Gamma radiation and lipid peroxidation

Radiation energy

Irradiation must be seen as a bombardment with high energy particles, called photons. To get a better idea of the energies involved, compare the following facts. For normal chemical processes such as the breaking and forming of bonds between molecules, an energy of 5 to 7 electron volt is needed.

X-rays for medical purposes on the other hand, carry photons of 100 000 electron volt. And the X-rays for food irradiation carry photons of 1 to 5 million electron volt (1, 2). Similar high energy photons are produced by radioactive materials like cobalt-60 or cesium-137. Then the radiation is called γ-radiation (gamma radiation).

So, compared with normal chemical processes, the energies of gamma radiation are immense.

Misrepresentation

Some promoters of food irradiation have suggested that because very little heat is developed, the energy for irradiation is too little to do much harm. However, this energy is not spread out evenly like heat and can therefore be very harmful. For example, a dose of X-rays that would kill a man if given to the whole body, would in terms of heat be less than that from drinking a cup of coffee (3).

So, to compare the intense energy of gamma radiation with the evenly spread out energy of heat is meaningless.

Violent snooker

To get a better picture of what is really going on during irradiation, you could compare the effects of high energy photons with a game of violent snooker.

Many high energy photons do not hit anything and pass right through. They are so tiny and there is so much open space on a molecular scale in and between molecules that they can do this and no harm is done. But the photons that do hit molecules wreck havoc.

Ionising radiation

Molecules that are hit by a γ-photon have an outer electron ripped off them through the high impact. Such molecules become electrically charged by losing this electron and are called ions. Hence the name ionising radiation. A more clumsy name would be ‘damaged molecules radiation’ and would spell out what is going on.

The electrons that are ripped off shoot away with the energy of the γ-photon and continue the snooker game. Thereby they rip electrons away from other molecules. So, there is a cascading effect and an increase in high energy electrons. This snooker game continues till all excessive energy has been dissipated. Excessive energy means here the difference between a million electron volt and 5 to 7 electron volt.

Free radical formation

The damaged molecules are extremely reactive because they try to get that electron back that was taken away from them. They are called free radicals.

As biological systems consist for 55-80% of water, the main interaction of radiation is with water molecules (4).This results in the formation of the hydroxyl and the superoxide radicals and hydrogen peroxide (2, 5, 6). All these substances are extremely reactive, call them corrosive if you wish, and react readily with the molecules of biological cells.

Cell membranes

The walls of biological cells are composed of so called membranes. These structures are selectively permeable, which means that they let certain substances through and block other ones. They maintain a suitable environment inside the cell by letting nutritional substances in and waste products out and perform many other functions. Cell membranes are therefore dynamic structures. They are composed of a double layer of lipids (fats and fatty compounds) with proteins dispersed throughout. Different cell membranes have different proportions of lipids. Membranes are generally high in polyunsaturated fatty acids and this makes them prone to free radical attack.

Lipid peroxidation

A chain reaction is started when lipid molecules are attacked by free radicals. This chain reaction goes as follows: a free radical reacts with a lipid molecule and destroys it. But a new free radical is formed in the process. This reacts with the next lipid molecule and destroys it, again with formation of a new free radical. And so on.

Only a free radical scavenger can stop this process. Then the scavenger reacts with the free radical and destroys it. Another way to stop this cascading process is when two radicals bump into each other. They destroy each other and form a stable product (7).

The effects of lipid peroxidation

As a result of this chain reaction cell membranes are severely compromised or even partly destroyed. They become leaky, mineral exchanges are hampered and essential life processes are slowed down or even halted.

A particularly important membrane is of course the one surrounding the cell nucleus. When leaky, reactive substances can enter the nucleus, they can react with the DNA that is located there and cause permanent damage. This can result in mutations. **Is it any wonder then that lipid peroxidation has been linked to the onset of tumors and cancer?**

Natural protection

Fortunately there are millions and millions of cells and nature has put a few breaks in place against lipid peroxidation. A number of enzyme systems counter superoxide damage and other biological molecules act as free radical scavengers, such as vitamin E, A and glutathion. This natural protection is needed because the superoxide radical is also produced by normally functioning enzyme systems such as the zanthine oxidase system (7).

Tissue levels of vitamin A, E and antioxidant enzymes protect against radiation damage. For example, experimental animals exposed to whole body radiation and placed on vitamin E deficient diets were more sensitive to radiation than control animals on normal diets. Also, mice receiving vitamin E supplements were less sensitive to radiation injury than mice on normal diets (7). In combination with selenium the antioxidant effect of vitamin E becomes even more pronounced (8).

And so what?

What has this all to do with food irradiation? So far we have discussed lipd peroxidation from whole body radiation.

It appears that animals fed irradiated food display the same symptoms as animals undergoing whole body radiation. This indicates that similar biochemical processes occur in animals fed irradiated food and animals undergoing whole body irradiation. The effect from food has been called **radiomimetic**.

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