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Microwave usage and cancer: Do microwaves cause cancer?

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Abstract— Materials containing water, for example foods, fluids or tissues, absorb microwave energy readily, which is then converted into heat. This principle is applied in microwave ovens, an electrical appliance that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range. Amidst the hustle and bustle of modern life, the microwave oven has been a great help, as the rapid development of technology keeps consumers in the fast lane. Cancer is defined as the uncontrolled growth and spread of cells. It can affect almost any part of the body. The growths often invade surrounding tissue and can metastasize to distant sites. In this paper, we will explore the function of microwave ovens, the pathophysiology of cancer, and whether there is any evidence of a relationship between microwave ovens and cancer.

Keywords— microwave; microwave oven, cancer

I. INTRODUCTION

Microwaves are part of the electromagnetic spectrum. They are high frequency radio waves that are used for TV broadcasting, telecommunications, diathermy treatment and in kitchens for cooking food (1). As the name suggests, a microwave oven is an electrical appliance that uses the frictional heat caused by microwaves to prepare foods and beverages. Its operating principle was accidentally discovered decades ago by a researcher named Percy Spencer during an experiment with a magnetic field tube (2). The popularity of microwave ovens has escalated over time. 93% of homes in the United Kingdom (3) and 91.4% of homes in the United States (4) have microwave ovens.

However, the knowledge regarding the safety of microwave oven is still less understood by the public, despite being commonplace. A survey among the Malaysian population showed that approximately 57.4% of respondents had a low level of knowledge of microwave oven safety (5). This has driven the interests of some researchers to study the safety of microwave ovens and their ability to produce healthy foods and beverages. Some studies suggest that the harmful effects of microwave ovens are greater than its benefits either through its products (foods and beverages) or by direct irradiation. The worst harm that we can get from the microwave ovens is cancer (6).

Cancer is a serious matter, as it leads to significant comorbidities towards its sufferers worldwide. Furthermore, its prevalence climbs year by year worldwide despite high technology modern medical interventions. Globally, cancer

is the second leading cause of death whereby in 2015, it had contributed to 8.8 million deaths (7). From 2007-2011, the cancer incidence in Malaysia was 86.9 in males and 99.3 in females per 100,000 populations (MNCR, 2016) (8). Cancer is caused by numerous factors such as exposure to carcinogens or radiation, lifestyle, inherited genetic mutations and age. In this paper, exposure to radiation and carcinogens is examined due to its correlation with microwave ovens. The objective of this review is to discuss whether can a microwave promote the development of cancer in humans, or whether this is just false information supported by questionable research.

II. METHODOLOGY

Two major databases, Google scholar and Medline, were searched with validated search strategies. Data were collected using the keywords *microwave*, *electromagnetic field*, *radiation* and *cancer*.

III. ELECTROMAGNETIC FIELD AND MICROWAVE

Whether we realise it or not, humans are commonly exposed to both natural and man-made radiation in our daily lives. Radiation is a form of energy that comes from a variety of sources and travels through space at the speed of light. Electrical and magnetic radiation that are moving together in space form an 'electromagnetic field' or 'electromagnetic waves', as they have wave-like properties (9).

The electromagnetic spectrum spans a broad spectrum from very long radio waves to very short gamma rays (10). Components of electromagnetic radiation include radio waves which are emitted by radio stations; microwaves in microwave ovens, infrared used in night vision; visible light, which is the only radiation that can be seen by the naked eye; ultraviolet rays emitted by the suns, X-rays as used in the medical field; and gamma rays, which are used in PET scans (11).

A microwave oven uses an element of electromagnetic spectrum called microwaves to do its job. It produces both non-ionising and ionising radiation, which are related to development of cancer. X-rays and Gamma rays emit ionising radiation, energy that acts by removing electrons from atom and molecules of materials which include air, water, and living tissue. It can travel unseen and pass through these materials (12).

Non-ionising radiation, on the other hand, is a form of radiation that exists all around us from many sources and possesses less energy as compared to ionizing radiation. It has the energy to move atoms in a molecule around or cause them to vibrate, but not enough to ionize them. Unlike the ionising radiation, it does not remove electrons from atoms or molecules of the aforementioned materials (13). Therefore, it is apparently safer, as it does not alter the molecules within the cells of human being that may cause eventual harm if it does so. Microwaves are non-ionising radiation. Based on this point of view, the microwave oven is claimed to be safe whether to its products (foods and drinks) or to its consumers.

IV. PRINCIPLE OF MICROWAVE OVEN

Microwave radiation is widely used in various industries especially food industry. There are three characteristics of microwaves that allow them to be used in cooking; their ability to pass through glass, paper, plastic, and similar materials; be reflected by metals; and ability to be absorbed by foods (10). In a microwave oven, there is an electron tube called a magnetron that produces the microwave inside the oven. Domestic microwave ovens operate with a power usually ranging from 500 to 1100 watts and at a frequency of 2450 MHz.

Once the microwave oven is switched on, the microwaves are dispersed inside the oven cavity, which are then being reflected by a stirrer fan so that they are propagated in all directions. Then, the microwaves are reflected by the metal sides of the oven cavity and absorbed by the food placed on a rotating glass plate, which is usually included with the microwave oven as a set. As the glass plate rotates along with the food, the microwaves will be evenly absorbed by all parts of the surfaces of the food, allowing it to be heated or cooked uniformly.

Moreover, microwave ovens do not cook the food from 'inside out'. The outer surface of the food which is the nearest to the source of the microwaves will first absorb it. Then, the water molecules inside the food will vibrate when they absorb microwave energy, and the friction between the molecules produces heat directly in the food which cooks it. The hot outer layer will then transfer the heat produced in it to the inner side of the food by a process called thermal

conduction (14). That is why foods that are high in water content, like fresh vegetables, can be cooked more quickly than other foods.

Cooking by using microwave ovens is often more energy efficient than conventional cooking, as the foods cook faster. Additionally, the energy heats only the food, not the whole oven compartment, reducing the probability of burn injuries.

V. ROLE OF RADIATION AS A CARCINOGEN

The exact cure for cancer is still less known despite numerous and tremendous studies been done as there are many types of cancer that is caused by different factors. Therefore, the only hope in controlling cancer is by learning more of its pathogenesis and molecular basis.

Ionising radiation is an established carcinogen, no matter what its sources are (UV rays of sunlight, radiographs, nuclear fission, radionuclides). Follow-up research was performed on survivors of the atomic bombs dropped on Hiroshima and Nagasaki, showing a substantial rise in leukemia incidence after an average latent duration of around seven years, as well as elevated mortality levels for thyroid, breast, colon and lung carcinomas (15).

Radiation has been claimed to have oncogenic properties, as it causes chromosomal rearrangements such as translocations and inversions, chromosome and double stranded DNA breakage and, less frequently, point mutations. Carcinogenesis caused by ionising radiation starts with the formation of pyrimidine dimers (16), a molecular lesion formed in DNA chain whereby two consecutive or adjacent pyrimidine bases (usually thymine) are covalently joined by a cyclobutane ring via photochemical reactions (17). Then, two types of pyrimidine dimers are formed (18). These dimers will block DNA replication by distorting the structure of DNA, as they will unwind and kink it. This kind of DNA damage is repaired primarily via nucleotide-excision repair or by photoreactivation pathway in other species.

However, with extensive exposure to UV light, the repair systems may be overwhelmed and subsequently fail, causing mutation in genome of somatic cells which in turn will cause the failure of activation of p53 dependent genes that plays an important role in maintaining the integrity of genome by triggering cell arrest, senescence, and apoptosis. Ultimately, mutant cells will be produced. Their growth is unregulated and continue to grow aggressively until they dominate the surrounding population, as they are subjected to Darwinian selection (16).

All of these examples, prevalence and mechanisms of radiation-related cancer refer to ionising radiation, which includes Ultraviolet rays, X-rays and Gamma rays. On the other hand, non-ionising radiation does not cause cancer. The occurrence of cancer cause by non-ionising radiation is rare and requires a very long time of exposure with high dosages (19).

VI. POTENTIAL HAZARDS AND CARCINOGENIC EFFECTS OF MICROWAVES ON HUMANS AND FOODS

Microwave cooking is well known to be convenient and energy efficient as compared to conventional cooking. Nevertheless, some studies have proven that microwaves can cause harm to human such as thermal injuries, diseases and the like. For example, it is inappropriate to use a microwave oven to heat a baby's milk in a bottle, as the build-up of steam in a closed container such as a baby bottle could cause it to explode. Therefore, improper handling may expose us to hazards. In addition, microwaving formula milk will lead to the conversion of one of its amino acids, L-proline, into its d-isomer, which is considered to be nephrotoxic and neurotoxic (6).

The nutrient value of foods is also claimed to be reduced or diminished when they are cooked or heated using microwave ovens. One study regarding the effects of microwave cooking to bioactive compounds in broccoli showed a general decrease in the levels of all the studied compounds, especially for Vitamin C. These losses are mainly due to degradation and leaching (20).

Microwave cooking is also claimed to cause food poisoning. Salmonella outbreaks may be caused by foods cooked with a microwave oven (21). Though microwave oven might be able to kill certain pathogenic bacteria in food, the cooking procedure may not eliminate pathogens completely (22). This may be due to the non-uniformity of temperature distribution during microwave heating, which creates hot and cold regions on the surface of food (23). Microorganisms in the cold spots are not destroyed effectively due to insufficient heat energy.

The worst disease that may be caused by microwave cooking or heating is cancer, as claimed by some researchers. An article appearing in issue 19 of the Journal Franz Weber stated that the consumption of foods cooked in microwave ovens has cancerous effects on the blood (6). They claimed that there were decreases in the values of all haemoglobin, HDL (High-Density Lipoprotein), and lymphocytes of respondents after the intake of microwave-cooked foods (6). The carcinogenic effect is believed to be greater if there are microwaves that leak from the ovens. Due to this, several studies have been performed.

VII. MICROWAVE OVENS' SAFETY

Despite the presence of articles supporting that exposure to microwaves may cause the development of cancerous cells, this research is untested and irrelevant, as a majority of the research was done way back in the 20th century. Research that has proven otherwise was done much more recently in 21st century. Furthermore, microwaves are non-ionising radiation, so they are less likely to cause neoplasms, as they do not have the ability to alter the molecules of materials that can absorb them (24). Microwave energy is not retained neither inside the oven nor the foods right after the microwave oven is switched off (1). Besides, we are exposed to low level non-ionising radiation every day, and injuries are uncommon, and are typically occupation related (13).

Although there have been a few incidences of microwave leakage (1,10,25–27) as reported by some researchers, the level of leakage is relatively very low (below 11 mW/cm²) and not enough to cause concern (28). The level of power density (produced from electromagnetic spectrum) and its potential to cause harm to human is well understood by referring the table below (29):

Power Density	Effects
100 mW/Cm ²	Clear Hazard
40 mW/Cm ²	Reproducible effects
4 mW/Cm ²	Unconfirmed reports of effects
1 mW/Cm ²	FCC public exposure standard (2000 MHz)
0.5 mW/Cm ²	FCC public exposure standard (00 MHz)
0.01 mW/Cm ²	Maximum near a cell phone tower
0.0002 mW/Cm ²	Typical near a modern phase tower

Moreover, the International Electrotechnical Commission (IEC), the International Committee on Electromagnetic Safety (ICES) of the Institute of Electrical and Electronics Engineers (IEEE) and the European Committee for Electrotechnical Standardization (CENELEC), have set a product emission limit of 50 watts per square metre (W/m²) which is equivalent to 5 mW/cm² at any point 5 cm away from the external surfaces of the oven (1). This emission limit is far below the amount known to cause harm to humans. Practically speaking, the emission of microwaves due to leakage is relatively low. Moreover, when an individual moves away from the microwave oven, the level of exposure significantly decreases. For example a person 50 cm from the oven receives about one one-hundredth of the microwave exposure of a person 5 cm away.

There are many organisations and agencies that are involved in the development of standards for radiation protection and establishment of new regulations for the protection against hazards caused by radiation, whether ionising or non-ionising. The agencies include the International Commission on Radiological Protection (ICRP), National Council on Radiation Protection and Measurements (NCRP), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (NAS-BEIR). In Malaysia, the Atomic Energy Licensing Act 1984 (Act 304) is used to control the usage of radiation, which includes both the use of medical and non-medical applications. There are a few regulations under the Act 304 includes Atomic Energy Licensing (Licensing) Regulations 1986, Atomic Energy Licensing (Basic Safety Radiation Protection – BSRP) Regulations 2010 and Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011. Act 304 and its subsidiary regulations are applied widely throughout every sector in Malaysia, especially the medical sector, which is monitored regularly by Ministry of Health (MOH) for the protection against the risk of developing cancer due to medical radiation among patients and healthcare workers. They also explain the concepts and principles of radiation protection to patients and radiation workers, as well as the public, in detail (30).

As for the injuries that may be caused by the microwave ovens, manufacturers under the supervision of authorised organisation such as FDA (Food and Drug Administration), SIRIM, WHO and the like include instruction manuals and some safety features to reduce the risks of microwave hazards and thermal injuries. Some microwave ovens are also built-in with child lock technology and the interference of microwaves with the electrical pacemakers is pretty well resolved, as the pacemakers nowadays are designed to shield against such electrical interference (10). Besides that, a trusted medium for consumers to report their damaged microwave ovens is also provided recently by the responsible authorities.

Even though there are studies showing that there is reduction of nutrients in microwave-heated food, these issues are debatable, as some research has demonstrated otherwise. There is no significant difference in the reduction of nutritional value in foods cooked by microwave ovens as compared to conventional cooking methods (31). The effects of microwave cooking on nutritive values of moisture, carbohydrate, protein, lipid, vitamins, and minerals are measured that turn out to be only minimal (32). In addition, microwave cooking also can reduce the toxins contained in the muscle of some species of fishes, including unconjugated microcystin and its subtype (33). Hence the nutritional retention for microwave-cooked foods is almost as good or sometimes better than other cooking methods (34).

VIII. MICROWAVE OVENS FROM AN ISLAMIC PERSPECTIVE

Muslims are permissible to cook or heat their foods and beverages using microwave ovens, as there are no undebatable facts regarding the harms of using microwave ovens unless it is not handled with care. Therefore, based on the fiqh method : “Everything originates from mubah (permissible) unless there are proves (nas) to make it otherwise (Makruh or Haram) ”, gives the rule (hukm) of using microwave ovens which is generally ‘harus’, because Islamic jurisprudence is not based on doubts or rumours. Moreover, Islam teaches adherents to always investigate and validate all news or information, as stated in surah Al – Hujurat, verse 6 : “O you who have believed, if there comes to you a disobedient one with information, investigate, lest you harm a people out of ignorance and become, over what you have done, regretful ”.

In today’s harmonic multiracial culture, sharing public microwave ovens with non-Muslims has been a concern for Muslims. Non-Muslims may use them to cook or heat foods and beverages that are haram or suspicious (syubhah), such as pork, foods that contain wine and the like. Fortunately, based on MUIS, it is permissible to eat food cooked by microwave ovens that have been used for non-halal foods and beverages, as the air particles that contain the najis are considered forgiven. This issue is ‘qias’ to bread which is cooked with a dry najis; it is permissible to eat the bread as ‘harus’, as stated in kitab Fathul-‘Allam (35).

Apart from that, with regards to the ruling on the use of food containers that are assumed to have been used for the storage of pork, we refer to al-Fiqh al-Manhaji, which states that it is

permissible to use the disbelievers’ containers, as according to a hadith from Abu Tha’labah RA, the Prophet PBUH said “Wash them and eat in them.” - Sahih al-Bukhari (5161). The instruction to wash the container is *sunnah*, since containers may have been used for consuming alcoholic drinks, eating pork, and others. The same applies when wearing non-Muslims’ clothing as with using their food containers (36).

IX. CONCLUSION

The benefits of microwave ovens have been well understood, as claimed by certain responsible organisations, researchers, and manufacturers. Meanwhile, their disadvantages are still debatable, because such evidence is based on rusty scientific studies performed decades ago and which do not consider several safety standards and improvements that have been implemented since then. Furthermore, microwave ovens should be periodically tested to detect any damage and removed from use if they are damaged. It also relies on the consumers’ insights and common sense precautions in the handling of the microwave ovens, hot foods and drinks, so that the ovens can work effectively with reduced risk of injury. Ultimately, risks are always there even though in the safest situation and thus, the advantages needs to be weighed carefully against the drawbacks of microwave cooking so that the public can make wise decisions.

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