Evaluation and measurement of bioethanol extraction from melon waste (*Qassari cultivar*)

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Abstract: As the world progresses, more energy is required to get along with everyday changes. Using bio-ethanol as one of the most important bio-fuels is an appropriate response to those changes. Much agricultural waste is being produced in Iran and the combination of such waste can turn it into a good source for the production of bio-ethanol. Thus, in this study, the amount of bioethanol extracted from melon waste was measured and evaluated. To do so, considering the 15 kg capacity of the device's fermenter, 12 kg of refined melon sugar syrup and 3 kg of water (with the standard ratio of 4 to 1), i.e. a total of 15 kg of substrate with the brix degree of 20, as well as 75 g of saccharomyces cervisiae yeast, cultured in standard conditions (5 g of yeast for each kilogram of substrate) were transferred into the fermenter. The tests were conducted in 35 h with three replications and at three different rotation speeds of the fermenter's mixer. Sampling was taken place every five hours. Fermentation temperature was set as 30°C and distillation temperature was set to be 78.5°C which is the standard temperature of bioethanol's boiling point. The results showed that about 60.5 g of bioethanol was obtained from each kilogram of melon. In addition, considering the alcohol produced and in order to optimize energy consumption, it was observed that the best speed for the mixer in the device's fermenter was 120 rpm.

Keywords: bioethanol, melon waste, fermenter, saccharomyces cervisiae, fermentation

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1 Introduction

Today, energy and how it is produced is one of the most important topics which have been the focus of policies in different countries (Ghobadian et al., 2009; Bahrami and Abbaszadeh, 2013). This topic gains special importance when one takes into account the challenges posed by fossil fuel use such as their finitude, being dependent upon the import of the fuels derived from crude oil like gasoline, the environmental issues brought about by burning fossil fuels and increase the pollution caused as a result. Ethanol in general and bioethanol in particular are considered as chemical compounds with high potentials to replace fossil fuels used in vehicles. Bioethanol has a high octane number and for the same reason it is used to increase octane number in spark ignition engines (Agarwal, 2007; Choi et al., 2015; Gupta and Verma, 2015).

Moreover, ethanol is one of the most important components of biodiesel as a fuel used in spark ignition engines (Makareviciene and Janulis, 2003). Ethanol can be obtained from cellulose, sugar and starch sources in agricultural products and used as a fuel in its pure form or mixed with other substances (Jahanbakhshi, 2018; Jahanbakhshi et al., 2018; Chintagunta et al., 2016; Smuga-Kogut et al., 2017).

Melon, whose scientific name is *Cucumis melo* belongs to the family of *cucurbitaceae*, is very popular among people due its high percentage of sugar and

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vitamin and is used in different ways (Derogar et al., 2013). The surface under the cultivation of melons in Iran comes to 81746 hectares with a production of 1572960 tons of melon. The highest amount of melon production belongs to the Khorasan province in Iran with 36347 hectares of land under cultivation and 523994 tons of melon produced (Anonymous, 2011).

Dodic et al. (2009) conducted a study in which they extracted ethanol from sugar beet syrup. The results of their study showed that among different concentrations of the syrup, a 20% concentration in the culture medium could create a maximum return of 68% bioethanol. This can lead to the production of 151 g of bioethanol for each kilogram of substrate. Chintagunta et al. (2016) studied the production of bioethanol from potato waste. Firstly, they placed the wastes under hydrolysis conditions through an enzyme and later, they conducted fermentation using saccharomyces. They reported that the maximum amount of ethanol extracted was within the range of 6.18- 9.30 volume percentage and around 117 g of bioethanol for reach kilogram of substrate. Tayeh et al. (2014) studied the production of bioethanol from ground olive waste and reported that the average rate of bioethanol produced was about three grams for each 100 g of dry matter.

In their investigation of sugar reduction and bioethanol and carbon dioxide production in the process of date fermentation, Vaezizadeh et al. (2010) reported that the trend of CO_2 changes during the fermentation process showed that with the passage of time, the rate of CO_2 changes decreased considerably until when it stopped. In addition, at the end of the process, the rate of the solution's sugar drops from an amount of 20^{o}Brix to an amount of 8^{o}Brix. In general, the total amount of bioethanol extracted from each kilogram of syrup with the brix of 20 was about 72 g. Smuga-Kogut et al. (2017) performed a study on the extraction of bioethanol from rye straw. They first put the product under the temperature of 50^{o}C for a period of 72 h in order to achieve maximum optimum sugar production using an enzyme through the hydrolysis process. They reported the extraction of 24.5 g of sugar from each liter of the rye straw product.

Iran is one of the important poles of melon production and the production of other cucurbits. Unfortunately, more than 30% of these products are destroyed in the production chain between the farm and the consumption areas. This is a very high percentage and thus we are required to conduct deep analyses about the processing of different parts of the products and the production of essential products and think about ways to optimally use the wastes. In this regard, the present study aims at assessing the amount of bioethanol extraction from melon waste (*Qassari cultivar*) which can significantly contribute to the optimization of melon waste use.

2 Materials and methods

This is a cross-sectional descriptive study which was conducted in 2016 in Gorgan University. Ethanol can be obtained from the cellulose, sugar and starch sources in agricultural products (Arapoglou et al., 2010). Thus, in this study the rate of the sugars in melon waste that could be transformed using an HPLC Waters 600 Controller was measured. Bioethanol extraction device used in this study consisted of two different parts: 1) hydrolysis reactor and 2) fermentation reactor (Figure 1).

Figure 1 Bioethanol extraction device

In this study, melon (*Qassari cultivar*) waste was used to extract bioethanol. To do so, melon waste was turned into a strong pulpy liquid by an electric fruit juicer. Syrup was made with a 70% concentration after refining the liquid. Then, considering the 15 kg capacity of the device's fermenter, 12 kg of refined melon sugar syrup

and 3 kg of water (with the standard ratio of 4 to 1), i.e. a total of 15 kg of substrate with the brix degree of 20 was transferred into the fermenter. In the next step, 75 g of the saccharomyces cervisiae (5 g of yeast for every kilogram of substrate) which had been cultured under standard conditions was added to the 15 kg of substrate in the tank (Sarkar et al., 2012; Duarte et al., 2009). After that, the rate of sugar that existed in the substrate with the brix degree of 20 was measured by the Hand Held Refractometer (PAL-3) which was made in Japan.

In order to assess the device's work and specify the standard rotation speed for the fermentation operation in the fermenter, the device was tested under anaerobic fermentation conditions for 35 h which included the time needed to make a suspension at the constant fermentation temperature of 30°C (the temperature 28-30°C is the appropriate and optimal temperature for the growth of the saccharomyces yeast), the rotation speeds of 120, 130 and 140 rpms and the distillation temperature of 78.5°C.

During the time the samples were being fermented (35 hours), sampling took place seven times (every five hours). After each sampling, the rate of the ferment growth and production of alcohol in the substrate was measured using a Digital Alcohol Tester with the brand name of Milwaukeeinst-MA884. The little differences in the data obtained after measuring the alcohol in the substrate (the 5th, the 6th and the 7th sampling) indicated that almost all of the convertible sugar that existed in the substrate could be turned into alcohol through the saccharomyces yeast. Thus, the continuation of that trend could affect the device's performance regarding energy consumption. Measuring the amount of alcohol produced by fermentation can be a better determiner of fermentation rate. The alcohol tester used in this study, reported the amount of the alcohol produced in the substrate based on the volume percentage of alcohol. Thus, to obtain the weight percentage of the alcohol produced, the values obtained were divided by alcohol's density (0.79). In similar studies, Zheng et al. (2012) reported that for all the substrates applied, the amount of the sugar remained after 36 h of fermentation could be ignored.

According to Equation (1), measuring the rate of glucose to ethanol transformation in the process of fermentation, one mole glucose is turned into two moles of carbon dioxide and two moles of ethanol:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \quad (1)$$

This phenomenon results in the reduction of weight and can give an ascending trend to ethanol production. Theoretically, each gram of glucose can produce 0.51 g of ethanol. So, 50% of glucose turns into ethanol and 50% of it changes to carbon dioxide. In the next step, the alcohol produced must turn into vapor. For this, the distillation temperature of 78.5°C which is the standard temperature of ethanol's boiling point was used. High purity ethanol cannot be produced through usual distillation methods. Although ethanol's boiling point is close to 79°C and water's boiling point is 100°C, when the solution of ethanol and water is heated up to ethanol's boiling temperature, only 95% alcohol can be obtained. After the distillation of ethanol and water, ethanol-water azeotrope (95% ethanol and 5% water) can be obtained. Therefore, for drying bioethanol, the output path for the bioethanol to exit the fermenter where bioethanol is at the vapor phase, was designed in a way that it passed through a zeolite column and the water was absorbed by the zeolite on the way (Tosheva, 2001). At the last stage, after passing through the zeolite column, the vaporized bioethanol enters a double-shelled cooling path where water is used as the liquid for cooling bioethanol vapor. Later, the bioethanol vapor is turned into bioethanol liquid and entered the tank where the produced ethanol is stored.

Each of the tests was replicated three times. In the end, the means of the data obtained were analyzed using Excel 2013 and the results were reported in the form of graphs.

3 Results and discussion

The rates of the convertible sugars existing in melon waste are illustrated in Figure 2.

As can be seen, due to the high rate of glucose and sucrose that existed in melon waste, we can use melon waste as one of the main sources of bioethanol production in our country. Changes in the rate of the alcohol produced in the process of melon waste fermentation at different rotation speeds of the fermenter's mixer are reported in Figure 3.

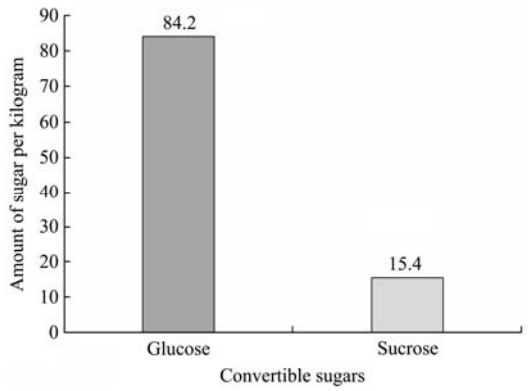

Figure 2 Convertible sugars existing in melon

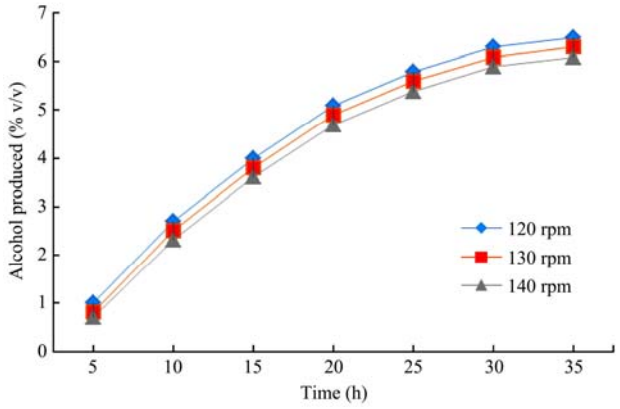

Figure 3 Changes in the rate of alcohol produced in the process of fermenting melon waste at different rotation speeds of the fermenter's mixer

The results implicated that at the speed of 120 rpm, the alcohol produced had a more favorable situation compared to other speeds and this might be due to a better blending and less turbulent flow. Moreover, it can be said that increasing the mixer rotation speed would reduce the rate of the alcohol produced. This is while no significant difference in the rate of the alcohol produced can be observed at different mixer rotation speeds in the fermenter which might be due to inaccurate comparisons made among different rotation speeds indicating low distance among different speeds. Therefore, it is suggested that in order to prevent energy waste, it is better not to use rotation speeds higher than 120 rpm in the fermenter. This is consistent with the results reported by Apar and Özbek (2004).

Changes in the rate of the alcohol produced in the process of melon waste fermentation, in a 30 hours' period (the sixth stage of measuring the alcohol) compared to a period of 35 h (the seventh and final stage of measuring the alcohol), show that the change in question is very little and stable. Therefore, it is suggested that in order to save energy and time in the process of bioethanol production from melon waste, the fermentation time be reduced from 35 h to 30 h. These results are consistent with those obtained by Vaezizadeh et al. (2010) in their investigation and modeling of sugar reduction and bioethanol and carbon dioxide production in the process of date fermentation.

The mean rate of bioethanol produced for each kilogram of melon syrup at different rotation speeds of the fermenter's mixer are shown in Figure 4. The results showed that the mean rate of bioethanol obtained from melon (*Qassari cultivar*) waste at different speeds of the fermenter's mixer (120, 130 and 140 rpms) were respectively 60.5, 58.2 and 56.2 g of bioethanol for each kilogram of melon with the brix degree of about 20. So, according to these results, it can be stated that the best performance of the device takes place at the mixer speed of 120 rpm not only with respect to the amount of the alcohol produced but also with regard to the rate of bioethanol produced compared to other speeds. In addition, in similar studies the rate of the bioethanol obtained from apples was 43 g and from grapes, it was 53 g (Hang et al., 1981; Hang et al., 1986). Therefore, the rate of the bioethanol produced in this study compared to that reported in similar studies by the researchers mentioned above shows a good amount and this is in fact also an indication of the bioethanol extraction device.

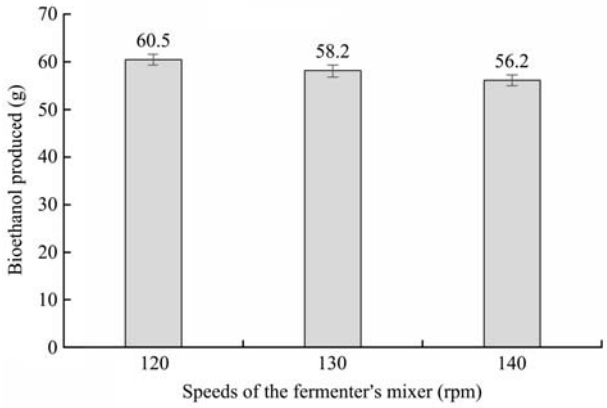

Figure 4 The rate of the bioethanol produced for each kilogram of melon syrup at different speeds of the fermenter's mixer

4 Conclusion

Considering the amount of bioethanol produced by melon waste (*Qassari cultivar*) which was 60.5 g of bioethanol for every kilogram of melon waste, we can

state that melon is one of the best options for the production of bioethanol because it contains a high percentage of sugar. The rate of the alcohol produced at the speed of 120 rpm had a more favorable situation than the other mixer speeds and this was due to better blending of the substances and less turbulence inside the fermenter.

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