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Research Article

Novel Method to Design and Construction a Dual-Purpose Solar Oven for Baking Bread

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ABSTRACT

In this study, new design of a dual-purpose solar oven for baking bread has been introduced and effective parameters on baking quality of bread has been experimentally investigated. In this method an electrical heat source which simulating the solar conditions is used in the optimization step and the temperature changes of the cooking container have been evaluated in three levels (150,180 and 210°C), the height of the container in three levels (2, 4 and 8 cm) and the incoming heat flux to the upper level in three levels (0,30 and 60 watts). According to the results, by increasing the height of the container, the bread must be turned upside down, to be fully baked, which increases the baking time and reduces the quality of the bread. The results show that the optimal conditions include a temperature of 210°C, a height of 2 cm, and an incoming heat flux of 60 watts. Finally, these optimal conditions were observed in the construction of the solar oven and the accuracy of the results was confirmed after performing the experiment with the solar energy of the sun.

Keywords: Solar oven; Baking; Radiation; Temperature

INTRODUCTION

The sun is an incredible and renewable resource that has the power to fuel life on earth and provide clean, sustainable energy to all of its inhabitants. In fact, more energy from the sun reaches our planet in one hour than is used by the entire population of the world in one year. One of the applications of solar energy is the solar cooker for baking. Baking bread is quite important, especially in Iran, where it is a strategic food for people. Among cooking conditions of bread, the temperature of the container plays a crucial role in quality and durability. Due to the special conditions that must be provided for baking the desired bread, a lot of energy is spent in each baking, which is mainly supplied from fossil and forest fuels. Reducing the amount of these fuels plays an important role in reducing costs and pollutants. 8.75 million Cubic meters of forest wood is used by nomads for cooking annually in the Zagros region alone [1]. 90% of home energy is consumed on cooking in the developed countries. Therefore, it's quite important to substitute other methods such as the solar cookers for baking bread.

There are three types of solar cookers, solar box cookers or oven solar cookers, indirect solar cookers, and Concentrating solar cookers [2-10]. Figure 1 shows different types of solar cookers namely.

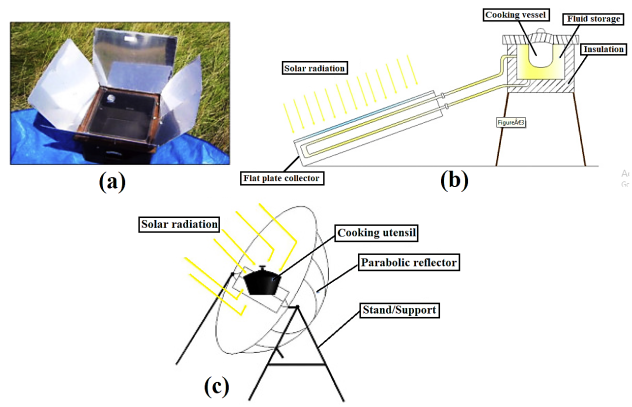

Figure 1: Different types of solar cookers, (a) solar box cookers or oven solar cookers, (b) Indirect solar cookers, (c) Concentrating solar cookers.

A common solar box cooker consists of an insulated box with a transparent glass or plastic cover that allows solar radiation to pass through. Solar radiation is absorbed by the inner part of the solar box cooker while the transparent cover prevents solar radiant

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energy from leaving the interior of the box through the greenhouse effect. Indirect solar cookers use heat transfer fluids such as molten salts or thermal oils to absorb heat from the heat source (at the focal region of the reflector) and transfer the heat to the cooking vessel. A category of solar cookers that are less popular but more efficient in terms of reaching higher cooking temperatures are the concentrating solar cookers [11].

A standard concentrating solar cooker is constructed with a framework stand to support the cooking vessel at the focal region and also the parabolic reflector. A solar optical mechanism is used to direct and concentrate the incident solar radiation to a focal region which enables the attainment of higher temperatures at the focal region. For direct concentrating solar cookers, the cooking vessel is placed at the focal region of the parabolic reflector during cooking periods. One of the most popular direct concentrating solar cookers that are easy to construct and operate is the parabolic dish cooker. A parabolic dish cooker can achieve high temperatures of between 350°C and 400°C as compared to other types of concentrating solar cookers [12]. The main disadvantages of the parabolic dish cooker are that it requires constant tracking of the sun, constant attention to prevent the burning of foods and to avoid fire risks during operation.

LITERATURE REVIEW

The present study aims to study the parameters of concentrating solar cooker to reach the optimum condition. Solar concentrating cookers have been used for intermediate to high-temperature applications using different test fluids [13-16]. However, these studies do not consider the incorporation of thermal energy storage into these cookers for off-shine cooking.

Malouh et al. built a concentrating solar cooker with a two-axis solar tracking system [17]. This system reached a temperature of 92°C in an environment with a temperature of 32°C, which is good for cooking. Lecuonah et al. designed a parabolic portable oven with heat storage capability that consisted of two coaxial cylindrical cookware [18]. The space between the two cylinders was filled with a phase changing material (a combination of paraffin). Khorasanizadeh et al. built a solar bread oven that used a parabolic surface to centralize the rays. This oven could bake 12 loaves of bread with 200 g weigh of dough every hour, and it works for 8 hours a day for 8 months of the year [19]. This system has a disadvantage, which the absorber plate is made of aluminum that is not suitable for baking bread, and in addition, user also need to turn the bread upside down for baking. Akram et al. examined Barbary bread in an electric oven at three temperatures (215,230 and 245°C) and found that bread which is baked at 230°C had the highest quality [20]. Naghipour et al. by examining semi-thick bread in a rotating oven at temperatures of (150,180,210,240,270 and 300°C) and at baking times of (5,10,15,20,25 and 30 minutes, respectively) found that increasing the baking time along with lowering the baking temperature reduces the quality of bread and increases the staleness of bread within 72 hours) [21]. Purlis et al. showed that the minimum temperature required to form the bread color is more than 120 degrees Celsius [22]. In 2007, Ozturk compared the energy and energy efficiencies of two parabolic and container ovens [23]. He found that the average daily water temperature from 10 am to 2 pm in the container and parabolic ovens was 344.4 and 333 degrees K, respectively. The average daily temperature difference between the two stoves was 42.97 and 31.56 K, respectively. The output energy in a container oven varies from 1.4 to 6.1 watts, while this value is between 2.9 and 6.6 watts for a parabolic oven. Energy and energy efficiencies vary from 3.5 to 35.2% for a container oven and from 0.58 to 3.52% and for parabolic stove it varies from 2.79 to 15.65% and from 0.4 to 1.25%, respectively. Tesfay et al. studied solar cookers with latent heat storage for intensive cooking applications [24]. The solar cooker experiment was composed of a parabolic collector with a receiver, a storage system where the baking plate was embedded with stainless steel steam pipes, and aluminum fins. Water was used as the heat transfer fluid and a nitrate salt mixture was used as the PCM. Baking experiments were carried out, and results indicated that Injera could be baked at lower temperatures (110-150°C) than previously assumed (180-220°C). Thermal performance evaluation of a solar cooker with a latent and sensible heat storage unit for evening cooking was done by Yadav et al. [25]. The main experimental components consisted of a parabolic solar dish collector, a storage solar cooking vessel, and an insulation box. A combination of latent and sensible heat was used in the storage solar cooker. Acetamide was selected as the PCM and sand, iron grits, stone pebbles, iron balls were the selected sensible heat materials. The storage solar cooker was charged throughout the day, and in the evening the storage solar cooker was placed with food in an insulated box. Results showed that a combination of PCM-sand and PCM-stone pebbles stored more energy compared to other combinations. The maximum cooking temperatures that were achieved were 70°C and 60°C for a cooking process that took 4 h. An investigation of a solar cooker with a parabolic trough concentrator was done by Noman et al. [26]. The parabolic trough collector was positioned at fixed latitude to reflect maximum solar radiation to the absorber tube. The absorber tube was fabricated with black painted copper which was used as a receiver for the cooker. Water was used as both the heat transfer fluid as well as the heat storage material. The results showed that the maximum cooking temperature achieved in 4 h was about 53°C at an ambient temperature of 31 °C and with the solar radiation being about 927 w/m. Akayleh et al. designed and developed a solar-based cooker with a mechanical sun tracking system [27]. The experimental setup was composed of an automated sun tracking system, hot dish for baking bread, a control unit, two pulleys connected to the gearbox and a parabolic trough. The objective of the experiment was to determine the efficiency of the solar cooker under various conditions. Baking experiments were carried out; the highest temperature achieved was found to be approximately 85°C. A novel technique based on artificial intelligence for a solar bread cooker was presented by Nazari et al. [28]. A parabolic dish concentrator was used to reflect solar radiation to the solar cooker. The solar cooker was composed of a stand and cooking plate with an insulated lid. Experimental and numerical studies were carried out to analyze and evaluate the thermal performance of the experimental setup during baking periods. The results indicated that a dough ball weighing 200 g attained a temperature of 180°C in period of 20-25 min.

The baking of Lavash bread with a diameter of 30 cm is investigated in this paper. Parabolic reflective surface, consisting of separate plastic parts which have been plated chrome immersing on, has been used. This parabolic surface reflects the incoming radiation under a cast iron baking sheet with a diameter of 30 cm and a thickness of 15 mm. The wall sides of the cooking container are insulated with a lid placed on it. The door is made of a 2 mm thick aluminum plate which there is a glass container placed on it and the space between the containers is vacuumed to trap the incoming radiation and minimize the losses.

MATERIALS AND METHODS

Conceptual design

Depending on the conditions of society and the habits that are common among people and in their daily lives, replacement of new tools should either have many more advantages than previous tools for people or appropriate culture should be given in account of using it. Therefore, conceptual design is an effective step in building or optimizing a device. The most important things that should be considered in the design of a solar oven for baking bread are:

- It must have the ability to bake high quality bread.
- It should take a short time to set up, while it should be usable for a long time. It should also be easy to maintain and do not require expertise to fix.
- It should be cheap and made from available materials.
- It also should be portable so that it can be used in nomadic areas.
- It must be safe and do not cause accidents to the people who work with it.
- The bread does not need to be turned over for baking as this will reduce the quality of the bread.

Practical design and construction

The amount of different components of incoming radiation to an inclined surface is different from the components of radiation to the horizontal surface and it is also related to the time and different angles of sunrays [29,30]. In this study, the relationships presented in have been used.

In this study, we calculate the required energy to bake ordinary lavash bread. The specific heat capacity for Lavash bread dough is about 92% of the specific heat capacity of water and the specific heat capacity of water is 4.18 J/g K, so the required heat to increase the dough temperature from the initial temperature of 25°C to the boiling point of water, which is assumed to be 97°C, is:

$$q_1 = C_{dough}(T_b - T_\infty) = 277.2\frac{J}{gr} \qquad (1)$$

Almost 20 percent of the dough weight is released as steam during baking, so the amount of energy required to evaporate 20 percent of the dough weight is calculated as follows.

$$q_2 = m_{vap} \times h_{fg} = 0.2 \times 2260 = 452\frac{J}{gr} \qquad (2)$$

Therefore, the total required energy for baking bread per unit mass of dough is:

$$q_t = q_2 + q_2 = 729.2\frac{J}{gr} \qquad (3)$$

So, about 730 joules of energy is needed for baking bread with dough weighing 100 grams. By assuming that the baking time is about 3 minutes, the thickness of the bread is about 1.0 cm and the density of the dough is 1.2 g/cm^3, the energy needed to bake per unit area is equal to:

$$e = t_{dough} \times \rho_{dough} \times q_t = 0.1cm \times 1.2\frac{gr}{cm^3} \times 729.2\frac{J}{gr} = 87.504\frac{J}{cm^2} \qquad (4)$$

The power required for baking per unit area is equal to:

$$P = \frac{e}{time} = \frac{87.504}{180s} = 0.4861\frac{W}{cm^2} \qquad (5)$$

By assuming that the overall efficiency of the cooker is about 50% and the intensity of received radiation is 800 watts per square meter, the available power per unit area of the reflective plate is equal to:

$$P_{eff} = G_r \times \eta = 800\frac{W}{m^2} \times 0.5 = 400\frac{W}{m^2} \qquad (6)$$

The efficiency of the top surface of the reflective plate is about 90%, so the power available from the top surface is equal to:

$$P_2 = 800 \times 0.071 \times 0.9 = 51.12\frac{W}{m^2} \qquad (7)$$

$$P_{cooke} = P_{cook} - P_2 = 4861 - 51.12 = 4810\frac{W}{cm^2} \qquad (8)$$

Now the ratio of the reflective surface of the plate to the absorber surface is obtained as follows:

$$R = \frac{P_{cooke}}{P_{eff}} = 12.025 \qquad (9)$$

Therefore, the surface of the reflective plate should be 12 times the container surface. Now, by considering that the diameter of the container is 30 cm, the diameter of the reflective plate is equal to 1.04 m. The parabolic focal length, P, is also calculated from the following equation, where X and Y are the coordinates of the center of the parabolic curvature:

$$X^2 = 4 \times P \times Y \qquad (10)$$

This lens is made of separate plastic parts that have been immersed in chrome plating. Chromium oxide coating is used to create reflective properties in parabolic parts, with a reflection coefficient of about 0.9 to 0.95. The reflection set should be rotated regularly to the south so that at noon the axis of symmetry is aligned with the direction of direct solar radiation. The required slope in the Northern Hemisphere for a specific day of each month is obtained from the following equation:

$$\theta_Z = \varphi - \delta \qquad (11)$$

For Mashhad, this amount at the beginning of the summer season is equal to θ

=36.16-23.5=12.66°. The bottom absorber plate is made of gray cast iron with a thickness of 15 mm, which in addition to the absorption coefficient of about 0.8, also has a capacitive property to store heat and on the other hand, its temperature increases rapidly. The top plate is made of 2 mm thick aluminum, the upper surface of which is blackened and has an absorption coefficient of about 0.9, and transfers the received heat quickly. The wall of the baking chamber along with the walls of the absorber plate is insulated by a 2 cm layer of fiberglass. The space between the top absorber plate and the glass housing is also vacuumed to minimize high-level losses. Figure 2 shows the different parts of the stove. Table 1 introduces the main parts of the stove.

Figure 2: Schematic of Solar oven made in the present work for baking bread.

Table 1: The main parts of the solar oven.

Section name	Section code	Duty
concentrator	R	Focusing the received radiation on the desired surface
the keeper	K	Location of the baking chamber
the base	B	Keep the baking tray at the desired focal length
Baking chamber	CH	Prevent heat loss and absorb maximum input radiation

Losses and overall efficiency

In this section, the heat loss of the system is investigated. The chamber is insulated from the surroundings and has no heat loss. The space between the door and the absorber surface is a vacuum, the losses of which are ignored. However, when removing bread or placing it, a lot of heat is lost, which due to the fact that the experiment showed that it returns to its previous state only after 17 seconds of placing the door, these losses are also ignored. Therefore, the only heat losses that are considered are related to the low adsorbent surface and the heat transfer and radiation related to it. Assuming that the average temperature of the lower adsorption plate is about 230°C and the ambient temperature is 35°C, the coefficient of heat transfer due to wind is equal to:

$$h = 2.8 + 3 \times V \qquad (12)$$

The average wind speed in Mashhad is about 2.5 meters per second, so the heat transfer coefficient is equal to $10.3\frac{W}{m^2.K}$. The heat loss due to wind flow per unit area is equal to $H = h \times \Delta T = 10.3 \times (230 - 35) = 2008.5\frac{W}{m^2}$

If the Reflection coefficient of the concentrators is about 0.9 to 0.95 and the absorption coefficient of the plate is 0.8, the radiation received by the absorber plate per unit area is equal to:

$$G_p = G_t \times R \times P_{MIROR} \times \alpha_p = 6278.4\frac{W}{m^2} \qquad (13)$$

Now the effective cooking capacitance per unit area is calculated as follows:

$$P_{eff} = G_p - H = 4269.9\frac{W}{m^2} \qquad (14)$$

Finally, the overall efficiency of the cooker is obtained as follows:

$$\eta = \frac{P_{eff}}{G_t \times R} \times 100 = 44.1\% \qquad (15)$$

Experimental studies

Measurements: The measuring instruments consist of Thermometer, Anemometer, lux meter, digital Balance, and Timer. The Model, accuracy, and experiment variable of these instruments are listed in the Table 2.

Table 2: Measurements of instruments with accuracy and experiment variance.

Accuracy	Instrument model	Experiment variance
$\pm 1 sec \frac{w}{m^2}$	Testo 1333 Made in Taiwan	The capacitance of the sun radiant
$\pm .3 mv$	Testo 922 Made in Germany	Container temperature
$\pm 0.01 gr$	Digital weighing	Weight
± 1sec	Regular timer	Time
± 0.02m/sec	Anemometer	Wind measurement

Experimental studies in the present study include the selection of the absorber plate, the appropriate cooking temperature, cooking container height, the inlet heat flux to the upper surface and the insulation role of the container. Investigation of these items on the system is done by a solar simulator and the optimal shape is verified by performing solar tests. As specified in the previous section when using the electric heat source, the design is done in such a way that the lower surface is exposed to a heat flux of 350 to 450 watts and the maximum heat flux from the upper source is about 60 watts. Figures 3 and 4 shows the solar baking oven made for this research and the centralized radiant on the absorbent surface.

Figure 3: Solar baking oven made for this research.

Figure 4: The centralized radiant on the absorbent surface.

RESULTS AND DISCUSSION

Optimum shape and validation

Once the experiments were performed with an electric source similar to the sun we obtained the optimal shape and we took this optimal shape for making the oven. Now it's time to bake bread with a solar oven to verify the tests performed. The bread baking test was performed for three days, May 15, 2022, May 17, 2022 and May 19, 2022, from 10:30 to 12:30, and the experimental data obtained from this test are given in the following Tables 3-5. In these experiments, time, environment temperature, radiation intensity and bread temperature were measured.

Table 3: The cooking container temperature changes versus time for 5/19/2022.

Environment temperature C	Wind speed m/s	Container temperature C	Radiant intensity W/m²	Time min
31	0.2	41.6	930	0
31	0.2	65.6	940	5
31	0	82.1	954	10
31	0.2	99	962	15
31	0.1	114	958	20
32	0	122.2	942	25
32	0.1	133.3	958	30
33	0.5	144.3	952	35
33	0	154.9	956	40
33	0.2	156.2	958	45
34	0	162.5	955	50
34	0.2	173.2	950	55
34	0.2	176.6	948	60

Table 4: The cooking container temperature changes versus time for 5/15/2022.

Environment temperature C	Wind speed m/s	Container temperature C	Radiant intensity W/m²	Time min
28	0.1	43	1000	0
28	0.3	67.1	1003	5
26	0.8	80.1	1009	10
26	0.7	96.8	1010	15
26	0.1	111	1013	20
26	1	119.7	1016	25
26	0.8	128.1	1025	30
26	0.6	139.6	1027	35
27	0.3	149.2	1020	40
27	0.2	158.6	1017	45
27	0.3	166.7	1017	50
27	0.1	173.1	1014	55
28	0.1	43	1000	0

Table 5: The cooking container temperature changes versus time for 5/17/2022.

Environment temperature C	Wind speed m/s	Container temperature C	Radiant intensity W/m²	Time min
31	1.1	42	1070	0
31	0.3	66.5	1072	5
31	1	86	1066	10
31	0.6	104.6	1062	15
31	0.1	118.2	1058	20
32	0.4	131.6	1053	25
32	0.8	141.2	1050	30
33	0.2	151.6	1046	35
33	0.2	160.5	1044	40
33	0.1	167.3	1041	45
34	0.1	175	1037	50
31	1.1	42	1070	0
31	0.3	66.5	1072	5

The temperature changes of the container in the three days (5/15/2022, 5/17/2022 and 5/19/2022) that the solar test was performed. Figures 5 and 6 shows the proximity of the electrical and solar test conditions, which shows the accuracy of the experiments performed with the electrical source. The bread is baked every two to three minutes, which indicates the accuracy of the tests performed with the electric source.

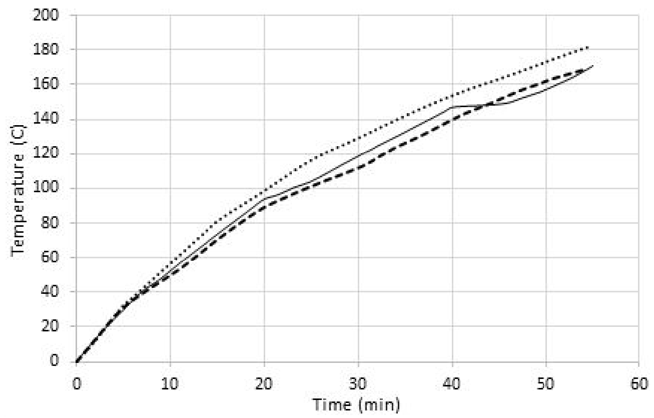

Figure 5: The cooking container temperature changes versus time for 5/15/2022, 5/17/2022, and 5/19/2022. **Note:** (---) 5/15/2022; (....) 5/17/2022; (–) 5/19/2022.

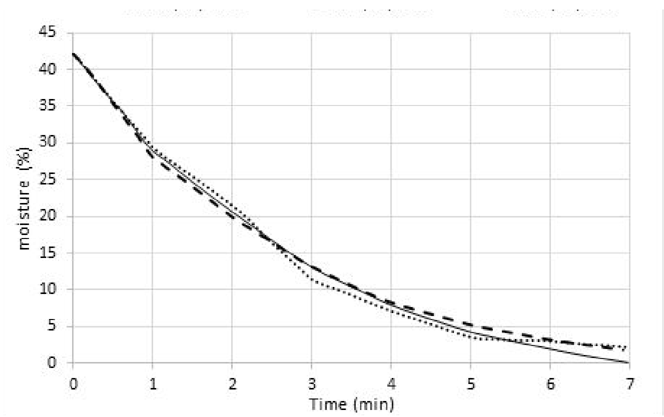

Figure 6: Dough moisture changes versus time for 5/15/2022, 5/17/2022, and 5/19/2022. **Note:** (---) 5/15/2022; (....) 5/17/2022; (–) 5/19/2022.

After conceptual design and knowing the general shape of the stove, the effective factors in cooking are investigated with an electric heater that simulated the sun and the following results were obtained.

Absorber plate

To investigate the appropriate thickness of baking plate, two plates are made of gray cast iron. The thickness of these two plates has been experimentally considered to be 1.5 and 3 cm. The choice of these thicknesses is due to the fact that in addition to the acceptable rate of increase in temperature, the plate has a capacitive characteristic and the temperature drops slowly. In order to evaluate the performance, these two plates were subjected to a heat flux of 800 watts and surface temperature changes were recorded. Figure 7 shows the surface temperature changes over time for two cases.

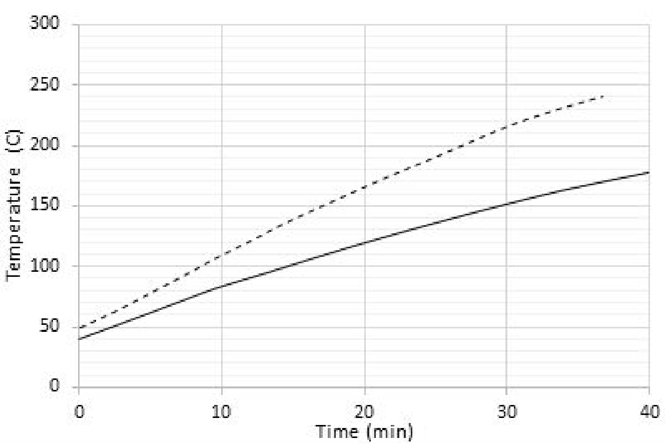

Figure 7: Temperature changes of the absorber surface versus time. **Note:** (–) Thickness=3 cm; (---) Thickness=1.5 cm.

According to Figure 6, after 30 minutes of sunlight on the plates, the temperature of the plates with a thickness of 1.5 and 3 cm reaches 150 and 220 Degrees Celsius, respectively. The rate of temperature increase in the 1.5 cm thick plate is much higher than the temperature increase in the 3 cm plate, so the selected plate is 1.5 cm thick. It should be noted that both selected plates have same capacitive state. Once the absorber plate selected, we insulate this plate and check the temperature changes with insulation and without it. Figure 8 shows the rate of temperature increase in plate for both isolated and un-insulated conditions.

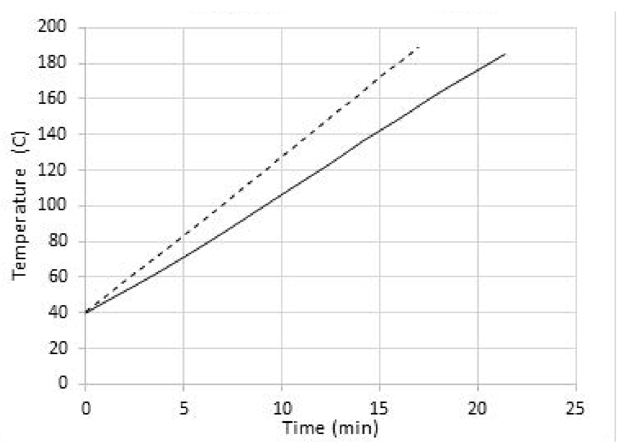

Figure 8: Comparing the absorption plate surface temperature changes versus time in insulated and un-insulated states. **Note:** (–) Non-insulat; (---) Insulat.

Baking container temperature

In this section, the effect of three different temperatures of container, 150,180 and 210°C have been investigated on dough moisture changes. Figure 9 is obtained by equating the input flux from the upper surface to 60 watts, the height of the chamber to 2 cm and the input heat flux to the lower surface to 400 watts. After providing the above conditions, the cooking process begins and within one minute intervals, the samples are photographed and sensory and physical tests are performed and the samples are weighed. The dough weighs about 70 grams.

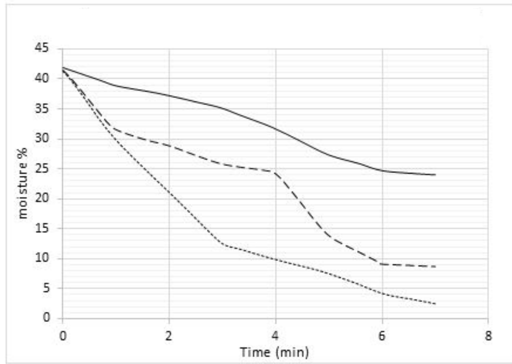

Figure 9: Dough moisture changes versus time at different temperature of the container. **Note:** (–) 150°C; (---) 180°C; (....) 210°C.

According to the Figure 10, the bread that is baked at a temperature of 150°C is formed in the middle layer of the crust due to the low temperature of the container, and therefore, this crust prevents heat to reach to the upper levels, and the bread is not cooked inside and doesn't have a good quality. The crust of the bread which is baked at a temperature of 180 degrees Celsius is higher than the previous bread, but still some part of the bread dough is not baked properly and in order to complete the baking process, the bread must be turned upside down. The bread baked at a temperature of 210 degrees Celsius has been almost baked and is considered good bread and no longer needs to be turned over. On the other hand, according to Figure 9 the bread which is baked at 210°C has the fastest baking time, which has effects on the shelf life of the bread. In Figure 10 baking at 210°C, the bread color is completely more monotonic than the other two cases, so according to the results of 210°C, the appropriate temperature of the baking container is selected.

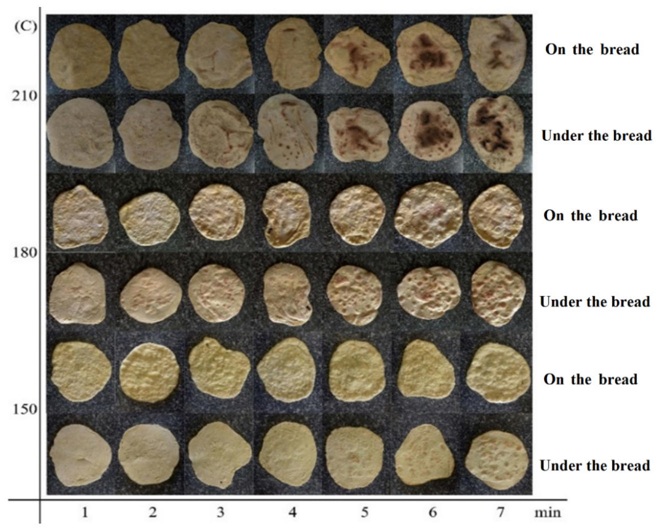

Figure 10: Dough shape changes versus time at different temperature of the container.

Incoming heat flux to the upper surface

After determining the appropriate temperature of the cooking chamber, it is time to determine the inlet heat flux from the upper surface. According to the calculations made in the previous section, it was found that due to the area of the top plate, the maximum heat flux received at this surface is about 60 watts. Therefore, the heat flux entering the upper surface is investigated in three states, insulated (0), 30 and 60 watts to found out either the flux is necessary for the upper surface or not. For this purpose, the height of the container is implemented to 2 cm and the desired flux to the upper surface is applied. When the container temperature reaches 210 degrees Celsius, then the baking starts. The samples were photographed and weighed every minute. Figure 11 also shows that the bread has the shortest baking time at an incoming temperature of 60 watts, so the heat flux of 60 watts is chosen as the basis for other tests.

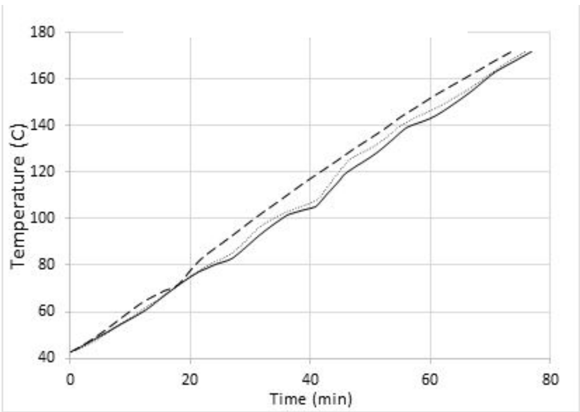

Figure 11: Temperature changes of the baking container versus time at thermal fluxes of 0, 30 and 60 watts incoming from the upper surface. **Note:** (---) 60W; (....) 30 W; (—) insulat.

According to the Figure 12 the higher incoming heat flux, the better the color of the upper surface of the bread, and it get more toasted and has a higher quality. On the other hand, the surface temperature decreases about 20°C after each baking that once the incoming flux increase, causes this temperature drop to get high faster.

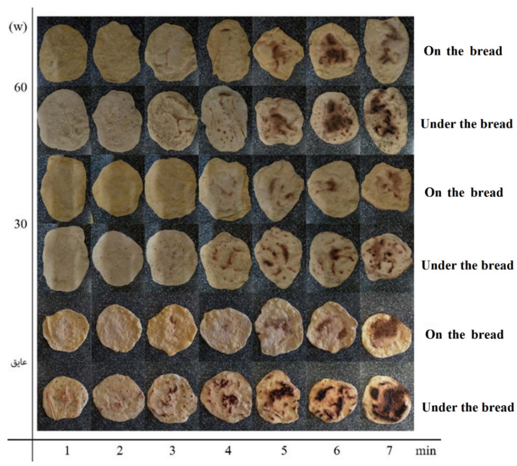

Figure 12: Shape changes of the baking container within the time at thermal fluxes of 0, 30 and 60 watts incoming from the upper surface.

Cooking container height

In order to determine the optimum height of the cooking container the three heights of 2,4 and 8 cm are investigated. The samples were photographed and weighed every minute. In these tests the incoming flux to the upper surface is 60 watts, and the container temperature is 210.

Figures 13 and 14 shows the Temperature changes and dough moisture changes of the baking container versus time at heights of 2, 4 and 8 cm of the container side's wall, respectively. Figure 15 shows the Dough shape changes of the baking container versus time at heights of 2, 4 and 8 cm of the container side's wall.

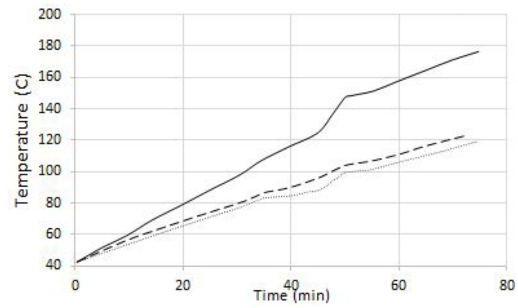

Figure 13: Temperature changes of the baking container versus time at heights of 2, 4 and 8 cm of the container side's wall. **Note:** (—)2 cm; (---) 4 cm; (...) 8 cm.

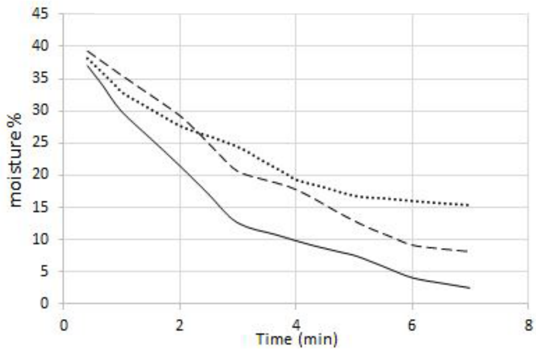

Figure 14: Dough moisture changes of the baking container versus time at heights of 2, 4 and 8 cm of the container side's wall. **Note:** (—) 2 cm; (---) 4 cm; (...) 8 cm.

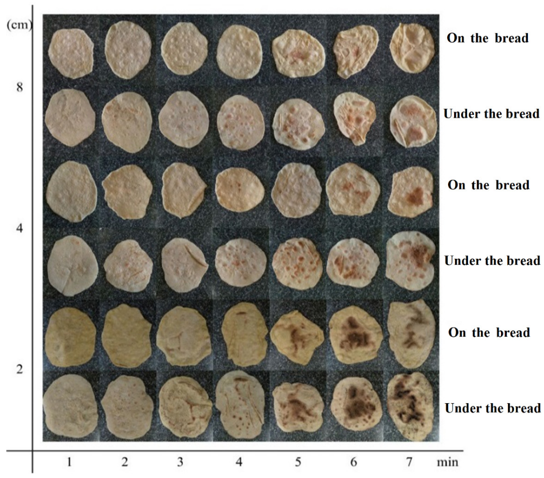

Figure 15: Dough shape changes of the baking container versus time at heights of 2, 4 and 8 cm of the container side's wall.

Temperature of the container increases by increasing the height of the container to more than 2 cm which makes the increases preheating higher On the other hand, increasing the height of the container would make us to turn the bread upside down to complete the baking process which increases the baking time and reduces the quality of the bread.

CONCLUSION

The design and construction of a dual-purpose solar oven for baking bread has been investigated in this research. After testing and reviewing the data, the following results were obtained:

The considered laboratory conditions are similar to the solar conditions, with a good approximation, and the actual and laboratory results are close to each other, and the optimal laboratory conditions for the solar oven are also acceptable.

The temperature of the oven lower than 150 degrees Celsius is not suitable for baking bread and for 180 degrees Celsius the bread should turn over to complete the baking process. The temperature of 210 degrees Celsius is suitable for cooking.

Increasing the heat transfer rate at a high level causes uniformity of baking and toasting the upper surface of the bread.

At heights more than 2 cm, the upper surface of the bread does not stain and baking is done similar to the teak method, and we need to turn it over to complete the baking process.

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