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A Study and Comparison Between Evaporation Rate and Thermostability of Processed Date Juice Using Different Methods

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A B S T R A C T

In this study, two date juices are prepared in two different methods of refinement and decolorization, and their thermostability (determines the amount of color variation in terms of time) and evaporation rates (indicates the amount of variations in dissolved solid juice materials in terms of time) are measured in order to compare and study parameters resulting from refinement and decolorization methods. We call date juice refined in alkaline method, juice "**a**"; and that refined with gelatin and bentonite, juice "**b**". Taking samples from each juice at time intervals of 5 minutes was carried out in order to measure Brix and also to measure the color in two wavelengths of 420 and 560 nanometers indicating the yellow and red colors of the date juice. juice**a** has had a higher evaporation rate and thermostability compared to juice **b**. Hence, it can be said that due to the omission of impurities and color compounds and active and pre-maker compounds of browning reactions, alkaline refinement and decolorization with resin has prevented the darkening of color during evaporation, and by omitting pectin, proteins and other colloidal impurities, it has caused an increase in water evaporation rate and as a result in decreasing energy consumption.

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INTRODUCTION

With regard to ever-increasing population of the world and the need for new food industries, technological processes have developed a lot. Nowadays, most of the sugar in the world is prepared from sugar beet and sugar cane, and the sucrose of main material stored in plant tissues is supplied to the market as sugar(keramat , 2002).Using the sugar in dates has been common since far in the past; however, it has not yet reached the production status in large commercial level. With regard to the existing statistics, 70 tons of product (with 10% sugar) and 30 tons of product (with 17% sugar) can be harvested from each hectare of sugar cane and sugar beet, respectively. At the same time, 12 tons of dates (with 60% sugar) can be harvested from each hectare of date palm with 120 date palms. With a simple calculation, it can be understood that the amount of sugar extracted from each hectare of date palms is several times as much(Iranian Date and its Market in the World , 2001).Dates are valuable fruit full of iron and vitamins A and B1. Moreover, because of containing phenolic, carotenoids, and flavonoids compounds as well as vitamins C and E, it possesses anti-oxidant properties(Al-Hooti et al , 2002).Only if we know that each kilogram of fresh dates has 1579 calories and each kilogram of dried dates has 3000 calories of energy, do we realize the food value of dates. And this suffices an individual's daily need for energy(Rolph GM ,1917). Because of the high sugar content in various types of dates and with regard to the fact that the major and base sugar in dates is fructose whose sweetness is 1.8 times that of sucrose, one of the logical ways to use date sugar and its wastes is to produce liquid sugar or date juice. With regard to the fact that Iran is one of the countries producing most dates in the world, it seems necessary to use this product optimally, to increase the date palms, and to enhance the industrial consumption of this product. In addition to being eaten fresh, date juice can replace sugar in various industries like cake and pie, ice-cream and candy; and in this way we not only add the nutritional value of the products, but also decrease the amount of sugar, resulting in a

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Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 814-820

decrease in its imports(keramat J ,2002).Moreover, due to its high percentage of fructose, date juice can be very useful as a dietary sweetener; particularly, for diabetics and individuals who have limitations in sugar consumption(Rolph GM ,1917). With regard to the superiorities and applications of date juice in various food products, a study of some of its features and behaviors seems to be necessary. Selection of favorable and suitable juice as a replacement in food products with respect to the processing conditions of the product such as applied temperatures and processing time and also standard features of food products like color and its clarity is of utmost importance. Method of refinement and decolorization of date juice affect many of its behaviors during different processes. Hence, in this study, two date juices are prepared in two different methods of refinement and decolorization, and their thermostability and evaporation rates are measured in order to compare and study parameters and behaviors resulting from refinement and decolorization methods.

Methodology:

Type of refinement and decolorization process of date juice is very effective on its behaviors during various stages of processing such as concentration and evaporation. Therefore, in order to study and compare these differences, date juice has been prepared in two different refinement and decolorization methods. The date juice has been prepared from Shahani variety of dates. A part of the date juice has been refined using liming, phosphatation or alkaline method, and has been decolorized by resin. In the alkaline refining method using lime milk, the pH of date juice has been increased up to about 9.5 so that proteins are denatured in this stage, and in the following stage by adding phosphoric acid 98%, refining operations took place up to the extent of sedimentation of colloid compounds (Chou CC ,2000). Finally, in order to decolorize, this juice was then passed through a resin containing column. Another part of the date juice was refined by type A gelatin and sodium bentonite, and its decolorization was carried out by active carbon. We call date juice refined in alkaline method, juice “a”; and that refined with gelatin and bentonite, juice “b”. The Brix of refined and decolorized juice was measured by a hand refractometer. With the help of a rotary evaporator, the thin juice with Brix 35 was concentrated under vacuum to reach a Brix of 70. The vacuum of the pump was adjusted on 0.4 bars and the temperature of the rotary operator was adjusted on 60 degrees centigrade. In order to study and compare the effects of refining and decolorization methods on date juice behaviors during evaporation, the thermostability and the evaporation rate of the two date juices “a” and “b” were measured. To carry out the thermostability test and to study the evaporation rate, 300ml of the two juices (a&b) with Brix 70 was heated in a rotary operator whose temperature was 60 degrees centigrade and whose revolution had been adjusted to 60 revolutions per minute. Taking samples from each juice at time intervals of 5 minutes was carried out in order to measure Brix by a hand refractometer and also to measure the color in two wavelengths of 420 and 560 nanometers indicating the yellow and red colors of the date juice. In order to measure the color of the two juices, the absorption in two wavelengths of 420 and 560 nanometer was read by spectrophotometer, and the amount of color was calculated using ICUMSA method (Kempf, 1980) To measure the evaporation rate of juices “a” and “b” during concentration, modeling equations of date juice with the highest correlation was calculated by Curve Expert 1.3 software. The slope of line in each of the equations should be calculated to find out the evaporation rate in each of the treatments; in other words, the obtained slope illustrates the speed of increase in dissolved solid materials (Brix) or the rate of water evaporation from date juice in terms of time. As a matter of fact, it can be said that the water evaporation rate $=dy/dt$ can be obtained by Curve Expert 1.3 software, and by taking derivations from obtained equations during various heating times, the rate of evaporation of a and b juices is obtained.

RESULTS AND DISCUSSION

Evaporation rate:

evaporation rate indicates the amount of variations in dissolved solid juice materials (Brix) in terms of time[9]. Table 1 shows modeled equations of date juices with the highest correlation coefficient by Curve Expert 1.3 software which is indicative of variations in dissolved solid materials (Brix) in terms of time.

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 814-820

sample	Equation	Coefficient	Correlation Coefficient	Standard devision
date syrup **a**	y=(a*b+c*t^d)/(b+t^d)	a =72.621265 b =592.39476 c =95.84497 d =2.7128099	0.99	0.046
date syrup **b**	y=(a*b+c*t^d)/(b+t^d)	a =72.594784 b =1701.7584 c =92.208478 d =3.252473	0.99	0.34

Table 1. Modeled equations of date syrup **a** and **b**.

by taking derivations from the above equations during various times of heating, by Curve Expert 1.3 software, the results of table 2 are obtained.

Time (minute)	evaporation rate of date syrups **a**	evaporation rate of date syrups **b**
5	1.55	1.5
10	0.83	0.68
15	0.4	0.26
20	0.2	0.11
25	0.11	0.05

Table 2. variations in evaporation rate of date syrups **a** and **b** in terms of time during evaporation

Figure 1 shows variations in evaporation rate in date juices a and b during evaporation.

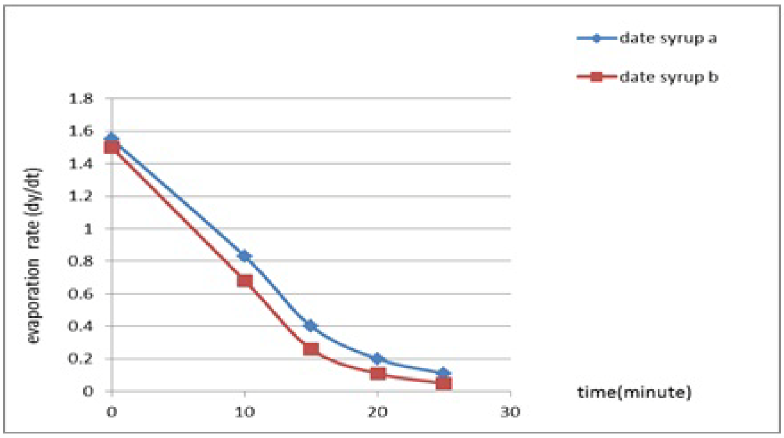

Fig 1. Variations in evaporation rate of syrups **a** and **b** in terms of time.

As specified in table 2, during the same time span, the obtained figures for evaporation rate during evaporation of juice **a** are more than those in juice **b**. Figure 1 confirms this, too. The reason for this difference refers to the method of refining these two juices. In order to analyze this issue, we deal with the mechanism of refining juices **a** and **b**. The refining of date **a** has been carried out by using liming-phosphatation or alkaline refining. On the whole, all methods of juice refining using liming are based on two principles: 1- Coagulation of colloidal compounds at isoelecric point and sedimentation of non-sugar compounds in acidic or basic

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 814-820

environments. 2- Absorption by crystals formed from the reaction between lime and carbon dioxide or phosphoric acid **(Asadi , 2007).**

One of the important methods in refining sugar juices is to use lime and phosphoric acid. The general formula for the reaction between phosphoric acid and lime is as follows**(Chou CC ,2000):**

$8Ca(OH)_2 + 6H_3PO_4 \rightarrow Ca_8H_2(PO_4)_6 + 16H_2O$

In the alkaline refinement method in the stage of liming, juice treatment operation is carried out through coagulation of proteins and pigment compounds in their isoelectric point, and pectin sediment as well as absorption of some anions like phosphoric anions and other acids are deposited as insoluble calcium salts. In the next stage, by adding certain amounts of phosphoric acid, refining operations are completed and the coagulated materials are decomposed. In the liming stage also non-sugar materials in the solution; particularly the pigment compounds, are absorbed by very small particles of calcium phosphate on the basis of adsorption phenomenon, and then are separated from the juice through special filters**(Asadi ,2007 and Poel et al ,2008).** In order to justify the materials' behavior during phosphatation, a mechanism called zeta potential is introduced. The particle within the fluid has a surface load, and around the surface of the particle in the fluid, there is always an increase in ion density with a charge opposite the surface of the particle. The layer created around the particle can be divided into two parts consisting of an inner and an outer layer. When the particle moves within the fluid, the inner and outer layers around it also move along with the particle (and move with the particle); and a hypothetical gap can be supposed between the particle and the fluid environment. The potential existing in this gap is called zeta potential which is in fact a parameter for the potential stability of colloidal systems**(Poel et al , 1998).** pH is the most important parameter in determining the size of zeta potential. A range within which zeta potential is zero is called the isoelectric point, and the colloidal system has the lowest stability in this point **(Kent ,2007).** In his studies, Bennet points out that during the flocculation phenomenon, the sedimentation rate and its amount increases while zeta potential approximates zero and the flocculated particles are adsorbed on calcium phosphate(Poel et al , 1998). With regard to the studies carried out by Loghmani et al in 2011, in order to omit turbidity-creating factors like pectin, protein, colloidal compounds and other sugar impurities such as tannins, the best pH for the alkaline refining operations of Shahani juice is about 5. In this pH, we will have the highest impurity and the lowest turbidity. With regard to the surveys conducted, during this study, after the liming stage, we increase the pH of juice a to 5 with the help of phosphoric acid. In this pH, the highest impurity sediments have been noticed. Then, we can conclude that in this pH, zeta potential is zero and the colloidal system has the lowest stability. Due to the existence of colloidal compounds, the heat transfer coefficient has increased and as a result, the evaporation rate of juicea as compared to juiceb will be higher during evaporation.

The refinement of date juiceb is carried out using type A gelatin and sodium bentonite. One of the important features of gelatin from the viewpoint of clarification and omission of impurities is its isoelectric point. If the juice pH is more or less than that, the electric charge of the protein and, as a result, the gelatin is varied; and above this point there will be a negative charge and below it there will be a positive charge(Khiyami and Pometto 2008). Gortex's studies in 2001 and 2005 show that at isoelectric point, the pH of type A gelatin is about 8.5. At the isoelectric point, gelatin has both positive and negative charges. Type A gelatin in pH lower than 8 has a positive charge. However, with regard to the fact that the farther from isoelectric point, the higher the density of electric charge gets, in juices such as date juice with a pH between 3 and 4.5, the density of the positive charge of gelatin A is higher, and as a result, it is better to use type A gelatin in order to omit impurities(Khiyami and Pometto 2008 and Riegel and Kent , 2003) . In refining date juiceb, sodium bentonite has been used as an auxiliary clarifying material. Bentinite has the feature of adsorption, that particularly affects proteins. The upper surface of montmorillonite crystal has a negative charge and its lateral surface has a positive charge, and on the whole, the density of the negative charge is more. Hence, apart from its feature for adsorption by giving negative charge to date juice, bentonite also causes it to be clear. Depending on the pH of the environment and the nature of bentonite, the density of the negative charge is varied. In pH between 3 and 4, zeta potential of sodium bentonite is between -15 to -20 millivolts(Khiyami and Pometto 2008 and Maxwell ,2010) . Therefore, with regard to the above explanations, it can be said that in the pH of juiceb, which is about 3 to 4, zeta potential is not zero and the colloidal system will be stable; and due to the existence of these impurities, the heat transfer coefficient and the evaporation rate during evaporation is lower in juiceb compared to juicea. Figure 2 illustrates the trend of increase of dissolved solid materials (Brix) during evaporation in terms of time. During evaporation and following the increase in juices Brix, in fact, dissolved solid materials consisting of pectin, protein and other colloidal compounds will increase. The existence of these impurities in the juice causes a decrease in heat transfer coefficient resulting in a decrease in evaporation rate[16]. As seen in the graph, both curves related to evaporation rate in figure 1 have a descending trend. Naturally during evaporation, with an increase in Brix, the density of impurities in unit volume increases, and consequently, heat transfer coefficient and ultimately the evaporation rate of juices decreases.

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 814-820

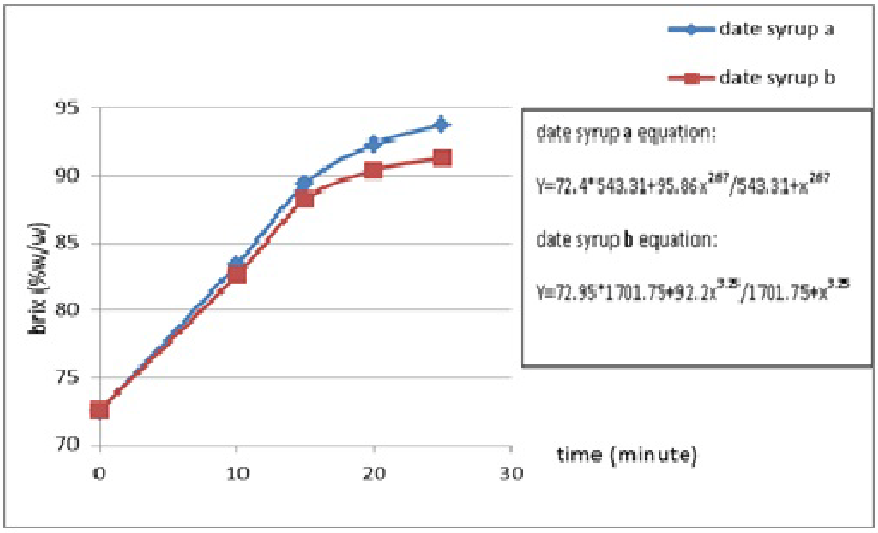

FIg. 2. Brix variations in terms of time during evaporation

Thermo stability:

The high heat transfer coefficient in juice a is of particular importance from the point of view of energy consumption, but it can also have bad effects like burning and darkening. Therefore, it seems essential to measure the thermostability of the two juices in order to compare and survey the effects of refining method on this factor. Thermostability determines the amount of color variation in terms of time(Poel et al , 1998).Graphs 3 and 4 show the amount of color variation in two wavelengths of 420 and 560 nanometers in the two juices a and b during evaporation in regular time intervals (every 5 minutes).

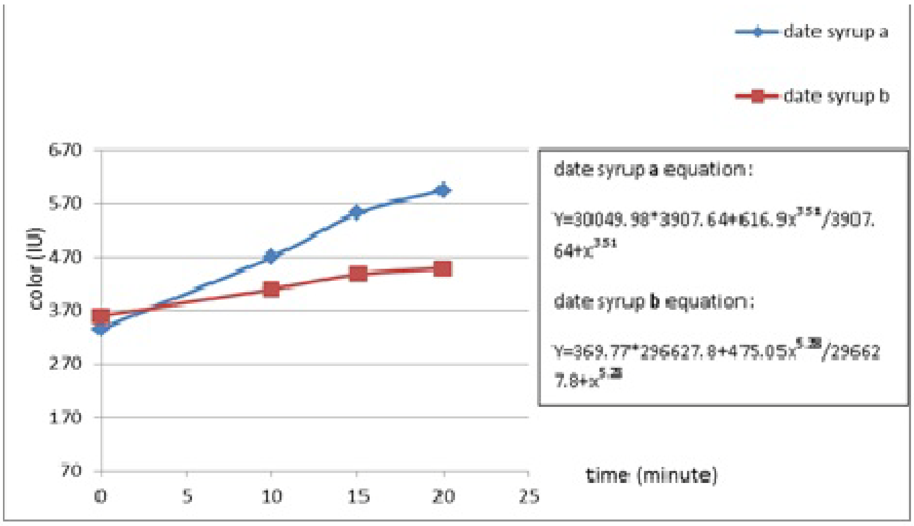

Fig 3. Thermostabilityin the wavelength of 420 nanometers.

As seen in figure 3, initially color intensity in wavelength of 420 nanometer in juiceb is more than that in juicea. And during evaporation, gradually there develops a yellow color in juicea compared to juiceb. The reason for the differences is related to different methods of refining and decolorization in these two juices. On the whole, factors involved in color intensity in date juice are two groups. One is the natural pigments in the date juice and the other is the browning reactions(Kent ,2007 and Jain et al , 2011). The amount of these factors in date juice or omitting them depends on the efficiency of refining and decolorization of date juice. Natural pigments of date juice consist of carotenoids, flavonoids, anthocyanin, chlorophyll and tannin. All these natural pigments except for flavonoids are destroyed in acid pH(Kent ,2007).Therefore, because of acidic nature of juiceb pH, it can be said that the reason for higher intensity of its yellow color up to the 5th minute of evaporation, in relation to juicea is the presence of flavonoids and lower efficiency of active carbon in omitting pigments in relation to resins(Maxwell ,2010).With the lapse of time, it is noticed that an increase in intensity of yellow color in juicea is higher. With regard to the fact that all natural pigments except for carotenoids are destroyed in phosphatation alkaline conditions and also with a view to figure 1, which is indicative of higher evaporation rate in juicea, it can be said that due to higher evaporation rate and omission of water from the environment, accumulation of carotenoids and increase in their density in unit volume of juice, an increase in intensity of yellow color during evaporation has been caused(Kent ,2007).

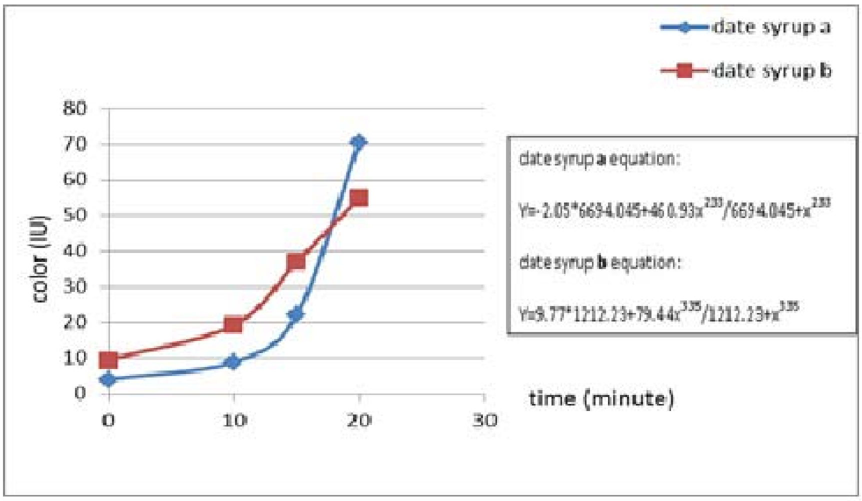

Fig 4. thermostability in wavelength of 560 nanometers.

In figure 4 which is related to the thermo stability in the wavelength of 560 nanometers, it is noticed that the intensity of red color in the beginning and an increase in red color during evaporation in juice b is more intense. The reason is the presence of natural red pigments and pigments resulting from Millard reaction. The browning non-enzyme reaction or Millard reaction occurs when there are reduction sugars and amine or amino acids in the reaction environment. According to studies conducted by Ale Ravi et al in 1976, most amino acids existing in date are sequentially glutamic acid (15%) and aspartic acid (11%). These two amino acids are decomposed during evaporation and concentration and pyrolidon carboxylic acid results from their decomposition. In Millard reaction, alpha amino butric acid is produced as a mediary product from pyrolidon carboxylic acid, through 2-pyrolidon and has a high activity to participate in Millard reaction(Kent , 2007 and Song PS, Chichester CO ,1967). All these color-preparing factors are omitted during the alkaline refining and phosphatation processes; therefore, the intensity of Millard reaction in juicea compared to that in juice b is much lower, and naturally the amount of melanoidine pigments resulting from Millard reaction and color intensity in wavelength of 560 nanometers will also be lower. From among factors effective on the intensity of Millard reaction, the concentration of reactive materials, temperature and time can be pointed out(Kent , 2007).As seen in figure 4, the intensity of color increase will be more after the tenth minute. The reason can be an increase in the intensity of Millard reaction due to an increase in the concentration of substrates of reaction and time. Some natural pigments of date juice such as anthocyanines also cause the evolution of red color. Anthocyanines are stable in acid conditions but are not so stable in high pH environments. Moreover, this pigment is one of the important phenol pre-makers in date juice and also participates in enzyme browning reaction (Song PS, Chichester CO ,1967). As time passes, an increase in concentration of this pigment and ultimately an increase in enzyme browning reaction rate can also be effective in an increase in color intensity in wavelength of 560 nanometers in juice b.

Conclusion:

On the whole, results obtained from measuring evaporation rate and thermo stability in juices a and b show that the method and process of refining and decolorization are very effective on the water evaporation rate and amount of thermo stability and color variation in the juice compared to concentration and evaporation, and juice a which has been refined using liming and phosphatation method has had a higher evaporation rate and thermostability compared to juice b which has been refined using gelatin and bentonite. Hence, it can be said that due to the omission of impurities and color compounds and active and pre-maker compounds of browning reactions, alkaline refinement and decolorization with resin has prevented the darkening of color during evaporation to a great extent., and by omitting pectin, proteins and other colloidal impurities, it has caused an increase in water evaporation rate and as a result in decreasing energy consumption during concentration.

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 814-820

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