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# INFLUENCE OF CORN SYRUP AND INVERTED SUGAR ADULTERATION ON PHYSICOCHEMICAL PROPERTIES OF ROMANIAN ACACIA HONEY

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***Abstract***

*The aim of this study was to analyze the influence of corn and inverted sugar syrups adulteration on physicochemical parameters of acacia honey. The adulteration of the acacia honey samples analyzed was done by the addition of concentrated corn syrup. For this purpose, acacia honey was adulterated with different percentages (5%, 10%, 20% and 50%) of corn syrup and inverted sugar. The color, pH, free acidity, electrical conductivity, moisture content, hydroxymethylfurfural content, as well as the sugar content (fructose, glucose, sucrose, turanose, maltose, trehalose, melesitose, and raffinose) were chosen as parameters for evaluating the influence of adulteration agents in honey. The moisture content of the honey samples were below the maximum level established by Codex Alimentarius (≤ 20%). The hidroxymethylfurfural content increased considerably from 18.97 in authentic honey to 337.31 mg/kg honey adulterated with 50% inverted sugar syrup, while a decrease occurred from 18.97 to 10.89 mg/kg honey adulterated with 50% corn syrup. Electrical conductivity decreased from 122.26 µS/cm to 107.08 µS/cm and from 122.26 µS/cm to 69.34 µS/cm with the addition of inverted sugar syrup and of corn syrup respectively. The fructose/glucose ratio decrease from 1.42 in authentic honey to 1.25 in honey adulterated with 50% inverted sugar syrup and from 1.42 to 1.34 in honey adulterated with 50% corn syrup. The results indicated that most of the values of the physicochemical parameters showed considerable changes on the adulterated honey with both types of syrups.*

***Key words***: *adulteration, honey, physicochemical parameters, syrups.*

## INTRODUCTION

Honey is a natural product used since ancient times due to its nutritional and therapeutic properties (antibacterial, antiviral, anti-inflammatory, antioxidant activity) (Sakač et al., 2019). According to international standards, authentic honey should not contain additives or other substances intentionally added (Amiry et. al., 2016). Furthermore, honey should not present uncharacteristic flavor, aroma and foreign matter that could affect its processing or storage (Frew et al., 2013).

Increasing consumption options for bee products stimulates the development of food products that use honey as a raw material, thus requiring a higher production of honey (Geană et al., 2020). This high market demand has led to illegal practices among producers, where the direct or indirect adulteration is widely used to increase both production and profit, while significantly affecting the quality of honey.

Adulteration of honey reduces its quality and safety. Honey adulterated with chemicals loses its medicinal value and may also harm the consumers (Naila et al., 2018). Adulterated honey may present changes in some chemical and/or biochemical parameters such as enzyme activity, electrical conductivity, content of specific honey compounds (HMF, glucose, fructose, sucrose, maltose, isomaltose, proline, and ash) when compared to pure honey. However, some parameters are ambiguous with respect to the accuracy of the results (Soares et al., 2017). For example, when honey is subjected to heat treatment or stored for a long time, pentoses and hexoses are broken down by slow enolization and rapid β-elimination of three water molecules, resulting in undesirable compounds such as furans. The main products of sugar degradation are: furfural derived from pentoses and 5-hydroxymethylfurfural (5-HMF) derived from hexoses such as glucose and fructose. Their presence in products is often

associated with Maillard reactions, degradation of sugars in acidic environment and caramelization reactions (Da Silva et al., 2016).
Sugars are the main components of honey, as this product mainly contains glucose, fructose, and also other oligosaccharides in lower concentrations. Therefore, adulteration through the addition of carbohydrates is a type of fraudulent practice that requires special control due to the fact that the variations of these compounds in honey and the similarities with the sugar syrup composition makes difficult the detection of these adulteration agents (Morales et al., 2008).
The presence of sugars in a high content following the adulteration of honey can be linked to a direct addition of different types of sugar syrups in certain concentrations after production in order to enhance the sweetness of honey or by stimulating the bees with sugar syrups during the main nectar period to produce a larger quantity of honey. For this purpose, the producers use low-cost industrial sugar syrups such as corn syrup, high fructose corn syrup, glucose syrup, sucrose syrup, invert sugar syrup, with high fructose inulin syrup (Soares et al., 2017).
In this study is presented the influence of corn and inverted sugar syrups adulteration on the physicochemical parameters of acacia honey, because this type of honey is widely used by the Romanian population due to its characteristic properties and benefits on human health. Analysis of variance (ANOVA) was used in this study as a means to emphasize the differences between authentic and adulterated acacia honey samples.

## MATERIALS AND METHODS

Acacia honey was purchased from a local beekeeper in Suceava Country, Romania. Honey was adulterated with corn syrup and inverted sugar, each adulteration agent was added in the authentic honey in 5%, 10%, 20% and 50% (w/w), respectively. The inverted sugar syrup was obtained using sucrose. Citric acid was used for the hydrolysis process to correct the sugar solution. The corn syrup was purchased from DAESANG EUROPE B.V. Importing company (product of South Korea). All samples were liquefied (50°C) and homogenized prior to any analysis.
The following physicochemical characteristics of honey samples were analysed: color (analysed with a portable chromameter and a photometer Pfund), pH, free acidity, electrical conductivity, moisture content, hydroxymethylfurfural content and sugar content. All the analysis were made in triplicate.

**Moisture content**
The moisture content was analyzed using the refractometric method (Abbé refractometer, Leica Mark II Plus), which is a method that determines the refractive index of honey and uses a Chataway table to determine the water content (%) (Bogdanov et al., 1999). Prior to analysis the samples were liquefied at 50ºC.

**Hydroxymethylfurfural content (HMF)**
In order to determine HMF presence in honey samples, 5 g of honey were dissolved in 25 g of distilled water. Then Carrez I and Carrez II solutions were added and the volume was made up with distilled water in a 50 ml volumetric flask. The solution was filtered and then divided into two clarified solutions, one containing 0.2% sodium bisulphite solution as the reference sample and the other containing distilled water as the sample. The absorbance was read at 284 nm and 336 nm using a UV-VIS-NIR 3600 spectrophotometer (Schimadzu Corporation, Japan). Calculations were made according to the formula below and the results were expressed in mg/kg honey:

$$HMF = (A_{284}-A_{336}) \times 149.7 \times 5 \times D/W,$$

where: $D$ is the dilution factor and $W$ is the weight of honey sample (g) (White, 1979).

**Color**
Two instruments were used to measure the color of the samples. The first one was a portable chromameter CR-400 (Konica Minolta, Japan) which uses the CIE L*a*b* color space for color analysis, namely Cartesian coordinates to determine a value in color space. The color is described by chromatic qualities, which are found in three components: brightness, hue and chroma (saturation) (Tuberoso et al., 2014).
The second instrument that was used for honey samples color analysis was a photometer Pfund HI 96785 (Hanna Instrumets, USA). The Pfund colorimeter is a simple tool by which allow the comparison of the samples color with a reference sample. The reference unit is the Pfund scale, whose variation is between 0 and

140 mm, from very light honey colors to the darkest hue (Dominguez, 2015).

**pH**

To determine the pH, a 10% honey aqueous solution was prepared and the measurements were made with a METTLER TOLEDO Five Go pH-meter (Mettler Toledo, USA).

**Free acidity**

The free acidity was determinated by following the steps below: 10 g of honey were dissolved in 75 mL of carbon dioxide-free water, it was measured the pH of the solution, and then it was titrated with 0.1 M sodium hydroxide to pH = 8.3 with a TITROLINE easy device (Schott Instruments, Germany).

The calculation was performed according to the formula presented below and the results were expressed in milliequivalents/kg of honey:

Free acidity = mL of 0.1 M NaOH × 10

**Electrical conductivity**

The electrical conductivity of 20 g of honey sample dissolved in 100 mL of distilled water was measured with a portable conductometer HQ14d (HACH, USA). The results were expressed in microSiemens per centimeter ($\mu S \cdot cm^{-1}$).

**Sugar content**

The sugar content was determined by high performance liquid chromatography (HPLC) with RI (refractive index) detection according to the method published by Bogdanov et al. (1988). Fructose, glucose, sucrose, turanose, maltose, trehalose, melesitose and raffinose were used as standard substances. Sample preparation was made as follows: 5 g of honey were dissolved in 40 mL of distilled water. 25 mL of methanol were added and the volume was made up with distilled water in a 100 mL volumetric flask. Then resulting solution was filtered and afterwards injected into the instrument. The mobile phase was a acetonitrile: water (80:20) mixture.

## RESULTS AND DISCUSSIONS

**Moisture content**

A very important constituent of honey composition is water. Its content may vary depending on different factors such as botanical origin and maturity level, storage conditions and also processing technique (Da Silva et al., 2016). According honey standard of the Codex Alimentarius and EU Honey Directive, the moisture content cannot be more than 20% (Bogdanov and Martin, 2002).

Some parameters of honey (viscosity, degree of crystallization, color, flavor, taste, specific weight, solubility, preservation degree) can be influenced by the moisture content (Da Silva et al., 2016). In this study the moisture content did not exceed the admitted limit of 20%. Its variation with the degree of adulteration was between 15.96% and 16.85% for honey adulterated with inverted sugar syrup and between 15.96% and 18.99% for honey adulterated with corn syrup (Table 1.b.).

**Hydroxymethylfurfural content (HMF)**

The HMF content is a quality indicator of the freshness and purity of honey (Naila et al., 2018). Depending on the degree of adulteration, the HMF content increased considerably from 18.97 mg/kg to 337.31 mg/kg in honey adulterated with inverted sugar syrup. This increase was due to inverted sugar syrup, which has a high HMF content, thus determining values that exceed the maximum allowed limit of 40 mg/kg honey, as shown in Table 1.b. Zábrodská (2015) reported a value of 200 mg/kg that was determined for honey adulterated with invert sugar syrup obtained by acid hydrolysis.

In the case of honey adulterated with corn syrup, the HMF content decreased from 18.97 mg/kg in authentic honey to 10.89% in honey adulterated with 50% syrup.

High HMF content may also be due to other conditions, such as heat treatment and long storage. For example, honey samples stored for more than 1-2 years contained 128-1131 mg/kg of HMF (Naila et al., 2018).

**Color**

Color is the most important feature from a commercial point of view. Honey color varies depending on different factors such as the geographical origin of the honey, the content of pigments (carotene and xanthophylls), and the content of polyphenols. Proper color measurement allows exporters to choose the most profitable commercial market for their products, this parameter being the only sensory

examination with precise coding within the regulations in force (Dominguez, 2015).
Depending on the degree of adulteration, the values of L* ranged between 44.07 and 45.68 ($p > 0.05$) for honey adulterated with inverted sugar syrup and between 44.07 and 43.94 ($p > 0.05$) for honey adulterated with corn syrup. The values of a* and b* varied between -3.34 and -2.62 ($p < 0.001$) and 24.76 and 31.13 ($p < 0.001$) for honey adulterated with inverted sugar syrup and between -3.34 and -3.91 ($p < 0.001$) and 24.76 and 21.17 ($p < 0.01$) for honey adulterated with corn syrup, respectively. ΔE* ranged from 3.60 to 8.06 for honey adulterated with inverted sugar syrup and from 1.91 to 3.64 for honey adulterated with corn syrup. Negative and positive values of a* and b* coordinates indicate that all the samples had nuance of colour between green and yellow (fourth quadrant of CIE L*a*b* color space). On the Pfund scale, the color of adulterated honey with inverted sugar syrup ranged from 12.87 mm Pfund to 26.40 mm Pfund (the color changed from extra white to white according to the Pfund scale) and of honey adulterated with corn syrup ranged from 12.87 to 6.93 (the color changed from extra white to water white according to the Pfund scale). Depending on the adulteration agent, the differences were significant ($p < 0.001$) for the both measurement methods. All these results are presented in Table 1.a. and Table 1.b.

**pH**

The results presented in Table 1.b. show that the pH values decreased with the increase of the degree of adulteration from 4.30 to 3.98 ($p > 0.05$) for honey adulterated with inverted sugar syrup. For honey adulterated with corn syrup the pH values increased from 4.30 to 4.40 ($p > 0.05$). Oroian et al. (2018) argued that the invert sugar syrup added in authentic honey leads to a decrease of pH due to the addition of citric acid in the syrup solution to prevent crystallization or hydrolysis. It can be assumed that the addition of citric acid to invert sugar syrup in a higher content would greater impact the pH of honey.
A pH level between 3.2 and 4.5 and the natural acidity of honey inhibits the growth of microorganisms, since the optimum pH for most organisms is between 7.2 and 7.4. The addition of high-fructose corn syrup to honey from Brazil has led to a significant increase in pH value compared to pure honey (Ribeiro et al., 2014).

**Free acidity**

The free acidity of honey is an important characteristic that can indicate microbial spoilage. When the values of the free acidity exceed the maximum allowed limit a fermentation of the sugar with formation of acetic acid resulting by the alcoholic hydrolysis should be expected (Geană et al., 2020).
The free acidity significantly increased with the degree of adulteration from 3.86 meq/kg to 5.10 meq/kg ($p < 0.001$) for honey adulterated with inverted sugar syrup, as it can be observed in Table 1.b. For honey adulterated with corn syrup the values decreased from 3.86 meq/kg to 3.61 meq/kg ($p < 0.05$). Oroian et al. (2018) found that the adulteration of honey with inverted sugar syrup in addition to the decrease of the pH produces an increase of free acidity. During honey deterioration, fermentation of sugars with the formation of organic acids leads to increased acidity. The maximum acidity level established by the Codex Alimentarius Commission (2001) is 50.00 meq/kg (Sakač et al., 2019). In this study the free acidity did not exceed the maximum allowed limit for any analyzed sample.

**Electrical conductivity**

The electrical conductivity of honey is related to the ash content and acidity. This parameter increases with the increase of the organic acid ions and proteins content. According to Codex Alimentarius, the maximum admitted value of electrical conductivity is 800 $\mu S \cdot cm^{-1}$ (Da Silva et al., 2016). In this study, the electrical conductivity showed a partially significant decrease ($p < 0.01$) from 122.26 $\mu S \cdot cm^{-1}$ to 107.08 $\mu S \cdot cm^{-1}$ for honey adulterated with inverted sugar syrup and a significant decrease ($p < 0.001$) from 122.26 $\mu S \cdot cm^{-1}$ to 69.34 $\mu S \cdot cm^{-1}$ for honey adulterated with corn syrup (Table 1.b.).

**Sugar content**

The content of sucrose, turanose, melesitose and also raffinose changed significantly ($p < 0.001$) depending on the degree of adulteration for the both agents with values that ranged from 0.44% to 0.23% (sucrose), 0.17% to 0.70% (turanose), 1.32% to 0.68% (melesitose) and from 0.51% to

0.28% (raffinose) for honey adulterated with inverted sugar syrup and values that ranged from 0.44% to 0.22% (sucrose), 0.17% to 0.08% (turanose), 1.32% to 18.17% (melesitose) and from 0.51% to 0.31% (raffinose) for honey adulerated with corn syrup, respectively, as shown in Table 1.b.

Depending on the degree adulteration the content of maltose and trehalose showed the same ranges for honey adulterated with both types of syrup, from 2.18% to 1.09% (maltose) and 1.15% to 0.58% (trehalose).

The decrease of the content of fructose was not significant ($p > 0.05$) for honey adulterated with inverted sugar syrup (the range was from 37.18% to 35.90%), while for honey adulterated with corn syrup was significant ($p < 0.001$) with values from 37.18% to 18.62%.

The content of glucose and F/G ratio changed partially significant ($p < 0.01$) for honey adulterated with inverted sugar syrup with values from 25.93% to 28.43% and from 1.42 to 1.25, respectively. For honey adulterated with corn syrup the content for glucose decrease significantly from 25.93% to 13.74%, and for F/G ratio the decrease was less significant with values from 1.42 to 1.34.

Different types of honey have different fructose/glucose ratios. This ratio indicates the ability of honey to crystallize, a ratio greater than 1 indicating a liquid honey (Geană et al., 2020). Floral honey has a fructose/glucose ratio of about 1. The crystallization of glucose has a stronger effect on honey with higher glucose content (Gleiter et al., 2006).

Regardless of the adulteration agent (inverted sugar syrup or corn syrup) the changes for maltose and trehalose content were not significant ($p > 0.05$), as shown in Table 1.a.

Detecting inverted sugar syrup adulteration honey can be difficult by common methods, because it can be adapted to imitate the sucrose-fructose-glucose profile of authentic honey. By adding a small amount of invert sugar the changes in glucose and fructose levels are not significant when compared to those of authentic honey (Geană et al., 2020). In Figure 1 is presented the chromatographic profil of acacia honey, inverted sugar syrup and corn syrup, it can be observed that corn syrup has a high peak for melesitose, while fructose peak is similar for acacia honey and inverted sugar syrup.

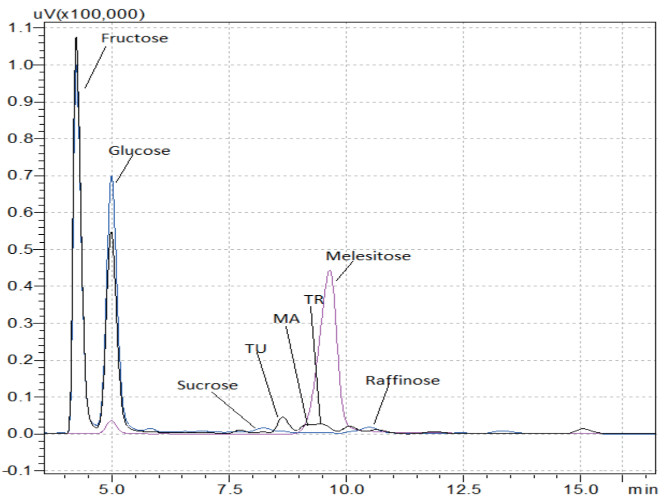


Figure 1. Chromatografic profile of acacia honey (black line), inverted sugar (blue line) and corn syrup (red line)
TU - turanose, MA - maltose, TR - trehalose

Table 1.a. Physicochemical parameters of adulteration agent and interaction agent-degree of adulteration

| Parameter | Adulteration agent | | F - ratio | Interaction |
|---|---|---|---|---|
| | Corn syrup | Inverted sugar syrup | | Agent - Degree of adulteration |
| **L*** | 43.01(1.01)b | 44.84(0.88)a | 42*** | 3.95* |
| **a*** | -3.34(0.32)b | -2.94(0.26)a | 380*** | 143.79*** |
| **b*** | 23.76(1.51)b | 28.73(2.32)a | 868*** | 97.20*** |
| **ΔE*** | 1.90(1.21)b | 4.72(2.93)a | 11262*** | 1482.33*** |
| **Color (mm Pfund)** | 11.74(2.86)b | 18.74(4.78)a | 4647*** | 1168.68*** |
| **pH** | 4.33(0.05)a | 4.19(0.13)b | 27*** | 7.47** |
| **Free acidity (meq/kg)** | 3.77(0.10)b | 4.28(0.46)a | 375*** | 102.81*** |
| **Electrical conductivity (μS/cm)** | 103.14(19.86)b | 115.97(5.82)a | 323*** | 88.29*** |
| **Moisture (%)** | 16.99(1.14)a | 16.26(0.37)b | 47*** | 12.92*** |
| **HMF (mg/kg)** | 16.22(3.03)b | 127.20(119.31)a | 20633*** | 5640.43*** |
| **Fructose (%)** | 30.87(6.96)b | 36.75(0.62)a | 719*** | 196.78*** |
| **Glucose (%)** | 21.78(4.57)b | 26.77(0.97)a | 1007*** | 275.41*** |
| **Sucrose (%)** | 0.32(0.08)a | 0.27(0.08)b | 1183*** | 231.80*** |
| **Turanose (%)** | 0.13(0.03)b | 0.35(0.20)a | 13595*** | 3742.20*** |
| **Maltose (%)** | 1.81(0.41)a | 1.81(0.41)a | 0ns | 0ns |
| **Trehalose (%)** | 0.95(0.21)a | 0.95(0.21)a | 0ns | 0ns |
| **Melesitose (%)** | 7.05(6.31)a | 1.10(0.24)b | 19731*** | 5391*** |
| **Raffinose (%)** | 0.44(0.07)a | 0.43(0.08)b | 13** | 3* |
| **F/G ratio** | 1.39(0.03)a | 1.36(0.06)b | 21*** | 4* |

ns - not significant ($p > 0.05$), *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, a-e - different letters in same row indicate significant differences between sample

Table 1.b. Physicochemical parameters of acacia honey adulterated with inverted sugar syrup and corn syrup

| Acacia honey analysis results | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Degree of adulteration for inverted sugar syrup** | | | | | **F - ratio** | **Degree of adulteration for corn syrup** | | | | | **F - ratio** |
| | **0.00%** | **5.00%** | **10.00%** | **20.00%** | **50.00%** | | **0.00%** | **5.00%** | **10.00%** | **20.00%** | **50.00%** | |
| **L*** | 44.07(0.63)a | 45.68(0.65)a | 44.16(0.63)a | 44.6(0.64)a | 45.68(0.65)a | 3ns | 44.07(0.62)a | 42.18(0.60)b | 42.04(0.60)b | 42.82(0.62)ab | 43.94(0.63)a | 4ns |
| **a*** | -3.34(0.05)e | -3.06(0.04)d | -2.9(0.04)c | -2.79(0.04)b | -2.62(0.04)a | 82*** | -3.34(0.05)b | -3.01(0.04)a | -3.12(0.04)a | -3.32(0.05)b | -3.91(0.06)c | 103*** |
| **b*** | 24.76(0.35) | 29.39(0.42) | 28.33(0.40) | 30.06(0.43) | 31.13(0.45) | 70*** | 24.76(0.35)a | 24.68(0.35)a | 24.92(0.35)a | 23.28(0.33)b | 21.17(0.30)c | 43** |
| **ΔE*** | 0e | 8.06(0.12)a | 3.60(0.05)d | 5.36(0.07)c | 6.62(0.09)b | 3198*** | 0d | 1.91(0.03)c | 2.04(0.03)b | 1.93(0.03)c | 3.64(0.05)a | 3230*** |
| **Color (mm Pfund)** | 12.87(0.18)e | 15.84(0.23)d | 18.81(0.27)c | 19.8(0.28)b | 26.40(0.37)a | 680*** | 12.87(0.18)b | 14.85(0.21)a | 13.19(0.19)b | 10.89(0.16)c | 6.93(0.10)d | 618.50*** |
| **pH** | 4.30(0.06) | 4.27(0.06) | 4.24(0.06) | 4.17(0.06) | 3.98(0.06) | 9* | 4.30(0.06)a | 4.31(0.06)a | 4.32(0.06)a | 4.34(0.06)a | 4.40(0.06)a | 0.77ns |
| **Free acidity (meq/kg)** | 3.86(0.06)d | 3.98(0.06)cd | 4.11(0.06)c | 4.35(0.06)b | 5.1(0.07)a | 127*** | 3.86(0.06)a | 3.84(0.05)a | 3.81(0.06)a | 3.76(0.06)a | 3.61(0.05)b | 6.42* |
| **Electrical conductivity (µS/cm)** | 122.26(1.75)a | 120.75(17.72)a | 119.23(1.71)ab | 116.19(1.66)b | 107.08(1.53)c | 25** | 122.26(1.75)a | 116.97(1.67)b | 111.68(1.60)c | 101.09(1.45)d | 69.34(0.99)e | 385*** |
| **Moisture (%)** | 15.96(0.23)b | 16.05(0.23)b | 16.13(0.23)b | 16.31(0.23)ab | 16.85(0.24)a | 4ns | 15.96(0.23)c | 16.26(0.23)c | 16.57(0.23)bc | 17.17(0.24)b | 18.99(0.27)a | 49*** |
| **HMF (mg/kg)** | 18.97(0.27)e | 50.80(0.72)d | 82.64(1.18)c | 146.31(2.09)b | 337.31(4.82)a | 5414*** | 18.97(0.27)a | 18.16(0.26)b | 17.35(0.25)c | 15.73(0.22)d | 10.89(0.156)e | 377*** |
| **Fructose (%)** | 37.18(0.53)a | 37.06(0.53)a | 36.93(0.53)a | 36.67(0.53a | 35.90(0.51)a | 1ns | 37.18(0.53)a | 35.33(0.50)b | 33.48(0.48)c | 29.76(0.42)d | 18.62(0.27)e | 536*** |
| **Glucose (%)** | 25.93(0.37)c | 26.18(0.38)bc | 26.43(0.38)bc | 26.93(0.38)b | 28.43(0.41)a | 13** | 25.93(0.37)a | 24.71(0.35)b | 23.49(0.34)c | 21.05(0.30)d | 13.74(0.20)e | 465*** |
| **Sucrose (%)** | 0.44(0.007)a | 0.23(0.005)b | 0.23(0.005)b | 0.23(0.005)b | 0.23(0.005)b | 666*** | 0.44(0.007)a | 0.42(0.007)b | 0.40(0.007)c | 0.35(0.007)d | 0.22(0.007)e | 311*** |
| **Turanose (%)** | 0.17e | 0.22(0.003)d | 0.27(0.006)c | 0.38(0.005)b | 0.70(0.008)a | 3686*** | 0.17a | 0.16(0.001)b | 0.15(0.002)c | 0.13(0.004)d | 0.08(0.004)e | 294*** |
| **Maltose (%)** | 2.18(0.03)a | 2.08(0.03)b | 1.97(0.03)c | 1.75(0.03)d | 1.09(0.02)e | 535*** | 2.18(0.03)a | 2.08(0.03)b | 1.97(0.03)c | 1.75(0.03)d | 1.09(0.02)e | 535*** |
| **Trehalose (%)** | 1.15(0.01)a | 1.09(0.02)b | 1.03(0.02)c | 0.92(0.01)d | 0.58(0.008)e | 485*** | 1.15(0.01)a | 1.09(0.02)b | 1.03(0.02)c | 0.92(0.01)d | 0.58(0.008)e | 485*** |
| **Melesitose (%)** | 1.32(0.01)a | 1.25(0.02)b | 1.19(0.02)c | 1.06(0.02)d | 0.68(0.01)e | 513*** | 1.32(0.01)e | 3.01(0.04)d | 4.69(0.07)c | 8.06(0.12)b | 18.17(0.26)a | 5075*** |
| **Raffinose (%)** | 0.51(0.007)a | 0.49(0.004)b | 0.47(0.009)c | 0.42(0.004)d | 0.28(0.005)e | 438*** | 0.51(0.007)a | 0.49(0.006)b | 0.47(0.006)c | 0.43(0.005)d | 0.31(0.004)e | 402*** |
| **F/G ratio** | 1.42(0.01) | 1.40(0.02) | 1.38(0.02) | 1.35(0.02) | 1.25(0.02) | 26** | 1.42(0.01)a | 1.41(0.02)a | 1.41(0.02)a | 1.40(0.02)a | 1.34(0.02)b | 6* |

ns - not significant ($p > 0.05$), *$p<0.05$, **$p<0.01$, ***$p<0.001$, a-e - different letters in same row indicate significant differences between samples

## CONCLUSIONS

In this study it was analyzed the influence of honey adulteration through the addition of corn syrup and inverted sugar syrup on the physicochemical properties of the product.

The statistical analysis of the results highlighted the significant differences between authentic and adulterated honey. Depending on the degree of adulteration, for honey adulterated with inverted sugar syrup, the differences were significant ($p < 0.001$) and partially significant ($p < 0.01$) for physicochemical parameters such as color parameters on both color CIE L*a*b* (a*, b*, ΔE* color parameters) and Pfund scales respectively, free acidity, electrical conductivity, HMF content, and sugar content (glucose, sucrose, turanose, maltose, trehalose, melesitose, raffinose and F/G ratio).

For honey adulterated with corn syrup, the significant and partially significant differences were for the same physicochemical parameters of honey adulterated with inverted sugar syrup with some exceptions: moisture content and fructose content presented significant changes and free acidity content and F/G ratio were the parameters with the less significant changes.

It is important to note that with the increase of the degree of adulteration, the changes of physicochemical parameters were more significant (for example, the HMF content increased 17.78 times in honey adulterated with inverted sugar syrup compared to the content of authentic honey, exceeding the maximum allowed level and the electrical conductivity ranged from 122.26 $\mu S \cdot cm^{-1}$ in authentic honey to 101.09 $\mu S \cdot cm^{-1}$ in adulterated honey with 20% corn syrup and 69.34 $\mu S \cdot cm^{-1}$ in adulterated honey with 50% corn syrup).

The less significant differences for honey adulterated with inverted sugar were obtained for pH ($p < 0.05$) and for honey adulterated with corn sugar were obtained for free acidity and F/G ratio. In the case of L* color parameter on color CIE L*a*b* color space the results obtained for honey adulterated with both types of syrup showed that the changes were not significant ($p > 0.05$).

Depending on the adulteration agent (corn syrup and inverted sugar syrup) the differences were significant or partially significant for almost all parameters presented in this article (physicochemical parameters and the sugar content), except maltose and trehalose ($p > 0.05$).

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