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Effect of Storage and Processing Temperatures on Honey Quality

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Abstract

The purpose of this research was to assess the impact of heating and storage conditions on the diastase number, invertase number and hydroxymethylfurfural (HMF) in three types of Iraqi honey from(Haj-Umran, Shaqlawa and Sedacan). Average values of the physico-chemical characteristics of fresh honey were as follows : HMF 3.916 mg/Kg, diastase number 17.66 , invertase number 17.27, proline 707 mg/Kg, reducing sugar 64.59 %, sucrose 5.07 %, moisture 17.593 %, ash 0.204 %, pH 3.9 , total acidity 28.763 mg/Kg and E.C. 0.287 ms/cm.

The three types of honey were heated at 55,65,75°C for 5,15,20,25 minutes then the honey samples were left to room temperature(20-23°C) and stored at this ambient temperature for 26 weeks to be assessed. The changes in the HMF, diastase number, invertase content were observed. Heating treatment applied to honey did not effect on diastase number and invertase, except the effect storage time. While, HMF content of honey samples affected significantly from storage time and heating.

الخلاصة

ان الغرض من هذا البحث لتقييم تأثير الحرارة وظروف الخزن على عدد الدياستاز وعدد الانفرتيز والهيدروكسي ميثايل فورفورال في ثلاثة انواع للعسل المحلي من(حاج عمران وشقلاوة وسيدكان).وكان متوسط القيم للخصائص الفيزيائية والكيميائية للعسل الطازج كالاتي: الهيدروكسي ميثايل فورفورال 3.916ملغم/كلغم و عدد الدياستاز 17.66 وعدد الانفرتيز 17.27والبرولين707 ملغم/كلغم والسكريات المختزلة64.59% والسكروز 5.07% والرطوبة17.593% والرماد% 0.204 ودرجة الحموضة 3.9 والحموضة الكلية 28.763 ملغم/كلغم والتوصيلية الكهربائيةms/cm 0.287 .عرضت العينات الثلاثة من العسل الى التسخين لدرجات 55,65,75 ° م لمدة 5,15,20,25 دقيقة. تركت عينات العسل في درجة حرارة الغرفة(23−20° م)وتم تخزينها لمدة 26 اسبوعا للتقييم. وقد لوحظت التغييرات التي طرأت على الهيدروكسي ميثايل فورفورال و عدد الدياستاز وعدد الانفرتيز .فالمعالجات الحرارية التي طبقت على العسل لم تؤثر على عدد الدياستاز وعدد الانفرتيز بأستثناء تأثير مدة الخزن. أما محتوى الهيدروكسي ميثايل فورفورال في عينات العسل تأثرت بشكل كبير لمدة الخزن والحرارة.

Introduction

The composition of honey depends on produced season, origin of nectar and climatic conditions(Fallico *et a1.*). The most important factor affecting honey composition is plant origin (Serrano *et al.,*2004). The honey contains, enzymes, water, carbohydrate, acids, dextrin, ash, vitamins, pollen and substance aroma(Silica,2002 ; Fallico *et a1.,* 2003), the contents of these components in honey are the most important quality criteria of honey and indicate some important deterministic quality and properties of the honey sample. Honey having high water content is more likely to ferment. It is frequently necessary to heat honey to prevent fermentation by sugar-tolerant yeasts and to keep it liquid as long as possible(Fallico *et a1.,* 2003). In Iraq, the consumer prefers the honey that is liquid phase which includes the exposure to heat. Diastase activity and hydroxymethylfurfural (HMF) are considered as the main parameters for evaluating: the freshness , the heat and storage history of honey(Sanho *et a1.,* 1992). Invertase like diastase, this enzyme is also susceptible to heating and storage factors so can be used also as a quality indicator.

Many authors have expressed different opinions about the propriety of those parameters. White, *et a1.(* 1964) demonstrated that invertase is preferable than

diastase as it is more sensitive to heating, he examined the effects of storage at several temperatures on some quality factors of honey to facilitate evaluation of commercial storage and processing conditions. White (1992,1994) criticizes severely the use of diastase and HMF content as quality criterion. Dustman (1993) maintained that invertase in combination with other analytical criteria can detect damage by heating or over storage and also HMF is rather inappropriate for the proof of heat damage, if taken into account as a sole criterion. Changes in HMF contents and diastase activity during storage have previously been studied by Tharasyvoulou (1986) and more others.

In the present study, HMF, diastase number, invertase number, proline, reducing sugar, sucrose, moisture, ash, pH, total acidity and electrical conductivity have been measured in three fresh honey samples collected from : Haj-Umran, Shaqlawa and Sedacan in Erbil, Kurdistan of Iraq were determined in October 2010. The changes in HMF contents, invertase and diastase number of the samples were also examined after 6 month storage at different temperatures .

Experimental procedure

Collection of Samples

Three honey samples were collected for this study from different regions (Haj-Umran, Shaqlawa and Sedacan) in Erbil, Kurdistan of Iraq . The samples were harvested in October, and analyzed immediately .

Chemical analysis

The samples of honey were analyzed by the standard methods of the Association of Official Analytical Chemists (AOAC, 2007). Moisture content was estimated by measuring refractive index (RI) using Abbe's refractometer, ash was determined by ashing at 550ºC. For acidity (as formic acid), 10 g honey was dissolved in 75 ml distilled water and titrated with 0.1N NaOH, pH values of the honey solution were measured by a pH meter . Reducing and non-reducing sugars (as sucrose) were determined according to official methods of analysis reported in AOAC ,2007). Electrical conductivity of honey was determined for a honey solution containing 20% of dry substance of honey in 100 ml of distilled water (Bogdanov *et a1.,*1997).

The HMF content was determined colorimetrically after dilution with distilled water and addition of p-toluidine solution. Absorbance of the solution was determined at 550 by UV spectrophotometer(White ,1979).

To determine the diastase number, a certain amount of honey was kept at a permanent temperature by mixing with 1% starch solution. The starch was hydrolyzed by the diastase enzyme of the honey. The results are expressed as ml of 1% of starch hydrolyzed by an enzyme in 1 g of honey per hour (Anonymous, 1990). Determination of proline in honey was based on its reaction with acid ninhydrin solution to form a coloured component after adding 2-propanol ,and was colorimetrically determined by measuring the absorbance at 520 nm using a 1 cm cell in a LKB-Biochrom spectrophotometer USA(Bogdanov,2002). Invertase number was determined according to the method of (Signthaler1977) which is based on the spectrophotometric measurement of decomposition of p-Nitrophenyl-a-D-glucopyrinoside(p-NPG) in p-nitrophenol at 400 nm. The results are expressed in units of the enzyme per kilogram(U/Kg). Then the value was expressed as invertase number (IN) which was indicates the amount of sucrose per gram hydrolysed in 1 h by the enzymes contained in l00g of honey under test conditions (Bogdanov *et a1.,* 1997).

Storage

Honey samples were left to room temperature(20-23°C) and stored at this ambient temperature for 26 weeks in the laboratory, every three month small portion of samples were taken for analyzed; HMF contents, invertase and diastase numbers.

Heating treatment

The experiment was conducted under isothermal treatment. Honey was divided into 12 portions, each of those being then submitted to one of the treatments under study heating at 55,65,75°C during 5,15,20 and 25 minutes, respectively. The heated samples were then left to room temperature(20-23°C) ,periodically, that is once every 3 month , small portion of samples were taken for analysis for 26 weeks. All experiments were conducted in duplicated. The effect was assessed ,of heating on changing the main quality characteristic during storage ; HMF contents, invertase and diastase numbers.

Statistical analysis:

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 11.5 for Windows®, ver. 2). Significance of differences was defined at $P < 0.05$ following (Tabachnick and Fidell, 1996).

Results and Discussion

Physico-chemical characteristics:

The chemical components of the fresh honey samples are shown in Table 1. Honey samples collected from Sedacan had the highest moisture content followed by Shaqlawa and Haj-Umran, where the corresponding percentages of moisture were 18.85, 17.92 and 16.01, respectively, similar values were found in Moroccan honeys (Terrab *et a1.*,2003). Moisture content is highly important for the shelf-life of the honey during storage because a high moisture content causes honey to ferment and spoil (Perez *et al.,*1994). The mean values of sucrose, ash and HMF in the honeys collected from Haj-Umran were lower than those of Shaqlawa and Sedacan as shown in Table 1.

The pH values of the three samples (Haj-Umran, Shaqlawa and Sedacan) were acidic with pH values of 4.01, 4.04 and 3.66 , respectively, which are in agreement with that reported in many counties by many investigators (Terrab *et al.,*2003; Azeredo *et al.,*2003 and Serrano *et al.,*2004). pH is a useful index of possible microbial growth. The higher total acidity values of Shaqlawa honey were (32.81 mg/Kg) followed by Sedacan (30.10 mg/Kg) and Haj-Umran (23.38 mg/Kg). The mean values for total acidity found agreed with those from other studies (Kaushik *et al.,*1993 and Costa et a1.,1999). The higher values of diastase and invertase number were obtained with samples collected from Haj-Umran (17.90 and 18.07) followed by Shaqlawa (17.60 and 17.52) and Sedacan (17.5 and 16.23). Honey samples collected from Sedacan had the highest proline and E.C. content (831 mg/Kg and 0.452 ms/cm) followed by Haj-Umran samples (790 mg/Kg and 0.241 ms/cm) and Shaqlawa samples (518 mg/Kg and 0.170 ms/cm). These results did not differ from that reported in many counties by many investigators (Terrab *et al.,*2003 and Azeredo *et al.,*2003). Results in Table 1 compared to those reported in European Union Commission (EUC) (1996) and Codex Alimentarius Commission (CAC) (2001), indicating good degree of maturity which are in agreement with EUC and CAC.

The effect of heating and storage on diastase number:

The values of diastase number in different temperatures and different storage time are summarized in Table 2 and Fig.(1,2 and 3).During the storage, the changes of

the diastase number in the three honey samples ,according to 12 treatments had similar behaviors as diminished continuously. When comparing the results of the three honey samples (Table 2) it indicate that heating does not cause a significant decrease of diastase number. Samples collected from Haj-Umran had a range between (17.89-3.73), for samples collected from Shaqlawa had a range between (17.77-3.58) and samples collected from Sedacan had a range between (17.7-3.76) during storage for 6 months. During the first three months the diastase activity decreased 19.45%, 22.06% and 21.63% in Haj-Umran, Shaqlawa and Sedacan honey samples. It decreased 79.15%, 79.85% and 78.75%, respectively after storage for six months. Similar trend was noticed by White and Subers (1963). Sancho *et al.,* (1992) reported depletion in diastase number after studied the effect of storage for two years at 20°C. Cervantes *et al.,* (2000) also reported decrease in diastase number after heating the honey at 55°C and then storing it for three and half months at 26°C. Castro-Vazquez *et al.,* (2008) also reported that diastase number was out of the legal limit in citrus honey stored for 12 months at 40ºC. The mean diastase number of the honey samples from different storage time was found to be statistically significant($P< 0.005$). On the other hand, there was no significant ($P > 0.005$) difference among the temperature of heating on diastase number.

The effect of heating and storage on invertase number:

The values of invertase number in different temperatures and different storage time are summarized in Table 3 and Fig.(1,2 and 3).During the storage, the changes of the invertase number in the three honey samples ,according to 12 treatments had similar behaviors as diminished continuously. The results indicate that heating does not cause a significant decrease of invertase number.

Samples collected from Haj-Umran had a range between (17.20-6.43), for samples collected from Shaqlawa had a range between (17.16-5.06) and samples collected from Sedacan had a range between (16.06-6.39) during storage for 6 months. During the first three months the invertase number decreased 10.7%, 10.2% and 3.11% in Haj-Umran, Shaqlawa and Sedacan honey samples. It decreased 62.61%, 70.5% and 60.21%, respectively after storage for six months. Despite the fact that Sedacan honey sample shows a lower level of initial value, it also shows highest resistance at the decomposition of the enzyme if compared it with the other samples with higher values. This may be due to the fact that Sedacan honey samples are usually honeys of early spring and the lower contents of the enzyme is caused by lower concentration of nectar with a higher participation of saccharide and a reduced activity of bee colonies during their growing (Oddo *et al.,*1999). When the mean invertase number of the honey samples from different storage time was found to be statistically significant($P< 0.005$). On the other hand, there was no significant ($P > 0.005$) difference among the temperature of heating on invertase number.

The effect of heating and storage on HMF content:

The initial content of HMF was low in the three samples of the honey and the heating to which honey samples were increased depend on the storage time. During the storage, the changes of the HMF content in the three honey samples ,according to 12 treatments had similar global behaviors, as HMF raised continuously during storage, although according to different ratio are summarized in Table 4 and Fig.(1,2 and 3).

During the first three months the HMF increased 32.7%, 6.8% and 8.3% in Haj-Umran, Shaqlawa and Sedacan honey samples. It increased 41.6%, 46.7% and 36%,

respectively after storage for six months. The maximum increase in HMF after storage for six months was found higher in Shaqlawa sample than in Haj-Umran and Sedacan honey samples. From the results in Table 4 indicates that heating the three honey samples at 55 ºC for (5,15,20 and 25) min does not cause a significant increase of HMF. At 65 ºC HMF content in Sedacan sample is still low, while in Haj-Umran and Shaqlawa samples show the same significant increase . At 75 ºC HMF content is high in the three honey samples. It was noticed that HMF increased slowly until 65ºC, then a sharp increase was observed at higher temperatures. Heating at these temperatures(55 ºC,65 ºC and 75 ºC) for 5, 15,20 & 25 min exhibited that rate of HMF formation was affected by heating time in temperatures that higher than 65 ºC . These observations agree with those given by Tosi *et al.,* (2001) who recorded that HMF increased from 10.1 ppm to 32.8 ppm by heating of honey for 1 min at 100ºC & 140ºC, respectively. Also, Karabournioti and Zervalaki (2001) found that heating cotton honey for 24 h at 45ºC, 55ºC, 65ºC & 75ºC increased HMF from 9.7 ppm (unheated) to 9.9, 11.40, 16.50 & 52.70 ppm, respectively. However, it was found that HMF contents in the three honey samples were lower than 40 mg kg^{-1},as recommended by Codex Alimentarius Commission (CAC) (2001)and European Union Commission (EUC) (1996).

Analyzing the increasing dynamic of the HMF concentration during storage a degree dynamics could be established, taking in to account a ratio of the type:

$K_t = C / C_\circ$

Where: C, is the concentration of HMF(mg kg^{-1}) after the storage time t, in weeks.

$C_\circ$, is the initial HMF(mg kg^{-1}) concentration at the beginning of the storage.

K_t, is the constant of the first degree.

According to obtained K constant (Table 5) in the three assessed samples of honey, there is confirmed the pattern is a good assessment, through the high correlation coefficients obtained, and the different speed of its formation in the three sorts of honey as values of the K constant. The increase of the HMF concentration might be to the diminution of the fructose content (Raminez Cervantes *et a1.,* 2000),temperature and time of heating(Karabournioti and Zervalaki ,2001; Fallico *et a1.,* 2003 and White, *et a1.,* 1964) , storage conditions , use of metallic containers (Fallico *et a1.,* 2003) and chemical properties of honey, which are attributed to the floral source from where the honey has been extracted. However, no information on the correlation between chemical characteristics and HMF level of honey is available (Fallico *et a1.,* 2003).

Conclusion

1. Invertase is more sensitive than diastase to thermal treatment and storage of honey, therefore invertase is better parameter for characterization of thermal treatment and storage time.
2. In the three assessed samples honey, the increase of the HMF concentration during storage followed a first degree reaction.
3. Activity of invertase and diastase as well as HMF and proline content were determined for the first time in honey of Erbil in Kurdistan of Iraq.
4. In all analyzed fresh honey samples of Erbil origin ,invertase number was not lower than 10 invertase units, as well as diastase activity was not lower than 8 degrees Schade and content of HMF was not higher than 40 mg kg^{-1} according to (EUC) and 60 mg kg^{-1} according to (CAC). Both these parameters certify the good quality of Erbil honey.
5. The other physico-chemical characteristics of the three assessed honey samples of

Erbil were well within the limits prescribed for good quality honey by the Codex Alimentarius Commission and European Union Commission.

Table (1): Physico-chemical parameters of fresh tested honey(Erbil) compared to CAC& EUC standards.

Parameters	Sample(1) Haj-Umran honey	Sample(2) Shaqlawa honey	Sample(3) Sedacan honey	Mean of Tested Honey(Erbil)	CAC**	EUC**
Moisture (%)	16.010	17.92	18.85	17.593	≤ 21	≤ 21
Electrical conductivity (ms/cm)	0.241	0.170	0.452	0.287	--	≤ 0.8
Reducing sugars (%)	63.83	67.61	62.33	64.59	≥ 65	≥ 65
Sucrose (%)	4.09	6.54	4.58	5.07	≤ 5	≤ 5
Total acidity (mg/Kg)	23.38	32.81	30.10	28.763	≤ 40	≤ 50
Ash (%)	0.112	0.377	0.125	0.204	≤ 0.6	≤ 0.6
HMF(mg/Kg)	3.56	4.06	4.13	3.916	≤ 40	≤ 60
pH	4.01	4.04	3.66	3.903	--	--
Diastase number (DN)*	17.90	17.60	17.50	17.66	≥ 8	≥ 8
Proline (mg/Kg)	790	518	831	707	≥180	≥180
Invertase number (IN)*	18.07	17.52	16.23	17.27	≥ 10	≥ 10

*** Grams substrate converted per 100 g honey per hr.**
**** CAC = Codex Alimentarius Commission ; EUC = European Union Commission.**

Table (2): Effect of storage and temperature on diastase number

Time and temp.	Sample 1(Haj-Umran) (Diastase no.)			Sample 2(Shaqlawa) (Diastase no.)			Sample 3(Sedacan) (Diastase no.)		
	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011
55°C-5min	17.9	14.2	4.8	17.5	13.8	4.0	17.8	13.8	5.5
55°C-15min	17.9	14.2	4.0	17.6	13.8	5.0	17.8	13.9	3.5
55°C-20min	17.9	14.2	5.0	17.9	13.8	5.8	17.8	13.9	7.3
55°C-25min	17.9	14.2	7.3	19.2	13.8	6.2	17.7	13.9	5.5
Mean($X\pm S_x$)	17.9±0.0	14.2±0.0	5.27±0.7	18.05±0.39	13.8±0.0	5.25±0.49	17.78±0.03	13.88±0.03	5.48±0.77
65°C-5min	17.9	14.1	3.0	17.6	13.9	2.0	17.8	13.9	4.5
65°C-15min	17.9	14.2	2.5	17.6	13.8	2.5	17.8	13.9	3.8
65°C-20min	17.8	16.5	2.5	17.6	13.9	2.5	17.8	13.9	2.0
65°C-25min	17.9	14.2	5.0	17.6	13.8	5.0	17.8	13.9	2.0
Mean($X\pm S_x$)	17.88±0.03	14.75±0.58	3.25±0.6	17.68±0.0	13.85±0.03	3.0±0.67	17.8±0.0	13.9±0.0	3.08±0.64
75°C-5min	17.9	14.2	2.5	17.6	13.9	2.5	17.7	13.8	2.0
75°C-15min	17.9	14.2	2.3	17.6	13.9	2.5	17.7	13.8	2.0
75°C-20min	17.9	14.2	3.6	17.6	13.9	3.0	17.8	13.9	2.5
75°C-25min	17.9	14.5	2.5	17.6	13.9	2.0	17.8	13.9	4.4
Mean($X\pm S_x$)	17.9±0.0	14.28±0.07	2.73±0.3	17.6± 0.0	13.9±0.0	2.5±0.20	17.75±0.03	13.85±0.03	2.73±0.57
Unheated	17.9	14.2	10.2	17.6	13.9	6.26	17.5	13.75	7.20
Mean	17.89	14.41	3.73	17.776	13.85	3.58	17.7	13.87	3.76

Table (3): Effect of storage and temperature on invertase.

Time and temp.	Sample 1(Haj-Umran) (Invertase no.)			Sample 2(Shaqlawa) (Invertase no.)			Sample 3(Sedacan) (Invertase no.)		
	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011
55°C-5min	18.0	16.7	7.5	17.5	15.4	5.5	17.2	16.5	7.6
55°C-15min	17.7	16.2	7.8	17.6	15.8	5.5	16.1	16.5	7.6
55°C-20min	17.8	15.9	7.2	17.6	15.8	5.5	16.5	16.5	6.9
55°C-25min	18.1	16.1	7.8	17.9	15.8	5.5	16.1	16.5	6.9
Mean($X\pm S_x$)	17.9±0.91	16.2±0.17	7.5±0.14	17.6±0.08	15.7±0.1	5.5±0.0	16.4±0.25	16.5±0.0	7.25±0.20
65°C-5min	17.2	16.2	6.9	17.4	15.5	5.1	16.4	16.2	6.4
65°C-15min	17.2	14.9	7.5	17.2	15.5	5.2	16.1	15.7	6.4
65°C-20min	16.8	15.4	7.8	17.2	15.5	4.6	16.1	15.4	6.5
65°C-25min	16.2	15.1	5.8	17.1	15.5	4.8	16.1	15.3	6.4
Mean($X\pm S_x$)	16.8±0.23	15.4±0.28	7.0±0.44	17.2±0.06	15.5±0.0	4.9±0.13	16.1±0.75	15.6±0.20	6.4 ±0.02
75°C-5min	17.1	14.5	5.2	16.8	15.2	4.8	16.0	14.9	6.2
75°C-15min	16.9	14.5	5.3	17.1	15.4	4.9	15.5	14.5	5.3
75°C-20min	16.7	14.5	4.5	16.5	14.7	4.8	15.8	14.8	5.4
75°C-25min	16.9	14.5	4.5	16.6	14.8	4.8	15.8	14.5	5.2
Mean($X\pm S_x$)	16.9±0.82	14.5±0.0	4.8±0.21	16.7±0.13	15.0±0.16	4.8±0.02	15.7±0.10	14.6 ±0.10	5.52±0.23
Unheated	18.07	16.8	7.8	17.52	15.8	5.5	16.23	16.5	7.7
Mean	17.20	15.36	6.43	17.16	15.4	5.06	16.06	15.56	6.39

Table (4): Effect of storage and temperature on HMF (mg/Kg).

Time and temp.	Sample 1 (Haj-Umran) (HMF)			Sample 2(Shaqlawa) (HMF)			Sample 3(Sedacan) (HMF)		
	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011	12/10/2010	16/1/2011	12/4/2011
55°C-5min	3.91	5.2	6.62	4.2	5.5	6.9	4.4	4.95	7.09
55°C-15min	3.80	5.76	7.21	4.9	5.8	7.18	4.9	5.3	6.80
55°C-20min	3.95	5.70	8.02	5.2	5.2	7.87	5.2	5.8	7.32
55°C-25min	4.06	6.2	8.58	5.4	5.9	8.10	5.9	6.5	7.96
Mean($X\pm S_x$)	3.93±0.05	5.72±0.21	7.61±0.43	4.93±0.26	5.6±0.16	7.51±0.28	5.1±0.31	5.64±0.34	7.29±0.25
65°C-5min	4.09	5.9	8.17	5.6	5.9	8.21	5.3	6.1	7.98
65°C-15min	4.21	6.50	8.29	5.9	6.0	7.95	5.9	5.79	8.12
65°C-20min	4.45	6.72	8.87	6.8	6.1	8.56	6.3	6.5	8.36
65°C-25min	5.6	7.2	9.08	5.8	6.3	9.15	6.8	7.2	8.87
Mean($X\pm S_x$)	4.59±0.35	6.58±0.27	8.60±0.22	6.03±0.27	6.08±0.08	8.47±0.26	6.1±0.32	6.39±0.30	8.33±0.19
75°C-5min	6.1	6.73	8.8	6.2	6.2	8.5	6.2	7.1	8.31
75°C-15min	5.9	7.31	8.97	6.3	6.5	9.08	6.8	7.3	8.72
75°C-20min	6.5	7.69	9.25	5.8	7.05	9.44	7.5	7.7	9.10
75°C-25min	6.8	7.93	9.80	6.5	6.9	9.76	7.1	8.1	9.69
Mean($X\pm S_x$)	6.33±0.22	7.42±0.26	9.21±0.22	6.2±0.15	6.66±0.19	9.195±0.27	6.9±0.27	7.55±0.22	8.96±0.29
Unheated	3.56	5.11	7.15	4.06	5.3	7.6	4.13	5.6	7.31
Mean	4.95	6.573	8.473	5.72	6.11	8.392	6.026	6.526	8.193

Time and temp.	Sample 1(Haj-Umran)		Sample 2(Shaqlawa)		Sample 3(Sedacan)	
	Correlation Coefficient	Dynamic constant, K	Correlation Coefficient	Dynamic constant ,K	Correlation Coefficient	Dynamic constant ,K
55°C-5min	0.89000	0.01693	0.95499	0.01643	0.90233	0.01611
55°C-15min	0.94457	0.01897	0.94700	0.01465	0.96744	0.01388
55°C-20min	0.97886	0.02030	0.97832	0.01513	0.97800	0.01408
55°C-25min	0.89340	0.02113	0.89509	0.01500	0.99920	0.01349
65°C-5min	0.93488	0.01998	0.97830	0.01466	0.93811	0.01506
65°C-15min	0.92116	0.01969	0.92048	0.01135	0.97880	0.01376
65°C-20min	0.99387	0.01993	0.99311	0.01258	0.99386	0.01327
65°C-25min	0.91887	0.01621	0.99201	0.01578	0.96995	0.01304
75°C-5min	0.99623	0.01443	0.93788	0.01371	0.79443	0.01340
75°C-15min	0.99407	0.01520	0.99033	0.01441	0.87723	0.01282
75°C-20min	0.99906	0.01423	0.88790	0.01628	0.90438	0.01213
75°C-25min	0.99573	0.01441	0.99660	0.01502	0.994231	0.01365
Unheated	-0.73405	0.02008	-0.65910	0.01872	-0.84526	0.0177

Table (5): Correlation Coefficient and dynamic constant(of the first degree) of HMF forming during honey storage.

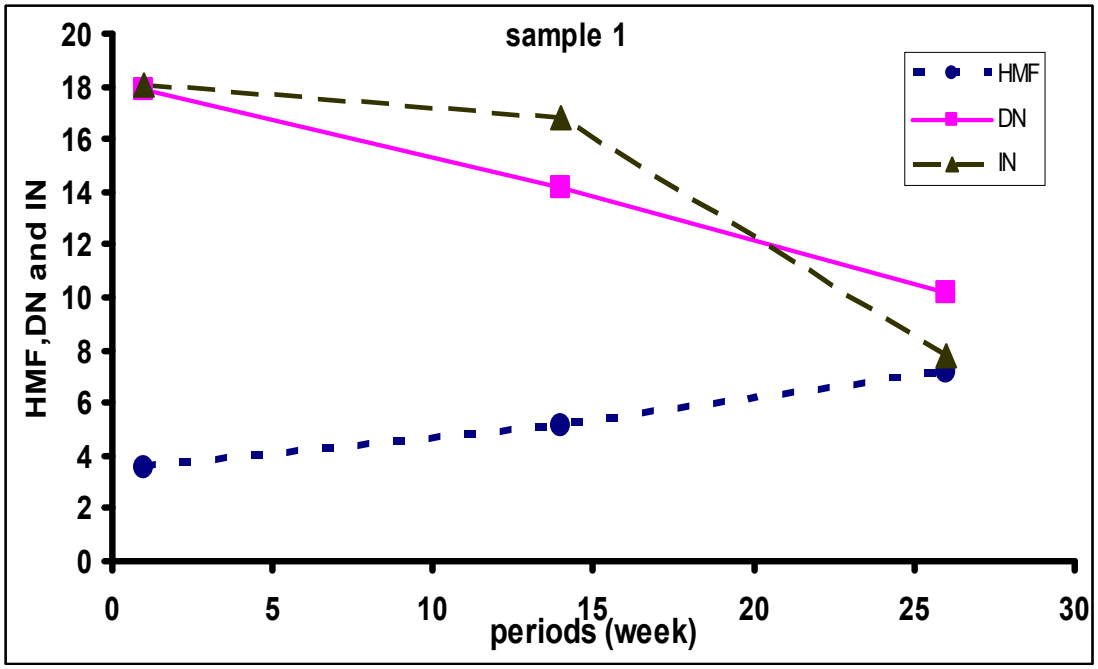

Fig. 1: Variation of HMF , diastase number and invertase number by storage time(week) for Sample 1(Haj-Umran).

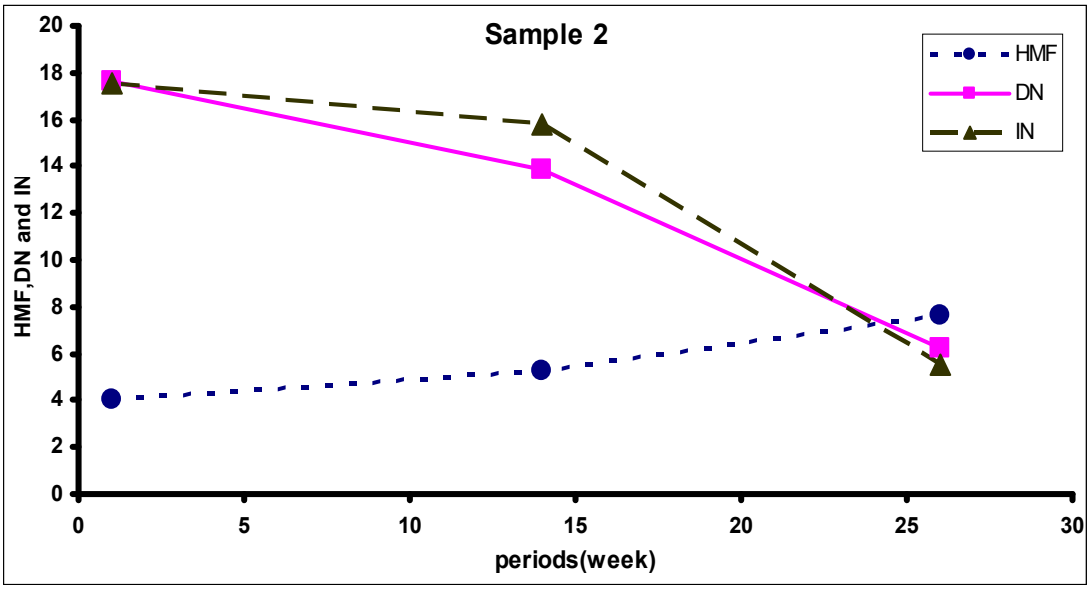

Fig. 2: Variation of HMF , diastase number and invertase number by storage time(week) for Sample 2(Shaqlawa).

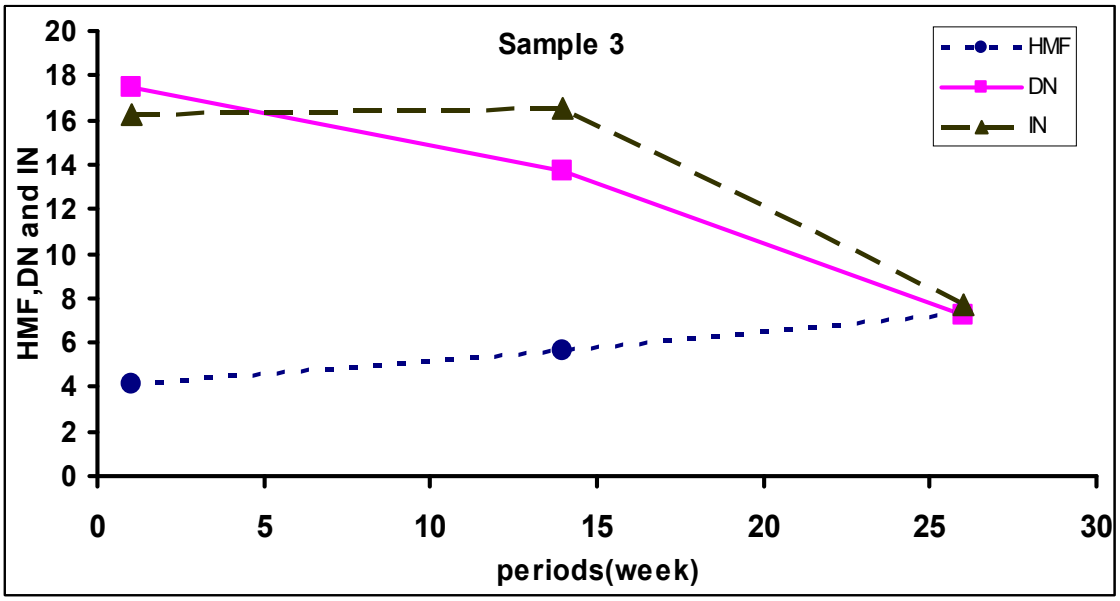

Fig. 3: Variation of HMF , diastase number and invertase number by storage time(week) for Sample 3(Sedacan).

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