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DOSIMETRY AND PROCESS CONTROL FOR RADIATION PROCESSING OF BULK QUANTITIES OF PARTICULATE FOODS

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ABSTRACT

Radiation processing of particulate foods in bulk quantities requires the determination of dose distributions. Due to variable flow patterns, miniature dose meters must be suspended in a reproducible and representative manner in the stream of food particles. It is also desirable that the material used for dosimetry be non-toxic and not foreign to food. Food components such as amino acids, or inert materials like quartz, would be acceptable. The dosimetric properties of some such materials are described and results from measurements in a pilot plant are presented.

KEYWORDS

Radiation dosimetry; food processing; bulk handling; particulate food; dose-meter material; dose range; process control.

INTRODUCTION

Radiation processing is now a well established method of improving the quality or changing the properties of many materials. Applied to food the process can be used to reduce the microbial load, thus reducing also the hygienic risk. However, there is one main difference between radiation processing of food and of other materials, namely the tolerable dose range, which in the case of food is rather narrow. Radiation processing must guarantee that the effective minimum dose is met at any given point within the goods; at the same time no impairment must be introduced by treatment with an excessively high dose at any position. The occurrence of minimum and maximum doses is inherent in the process and reduction of the range would introduce excessive costs. Some foods are very sensitive to overdoses, e.g. fruits and vegetables suffer from skin damage and meat may develop an off-flavour.

The special needs for the dosimetry applied to radiation processing of food have been well described elsewhere (Chadwick *et al.*, 1977). The subsequent discussion (Chadwick and Oosterheert, 1986; Vas *et al.*, 1977) revealed the implications of maximum and minimum dose in a particular food consignment and during the long-run application of the process. However, the question of the correct application of dosimetry for radiation processing of food has not yet been finally resolved (Bögl *et al.*, 1988). A lot of dosimetry procedures (Mahesh and Vij, 1985) are available and well established, and their transfer to food applications is under discussion (Miller, 1988; Regulla, 1988).

FOOD COMPONENTS AS DOSE-METER MATERIALS

There is one basic method in radiation dosimetry and that is calorimetry. As the radiation-absorbing body it can use any food compound and even the standard material graphite is not too far removed from genuine food compounds with respect to radiation absorption. However, calorimetry can only be used as a routine method in a few applications and the development of a miniature version, with the calorimetric bodies suspended in a stream of particulate materials, is inconceivable. Dosimetric properties of food components and their use in radiation dosimetry of food processing have already been described (Ettinger *et al.*, 1978). Consequently, the remaining task was to find a compound with suitable sensitivity and accuracy for the dose range of interest (i.e. insect disinfestation at about 200 Gy up to spice decontamination at 10 to 30 kGy) and a reading system appropriate for routine application. ESR dosimetry of alanine would be the ideal choice. Unfortunately, the reading equipment is not yet available for routine use and, furthermore, rather expensive. Many cristalline food compounds show luminescent properties and a response suitable for dosimetry. The method of lyo-, chemi- and thermoluminescence can be applied and the appropriate readers are already available in many analytical laboratories.

In the dose range applicable for insect disinfestation, several compounds were studied: Glutamine and table salt are both useful for chemiluminescence, alanine can be employed by optical absorbance (through indirect oxidation of ferrous ions), and quartz (as a concomitant substance inherent in grain) is read by thermoluminescence. All substances are available as fine, preconditioned powders. For comparison also LiF - a standard material used for thermoluminescent dosimetry - was empolyed. The variability of the readings was unexpectedly small. Sensitivity was always sufficient in the dose range of interest.

DOSE METERS SUSPENDED IN A STREAM OF PARTICLES

Processing of particulate materials in bulk quantities is usually carried out with equipment like silos, pipes, elevators, conveyors, channels, etc. The individual paths of the particles are not easily predicted or determined and any dose meter should be suspended in the stream in a way that disturbs the flow behaviour of the goods under study as little as possible. Not much published data are available, despite the fact that many experimental set-ups have been reported. In particular, virtually no information on the dosimetry at the commercial scale grain irradiator at the harbour of Odessa, USSR, is available. Well documented, on the other hand, is the Savannah river (USA) grain irradiator (Tilton *et al.*, 1971) and the dosimetry applied there. However, the velocity of the grain passing the source was rather small compared to high-throughput electron irradiator facilities. The suspension of semi-conductor diodes (Ehlermann *et al.*, 1985) was rather succcessful with regard to the flow behaviour of the diodes; however, the composition of the dosimetric bodies did disturb the radiation field (dose build-up etc.) and the measurements were difficult to interpret; furthermore, the semi-conductor compound is foreign to food and the loss of some dose meters might conceivably taint the whole consignment of grain. Consequently, the older approach (Tilton *et al.*, 1971) was resumed and several dose meter powders were filled into small capsules. Bulk density was adjusted using small iron pieces which also facilitated re-collecting of the capsules (Ehlermann, 1988b). The direct use of particulate foods as a dose meter (Ehlermann, 1988a) has not yet been successful under the conditions of the available pilot plant (see below). When the capsules containing the dosimetric powder and a balancing weight piece were homogeneously mixed with the grain in the feeding silo, it could be proven that their stream resembled the stream of the grain and, hence, the measured dose distribution was representative of the dose distribution in the bulk material (Ehlermann *et al.*, 1988).

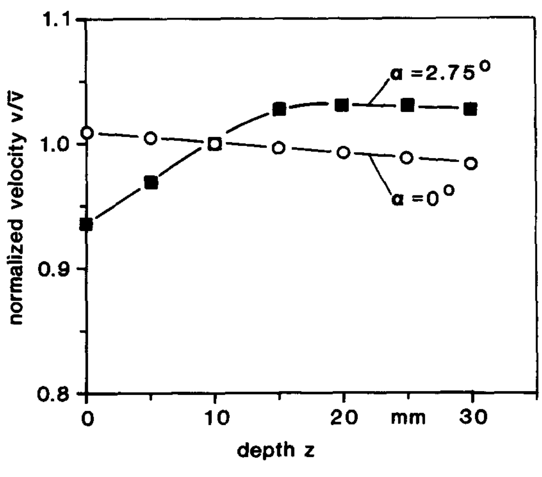

Fig. 1. Velocity (normalized to mean velocity) versus depth in a vibrating trough conveyor, α = inclination of the trough

RADIATION PROCESSING OF BULK QUANTITIES

A pilot-plant was set up to handle grain in bulk quantities and to study its behaviour in the radiation treatment zone (Schubert and Ehlermann, 1988; Ehlermann *et al.*, 1988). The lateral and vertical velocity distributions in a vibrating trough conveyor were determined by optical detector and cross-correlation techniques. There was no significant variation in lateral direction. However, the vertical distribution of velocities could be influenced by the inclination of the trough (Fig. 1). This shape could be used to compensate for the usual depth dose curves (cf. Fig. 2) which were also reconfirmed for the non-agitated grain. When the vibration is switched on, the particles are lifted up and a small reduction in gross density takes place. However, with regard to radiation absorption this effect is of no consequence. From a combination of both curves the resulting depth dose distribution in the vibrating trough can be calculated (Fig. 3). The ratio of maximum to minimum dose is considerably reduced.

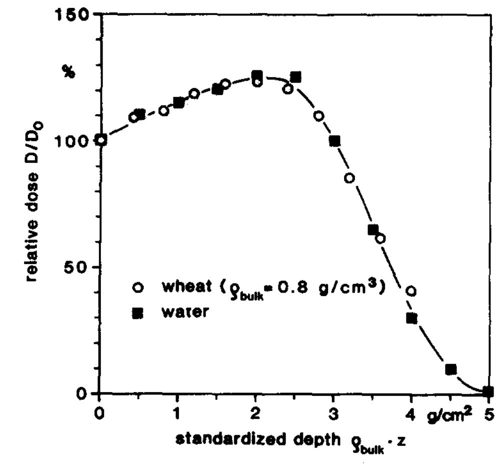

Fig. 2. Depth does curves for water and a bed of grain irradiated with 10 MeV - electrons

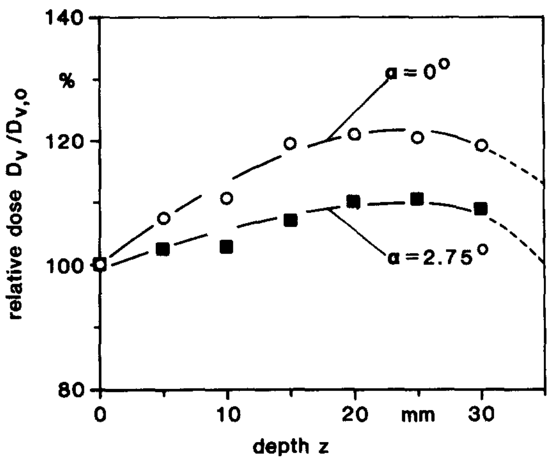

Fig. 3. Calculated dose distribution in a vibrating trough conveyor at different inclinations (10 MeV-electrons) ρ_{bulk} = bulk density; z = depth

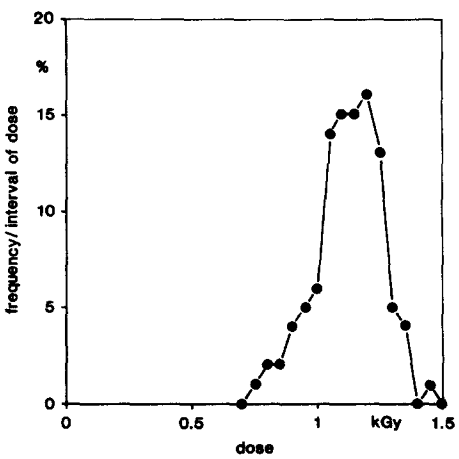

Fig. 4. Frequency distribution of dose for grain irradiated by 10 MeV-electrons in a vibrating trough conveyor (layer height 45 mm; class width 50 Gy; total 100 dyed nylon films; inclination α = 0°)

After these more theoretical studies a real run for radiation processing of grain was executed. For this particular experiment a dyed nylon film was inserted as a dose meter into the capsules and the frequency distribution of dose readings was determined (Fig. 4). It is apparent, that the ratio of maximum to minimum dose is about 2, which is in good agreement with the theoretically expected value. It is not yet clear which factor is responsible for the broadening of the distribution. When the study was repeated with some of the dose-meter powders described above, the target dose could be set at 200 Gy (according to the better suited sensitivity) when compared to the earlier experiment using the nylon films. The

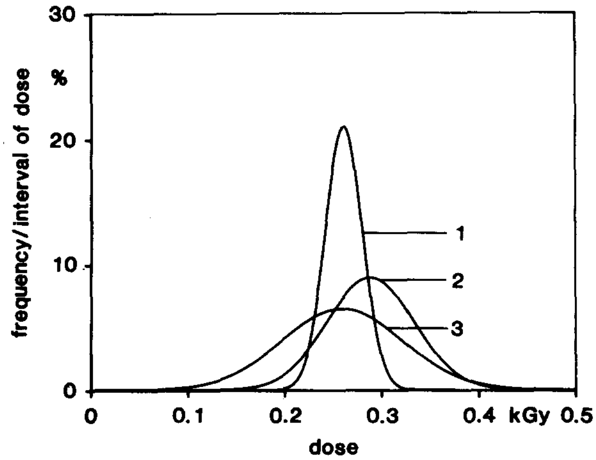

Fig. 5. Comparison of depth dose distributions for grain (conditions as in Fig. 4; curves are Gaussian fits) measured by several dose meter types 1 = LiF; 2 = glutamine; 3 = quartz

curves (Gaussian fits) reveal that the width of the distribution is influenced by the characteristics of the dose-meter material. As the capsules were added simultaneously to the irradiated grain the widening of the distributions cannot be attributed to any difference in the treatment. Consequently, during subsequent experiments efforts must be taken to reduce the variability of the chosen materials. The resulting distribution from LiF closely corresponds to the one determined using dyed nylon films (Fig. 5). studies will be continued in order to find conditions which are more suited to affect velocity distributions within the vibrating trough. Hurdles seem to be effective, but put too close to the radiation zone the risk of dead zones and excessive dose to a few particles has to be taken into account.

RESULTS AND DISCUSSION

It could be shown that food compounds or inert material like quartz can, in principle, be used as dose meters in radiation processing of bulk quantities of particulate foods. Such a system might also be useful for applications in the area of official inspection and control of radiation facilities. The official in charge might insert a set of dose meters in a feeding silo and retrieve them after processing.
As the capsules do not contain any material which is toxic or foreign to food the loss of a dose meter would not present any problems for the further utilization of the treated goods.

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