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ELECTRON IRRADIATION OF DRY FOOD PRODUCTS

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ABSTRACT

The interest of the industrial food producer is increasing in having the irradiation facility installed in the food processing chain. The throughput of the irradiator should be high and the residence time of the product in the facility should be short. These conditions can be accomplished by electron irradiators.

To clarify the irradiation conditions spices taken out of the industrial process, food grade salt, sugar, and gums as models of dry food products were irradiated.

With a radiation dose of 10 kGy microbial load can be reduced on 10**4 microorganisms/g. The sensory properties of the spices were not changed in an atypical way. For food grade salt and sugar changes of colour were observed which are due to lattice defects or initiated browning. The irradiation of several gums led only in some cases to an improvement of the thickness properties in the application below 50 °C, in most cases the thickness effect was reduced.

The products were packaged before irradiation. But it would be possible also to irradiate the products without packaging moving the product through the iradiation field in a closed conveyor system.

APPLICATION OF ELECTRON RAYS

Gamma-rays, electron-rays, and X-rays show the same ionizing effects. Differences exist only with regard to depth dose distribution, and higher dose rates are achievable only with machine sources.

In the dose range used for food irradiation no difference in the effect has been verified so far which would be exclusively attributable to the kind of irradiation. It is therefore, for scientific reasons, hardly understandable that the last version of the "General Standard for Irradiated Food" of the Codex Alimentarius Commission still discriminates the application of X-rays against the application of electron rays produced by the same machine (Anonymus, 1982). An equalize treatment could extend also the range of application of electron accelerators for food irradiation to the cases where very high penetration is required.

Our recent experiences revealed that the food processing industry shows increasing interest in own irradiation plants incorporated in the production chain. Here electron irradiators especially self shielded machines, show indeed certain advantages in some respect as compared to Co-60 plants, also because the Co-60 supply must not be regarded only from economic viewpoints. Certainly, in electron accelerators the throughput is not higher than in Co-60 plants of comparable capacity but the residence time in the irradiation cell of the electron accelerator is much shorter. The cause of this is the much higher dose rate which enables supplying the dose within seconds or minutes at most. This may involve elevated temperatures which, as the formation of ozone also, may complicate in some instances seperating the causalities for undesired side effects of the irradiation process.

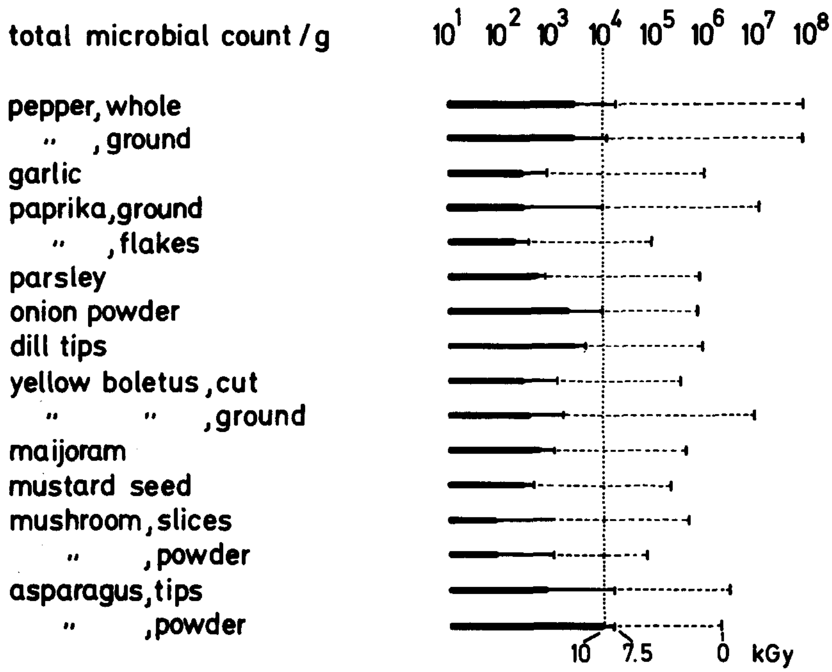

Fig. 1 Reduction of total microbial count of spices by electon irradiation with 7.5 and 10 kGy.

IRRADIATION OF DRY PRODUCTS

The side effects are most obvious if they lead to changes in the physical or sensory properties of the product and they can be unacceptable, if they concern properties of the product which are of great importance for the processing technology. The changes are the more distinct, the more homogenious the material is. To the homogenious products belong for example spices, ingredients, and gums, that means dry products. In the following I shall report some examples from our experiences in the field of irradiating dry products with electrons.

Spices

In cooperation with industry different spices which were taken out of the production chain were irradiated. The irradiation machine was the 10 MeV electron linear-accelerator of the Federal Centre for Nutrition, Karlsruhe (Grünewald, 1982). Figure 1 shows the results in reducing the total number of microorganisms by an irradiation with doses of 7.5 and 10 kGy. It was found that for all sixteen products a dose of 10 kGy was sufficient to reduce the total microbial count down to 10**4/g also in presence of heavy contamination as, for instance, in pepper. In a sensory test under industrial conditions with eight participants changes in the colour or taste or in other sensory properties were scarcely detectable. They concerned mostly a reduction of the spicing intensity which can be compensated by higher concentration. The trend of taste of the spices was not influenced, no off-flavour was detected.

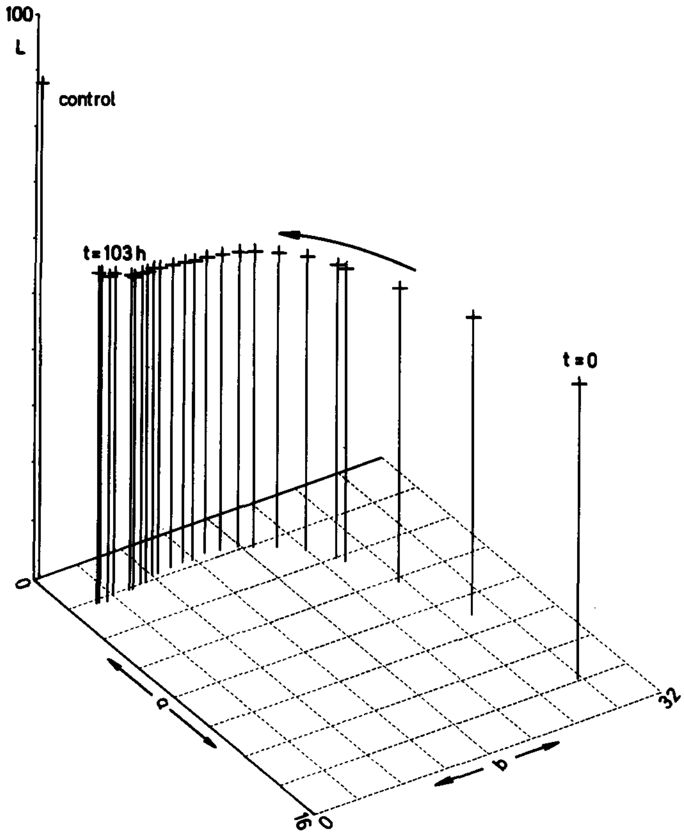

Fig. 2 Colour values in the Hunter system of food grade salt irradiated with 10 kGy in dependence of the time of exposition to daylight after the irradiation.

Food grade salt

There is a trend in producing spice mixtures containing food grade salt as one of the ingredients. Salt as a homogenious material shows pronounced changes in colour due to the irradiation. The salt crystals turn dark by irradiation. This effect has been observed as side effect in the X-ray fluorescence analysis without any information about the correlation between discolouration and irradiation dose. It could be clarified that discolouration of commercial food grade salt appears in the dose range used in food irradiation. The irradiated samples had in comparison to the non-irradiated sample a brownish colour with increasing intensity due to the applied dose (maximum 50 kGy).

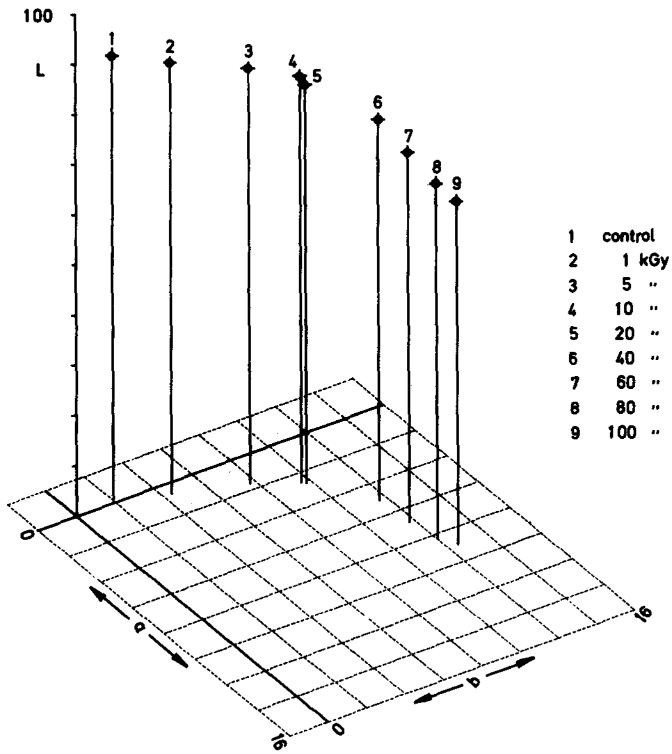

Fig. 3 Colour values in the Hunter system for crystalline sugar irradiated with different doses.

If exposed to daylight after irradiation the colour is changing rapidly from brown to gray. The diagram shown in Fig. 2 obtains the colour values measured by means of a trichromatic colour-measuring instrument plotted in the Hunter colour system (Francis, 1975). These are the colour values, as function of time, for a sample irradiatied with 10 kGy. After about 100 hours the colour stabilizes and remains practically unchanged for many weeks. It remains a gray product which has no longer a discolouration but only a lower reflectivity than the non-irradiated product.

This effect, also impressive and distinct, is based merely on lattice defects in the crystal and not on chemical changes of the salt. Irradiated salt dissolved in water loses its brown or gray colour immediately again and identical absorption curves in the range between 200 and 800 nm for solutions of irradiated and non-irradiated salt are obtained. The recrystallised salt shows no difference in colour as compared to the non-irradiated sample. Of course the observed discolouration of salt is of importance only if salt is present as ingredient in crystalline state.

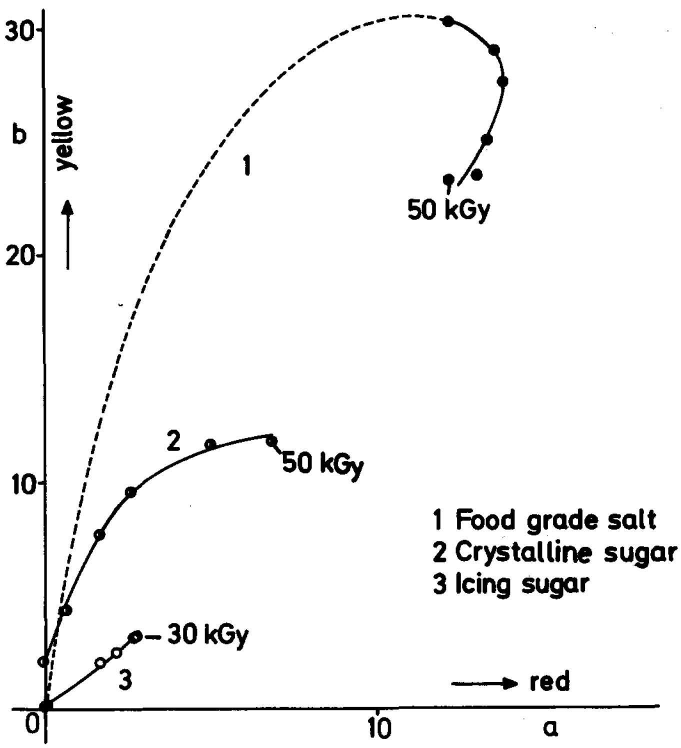

Fig. 4 Colour values a and b in the Hunter system of irradiated food grade salt, crystalline sugar and icing sugar.

<u>Sugar</u>

Sugar or sucrose as another ingredient of food products react in another way than salt to irradiation, because pure carbohydrates are very sensitive to radiation when in crystalline state (Urbain, 1978). If commercial crystalline sugar and icing sugar are irradiated a red discolouration appears already at a dose of 10 kGy. Figure 3 shows the colour values in the Hunter system for samples of crystalline sugar irradiated with different doses.

The discolouration is not nearly as obvious as the discolouration of salt. In Fig. 4 food grade salt as well as crystalline and icing sugar are compared. Crystalline sugar and icing sugar irradiated with the same dose show different colours on account of the different particle size and the different porosity. The discolouration is less evident for smaller particles. Due to this dependence no exact correlation between the chemical reaction and the measured colour deviation can be found.

For sugar the effect of discolouration seems not to be a lattice defect, because the discolouration is resistant against daylight over a long time and the colour is not lost even if the sugar is dissolved in water. The transmission curves in the UV-range which are shown in the Fig. 5 have the same shape as for a non-enzymatic browning effect. Because proteins were not present during the irradiation caramelisation may be the reason for the browning effect. Possibly this process has been enhanced by the elevation of temperature in consequence of irradiation, which was about 30°K for 50 kGy.

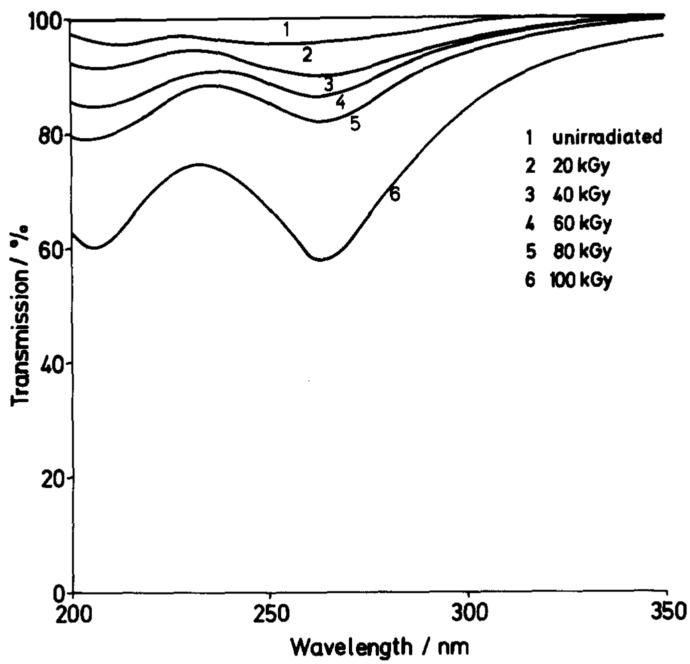

Fig. 5 Transmission curves of irradiated sugar in the UV range, concentration 5 g/l H_2O.

The effect has not been reported under the aspect of surprising chemical changes. The radiation induced changes in carbohydrates are well-known (Adam) and it was clearified also that in respect to irradiated sucrose no wholesomeness problems arise (Elias, 1977). The intention was only to demonstrate that irradiation can influence the colour as physical and sensory property of sugar. It is true that discolouration of sugar is of interest only, if the irradiated product contains crystalline or icing sugar in a not too modest amount e.g. as cover. At the normal low concentrations the discolouration is without significance.

There are also dry products, however, the physical properties of them are particulary critical because these properties are the reason for adding the product to a certain food. Gums for example, which are added as lubricants, belong to this product group. Their rheological properties are a criterium for suitability and quality.

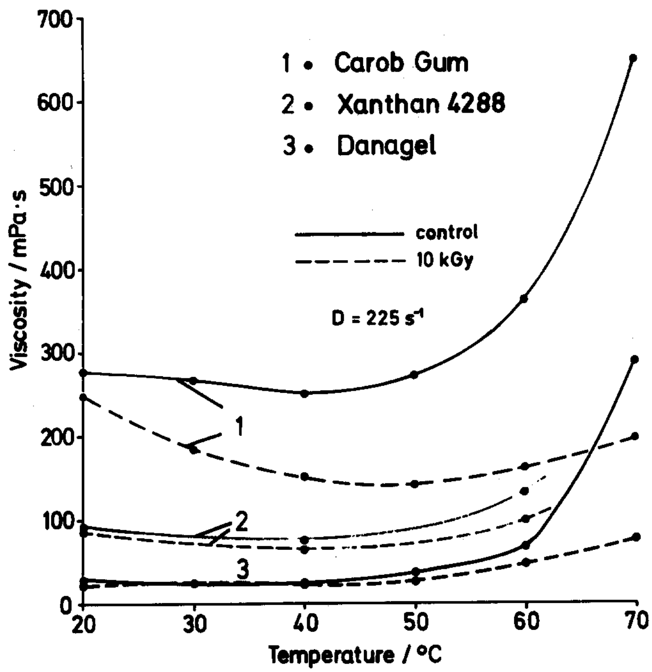

Fig. 6 Viscosity of gums suspended in water at a shear rate of 225/s in dependence of temperature.

Gums as natural products are highly contaminated in some cases. This demands a treatment with ethylenoxide or by irradiation. Gums as pure polysaccharides are certainly changed in an unfavorable way by irradiation. Beside clearly visible changes in colour also the rheological properties of the irradiated product are impaired obviously by fragmentation into smaller molecules. Figure 6 shows the influence of irradiation with a dose of 10 kGy on the viscosity of aqueous suspensions of the three different gums with the commercial names Carob Gum, Xanthan 4288, and Danagel. The products have been irradiated at ambient temperature and suspended in water in a concentration of few g/l. The suspensions were then heated to the measuring temperature for a definite time and the measurements were made with a rotating viscosimeter at different shear rates. Figure 6 shows only the results for a shear rate of 225/s. It is evident that the effect depends on the product and above all on the temperature. The advantage of the reduction of the microbial count is in competition to the undesired reduction of viscosity. But this undesired effect may be compensated in some instances by a slight increase in concentration already, since the consistency increases exponentially with the concentration of the gum.
Indeed we found also one case in which the properties of the product were favourably influenced by irradiation, namely a gum available under the commercial name SS 4324 which

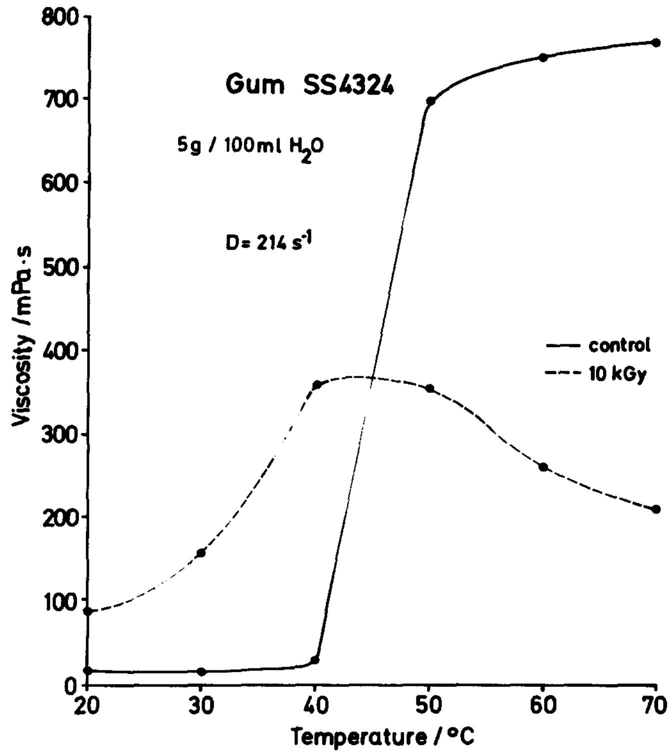

Fig. 7 Viscosity of the gum SS 4324 suspended in water at a shear rate of 215/s in dependence of temperature.

in fact stands for a mixture. As Fig. 7 shows, the viscosity of an aqueous suspension is higher in the product irradiated with 10 kGy than in the non-irradiated sample provided that the temperature for the application and processing of the gum remains below 40 °C. Here irradiation not only reduces microbial counts, but offers the additional advantage of reducing consumption. At temperatures above 40 °C, however, irradiation clearely decreases the viscosity in the same way as for the other three products.

IRRADIATION TECHNIQUE

The products referred above were irradiated at the irradiation plant of the Federal Research Centre for Nutrition, Karlsruhe in such way that the packaged material passed through the radiation field of a linear accelerator on a normal conveyor belt. This has the disadvantage especially if the machine is installed for the industrial application in the production line that the product must be packaged in very small bags, according to the limited penetration depth of 10 MeV electrons. However it is conceivable that the products are irradiated, unpackaged as bulk material. Consequently in order to avoid reinfection and to prevent dust formation, the conveyer belt must be protected by a cover and form a kind of channel.

If the dose rate of the accelerator is high enough that the product can be transported with a high speed that the bulk material may be transported through the irradiation field using vibratory conveyors (Schubert, 1982). Thereby the product may be supplied pneumatically from a first silo or bunker to the vibratory conveyor and from the end of the vibratory conveyor in the same way back to a second silo or bunker. At low dose rates and therefore at low transportation speeds normal but closed conveyor belts have to be used. One of the important problems which has to be solved still is the control of dose distribution in the transported bulk material to guarantee the necessary dose and to ensure an uniformity ratio of the dose not higher than the approved ratio.

Our plans are to test the available possibilities aiming at the elimination of the difficulties connected with the irradiation of bulk material. Such irradiation of food products as bulk material is scarcely possible with Co-60 plants and demonstrates the importance of electron accelerators for food-processing industry.

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