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USING HEATING AND VACUUM AS A NEW SYSTEM TO ACHIEVE SHORT COOKING TIME FOR PRODUCING BLACK HONEY

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Abstract

The experiments were conducted at Agricultural Engineering Department Laboratory, Faculty of Agriculture Al-Azhar University, Assiut Governorate during 29th of July to 15th of November 2022, in order to develop and manufacture a small unit for producing high quality black honey depends on heating and vacuum system. Also, to determine the optimum treatment forsafe method taken into consideration the environmental impact and evaluate changes in black honeyquality during cooking. This unit consisting of pan vessel, heater, compressor, condenser, rectifier, vessel receiver oil and smart control system.The experimental treatments for black honey cooking unit were tested on three heating temperatures different at 200, 350 and 500 °C and four vacuum levels at 150, 300, 450 and 600 mbar and atmospheric pressure.The results shows a decreasing of cooking time at vacuum pressure less than from atmospheric pressure. At vacuum pressure samples, cooking time ranged from 30 to 172 minutes. The highest cooking time was (177, 77and 40 minutes) recorded with atmospheric pressure at different heating temperatures (200, 350 and 500ºC), respectively. The lowest cooking time was (155, 64and 30 minutes) recorded with vacuum pressure (-600 mbar) with different heating temperature (200, 350 and 500ºC), respectively. The data shows an increasing of evaporation rate of water from sugar cane juice at vacuum pressure more than from atmospheric pressure. At vacuum pressure samples, evaporation rate ranged from 4.53to 26 gH_2O/min. The lowest evaporation rate was (4.41, 10.13 and 19.50 gH_2O/min) recorded with atmospheric pressure at different heating temperatures (200, 350 and 500ºC), respectively. The highest evaporation rate was (5.03, 12.19 and 26 gH_2O/min) recorded with vacuum pressure (-600 mbar) with different heating temperature (200, 350 and 500ºC), respectively.

***Key words*: *black honey, cooking, heating and vacuum system*.**

INTRODUCTION

Black honey or sugarcane honey is one of the healthy natural sweeteners, unlike sugar and artificial sweeteners such as saccharin and aspartame, which do not contain any useful substances and may cause some problems for people with sensitive bodies. Sugarcane honey is in great demand in the natural food market because it retains nutrients from cane juice, such as iron, phosphorus, magnesium, calcium, potassium, and chlorine [12].
reported thatsugarcane is the cheapest source of energy because it contains fructose and glucose. and an excellent source of iron, as filtered sugarcane juice contains [8].
Honey is a carbohydrate which is constituted mainly of inverted sugars and sucrose and light brown color, it is due to the concentration of sweet substances of sugar cane juice. Sucrose hydrolysis in inverted sugar is gotten by the action of an acid to high temperatures or by enzymes. The sucrose inversion of sugar cane juice starts at 80°C. It is evident at 100°C and it depends on factors such as pH, temperature, and boiling duration. The final concentration gets hydrolyzed honey, it influences the yield and consequently the productivity and profit. The lower time it takes, the better results, the more productive is the process. In order to obtain honey cane or molasses is necessary to incorporate citric acid from 100 to 110 °C and from 103 to 106 °C (65 to 75 °brix) in this way is possible to obtain the final concentration [5].
To produce honey, sugar cane juice extraction, cleaning and clarification, hydrolysis and evaporation, final concentration and bottled. All stages in the

process are important for the quality of the final product. Natural clarification stages, concentration and juices concentration, pH factors, temperature and time of the process have an impact in the production, since quality characteristics, as well as viscosity, turbidity, brightness, color, flavor and odor, stability andabsence of crystals in the product are demonstrated. Alsostated that cane honey until its final concentration gets temperatures higher than 105°C, it is rich in inverted sugar and minerals, easy to use and especially harmless (healthy and safe food) since it is bottled in hot and due to its nature, air-tight containers are used [11].

Therow black honey is obtained by crushing, squeezing and sieving sugar cane. Juice is then clarified evaporated and concentrated by heating and then cooled to be a black honey. Solids remained after crushing, squeezing and sieving sugar cane are bagasse. In a black honey processing units solid raw bagasse is sun dried and usually used as a fuel for combustion process. Juice concentration process is performed in black honey ovens is longitudinal oven of length, width and height of about 13 x 5 x 4 m built of bricks 40 cm thickness of thermal conductivity 0.2 W/m.^{o}K, has one or two production lines, each line has three or four pans for molasses concentration process [8].

Sugarcane honey is the syrupy liquid obtained by evaporation of the sugarcane juice, concentrated until it reaches solids content between 65 and 75%. The necessary temperature to achieve the solids content is 105-110°C [1].

Concentration at normal atmospheric pressure, so it is better concentration under vacuum pressure. Non good peeling sugar cane sticks, resulting in a dark color of honey. Finding some foaming material and impurities,so good filtering must be done to remove it. Use of red copper in the concentrate metal causes darkening of the color, so it is better use stainless steel or aluminium [3].

Some honey producers used raw bagasse as fuel in private manufacturing plants of moisture content ranged between 12 to 35 % wet basis, bulk density ranged between 70 to 100 kg/m^3 and particle size ranged between 10 to 50 cm [7].

The combination of microwave heating and a vacuum system allows a quicker mass and energy transfer at low temperature over a short time. More water vapor is separated from the product using a vacuum microwave evaporation (VME) system, working at suitable power and vacuum levels, due to the rapid heating of the product [2].

Compared the vacuum microwave evaporator (VME), rotary evaporator (RE) and rising film evaporator (RFE). The results show that the evaporation rate of (VME) was three times higher than that of (RE) and was two times higher than that of (RFE) [4].

Ohmic vacuum concentration treatment enabled rapid heating to the concentration temperature because heat loss was minimized under the vacuum. In addition, the OVC treatment required less energy input for moisture evaporation at lower boiling temperatures. The required amount of heat energy to boil the liquid decreases, and subsequently, the heating time a decreases when the boiling point of the liquid decreases under vacuum [6].

The higher voltage gradients in the ohmic vacuum concentration (OVC) will save the concentration time with more internal energy generation. Moisture was evaporated at a lower temperature of 66^{o}C during OVC compared to 100^{o}C during ohmic atmospheric concentration (OAC) because the boiling point of water decreases under a vacuum. OVC treatment reduced the concentration time compared to OAC treatment [10].

The potential of ohmic vacuum concentration to produce value-added fruit juice concentrates. Efficacy of ohmic vacuum concentration (OVC) was evaluated for the production of value-added orange juice concentrate under different voltage gradients. OVC enables the evaporation of moisture in fruit juice at low temperatures under a vacuum. During OVC treatment, orange juice extract was ohmically heated to 66^{o}C using different voltage gradients (15, 20, 25, and 30 V/cm) under 27 kPa vacuum. The highest concentration of OVC was 22 min, producing 2 kg water/kg dry solid orange concentrate.

However, it took 40 min to produce the same concentration using ohmic atmospheric concentration (OAC) treatment. OVC also enabled a slower concentration time in which the orange concentrate was exposed to less thermal abuse [9].

The industry of extracting black honey in Upper Egypt is primitive, polluting the environment, consuming energy, high costs and long time, in addition to classical black honey industry have a lot of many risks which causes a polluting effect on the environment

The main objectives of this study is to use heating and vacuum as a new system to achieve short cooking time.

MATERIALS AND METHODS

Experiments were carried out through 29th of July to 15th of November 2022 at Agricultural Engineering Laboratory, Faculty of Agricultural Engineering Al-Azhar University, Assiut Governorate order to develop and manufacture a small unit for producing high quality black honey. In this study using heating and vacuum system to suitable for black honey cooking. This unit consisting of pan vessel (evaporator), heater, vacuum pump (compressor), vacuum pressure gauge, condenser, rectifier, Oil receiver and smart control system as showing in Figure 1.

The experimental treatments for black honey cooking unit were tested on three different levels of temperature at 200, 350 and 500^{o}C, four vacuum levels at -150, -300, -450 and -600 mbar and atmospheric pressure. The measurement indices were thermal energy consumed, useful heat energy, evaporation efficiency, heat exchange efficiency, thermal loss percentage, cooking time.

A small unit for producing black honey and homogeneous cane juice were used.

The cane juice was obtained from the El Roddavillage, Malawi city, EL Minya Governorate, Upper Egypt. (45 liters for all experiments and replications).

The percentage of total solids was 20.2% and the pH value is 5.25. The quantity was mixed to be homogeneous.

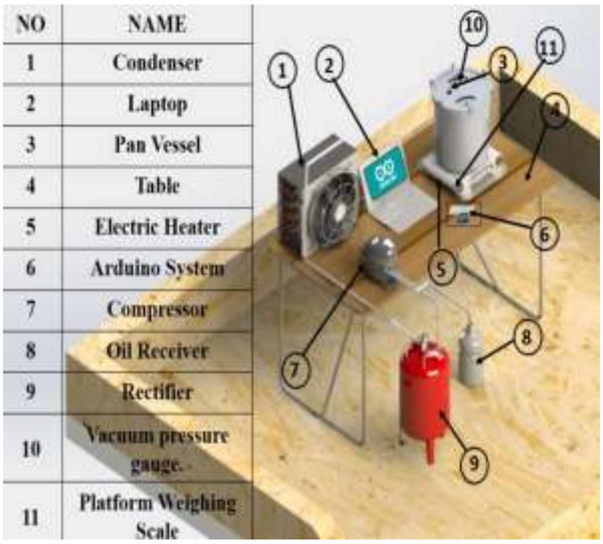

Fig. 1. Sketch of the unit producing black honey
Source: Authors' drawing.

A sample of one liter of cane juice (with a weight of 1,090 g) was taken in each replicate. Sugar cane juice was providing the best heat transfer properties, it was limited by its temperature range since can be evaporated and boils at 110-120^{o}C at atmospheric pressure.

Unit for producing black honey (UPBH)

The heating processes were carried out by mechanisms and devices of periodic and continuous action. The system consisting of:

-Electric heater - vacuum pump
- Pan vessel (evaporator) - Oil receiver
-Condenser and fan -Smart control system
Rectifier - vacuum pressure gauge

Heating system used for heating, evaporating and concentrating sugarcane juice. The system consists of an evaporator and electric heater (Fig. 2).

Fig. 2. Photo of heating system
Source: Authors' drawing.

Evaporator

Evaporator was used to cooking honey at different temperaturesmade from Stainless steel have thermal conductivity of 80 W/m.K, thickness was 2 mm, diameter out was 289 mm. and diameter in was 285 mm. Pan vessel volume was 19.1 liters and insulated by glass wool 0.05 m thick asshown Fig. (3), specifications of pan vessel as shown

Fig. 3. Photo of evaporator
Source: Authors' drawing.

Electric heater

The electric heater is source that supplies the evaporating vessel with latent heat to evaporate the amount of water to be removed from the sugarcane juice.

Vacuum system

Vacuum system used to remove air and water vapor from evaporator It consists of vacuum pump, condenser, rectifier, pressure gauge, tubes and oil receiver as shown in Figure 4.

Vacuum pump

Compressor: the specifications of compressor ACC Cubigel Huayi Electrolux ZEM GL90TB, HMBP 220 - 240V/1/50Hz, 1/5 HP, discharge 7.9 cm^3, motor type CSIR, oil charge 300 cm^3 and weight 8.8 kg. The vacuum pump is a device for removing non-condensable gases, so as to obtain the required vacuum in the evaporation vessel. Figure 5 shows the description of vacuum pump.

Fig. 4. Photo of vacuum system
Source: Authors' drawing.

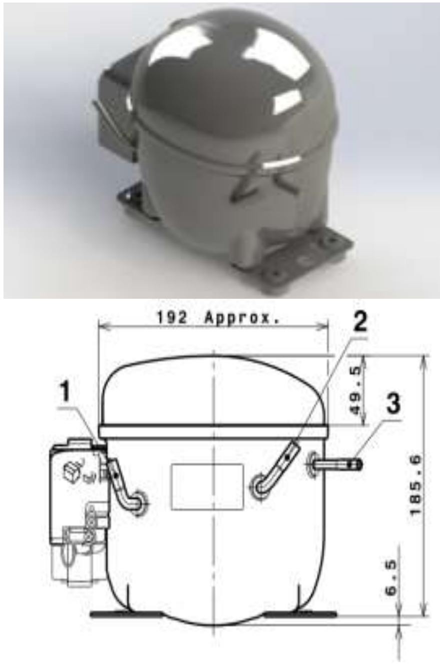

Fig. 5. Photo of vacuum pump
Source: Authors' drawing.

Fan and condenser

Condenser of type GTB 1000 air cooled condenser. Condenser used to condense vapor coming from evaporation vessel while cooking process to come out in the form of water droplets. Condenser consists of 22 tubes with 69 fins; each fin has a dimension of 250* 80*1 mm, capacity 1,000 W, with fan of 5 vane.
Water vapor in the condenser is condensed by ambient cooled air. The liquid water leaving condenser flows under gravity and vacuum pump pull to the rectifier. The condenser can be used to do such as compressors. as shown in Figure 6.

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Rectifier

Iron local manufacture container use as rectifier to receipt water droplets from condenser during the honey manufacturing process. Rectifier dimensions were diameter 250 mm, height 350 mm, and volume 17.2 liters as shown in Figure 7. It contains a pressure gauge, two valves to adjust the operating pressure, and two connections in the form of the letter T for entry and exit. The rectifier was connected to the condenser outlet vacuum pump inlet.

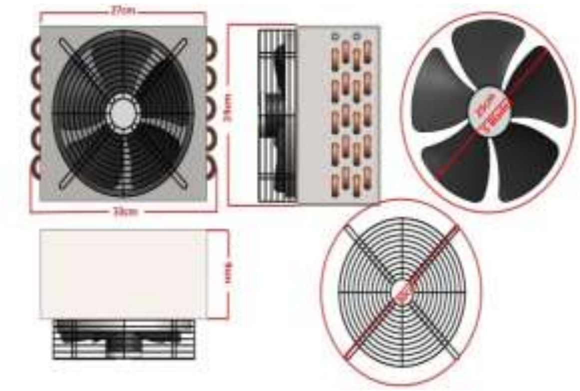

Fig. 6. Photo of fan and condenser
Source: Authors' drawing

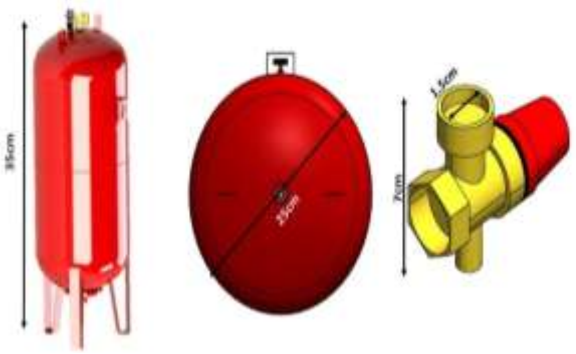

Fig. 7. Photo of rectifier
Source: Authors' drawing

Vacuum pressure gauge

Vacuum pressure gauge (mechanical pressure measuring instruments) for gauge, absolute and differential pressure have been proven millions of times over. For the optimal solution for the widest range of applications, there is a choice of measuring systems in Bourdon tube, diaphragm element and capsule element technologies. The pressure gauges cover scale ranges from 0-0.1 MPa (0-1,000 mbar) and indication accuracies of up to 0.1 %. For the various requirements in industrial and process instrumentation there are pressure elements from copper alloys, stainless steel or special materials. pressure gauges were used as showing in Figure 8.

Fig. 8. Photo of vacuum pressure gauge
Source: Authors' owns.

Oil receiver

Oil receivers presented by models from 0.5 to 2.5 liters is designed for temporary storage of unused refrigeration system oil. as showing in Figure 9.

Fig. 9. Photo of oil receiver
Source: Authors' owns.

Smart control system

Smart control system, which consists of laptop, control unit (Arduino Uno R3, two converters, two Thermocouples, relay, load cell and Amplifier

Temperature sensor

Temperature sensor connection of two thermocouples, two converters and Arduino Uno R3. as shown in Figure 10 to measure and storage the temperature for sugarcane juice every one minute during the experiment.

Fig. 10. Connection between two thermocouples with converters
Source: Authors' owns.

Weight sensor

Weight sensor connection of load cell, Amplifier and Arduino Uno R3. as shown Figure 11 to measure and storage weight of the sugarcane juice every one minute during the experiment.

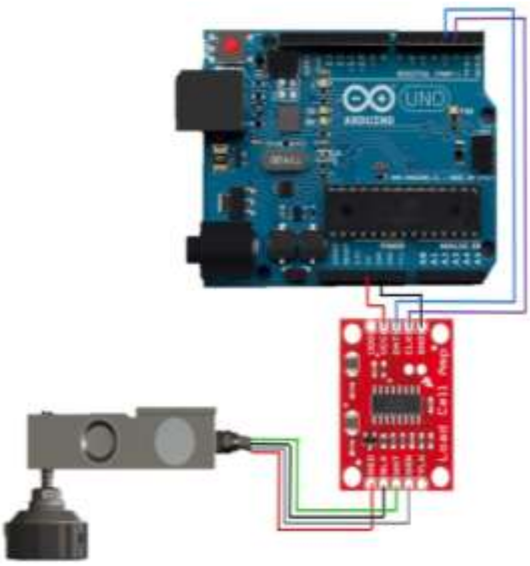

Fig. 11. Connection between load cell and amplifier
Source: Authors' owns.

Turn on/turn off the heater sensor

Turn on/turn off the heater sensor connection using a relay of one channel and Arduino Uno R3. as shown Figure 12. For turn on/turn off the heater at end of experiment.A relay was used to turn on heater when weight from sensor is greater than (14.02 kg), A relay was used to turn off heater when weight from sensor is less than (13.24 kg).

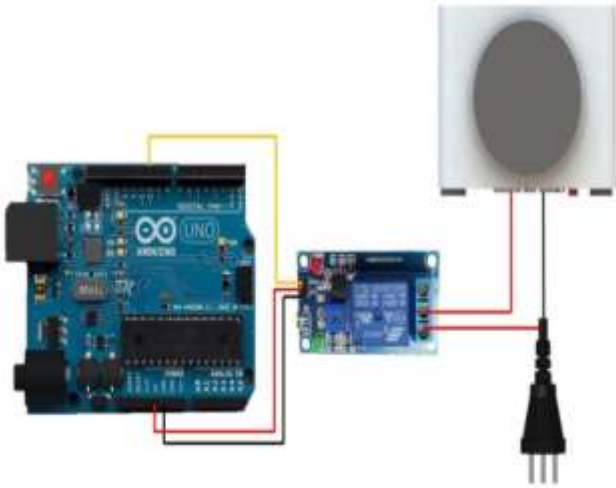

Fig. 12. Connection between relay one channel with heater
Source: Authors' owns.

RESULTS AND DISCUSSIONS

The cooking process affected by cooking time, evaporation rate, total soluble solids, mass of juice and temperature of juice.

Effect of pressures and temperature levels on cooking time

Figure 13 showed the effect of atmospheric pressure and different four levels vacuum pressures (-150, -300, -450 and -600 mbar), with three levels of heating temperature (200, 350 and 500°C) on black honey cooking time. The data shows a decreasing of cooking time at vacuum pressure less than from atmospheric pressure. At vacuum pressure samples, cooking time ranged from 30 to 172 minutes. The highest cooking time was (177, 77and 40 minutes) recorded with atmospheric pressure at different heating temperatures (200, 350 and 500°C), respectively. The lowest cooking time was (155, 64 and 30 minutes) recorded with vacuum pressure (-600 mbar) with different heating temperature (200, 350 and 500°C), respectively. The study finds a direct relationship between decrease in cooking time as a result of pressure decreasing, and inverse relationship was found between cooking time and heating temperature. At any pressure, heating temperature increasing leads to decreasing cooking time, at any heating temperature, decrease in pressure leads to decrease cooking time.

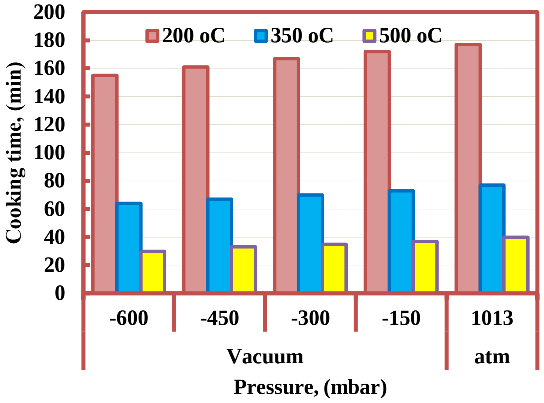

Fig. 13. Effect of pressures and temperature levels on cooking time
Source: Authors' determination.

Effect of pressures and temperature levels on evaporation rate

Figure 14 presented the effect of atmospheric pressure and different four level vacuum pressures (-150, -300, -450 and -600 mbar), with three level heating temperatures (200, 350 and 500°C) on evaporation rate of water from sugar cane juice.

The data shows an increasing of evaporation rate of water from sugar cane juice at vacuum pressure more than from atmospheric pressure. At vacuum pressure samples, evaporation rate ranged from 4.53 to 26 gH_2O/min. The lowest evaporation rate was (4.41, 10.13 and 19.50 gH_2O/min) recorded with atmospheric pressure at different heating temperature (200, 350 and 500°C), respectively. The highest evaporation rate was (5.03, 12.19 and 26 gH_2O/min) recorded with vacuum pressure (-600 mbar) with different heating temperatures (200, 350 and 500°C), respectively.

The study finds an inverse relationship between increase in evaporation rate as a result of pressure decreasing, and direct relationship was found between evaporation rate and heating temperature. At any pressure, heating temperature increasing leads to increasing evaporation rate at any heating temperature, decrease in pressure leads to increase evaporation rate.

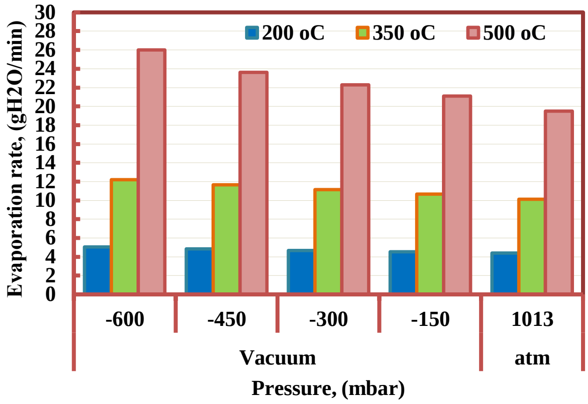

Fig. 14. Effect of pressures and temperature levels on evaporation rate.
Source: Authors' determination.

Effect of pressures and temperature levels on mass of juice

Mass of juice affected by heating temperature at 200, 350 and 500°C. with atmospheric pressure and different four levels of vacuum pressure.

Effect at a heating temperature 500°*C*

Figure 15 depicted the relationship between the mass of sugar cane juice as affected by cooking time of sugar cane juice at temperature of heating 500°C at pressures: -600, -450, -300, -150 mbar and atmospheric.

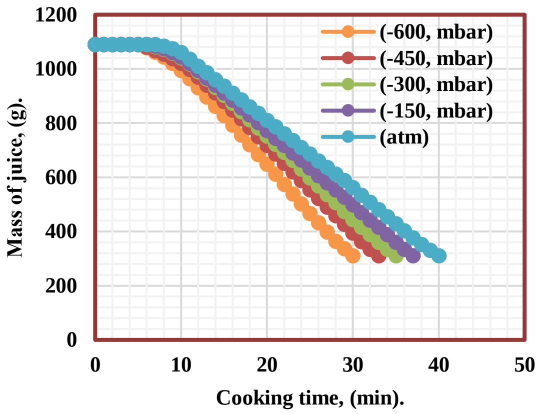

Fig. 15. Mass of juice as affected by cooking time at heating temperature 500°C with deferent pressures
Source: Authors' determination.

It is clear that as the time of cooking sugar cane juice increased, mass of juice decreased. The maximummass of sugar cane juice was 1,090g at zero time with all pressures. Minimum mass of sugar cane juice was 310g at times 30, 33, 35, 37 and 40 minutes at pressures -600, -450, -300, -150 mbar and atmospheric respectively. After 30 minutes, the mass of juice was 310, 394, 444, 498 and 562g at pressures -600, -450, -300, -150 mbar and atmospheric respectively. At the same time, a decrease in pressure leads to a decrease in the mass of juice.

Effectat a heating temperature 350°C

Figure 16 depicted the relationship between the mass of sugar cane juice as affected by cooking time of sugar cane juice at temperature of heating 350°C at pressures: -600, -450, -300, -150 mbar and atmospheric. It is clear that as the time of cooking sugar cane juice increased, mass of juice decreased. The maximummass of sugar cane juice was 1,090g at zero time with all pressures. Minimum mass of sugar cane juice was 310g at times 64, 67, 70, 73 and 77 minutes at pressures -600, -450, -300, -150 mbar and atmospheric respectively. After 64 minutes, the mass of juice was 310, 342, 376, 412 and 458g at pressures -600, -450, -300, -150 mbar and atmospheric respectively. At the same time, a decrease in pressure leads to a decrease in the mass of juice.

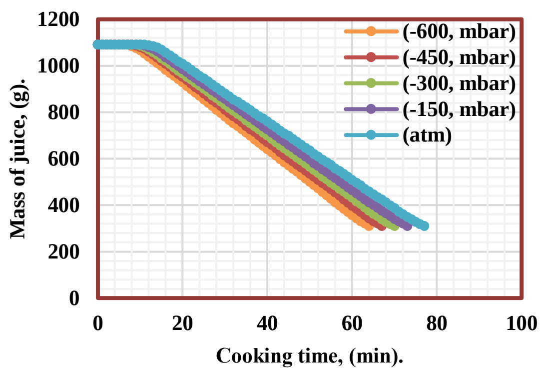

Fig. 16. Mass of juice as affected by cooking time at heating temperature 350°C with deferent pressures
Source: Authors' determination.

Effect at a heating temperature 200°C

Figure 17 depicted the relationship between the mass of sugar cane juice as affected by cooking time of sugar cane juice at temperature of heating 200°C at pressures: -600, -450, -300, -150 mbar and atmospheric. It is clear that as the time of cooking sugar cane juice increased, mass of juice decreased. The maximummass of sugar cane juice was 1,090g at zero time with all pressures. The minimum mass of sugar cane juice was 310g at times 155, 161, 167, 172 and 177 minutes at pressures -600, -450, -300, -150 mbar and atmospheric respectively. After 155 minutes, the mass of juice was 310, 334, 366, 384 and 412g at pressures -600, -450, -300, -150 mbar and atmospheric respectively. At the same time, a decrease in pressure leads to a decrease in the mass of juice.

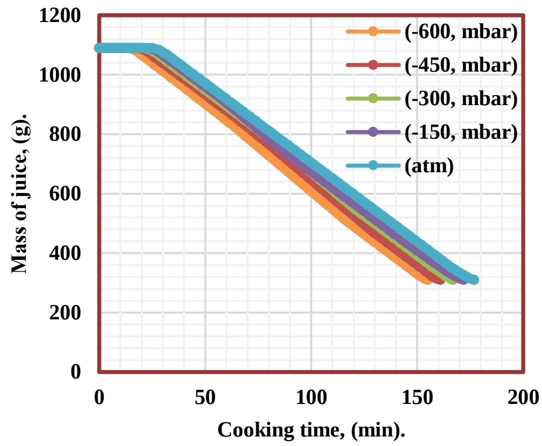

Fig. 17. Mass of juice as affected by cooking time at heating temperature 200°C with deferent pressures
Source: Authors' determination.

CONCLUSIONS

A small unit were developed and manufactured for producing high quality black honey depends on heating and vacuum system. This unit consisting of pan vessel, heater, compressor, condenser, rectifier, vessel receiver oil and smart control system. The experimental treatments for black honey cooking unit were tested on three heating temperatures different at 200, 350 and 500 °C and four vacuum levels at 150, 300, 450 and 600 mbar and atmospheric pressure. The data showed that the stability of the samples produced under vacuum pressure was better, as the highest values for all studied quality traits were recorded compared to their counterparts at atmospheric pressure.

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