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COVID 19 virus elimination from food using microwave oven

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ABSTRACT

The worldwide spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) famously known as the COVID-19 pandemic is making shocking sceneries all over the globe. The COVID-19 virus can survive on the surface of several materials and infect the person that comes in contact with that surface during the virus life-span. Therefore, it is recommended to ensure that bacteria, microorganisms, and viruses, including COVID-19, are eliminated from food surfaces. In this work, a study has been conducted based on COMSOL Multiphysics to evaluate the temperature at micro-droplet surfaces located at different positions and locations in microwave ovens, which are used globally to reheat food. It was found that the micro-droplet surface temperature within two and a half minutes is enough to kill the bacterial and viral microorganisms on the droplet surface. As COVID cannot tolerate 70 $^{\circ}C$ temperature, within this time, it can be eliminated from the food surface. The time requirement can be shortened by using high-power microwave ovens.

1. Introduction

The SARS-CoV-2 known as the COVID 19 or coronavirus causes severe diseases that affect mainly the respiratory system (Azoulay & Jones, 2020; Knill & Steinebach, 2022; Zhao et al., 2022). Until March 05, 2022, it is estimated that the virus is responsible for the death of more than 6,014,940 people worldwide, and a total of 445,115,898 people got infected by COVID 19 till that day (Worldometer, 2022). This virus had an extremely negative impact on the global economy, especially during the days of complete lockdown. It is estimated that because of this pandemic, every country will face a 4.5% decrease in its Gross Domestic Product (GDP), and the total cost so far is $2.96 trillion US dollars (Szmigiera, 2022).

COVID-19 can be transmitted via respiratory means or with direct contact. Respiratory droplets are created when an infected person sneezes or coughs. People surrounding the infected person are at high risk of COVID-19. People can also get infected when the droplet containing the virus is stuck to a surface and the person comes in contact with that surface (Organization, 2020a, 2020b). If that person touches the contaminated surface and later touches their mouth or face, the virus will be transmitted to them. Still, there is no evidence of how much time COVID-19 can survive on surfaces, but it seems that it follows the behavior of other coronaviruses. That means it can survive from 2 h to 9 days. The survival time also depends on many factors such as surface type, relative humidity, the strain of the virus, and surface temperature (Organization, 2020a, 2020b). It was found that the COVID-19 virus can survive on plastic or stainless-steel surfaces for up to 72 h, 24 h on cardboard, and 4 h on copper (Organization, 2020a, 2020b). Another study found that the virus is transmitted through frozen meats and packaging (Han et al., 2021). Unfortunately, there is still not enough research done on the probability of survival for the COVID-19 virus when exposed to temperature over a period of time. Most outcomes or conclusions were adopted from research on SARS-CoV and MERS-CoV. For those viruses, thermal processing and microwave irradiation were highly effective in deactivating the viruses.

Several measures were taken globally to prevent the spread of COVID 19 like imposing social distancing, vaccination, lockdown, and isolation (Reich & Elward, 2022). It appears that temperature has a great impact on the survival time of the COVID-19 virus. Countries with cold climates are affected more by the COVID-19 virus when compared to countries with warmer climates (2020UNICEF). Heating the coronavirus to 65 $^{\circ}C$ for 1 min is a good way to deactivate it (Farahmandfar et al., 2021).

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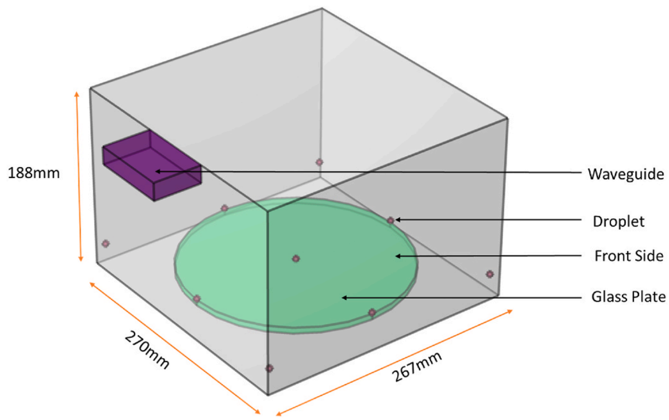


Fig. 1. Microwave oven dimensions. Air was considered inside the microwave oven as the material surrounding the metal (Copper) wall. The waveguide dimensions were taken as 50 × 78 × 18 mm. The droplet size had been multiplied by 100 for better visualization (63 μm x 100).

SARS-Cov-2 cannot tolerate 70 °*C* temperature (Mathur, 2021). This finding was used to kill the virus using different systems like air purifiers (Mathur, 2021), and heated air disinfection (Yu et al., 2020). In this work, a microwave oven is used to heat the food at a certain temperature so that coronavirus living on that food surface is deactivated or eliminated. Since microwave ovens do not heat areas in the oven evenly, the temperature at different positions and locations had been analyzed so that it reached at least 65 °*C* everywhere. The minimum time requirement for a standard microwave oven to get to 65 °*C* all over the oven had been estimated.

2. Methodology and materials

A microwave oven was modeled with a dimension (Width x Depth x Height) of 167 × 270 × 188 mm using.

COMSOL Multiphysics software (Version: 6.0). The round-shaped glass plate radius was taken as 113.5 mm with a height of 6 mm. A waveguide was placed at the top to guide the wave in the oven. Fig. 1 depicts the microwave oven dimension.

Electromagnetic Waves, Frequency Domain (ewfd), and Heat Transfer in Solids (ht) were taken as applied physics in the simulation considering the frequency-dependent microwave oven mechanism and heat transfer to a solid piece of potato (as the sample). The whole system was considered in a standard environment of 1 atm pressure. The waveguide was considered confined in the metal (copper) boundary with 1 atm pressure and 293.15 K temperature. Air filled the inside of the metal box. The impedance boundary conditions (relative permittivity, relative permeability, electrical conductivity) depend on the material properties i.e., different for the glass plate, copper, and potato. The relative permittivity was considered for the electric displacement field model in the boundary section. From the waveguide part, the high frequency of 2.45 GHz wave enters the oven with Transverse Electric (TE) of mode number 10. Initially, all the systems' temperatures and pressure were considered as 273.15 K and 1 atm respectively.

Considering the heat transfer mechanism, electromagnetic heating (emh) Multiphysics was also considered as by this way waveguide's frequency heats the food in the oven. Free Tetrahedral shape geometry was used for meshing, with a custom minimum parameter size of 4.76 x 10^{-6}. Frequency domain was used for the spread of high frequency in the oven while time-dependent analysis was done to study the heat received by the particles in the oven by the electromagnetic heating system.

The water droplet (on which SARS-CoV-2 can be attached to and survive) with a diameter of 63 μm had been considered at nine different locations in three positions (altitudes) as illustrated in Fig. 2. The bottom position was considered at 1.5 mm above the glass plate while the middle and upper positions were at a height of 72.9 mm and 166.9 mm respectively. The simulation ran for two and a half minutes using Windows operated desktop PC with 64 GB RAM. The data achieved from the simulation was plotted using MATLAB.

3. Results and discussion

SARS-CoV-2 is a large genomic RNA virus with a genome size of 27–34 kb (Al-Kuraishy et al., 2022a). It primarily infects lung cells because they express angiotensin-converting enzyme 2 (ACE2) (Babalghith et al., 2022). Middle East Respiratory Syndrome CoV (MERS-CoV), SARS-CoV, and SARS-CoV-2 share genetic similarities, though SARS-CoV-2 is less pathogenic and has a higher transmissibility rate than SARS-CoV (Al-Kuraishy et al., 2022b).

To avoid COVID-19 contamination and transmission, WHO recommends keeping environmental surfaces clean. A shorter stay was observed in the case of MERS-CoV at temperatures ranging from 30 °C to 40 °C. However, for SARS-CoV-2, a longer stay was observed, which was aided by higher relative humidity (Abolmaaty et al., 2022). Microwave heating, like electron beam radiation, can kill COVID-19 (Feng et al., 2020). The effect of temperature and time on the half-life or inactivity of SARS-CoV-2 was described in the introduction section, and the details can be found in (Geng & Wang, 2022), (Biryukov et al., 2021).

Microwaves are a combination of electric and magnetic waves or energy moving in space. Once the oven is switched on, the microwave produces electric and magnetic fields in the oven according to its power rating. The waves heat the water molecules in the food and the temperature rises. In this work, the simulation took the oven to 1 KW this time; later the impact is discussed considering another power rating too. The electric field, magnetic field, and temperature distribution for XY, YZ, and ZX planes are shown in Fig. 3 considering the droplets are in the bottom of the oven (Fig. 2(a)). It is seen from the figures that the electric

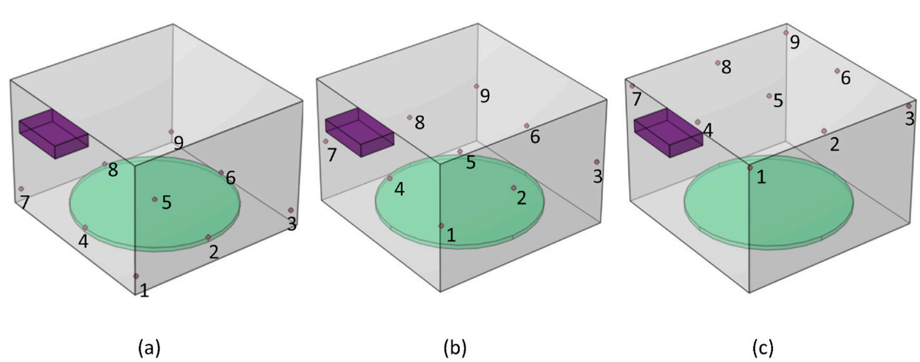


Fig. 2. Droplet locations at (a) bottom (b) middle and (c) top of the microwave oven glass plate. Droplets 2, 4, 6, 8 are on/above the glass plate, droplet 5 is in the middle of the oven and the other four droplets (1, 3, 7, 9) are at four corners of the oven. Droplet size is multiplied by a hundred for better visualization.

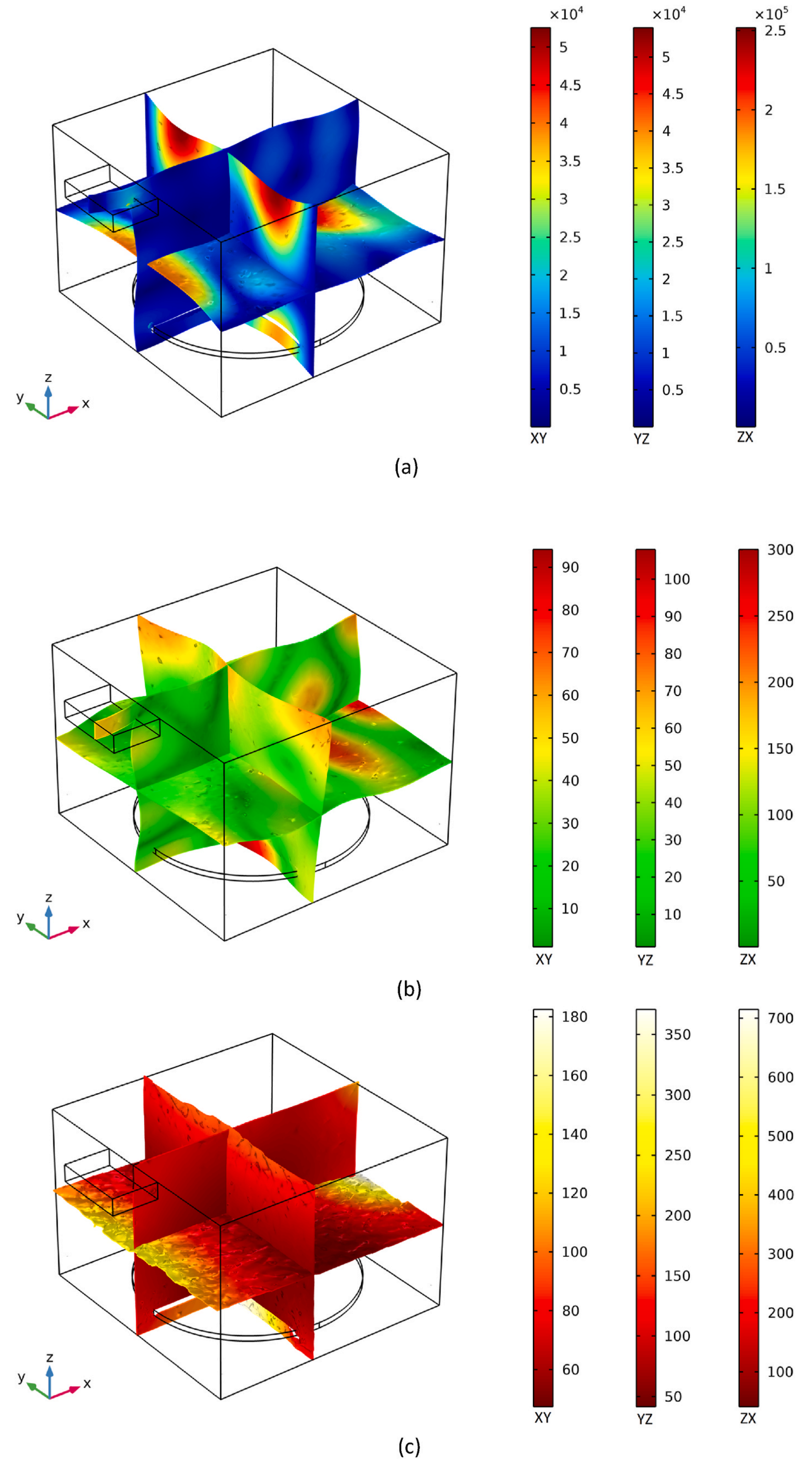


Fig. 3. (a) Electric field norm, (b) Magnetic field norm, and (c) Temperature distribution in the microwave oven while the droplets are in the bottom position. The three planes exhibited different distributions.

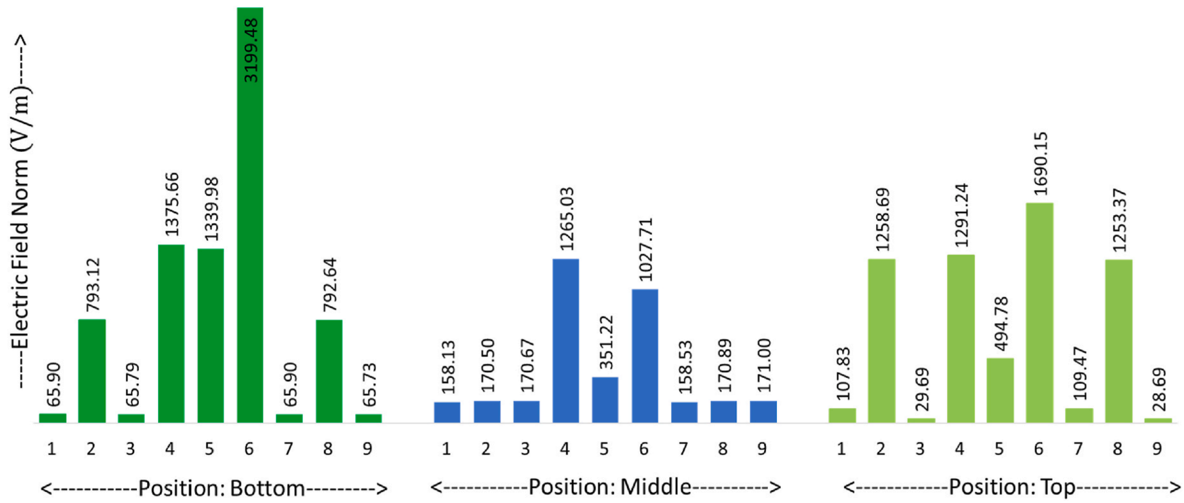


Fig. 4. Electric field norms at three different positions for all droplets.

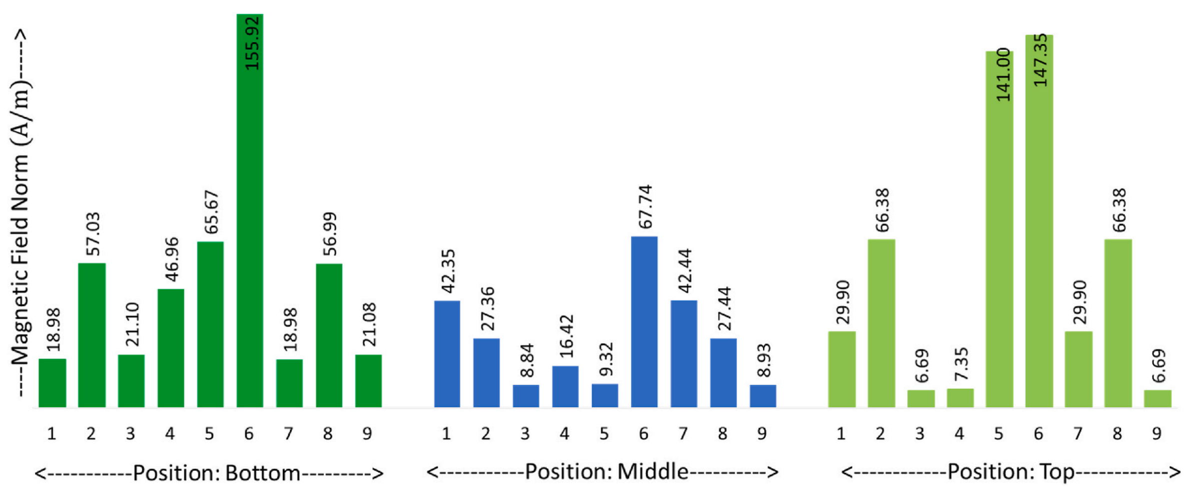


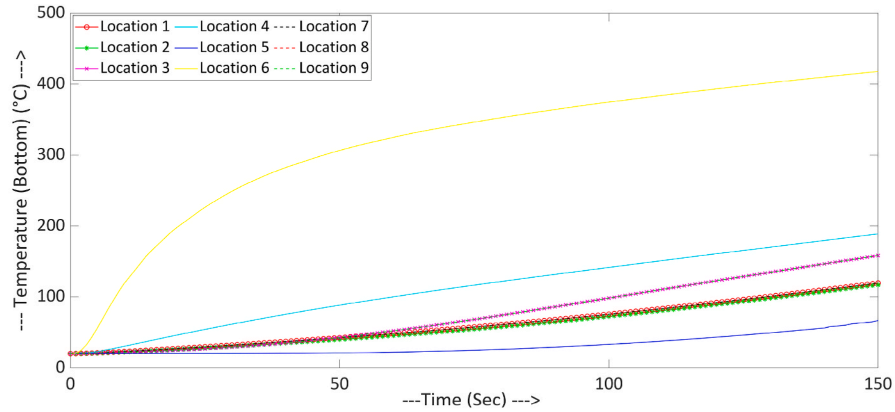
Fig. 5. Magnetic field norms at three different positions i.e., bottom, middle, and top of the oven for all droplets.

and magnetic fields do not spread evenly, rather it is high at some locations and low in others. Therefore, the temperature also is not distributed evenly. In between the XY and YZ planes, though the electric field is stronger in the XY plane, the magnetic field is stronger in the YZ plane, and consequently, the temperature is high at the YZ plane. In the ZX plane, both the electric and magnetic fields are stronger than in the other two planes and as a result, the temperature is higher there (Fig. 3 (c)).

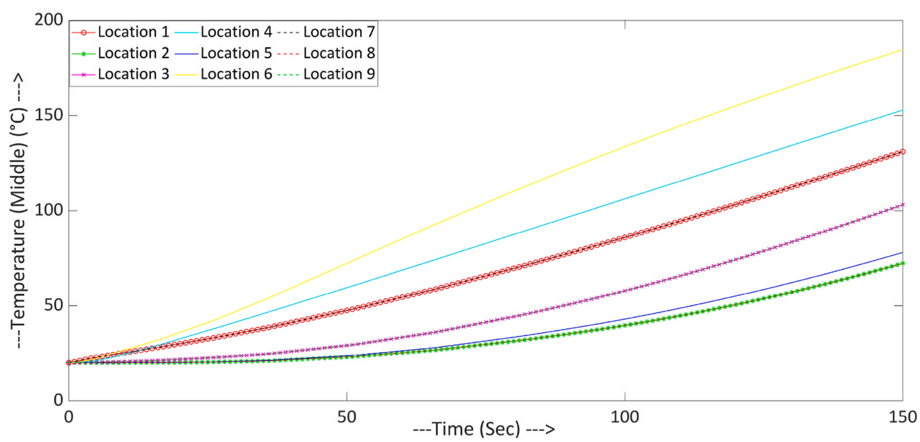
The droplets got exposed to the maximum electric and magnetic fields when they are placed at the bottom of the oven. Figs. 4 and 5 show the electric and magnetic field norms for all nine locations at three positions. It was found that droplet 6 got the maximum electric and magnetic fields at the bottom position. The electric field norms for droplet 6 was 3199.48V/m, 1027.71V/m, and 1690.15V/m for the bottom, middle and top positions respectively, whereas the magnetic fields for those positions were 155.92A/m, 67.74A/m, and 147.35A/m respectively.

The droplet's temperature for three different positions, bottom, middle, and top of the microwave oven shown in Fig. 2 is presented in Fig. 6. It can be seen that at the bottom position, droplet 6 gets maximum heat as both the electric and magnetic fields are maximum. The droplet temperature was 417.86 $^{\circ}C$ while droplet 5 gets minimum heat and reached 68.82 $^{\circ}C$. All other droplet temperatures got above 115 $^{\circ}C$ after 150 s. It is noticed from Fig. 6 (a) that after 96 s, all the droplets other than droplet 6 got up to more than 70 $^{\circ}C$ temperature. As seen in Figs. 4 and 5, the electric and magnetic fields were less powerful in the middle position and thus the droplets got less heat. The maximum temperature for droplet 6 in the middle position is 184.74 $^{\circ}C$. At that position, it takes 148 s for all droplets to get up to 70 $^{\circ}C$. But as seen from the electric and magnetic field distributions in Fig. 3, at the top positions, the droplets got more heat and reached a higher temperature compared to the middle positions. The maximum temperature for droplet 6 was 307.39 $^{\circ}C$ and it took only 111 s to get up to 70 $^{\circ}C$ for all the droplets. The highest temperatures after two and a half minutes are presented in Fig. 7 for all three positions and nine droplets.

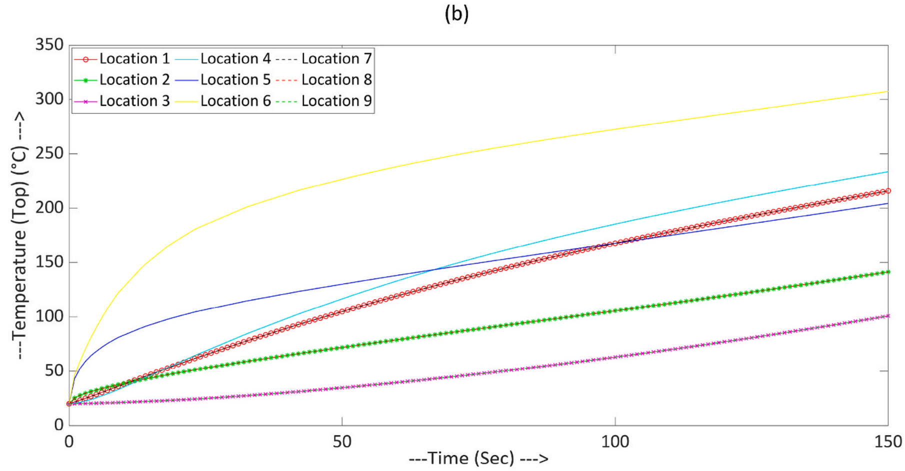
The impact of droplet radius on temperature was also investigated. Fig. 8 (a) depicts the temperature variations for radius change of droplet 5 in the middle position (Fig. 2 (b)). It is seen that the droplet size had a very small effect on the temperature change up to the radius of 3150 μm and in all cases, the final temperature after two and a half minutes was more than 70 $^{\circ}C$, which is excellent to deactivate the coronavirus including SARS-CoV-2. In Fig. 8 (b), the temperature variation is illustrated, where the radius is increased to 31.5 mm. It is noticed that for a droplet size smaller than 30 mm radius, the temperature increases to more than 70 $^{\circ}C$ within two and half minutes. As the size increased, the droplet came into contact with more microwave radiation at the same time, but when droplet mass increases, it will take more time to get up to higher temperatures (Heddleson & Doores, 1994).



(a)



(b)



(c)

Fig. 6. Temperature for droplets at different locations (1, 2, 3, 4, 5, 6, 7, 8, 9) with time when the droplets are at the (a) bottom, (b) middle, and (c) top positions. The initial temperature was considered at 20 °C. The legends shown in b, are applicable for a and c too.

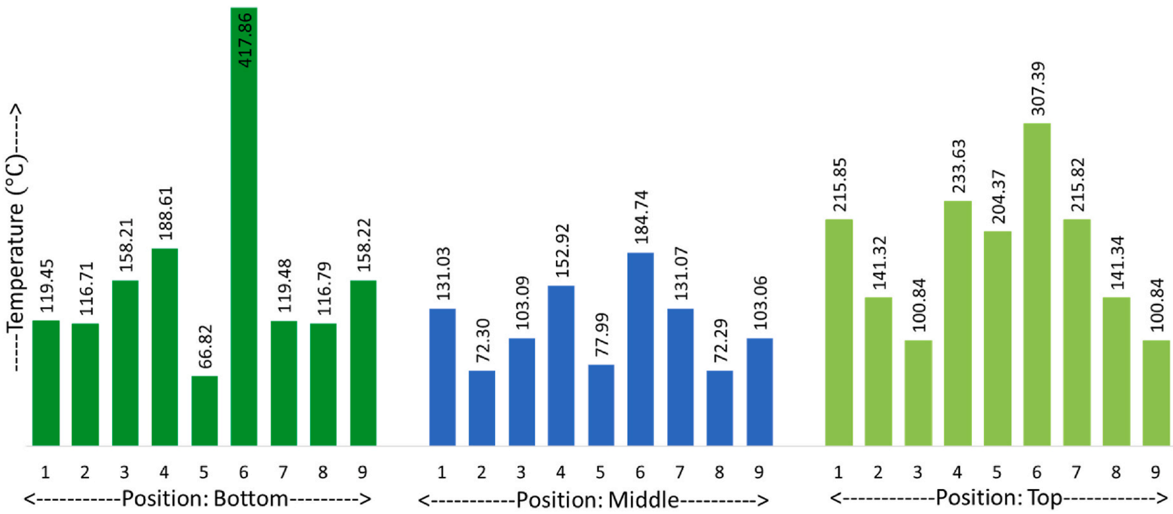


Fig. 7. Temperature after two and a half minutes by the droplets at different positions (bottom, middle and top) and locations (1, 2, 3, 4, 5, 6, 7, 8, 9).

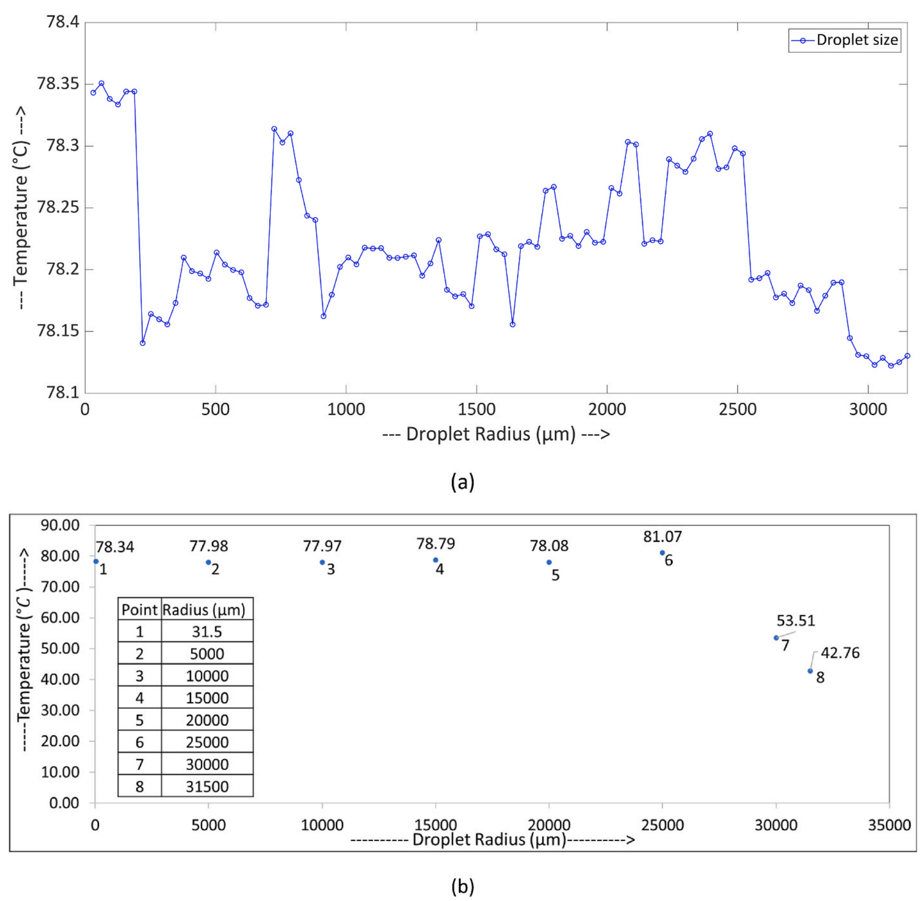


Fig. 8. Temperature variation for droplet size change for droplet 5 in the middle position. (a) The radius was doubled at every step up to 3.150 mm. The temperature was measured after 150 s. (b) Temperature change for larger droplets.

The effect of the microwave oven power was also investigated. The higher the power, the less time it is required to get up to 65 °C temperature. Fig. 9 depicts the temperature of droplet 5 when it is in the middle position for several power levels.

The simulation was run from 0 to 150 s for the droplet 5 (Location – 5, position – middle) and within that time, the 65 °C temperature threshold was attained by all microwave ovens whose power range was between 1 and 5 kW. Different results came out for the oven with 0.5 kW power; as it could not heat the droplet to 65 °C within two and a half minutes; rather it took 277 s (not shown in the figure). It took only 70 s to reach the droplet's (Location – 5, position – middle) temperature at 65 °C and this time had been increased with the decrease of power ratings.

4. Conclusion

The microdroplets placed at different positions and locations in the microwave oven got to a temperature greater than 65 °C within two and half minutes, which is an excellent way to deactivate the coronaviruses

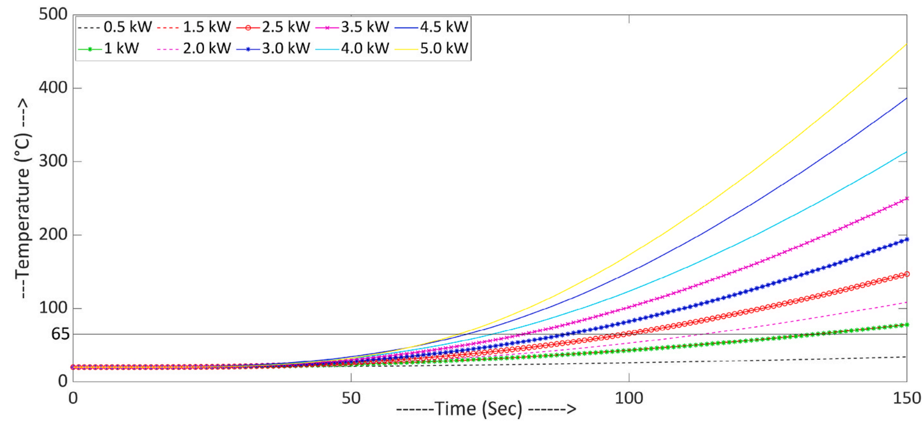


Fig. 9. Temperature variation for droplet size change. (a) The radius size was doubled at every step and reached 3.150 mm. The temperatures have been taken at 150 s. (b) Temperature change for larger droplets.

including SARS-CoV-2. The time taken by the microwave oven can be reduced by using higher power ovens. The droplets on the glass plate and at the top positions are exposed to higher magnetic and electric fields and thus get to higher temperatures faster. The droplet size has almost no effect on the temperature until it is in the micro range.

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