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FOURIER TRANSFORM INFRARED SPECTROSCOPY TECHNIQUE FOR DETECTION OF HONEY AUTHENTICATION

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ABSTRACT

Physico-chemical properties of honey and honey samples adulterated with glucose or sucrose were determined. Total soluble solids (TSS), pH and electrical conductivity of honey and its adulterated samples ranged between (84.10-84.50%), (3.80-4.63) and (11.73 – 232.32µS), respectively. Sensory properties of honey and its adulterated samples showed that, no differences in the sensorial properties were found in authentic honey and honey adulterated with 25% sucrose or 25% glucose. Increasing adulteration ratio to 50% glucose decreased taste, flavor, color and general appearance, while adulterated honey with 50% sucrose caused significant decrease in taste and general appearance. The possibility of using HPLC to detect adulteration of honey through determining their sugars content was evaluated. The obtained results indicated that, authentic honey was characterized with its higher fructose/glucose ratio (1.21) compared to adulterated honey samples (ranged between 0.35 - 0.94). FT-IR spectroscopic technique was used to evaluate honey quality. Reliability FT-IR for quantitative and qualitative analysis of sucrose, glucose and fructose were evaluated. The main FT-IR spectral bands of sucrose, glucose and fructose were identified at different concentration levels. The relationship between sugars concentration (sucrose, glucose and fructose) and its spectral bands absorbance (peak height) were evaluated to prepare sugars standard curves and their linear equations. Selected main peaks of sucrose, glucose and fructose provide the best calibration model with correlation coefficient (r^2) higher than (0.9). Honey samples adulterated with glucose were characterized with specific spectral peaks, in which the absorbance was increased by increasing the ratio of adulteration with glucose at 1087, 1105, 1189 and 984 cm^{-1}, while the adulteration with sucrose lead to increase in the absorbance of spectral bands of sucrose as 1054, 1149 and 984 cm^{-1} especially in honey adulterated with 50 % sucrose.

INTRODUCTION

Honey is a natural biological product used as food and medicine since ancient times. The different proportions of nectar incorporated in honey vary depending on the geographic zone, the vegetation type as well as the flowering period of the plants **(Hewitson, 2009)**. In general, Honey contains 12.4–20.3% moisture, less than 0.25% ash and 60.7–77.8% sugars, of which about 0–2% may be sucrose, 25.2– 35.3% glucose, and 33.3–43.0% fructose (**Paradkar and Irudayaraj 2001)**.

As a kind of health product with high nutritional value, honey is very popular for consumers. However, it has become the target of adulteration with cheaper sweeteners such as refined cane sugar, beet sugar, and corn syrup. In this concern, adulteration of honey has been reported by several investigators **(Cienfuegos et al 1997; Gonzalez et al 1998; Velàzquez et al 2009)**. Consequently, discrimination between adulterated and authenticity of honey become very important issue for processors, retailers and consumers as well as regulatory authorities. Therefore, several techniques were investigated to detect the adulterated honey,

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for example, isotopic and chromatographic. Moreover, the stable carbon isotope ratio analysis was used as a standard method to detect adulteration of honey for several years **(Arvanitoyannis et al 2005)**. The utility of these methods to evaluate the adulteration of honey has been revealed. Nevertheless, these techniques are time-consuming, destructive and expensive. Consequently, there is an interest in developing fast, accurate, easy to use and low-cost analytical methods to detect and quantify adulteration in honey. For this reason, spectroscopic techniques **(Anjos et al 2015)** and chromatographic techniques **(Manzanares et al 2011)** were used to evaluate some quality parameters of honey. The FT-IR technique requires low sample volume and minimal or no sample preparation is required, which greatly speeds up sample analysis **(Edelmann et al 2001)**. Also, high-performance liquid chromatography (HPLC) has been used to identify honey authenticity using conventional sugar profile of glucose–fructose ratio **(Mateo and Bosch-Reig, 1998)**.

This study aimed to evaluate quality attributes and adulteration of honey samples using FT-IR and HPLC techniques as a fast and simple method. The quality of honey and adulterated honey was assessed by classical methods and FT-IR spectroscopy to identify and create a unique fingerprint that resembled the samples under investigation. The obtained fingerprints could be used for quality assessments.

MATERIALS AND METHODS

Materials

Reference material of D-sucrose (GR crystals), glucose (crystals) and D-fructose (USP crystals) were obtained from Fisher Chemicals. Potassium bromide was obtained from Sigma Chemicals.

Standard solutions from sucrose, glucose and fructose were prepared in de-ionized water at concentrations from 5 to 40 % in case of FT-IR technique and from 1 to 5 mg/ml for HPLC coupled with Refractive Index detector (RID).

Authentic alfa alfa honey sample was obtained from local bee keeper in Giza province, Egypt (during season 2012), and glucose syrup was obtained from local market. Also, sugar syrup was prepared in lab by dissolving 430 g Sugar in 225 ml water and concentration (with lemon juice) under heating until 84.5%.

Adulterated honey samples

The series of adulterated honey samples were prepared separately by mixing authentic honey with 25 or 50% glucose corn syrup and 25 or 50% cane sugar. Furthermore, sugar solution were prepared to be similar for honey using 100% glucose corn syrup, 100% cane sugar or mixing 50% glucose corn syrup with 50% cane sugar.

Analytical Methods

Determination of electrical conductivity, pH and TSS

The determination of electrical conductivity of a honey samples at 20% (dry matter basis) in deionized water was measured at 20 °C using Jenway Conductivity Meter model 4510 **(AOAC, 1990)**. Results were expressed as µS cm-1. The measurements of pH and TSS were preformed as described by **Manzanares et al (2014)**.

- Fourier Transform Infrared spectroscopy (FT-IR)

The spectra or fingerprints of the selected samples were obtained using FT-IR spectroscopy (FT-IR-6100 Jasco, Japan) at Central Lab of National Research Center, Dokki, Giza. Samples were prepared using potassium bromide disks. FT-IR spectral resolution was 4 cm^{-1} and wavenumber ranged from 4000 – 400 cm^{-1}.

- High performance liquid chromatography (HPLC)

The HP1100 system was equipped with autosampler, quaternary pump, on-line degasser and refractive index detector, controlled with Chemstation software (Hewlett Packard, Waldbronn, Germany). The analytical column was Agilent carbohydrate column (25 cm x 4.6 mm I.D., 5 µm, Germany). The separation of glucose, fructose and sucrose was performed as isocratic separation with acetonitrile: water (75:25%) as mobile phase. The separated sugars were detected using refractive index detector and the quantitation was integrated by Chemstation chromatographic software interfaced to a personal computer.

Sensory Evaluation

Sensory properties of authentic and adulterated honey samples were evaluated according to **Paulus et al (1979)**. The samples were served to ten trained panelist to evaluate sensory attributes (color, taste, odor, texture and general acceptability) using 9 points descriptive scale. According to the scoring tables, scores (7-9) indicated “high quality”, scores (4-6) indicated “moderate quality and scores (1-3) indicated the limit of “unacceptability”.

Statistical analysis

Results were evaluated statistically using analysis of variance as reported by **McClave and Benson (1991)**.

RESULTS AND DISCUSSION

- Physicochemical Properties

Total Soluble Solids (TSS) is the most important measurement related to honey quality, where increasing TSS is related to lower moisture content and could be related to lowering the risk of spoilage due to fermentation. **Table (1)** shows that total soluble solids (TSS) of authentic honey (control) was 84.47% while, honey samples adulterated with sugar cane or glucose syrup between 84.50 – 84.10%. This result indicated that, TSS was not affected during processing steps of adulteration with sucrose or glucose. Therefore, TSS is not a reliable indicator for detecting adulteration.

Honey is acidic due to the presence of organic acids that contribute to honey flavor and stability against microbial spoilage. **Table (1)** shows that pH values of authentic honey (control) was 4.49, while pH values of honey samples adulterated with 25, 50 and 100% glucose were 4.63, 4.01 and 4.53, respectively. Also, pH values of honey adulterated with 25, 50 and 100% sucrose decreased to 3.95, 3.80 and 3.72, respectively. Moreover, mixed syrup of 50% glucose and 50% sucrose was 3.84. These results indicated that there were slight differences in acidity of adulterated honey, where slight higher acidity of adulterated honey of sucrose syrup could be due to using lemon juice to avoid sugar crystallization.

Regarding the electrical conductivity a comparative study was carried out between the authentic honey and those adulterated with different glucose and sucrose percentages as shown in **Table (1)**. Results indicated that, there were significant differences ($p < .05$) in electrical conductivity between authentic honey (232.32µS) and adulterated honey samples, where electrical conductivity values decreased in honey adulterated with 25, 50 and 100% sucrose (ranged between 59.51- 180.84µS); and decreased in honey adulterated with 25, 50 and 100% glucose (ranged between 11.73-174.13 µS). As stated by **(Codex Alimentarius Commetee, 2001 and European Commission, 2002)** electrical conductivity should not be more than 800 µS in alfa alfa honey and this reflect the amount of ash content **(Sancho et al 1991)**. Therefore, the obtained result could be used to predict the quality (ash & minerals) of honey, while the confirmation test still needed to detect honey adulteration.

Furthermore, the possibility of using sensory evaluation to detect the authenticity of honey samples was studied. **Table (2)** shows that the best sensorial properties were found in authentic honey (control sample) and honey adulterated with 25% sucrose, where there was no significant difference between them. Also, adulterating honey with 25% glucose syrup did not cause significant change in taste, flavor and consistency, while color and general appearance were significantly affected. Increasing adulteration ratio to 50% glucose decreased taste, flavor, color and general appearance compared to authentic honey, while consistency was not affected. Using 50% sucrose to prepare adulterated honey caused significant decrease in taste and general appearance, while flavor, color and consistency were not significantly affected. Furthermore, using 100% glucose syrup or 100% sucrose caused drastic changes in all sensory parameters except consistency compared to authentic honey. It could be concluded that, determination of sensory properties of honey was not enough to detect adulterated honey, but it needs also to be tested to confirm the authenticity of honey.

High performance liquid chromatography

Sugars are the main constituents of honey, accounting for about 95% of honey dry matter. Especially fructose and glucose concentration as well as the fructose/glucose ratio are useful for the classification of unifloral honeys **(Oddo et al 1995; Oddo and Piro, 2004)**. Therefore, high performance liquid chromatography (HPLC-RID) was used to evaluate authenticity of honey and adulterated honey samples. The obtained standard curves of fructose, glucose and sucrose are clearly shown in **Fig. (1)**.

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Table 1. Effect of adulteration of honey with glucose syrup or cane sugar on Total Soluble Solids (TSS), pH and electrical conductivity (mean ± SD)

Samples	TSS	pH value	Electrical Conductivity (µS)
Authentic honey	84.47 ± 0.896	4.49^{a} ± 0.006	232.32^{a} ± 3.5
Adulterated honey with :			
Glucose (25%)	84.35 ± 0.76	4.63^{a} ± 0.045	174.13^{c} ± 2.33
Glucose (50%)	84.13 ± 1.24	4.01^{b} ± 0.059	120.67^{e} ± 2.65
Sucrose (25%)	84.20 ± 0.956	3.95^{d} ± 0.065	180.84^{b} ± 3.11
Sucrose (50%)	84.43 ± 0.117	3.80^{c} ± 0.046	141.46^{d} ± 1.43
Sucrose syrup (100%)	84.50 ± 0.362	3.72^{c} ± 0.035	59.51^{f} ± 0.65
Glucose syrup (100%)	84.37 ± 0.503	4.53^{a} ± 0.121	11.73^{h} ± 0.11
Glucose: Sucrose (1:1)	84.10 ± 1.01	3.84^{c} ± 0.021	34.595^{g} ± 0.87

a, b, c, d, f, g, h: Means having different letter exponents within column are significantly different ($p < 0.05$)

Table 2. Sensory evaluation of adulterated honey. (mean ± SD of 10 panelists)

Samples	Taste	Flavor	Color	texture	General Appearance
Authentic honey	17.5^{a} ± 1.35	17.1^{a} ± 1.73	17.7^{a} ± 1.49	16.7^{ab} ± 2.26	18.1^{a} ± 0.74
Adulterated honey with :					
25% Glucose	16.3 ^{ab} ± 1.57	15.3^{ab} ± 2.00	15.8^{bc} ± 2.20	16.8^{ab} ± 2.30	16.0^{b} ± 2.54
50% Glucose	15.2^{bc} ± 1.48	14.9^{b} ± 2.18	14.8^{cd} ± 1.54	16.2^{ab} ± 2.44	15.5^{bc} ± 1.65
25% Sucrose	17.3^{a} ± 1.83	17.1^{a} ± 2.02	16.9^{ab} ± 1.91	17.9^{a} ± 1.85	16.9^{ab} ± 1.80
50% Sucrose	15.4^{dc} ± 2.46	15.3^{ab} ± 2.71	16.^{abc}1 ± 1.85	16.9^{ab} ± 2.23	15.6^{bc} ± 3.31
100% Sucrose	14.6^{bc} ± 1.90	14.4^{b} ± 2.32	15.7^{bc} ± 2.00	15.4^{b} ± 2.41	15.5^{bc} ± 2.27
100% Glucose	14.1^{c} ± 2.77	15.1^{b} ± 2.13	14.5^{cd} ± 1.78	15.5 ^{b} ± 3.06	13.8^{c} ± 2.74
50% Glucose + 50% Sucrose	14.8^{bc} ± 2.15	14.4^{b} ± 1.51	13.8^{d} ± 1.55	16.2^{ab} ± 2.10	14.9^{bc} ± 1.37

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a, b, c, d: Means having different letter exponents within column are significantly different (p < 0.05)

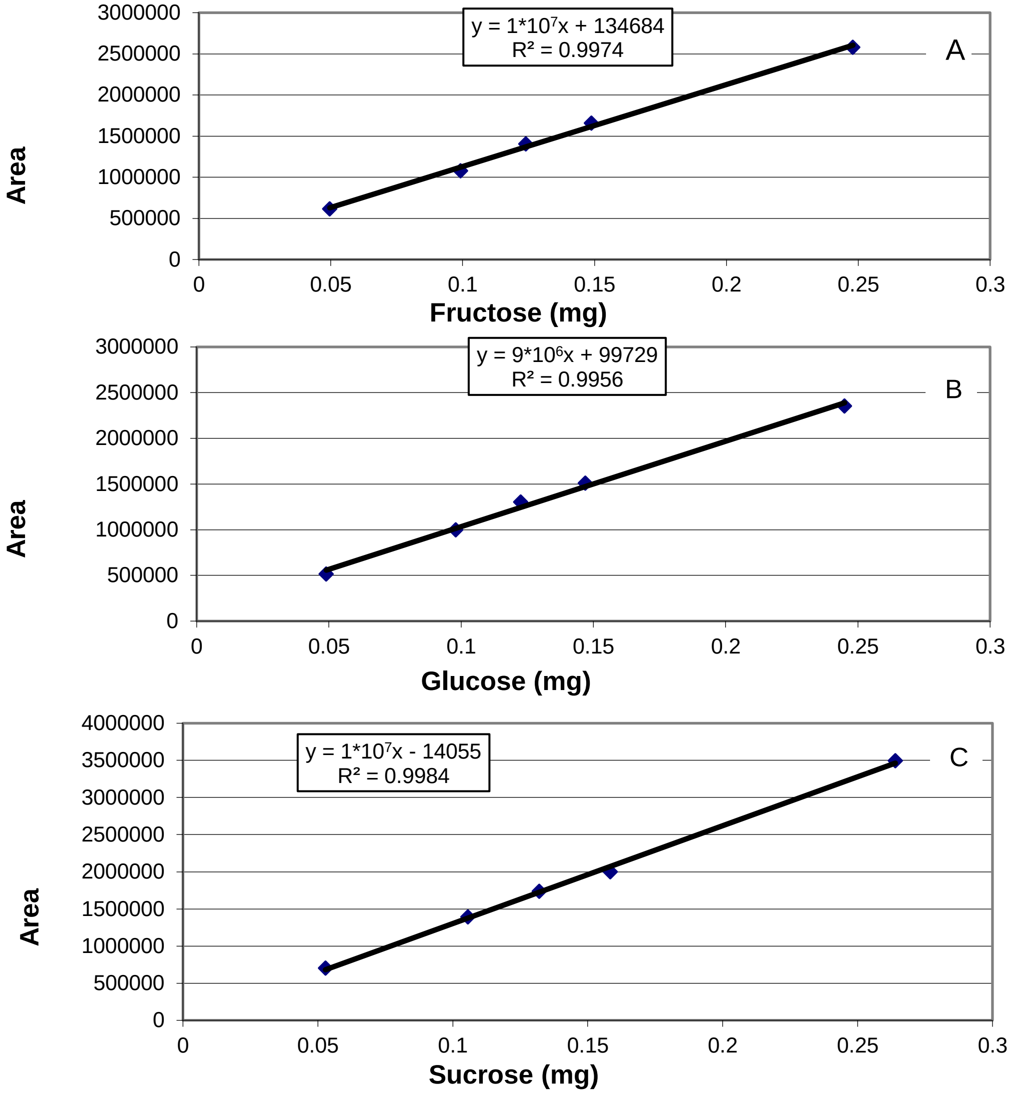


Fig. 1. HPLC standard curves of fructose (A), glucose (B) and sucrose (C).

The possibility of using HPLC to detect adulteration of honey through determining their sugars content was evaluated as shown in **Table (3)**. The obtained results indicated that, authentic honey is characterized by its higher glucose/fructose ratio (1.21) compared to adulterated honey samples (ranged between 0.35 - 0.94). This result agree with **Cotte et al (2003)**. Also, adulterated honey with sucrose showed higher fructose/glucose ratio than adulterated honey with glucose syrup. This result could be due to acid hydrolysis of sucrose syrup during preparing adulterated honey. Using HPLC to determine sugars profile could be recommended as a confirmed method for the easy and fast method such as (FT-IR).

FT-IR Spectroscopy

In the recent years, (FT-IR) spectroscopy (4000-400 cm^{-1}) has gained wide acceptance in the field of food science for quantitative and qualitative analysis because of its advantages over other analytical techniques. This technique is rapid, low-cost, non-destructive and easy to use. Therefore, FT-IR spectral bands of sucrose, glucose and fructose were evaluated to select the main peaks that could be used for identification and quantification of sugars in honey.

Table 3. Sugars contents of adulterated honey as determined by high performance liquid chromatography (HPLC)

	Fructose (%)	Glucose (%)	F/G ratio	Sucrose (%)	Total (%)
Authantic Honey	34.675	28.737	1.21	2.855	66.267
Adulterated honey with					
25% Glucose	24.367	26.961	0.901	2.604	53.932
50% Glucose	21.905	26.589	0.821	2.804	51.298
25% Sucrose	28.935	30.759	0.941	12.799	72.493
50% Sucrose	26.245	28.86	0.91	19.404	74.509
Formulated sugar syrup					
Glucose (100%)	ND	16.783	--	--	16.783
Sucrose (100%)	5.196	7.168	0.72	50.738	63.102
Glucose + Sucrose (1:1)	3.998	11.22	0.35	28.163	43.381

- Sugars calibration Curve

Fig. (2) shows spectral bands of different sucrose concentrations, ranging from 5% to 40%. The intensity of the absorption peaks of the corresponding sucrose shows a concentration-dependent change in the spectra. The main FT-IR spectra of sucrose solution at different concentration levels are clearly shown in **Fig. (2)** and given in **Table (4)**. Sucrose solution shows multiple peaks that are significantly different in the range of 900 to 1300 cm^{-1} wavenumber. The predominate peaks in the 900 to 1300 cm^{-1} wavenumber range of the spectrum are given in **Table (4)** as well as their peak assignments. The main peaks are concentrated at 1048 ± 5 cm^{-1} (C-O stretching), 1138 ± 5 cm^{-1} (C-O-C antisymmetric stretching) and 990 ± 5 cm^{-1} (CH_2 out-of-plane deformation).

Peaks height of dominant spectral absorption band at 1138, 1048 and 990 cm^{-1} ± 5 cm^{-1} were calculated for each concentration (triplicate) using the corrected baseline method. The relationship between sucrose concentration and the absorbance (peak height) with its mathematical relationships are presented in **Fig. (3)**. This figure exhibits linear relationship; and represents the direct univariate standard curve of the sucrose (the coefficient of determination R^2 ranged between 0.96 - 0.98).

The main FT-IR spectra of glucose at different concentration levels are presented in **Fig. (4)**. The predominate peaks in the 985 to 1152 cm^{-1} wavenumber range of the spectrum and their relation to glucose concentration are given in **Table (5)** as well as their peak assignments. The main peaks are concentrated at 1152 ± 5 cm^{-1} (C-O-C antisymmetric stretch), 1105 ± 5 cm^{-1} (C–O and C–C vibrations), 1077±5 cm^{-1} (Stretching CO & CC), 1030±5 cm^{-1} (Stretching CO) and 985 ± 5 cm^{-1} (CH_2 out-of-plane deformation).

The relationship between glucose concentration and the absorbance (peak height) are presented in **Fig. (5)**. Glucose standard curves were characterized with their linear relationship; and their higher coefficient of determination, where R^2 were higher than 0.9 at different selected wave numbers.

Furthermore, FT-IR spectra (fingerprints) of different fructose concentration were determined as shown in **Fig. (6)**. The main FT-IR spectra of fructose were found in the region of 1057 to 1632 cm^{-1}. The main peaks are concentrated at 1632 ± 5 cm^{-1} (bending OH), 1084 ± 5 cm^{-1} (Stretching CO & CC) and 1057 ± 5 cm^{-1} (C-O stretch). Peak heights of dominant spectral absorption band at different fructose concentrations are clearly shown in **Table (6)**. The relationship between concentration of fructose and the absorbance (peak height) of main peaks are presented in **Fig. (7)**. The obtained standard curves are characterized with their linear relationship and higher R^2 (>0.9) for all selected spectral bands.

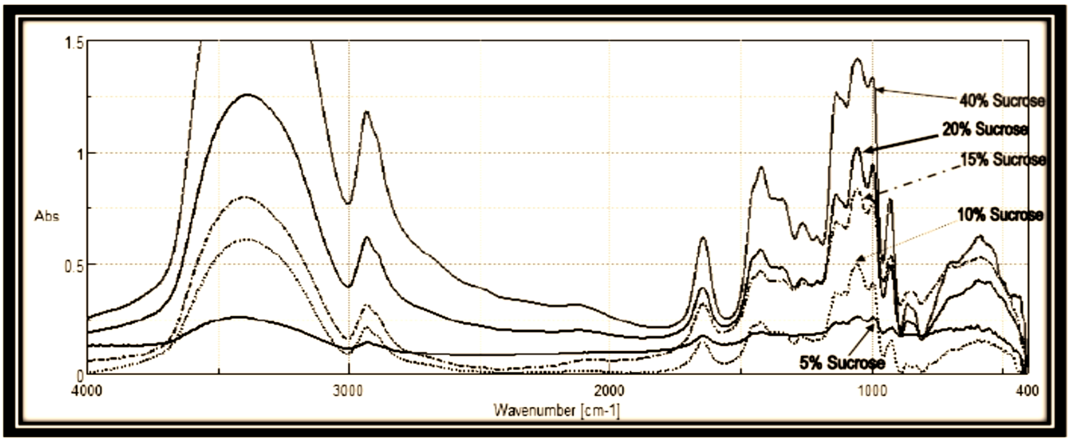
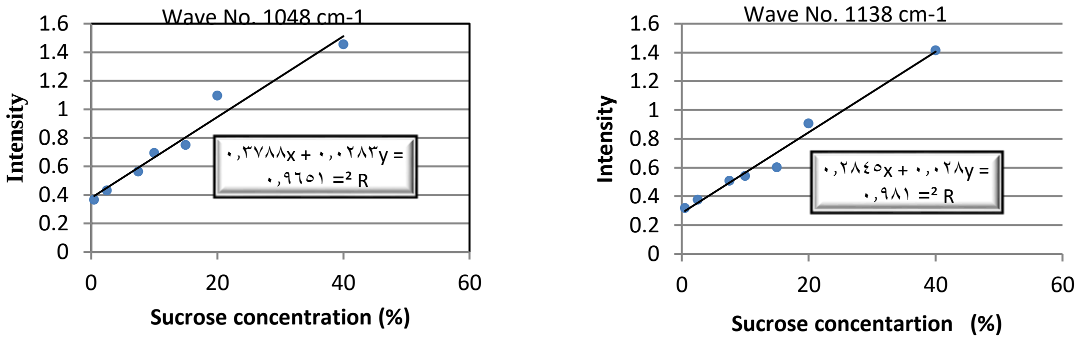


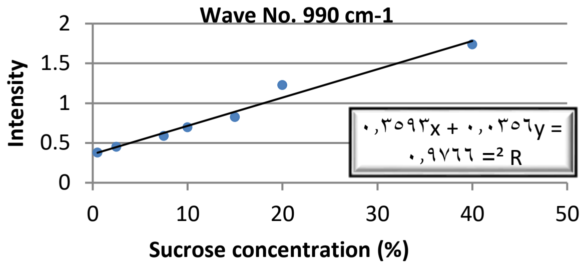
Fig. 2. FT-IR spectra of sucrose solution (dried on KBr disc) at 5, 10, 15, 20 and 40% concentration levels

Table 4. FT-IR spectral bands of sucrose solution (dried on KBr disc) at wave numbers 1048 (A), 1138 (B) and 990 (C) ±5 cm^{-1}

Wave No. cm^{-1}	Intensity							Assignments
	Concentration (%)							
	0.5	2.5	7.5	10	15	20	40	
1048±5	0.366	0.431	0.564	0.695	0.751	1.096	1.455	C-O stretching
1138±5	0.318	0.377	0.508	0.542	0.600	0.907	1.415	C-O-C antisymmetric stretch
990±5	0.379	0.453	0.588	0.699	0.826	1.228	1.738	CH2 out-of-plane deformation



(A) (B)



(C)

Fig. 3. FT-IR of sucrose solution (dried on KBr disc) standard curves at wave numbers 1048 (A), 1138 (B) and 990 (C) ±5 cm^{-1}.

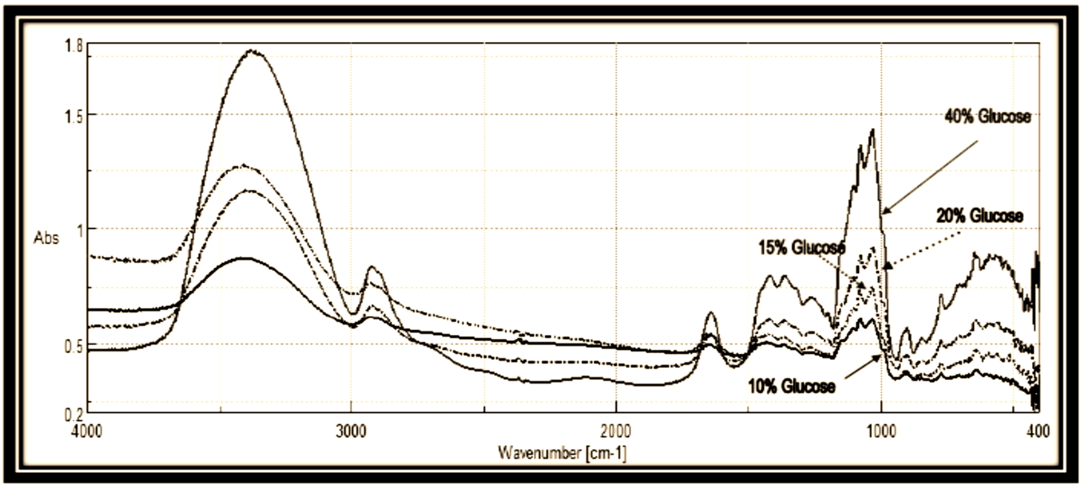
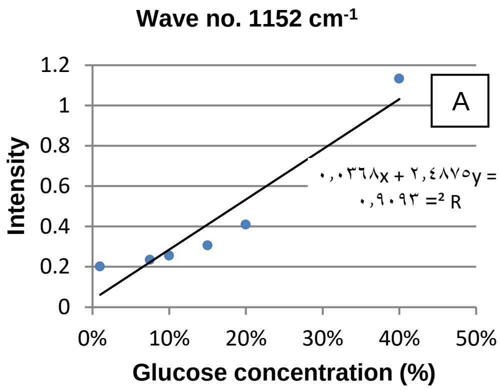


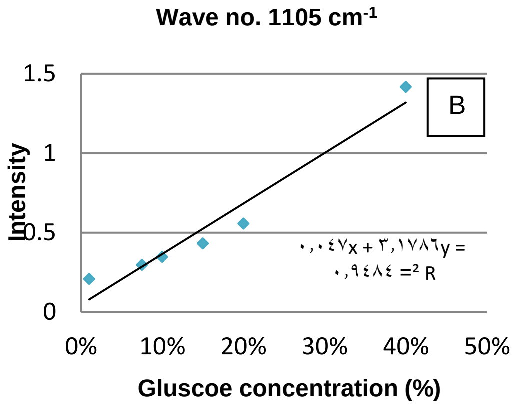
Fig. 4. FT-IR spectra of glucose solution (dried on KBr disc) at concentration levels 10, 15, 20 and 40%

Table 5. FT-IR spectral bands of glucose solution (dried on KBr disc) at 1152 (A), 1105 (B) 1077 (C), 1030 (D) and 985 (E) ±5 cm^{-1}

Wave No. cm^{-1}	Intensity						Assignments
	Concentration (%)						
	1	7.5	10	15	20	40	
1152±5	0.203	0.236	0.256	0.308	0.410	1.134	C-O-C antisymmetric stretch
1105±5	0.208	0.296	0.346	0.432	0.557	1.415	C–O and C–C vibrations
1077±5	0.221	0.409	0.501	0.637	0.768	1.839	Stretching CO and CC
1030±5	0.215	0.341	0.408	0.523	0.678	1.641	Stretching CO
985 ±5	0.156	0.232	0.257	0.337	0.523	1.385	CH_2 out-of-plane deformation



(A)



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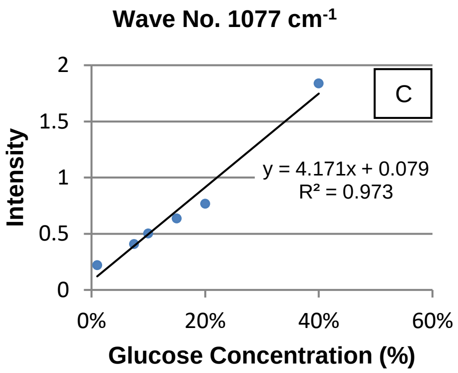
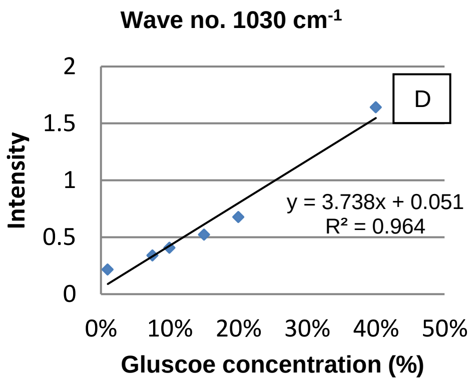




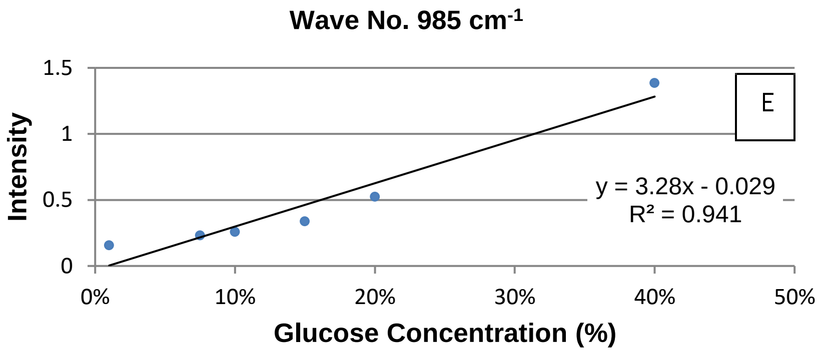


Fig. 5. Standard curves of glucose at several wave numbers (A-E)

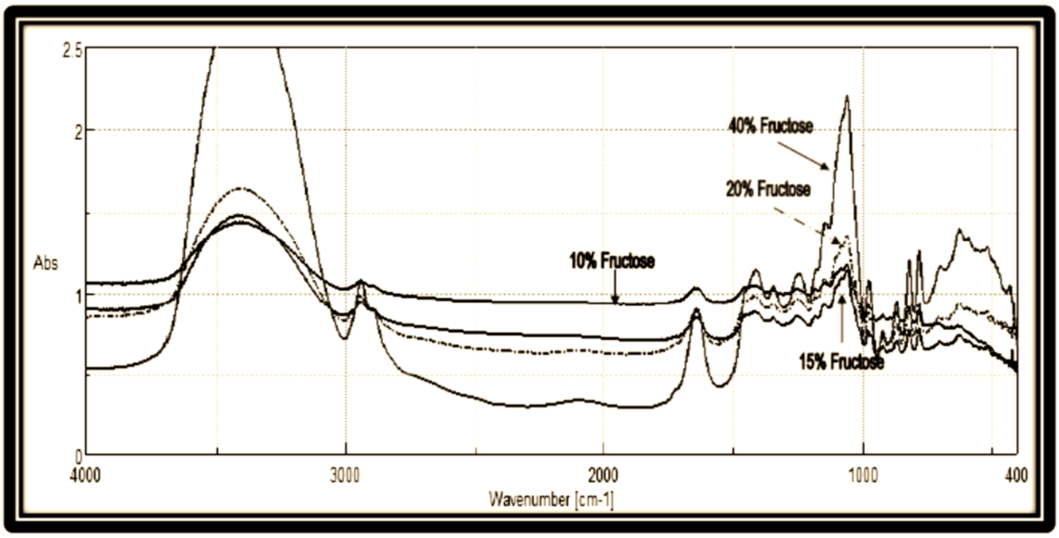
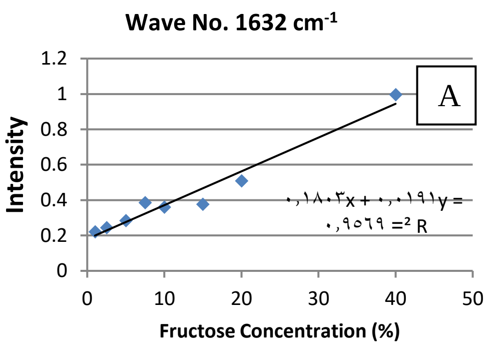
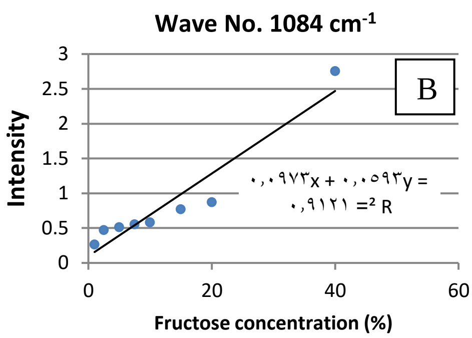


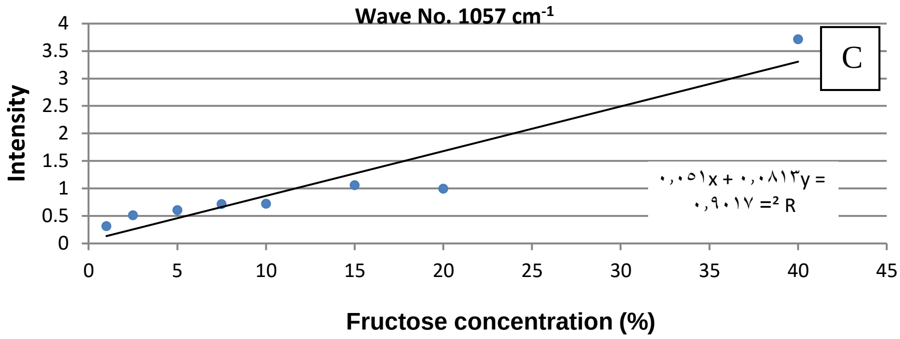
Fig. 6. FT-IR spectra of fructose solution (dried on KBr disc) at 10, 15, 20 and 40% concentration level

Table 6. FT-IR spectral bands of fructose solution (dried on KBr disc) standard curve at 1632 (A), 1084 (B) and 1057 (C) ±5 cm^{-1}

Wave No. cm^{-1}	Intensity								Assignments
	Concentration (%)								
	1	2.5	5	7.5	10	15	20	40	
1632±5	0.220	0.244	0.284	0.386	0.361	0.375	0.507	0.995	bending OH
1084±5	0.265	0.470	0.511	0.551	0.580	0.768	0.871	2.752	Stretching CO & CC
1057±5	0.310	0.510	0.602	0.715	0.720	1.058	0.994	3.713	C-O stretch







(C)

Fig. 7. Standard curves of fructose solution (dried on KBr disc) at 1632 (A), 1084 (B) and 1057 (C)±5 cm^{-1}.

FT-IR spectral of authentic and adulterated honey

FT-IR spectral bands of authentic and adulterated honey with different ratios of glucose and sucrose are shown in **Figs (8 & 9)**. The appearance shape for spectra of all samples are similar by naked eye, but each of them was differ from others in absorbance degree. The Spectra of the samples show absorbance bands at three regions (3363 ± 6 : 2886±3 cm^{-1}), (1640 ± 3 : 1260 ± 1 cm^{-1}) and (1186 ± 10 : 921 ± 2 cm^{-1}). These bands are representative of the chemical groups of components present in the pure and adulterated honey samples. Assignments of the functional groups of the components corresponding to the vibration modes was based on identification of the spectra peaks and matching the frequency with the corresponding chemical group that absorbs in this region.

The region (800:1500 cm^{-1}) corresponds to the absorption zones of the 3 major sugar constituents of honey, fructose, glucose and sucrose, while the 750 : 900 cm^{-1} region is the anomeric region and is characteristic of the saccharide configuration **(Ozaki, 1999)**.

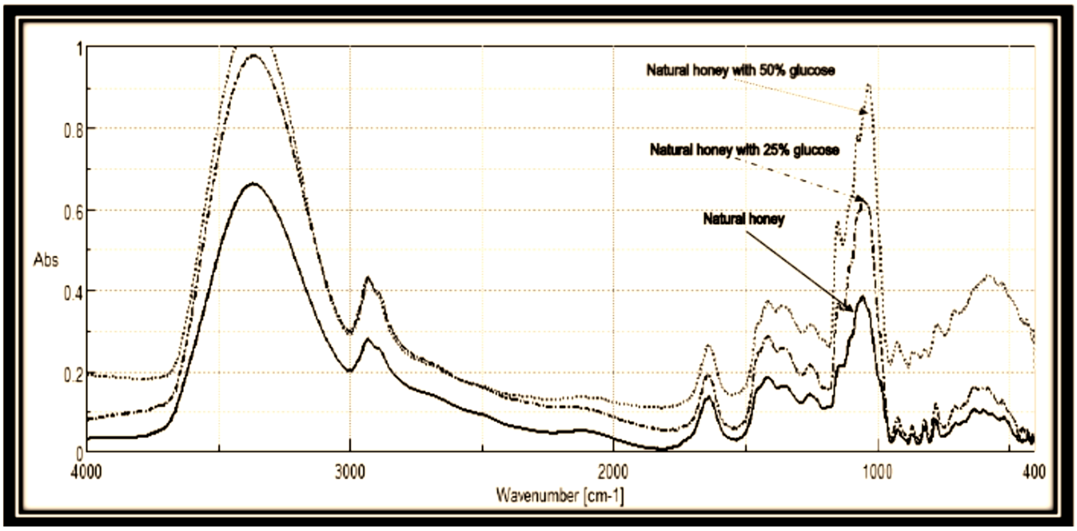


Fig. 8. FT-IR spectral bands of authentic and adulterated honey with different concentration levels of glucose

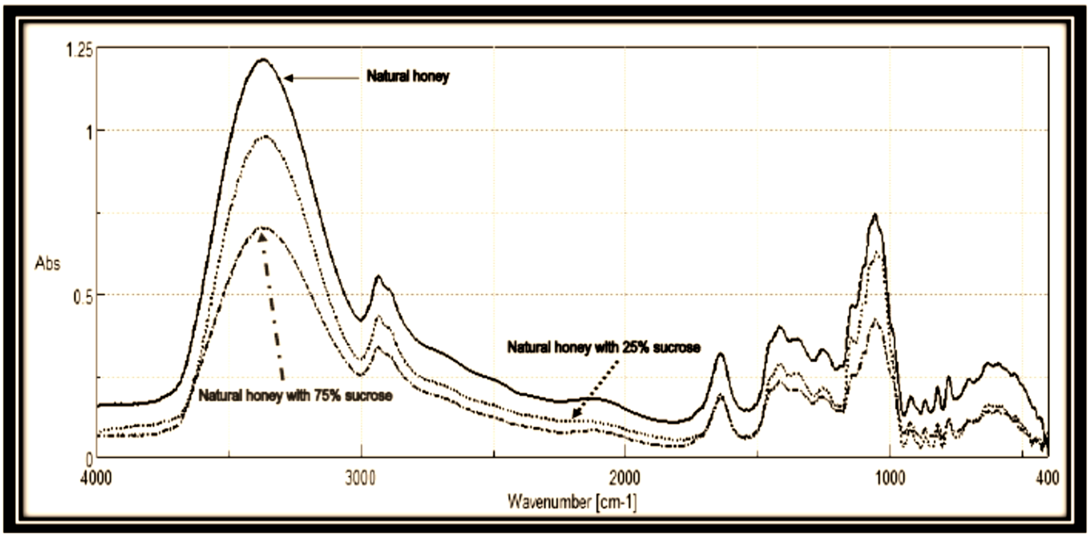


Fig. 9. FT-IR spectral bands of authentic and adulterated honey with different sucrose concentration levels

The bands in the (3363 : 2886 cm^{-1}) region are assigned to Stretching OH, C-H stretching symmetric of carboxylic acid and NH3 band of free amino acids and C-H stretching asymmetric of alkene, while those around (1640 : 1230 cm^{-1}) are due to lower water content in the samples and they are characteristic to O-H Bending, O-CH Bending, OH Bending of C-OH group, C-C-H bending, OH bending of C-OH group and C-C-H bending which indicates that discrimination of honey sugars is based mostly on the differences in these critical regions related to sugars in the spectra **(Sivakesava and Irudayaraj, 2001)**. The last region from 921:1189 cm^{-1} is mainly corresponds to C-OH bending, C-C stretching, C-O stretching of C-O-C, combination of C-O and C-C stretching, CH2 out of plane deformation and C-H bending of carbohydrates.

Adulterated honey samples with glucose were characterized with specific spectral peaks where the absorbance was increased by increasing the ratio of adulteration with glucose at 1087, 1105, 1189 and 984 cm^{-1} while the adulteration with sucrose led to increase in the absorbance of spectral bands which are characterized for sucrose at 1054, 1149 and 984 cm^{-1} especially in adulterated authentic honey with sucrose (50 : 50 %).

Fig. (10) shows FT-IR spectral bands of adulterated honey (product like honey) with sucrose 100%, glucose 100% and mixture of sucrose (50%) plus glucose (50%). Adulterated sucrose honey (100 %) has a definite spectral peaks that attributed to main functional groups in sucrose with a high absorbance at 922, 988, 1051, and 1138 cm^{-1}, while honey with 100% glucose was characterized with spectral bands at 993, 1049, 1078, 1106 and 1152 cm^{-1} with high absorbance. In mixed adulterated honey with 50 % sucrose plus 50% glucose, it was found that some of characteristic bands were high in their absorbance than sucrose and low in their absorbance than glucose such as 921, 989, 1048, 1078 and 1151 cm^{-1}.

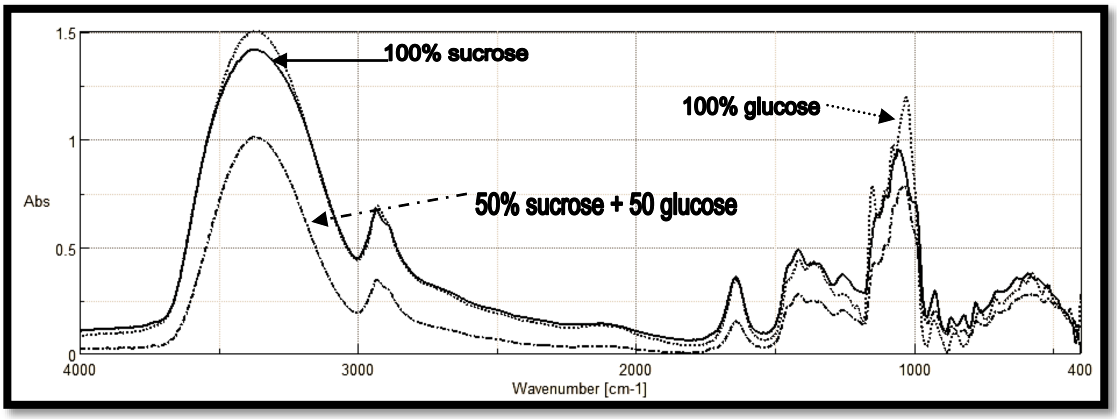


Fig. 10. FT-IR spectral bands of full adulterated honey of 100% sucrose, 100% glucose or 50% sucrose plus 50% glucose syrup

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