Electron beam processing of chicken carcasses

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1. SYNOPSIS

Radiation processing of whole chicken carcasses with 10 MeV-electrons and 5 MeV-bremsstrahlung in commercial cardboard boxes is possible. The minimum dose of 1 kGy for the reduction of contamination by pathogenic microorganisms is achievable and the ratio of maximum to minimum dose need not exceed 2.0. Consequently, machine sources may be used to complement existing gamma-processing facilities and could contribute to public health whenever compulsory 'radicidation' of poultry is introduced.

2. INTRODUCTION

Poultry is a major carrier of hygiene hazards and Salmonella and Campylobacter are the most frequent causes of illnesses from the consumption of chicken. Absolute cleanliness in the kitchen as well as improved rearing and slaughtering methods for poultry can contribute to reducing the risk from pathogenic microorganisms. However, a pathogen-free environment cannot be maintained during mass-rearing operations and some level of contamination by such pathogenic microorganisms cannot in practice be avoided. Consequently, compulsory 'radicidation' for poultry, especially chicken, could contribute considerably to public health. This implies the practical elimination or reduction below an infective level of the relevant pathogenic microorganisms. Depending on the initial microbial status of poultry after slaughter, doses as low as 1 kGy may be sufficient; 3 kGy is the upper dose limit to avoid off-flavours. For deep-frozen poultry the corresponding range is reported to be 3 kGy to 7 kGy.

Use of electron beam (EB) facilities would supplement gamma processing, especially in a situation where existing gamma irradiators could not meet a sudden increase in demand for processing capacity. For example, in Germany alone, the annual consumption of poultry in 1994 was about 1,000,000 t in 1994; to treat this quantity at a dose of 1 kGy a processing capacity of about 15 commercial facilities (each 2 - 3 MCi Cobalt-60 or 10 kW 10 MeV-electrons) would be required, 24 h per day and 365 days per year.

In the USA, a commercial food-irradiation facility (Cobalt-60) is radiation-processing chicken parts, among other products. In France, an electron facility is devoted solely to radiation-processing of mechanically-deboned poultry meat in deep-frozen blocks. Irradiation of whole chicken carcasses by electron beam has not yet been studied in detail, especially with regard to achievable dose distributions.

3. MATERIALS AND METHODS

Fresh chickens were procured from a nearby supermarket. Depending on the chicken carcass sizes (900 g, 1,200 g or 1,500 g) a commercially cardboard box (40 cm x 60 cm x 10.5 cm) usually contained 12, 10 or 8 carcasses. Irradiation was always from top. 10 MeV electrons at a beam power of 10 kW resulted in a dose rate of 10^8 Gy/s; 5 MeV electrons were also converted into bremsstrahlung (X-rays) and the dose rate was reduced to 10^6 Gy/s. Dose rates given here are instantaneous values, ie during each pulse.

GAFchromic DM-100 dosimetry films were calibrated against a secondary standard. The films were always packed in plastic pouches to protect them from scratches and humidity; readings were taken after about 24 h to allow for colour development. Absorbance reading was at 405 nm (interference filter) in a CIBA CORNING 257 colorimeter; films were mounted on a special holder to fit into the standard cuvette holder.

The carcasses were spiked with 8 dosimeters per body at pre-determined, identical positions. These positions were chosen to represent possible locations of extremely high or low doses. A randomized positioning was not used because of the very regular arrangement of the carcasses in the boxes.

Frequency distributions of dose obtained were analyzed for deviation from normal (Gaussian) distribution. The dose scale is in the standardized form, ie normalized to a mean of zero and a standard deviation of 1; on the frequency scale conversion to probit-units is also shown.

4. RESULTS AND DISCUSSION

A single-side treatment by 10 MeV-electrons was not enough to irradiate through the carcasses; this implies that the effective pathway of the radiation through meat and bone is longer than the useful range of electrons (entrance dose equals exit dose at about 32 mm, or the ratio of maximum to minimum dose is less than or equal to 2.0 at about 35 mm in water). A double-side irradiation improves the situation: a minimum dose of 1 kGy and a maximum/minimum ratio of less than 2.0 could be achieved for all three sizes of carcasses (Fig. 1). The maximum dose was always found inside the chicken carcasses. Both maximum and minimum doses decreased with increasing chicken size at constant irradiator settings. In order to adjust the minimum dose to 1 kGy also the larger carcasses, the conveyor speed was reduced accordingly.

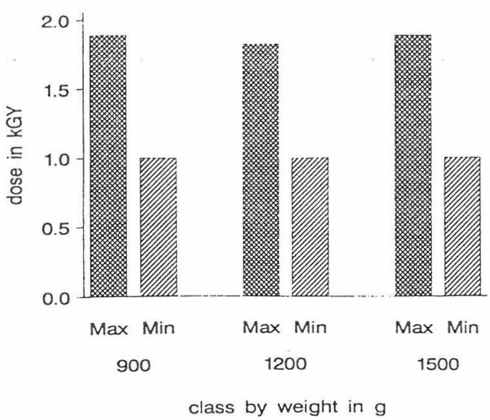

Figure 1: Relation of maximum and minimum doses for chicken carcasses of three weight-classes in cardboard boxes, double-side irradiation, 10 MeV-electrons

For 5 MeV-bremsstrahlung an improvement in the dose distribution was expected, as the penetration is comparable to that of cobalt-60 gamma-rays; only one-side irradiation was used. Figs. 2 and 3 compare electron and bremsstrahlung processing for 1,500 g chicken carcasses. A systematic deviation from the normal distribution is clear. The width of the dose distribution is also narrower for bremsstrahlung, the 'standard error' (standard deviation divided by mean value) being reduced from 0.252 for electrons to 0.103 for bremsstrahlung. Both curves show that the number of dosimeters used was not large enough to extrapolate for the extreme values of dose. However, such frequency distributions enable the irradiator settings to ensure radiation treatment at a certain confidence probability within preset dose limits to be made.

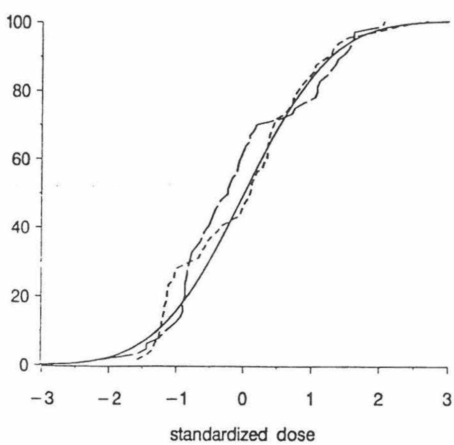

Figure 2: Normalized sum-frequency distribution of dose in chicken carcasses irradiated with 10 MeV-electrons and 5 MeV-bremsstrahlung; the sigmoid reference line is the normal distribution; carcass weight 1,500 g; lines: solid, normal distribution; dotted, 10 MeV-electrons; dashed, 5 MeV-bremsstrahlung

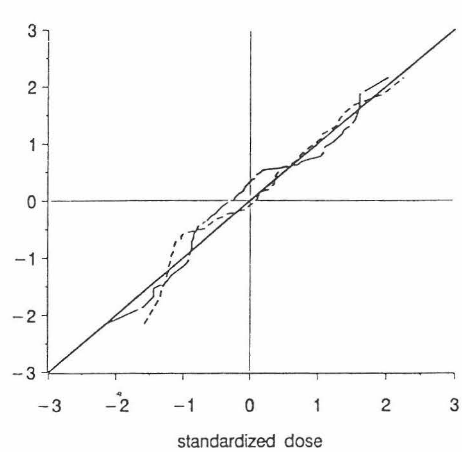

Figure 3: Normalized sum-frequency distribution as in Fig. 2 but on a the normal probability grid; the linear reference line is the normal distribution; carcass weight 1,500 g; lines: solid, normal distribution; dotted, 10 MeV-electrons; dashed, 5 MeV-bremsstrahlung