0.000*	0.000*
Average	**16,922**	**12,692**	**69,385**	**3,2262**	**0,0287**	**5,795**	**15,217**	**174,97**

Similar to acacia and meadow honey, it met both domestic and foreign quality standards (Table 5). Meadow honey had the most water in the rainy year (2023), and in the warmest year 2024, the highest percentage of reducing sugars. Meadow honey had the most free acids and the highest diastase number in 2021, and then it had the least sucrose. This honey had the highest electrical conductivity in 2022.

Table 5. Quality parameters of meadow honey in Rasin region in the period of 2019-2024.

Year	Water (%)	Free acids (meq/kg)	Reducing sugars (%)	Sucrose (%)	Matters insoluble in water (%)	HMF	Diastase activity	Electrical conductivity (μS/cm)
2019	16,7±0,2^{bc}	19,0±1,4^{c}	68,2±0,5	3,39±0,22^{a}	0,029±0,002^{a}	4,89±0,32^{b}	22,3±1,7^{b}	500±35,5^{a}
2020	16,5±0,2^{bc}	15,7±2,0^{c}	68,4±0,5	3,41±0,24^{a}	0,020±0,001^{b}	5,93±0,45^{a}	19,1±1,5^{b}	351±62,4^{b}
2021	16,9±0,4^{abc}	32,6±2,2^{a}	69,7±0,4	1,76±0,30^{b}	0,027±0,005^{ab}	4,47±0,54^{b}	34,7±2,9^{a}	494±19,8^{ab}
2022	17,1±0,2^{ab}	19,0±2,9^{bc}	67,5±1,2	3,76±0,46^{a}	0,024±0,002^{ab}	3,75±0,18^{b}	19,9±1,8^{b}	429±86,0^{ab}
2023	17,8±0,3^{a}	29,5±1,1^{a}	68,6±0,4	2,99±0,11^{a}	0,020±0,001^{b}	4,41±0,34^{b}	21,2±1,3^{b}	299±13,9^{b}
2024	16,1±0,3^{c}	25,1±1,4^{ab}	69,5±0,8	3,52±0,34^{a}	0,028±0,001^{a}	4,07±0,44^{b}	22,2±1,7^{b}	425±26,0^{ab}
p value	0.004*	0.000*	0.418 ^{ns}	0.018*	0.001*	0.010*	0.003*	0.039*
Average	**16,853**	**23,880**	**67,892**	**3,210**	**0,0247**	**4,653**	**23,380**	**447,95**

Except for the amount of reducing sugars where the differences were not significant, for all other characteristics the differences were statistically significant depending on the year of observation (Table 5).

The weather may have had the least effect on honeydew. However, only the differences in the amount of HMF were not statistically significant, the others were (Table 6). Overall, honeydew

has the least water of all analyzed honeys, but in the rainy year it had the most water compared to all other honey samples. In the dry year, honeydew had by far the least amount of water, even when considering the other two types of honey (acacia and meadow). We note that during 2022 and 2023, the content of reducing sugars in the honeydew increased, and diastase activity and electrical conductivity decreased. This situation probably did not arise under the influence of climatic factors, but the bees collected along with the honeydew some meadow or even acacia honey.

Table 6. Quality parameters of honeydew in Rasin region in the period of 2019-2024.

Year	Water (%)	Free acids (meq/kg)	Reducing sugars (%)	Sucrose (%)	Matters insoluble in water (%)	HMF	Diastase activity	Electrical conductivity (μS/cm)
2019	$16,2\pm0,4^{bc}$	$22,3\pm1,6^{b}$	$64,3\pm0,5$	$4,20\pm0,41^{a}$	$0,037\pm0,003^{a}$	$3,50\pm0,01$	$41,0\pm2,3^{ab}$	1058 ± 67^{ab}
2020	$16,4\pm0,4^{b}$	$32,5\pm3,3^{a}$	$64,4\pm1,2$	$4,18\pm0,41^{a}$	$0,025\pm0,003^{b}$	$3,86\pm0,48$	$33,7\pm0,5^{bc}$	1122 ± 86^{a}
2021	$16,2\pm0,8^{bc}$	$37,4\pm3,1^{a}$	$66,7\pm0,4$	$3,20\pm0,37^{abc}$	$0,027\pm0,006^{ab}$	$3,62\pm0,12$	$50,2\pm6,9^{a}$	903 ± 76^{ab}
2022	$15,7\pm0,2^{bc}$	$30,2\pm3,2^{ab}$	$68,0\pm0,1$	$3,03\pm0,14^{bc}$	$0,030\pm0,001^{ab}$	$3,50\pm0,01$	$24,7\pm1,4^{cd}$	843 ± 13^{b}
2023	$18,7\pm0,2^{a}$	$30,4\pm1,7^{ab}$	$68,4\pm0,4$	$2,17\pm0,40^{c}$	$0,020\pm0,001^{b}$	$3,50\pm0,01$	$18,7\pm2,2^{d}$	945 ± 46^{ab}
2024	$14,9\pm0,5^{c}$	$30,5\pm0,4^{ab}$	$63,7\pm3,0$	$3,22\pm0,38^{abc}$	$0,020\pm0,000^{b}$	$4,19\pm0,34$	$35,1\pm2,4^{b}$	1097 ± 85^{a}
p value	0.002*	0.039*	0.107^{ns}	0.016*	0.028*	0.858^{ns}	0.000*	0.043*
Average	**16,158**	**30,803**	**65,700**	**3,308**	**0,0265**	**4,655**	**34,838**	**1006,5**

Conclusions

After analyzing the impact of weather conditions on the yield and quality of honey in the period of 2019-2024, we can draw the following conclusions:

- the common characteristic of all honeys is that in 2023 (rainy year) they had the highest percentage of water and the lowest percentage of sucrose.
- meadow honey and honeydew had the most acids in 2021 (year with the lowest temperature), and acacia in 2023 (rainy year).
- the amount of reducing sugars in honey did not differ statistically significantly regardless of the climatic conditions of the year in which they were obtained.
- other parameters of honey quality had significant differences depending on the year of observation, but they were more influenced by some other factors (method of preserving, types of honey, etc.) in relation to the climatic conditions in that year.

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