Low Energy Electron Beam Dosimetry for Food Irradiation Purpose

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Abstract: ***This research aims to study low energy dosimetry for food irradiation in order to do the decontamination purpose of food commodities like dried spices, grains, seeds, nuts and similar dry ingredients. Low - energy electrons (200, 230, 260, 300) keV irradiation were applied to a stack of Riso B3 dosimetric foils of 18um thickness. Preparation of depth dose distribution is presented. In this work, ILU 6 accelerator at Institute of Nuclear Chemistry and Technology (INCT), Warsaw, Poland was used.***

Keywords: low energy electron beam, food irradiation, dosimetry, RISO B3 dosimeter, microbial contamination

1. Introduction

Food irradiation is a process of exposing food to ionizing energy in order to eliminate insects, fungi or bacteria that cause human disease or spoilage. Dried foods such as spices or nuts are often contaminated with high levels of bacteria, moulds and yeasts originated from the plant environment, namely soil, water and air. In the process where high energy electrons are used, the whole volume of food is irradiated. However, in recent years, the application of low energy electron beam has been developed as an alternative to currently used highly penetrating ionizing radiation. Since microorganisms reside mostly on the surface of dry food, the irradiation of the external layer should be sufficient to eliminate food - borne microorganisms. The effectiveness of such beam in comparison with high energy electrons was proved for reduction of microbial load in dried spices. [1]

Low energy electron beam treatment is an emerging non - thermal technology that performs surface decontamination with a minimal influence on food quality. Food industries and scientists have been continuously searching for novel non - thermal decontamination processes that can ensure microbiological safety as well as better preserve the freshness and nutritional value of the food products.

Spices are often contaminated with high levels of bacteria, moulds and yeasts originating from the plant environment: soil, water and air. If untreated, herbs and spices will result in rapid spoilage of the products, or when contaminated with pathogenic bacteria can also cause serious food - borne illnesses. In contrary to the high energy electron beam which can penetrate centimeters of irradiated material the low energy electrons are absorbed over micrometers below surface. There are number of factors which must be considered when determining the range of electrons having energy below 300 keV in an irradiated product. The penetration ability of low energy electron beam depends not only on the density of irradiated material but also on the accelerator's construction itself, like the thickness of the foil in the accelerator window and on irradiation conditions, because significant energy of the beam can be absorbed in air. In the case of a low energy electron beam, the control of the dose is problematic due to limited penetration of the beam in comparison to the thickness of most available dosimeters. For low energy electron radiation, a new dosimetry term has been introduced, namely Dμ which is the dose in the first micrometre of an absorbing medium [1].

2. Materials and Methods

In this experiment, to study of low energy electron beam dosimetry for food irradiation, the ILU - 6 accelerator at INCT, Warsaw, Poland was used. Electrons energy range of 200keV, 230keV, 260keV and 300 keV were delivered on the Riso B3 foil dosimeter that will be measured. Its beam power is up to 0.5 kW, average beam current is up to 1 mA. Pulse duration temp = 400 μs (const.) Pulse repetition rate 10Hz. Width of scanned beam up to 50 cm. Stack of B3 foil was used to measure the range of electrons depending on the energy of the beam.

The real exposed energy is lower due to absorption in Titanium foil of 50um thickness and 10cm air gap between the sample and window. The low dose energy should sufficient to eliminate microorganism on surface of food like dried spices.

2.1 Dosimetric Method

The most suitable is thin dosimetric foil however the challenge is to develop dosimetric system dedicated to low energy electron beam which would be able to measure the dose on the surface, to monitor dose distribution on the surface and to control depth at which electrons can penetrate food products.

RISO B3 dosimetric foil is one of the thinnest dosimeter, which is manufactured as a highly - uniform, thin film with a nominal thickness 18μm and its dose ranges are <1.0kGy to >150kGy and can be measured using specialized software called RisøScan. B3 dosimeter has been developed at the Risø National Laboratory as a polyvinyl butyral film containing leucocyanide of pararosaniline. During irradiation up to 100 kGy, the additive gradually becomes pink. B3 dosimeter has found a widespread application in both gamma and electron beam radiation processing.

RisøScan B3 dosimeter measurement software allows users to scan and analyze B3 dosimeter film using high - resolution bitmap scans from a flatbed scanner. The stack of dosimeters were irradiated with electron of energy 200, 230, 260 and 300 keV, (INCT – ILU 6 accelerator). Each layer of dosimeter must be separated and stick to A4 white paper and scanned. Measurements of the dose using RISOSCAN software for every layer of the stack.

2.2 Preparation of depth dose curves.

The depth dose curve was measured using a stack of RisøB3 dosimeters. The measured doses of the dosimeters in the stack are shown in Table1, Table 2, Table 3 and Table 4 for different energies of 200keV, 230keV, 260keV and 300keV respectively. Each depth point is determined as the midpoint of the individual dosimeters in the stack. The depth dose curve in a different dosimeter material is determined by scaling with the ratio of the densities of the two materials [2]. The ratio of densities can be used as an approximation to translate depth dose curves between different materials.

Table 1: Measured depth dose distribution in a stack of B3 dosimeter for 200keV

B3 film layers	Thickness (um)	Thickness (mg/cm2)	Normalized Dose
1	9	1.017	1
2	27	3.051	0.938547486
3	45	5.085	0.804469274
4	63	7.119	0.631284916
5	81	9.153	0.441340782
6	99	11.187	0.30726257
7	117	13.221	0.195530726
8	135	15.255	0.100558659
9	153	17.289	0.039106145
10	171	19.323	0

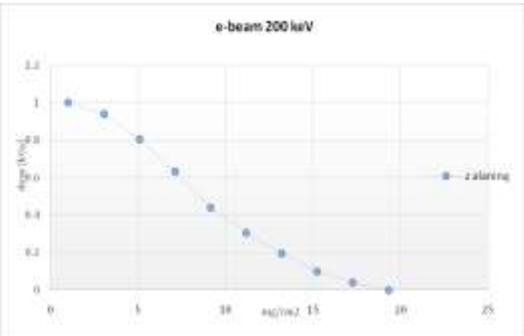

Figure 1: Measured depth dose distribution in a stack of B3 dosimeter for 200 keV

Table 2: Measured depth dose distribution in a stack of B3 dosimeter for 230keV

B3 film layers	Thickness (um)	Thickness (mg/cm2)	Normalized dose
1	9	1.017	1
2	27	3.051	1.020547945
3	45	5.085	0.993150685
4	63	7.119	0.95890411
5	81	9.153	0.890410959
6	99	11.187	0.794520548
7	117	13.221	0.684931507
8	135	15.255	0.547945205
9	153	17.289	0.438356164
10	171	19.323	0.342465753
11	189	21.357	0.273972603
12	207	23.391	0.205479452
13	225	25.425	0.130136986
14	243	27.459	0.054794521
15	261	29.493	0.01369863
16	279	31.527	0

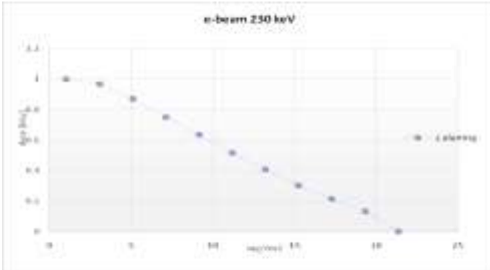

Figure 2: Measured depth dose distribution in a stack of B3 dosimeter for 230 keV

Table 3: Measured depth dose distribution in a stack of B3 dosimeter for 260keV

B3 film layers	Thickness (um)	Thickness (mg/cm2)	Normalized Dose
1	9	1.017	1
2	27	3.051	0.967741935
3	45	5.085	0.870967742
4	63	7.119	0.751612903
5	81	9.153	0.635483871
6	99	11.187	0.516129032
7	117	13.221	0.406451613
8	135	15.255	0.303225806
9	153	17.289	0.212903226
10	171	19.323	0.132258065
11	189	21.357	0

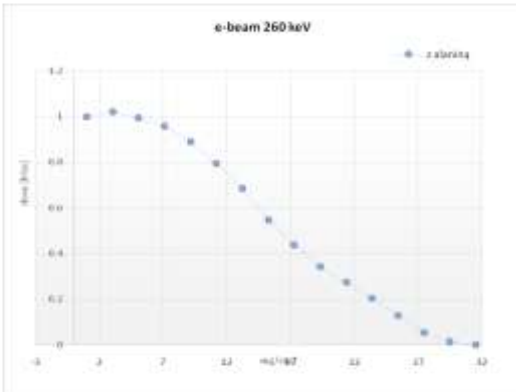

Figure 3: Measured depth dose distribution in a stack of B3 dosimeter for 260keV

Table 4: Measured depth dose distribution in a stack of B3 dosimeter for 300keV

B3 film layers	Thickness (um)	Thickness (mg/cm2)	Normalized dose
1	9	1.017	1
2	27	3.051	1.060402685
3	45	5.085	1.060402685

4	63	7.119	1
5	81	9.153	0.919463087
6	99	11.187	0.832214765
7	117	13.221	0.731543624
8	135	15.255	0.644295302
9	153	17.289	0.563758389
10	171	19.323	0.483221477
11	189	21.357	0.382550336
12	207	23.391	0.308724832
13	225	25.425	0.268456376
14	243	27.459	0.201342282
15	261	29.493	0.167785235
16	279	31.527	0.100671141
17	297	33.561	0.053691275
18	315	35.595	0.040268456
19	333	37.629	0.013422819
20	351	39.663	0

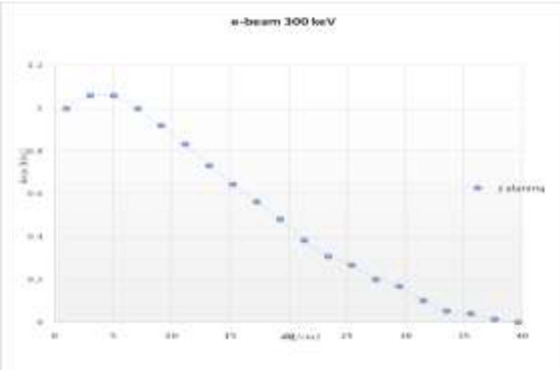

Figure 4: Measured depth dose distribution in a stack of B3 dosimeter for 300 keV

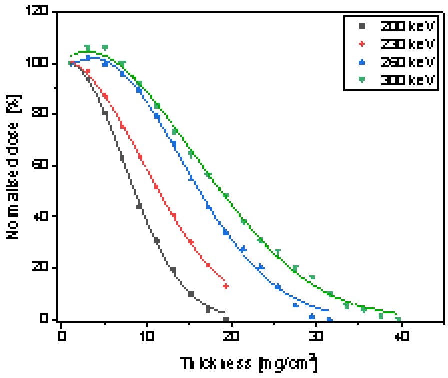

Figure 5: Range of electrons having energy 200, 230, 260 and 300 keV measured in stack of B3 dosimetric foil irradiated using ILU 6 accelerator

3. Results and Discussion

By using electron beam (ILU - 6) accelerator with Riso B3 dosimetry, the obtained results of depth dose distributions can be found at different low energies of 200, 230, 260, 300 keV. From Figure5, at 200keV electron energy, the maximum penetration depth is around 19 mg/cm^2 and at 230, 260, 300keV energies, around 21, 31, 39 mg/cm^2 respectively. It can be clear seen that these results are the higher energies can penetrate more than the lower energies from 19 mg/cm^2 to 39mg/cm^2 between 200keV and 300keV. From this observation, we can choose which type of food commodities should be irradiated for the purpose of decontamination. It is important to select groups of products dedicated for low energy electron beam treatment, taking into account if the depth at which microorganisms grow can be penetrated by defined electron beam. Low energy electron beam can effectively reduce microbiological contamination from surface of food products.

In addition, from these depth dose curve shows that the lower the thickness of a dosimeter the lower gradient of the dose. The efficiency of low energy electron beam irradiation depends on the dose delivered and penetration ability of the beam, which must be controlled using appropriate dosimetric system. In this measurement, Riso B3 foil stack is very effective for lower gradient of dose as it is very thin (in micrometer range thickness).

4. Conclusion

Low energy electron beam can effectively reduce microbiological contamination from surface of food products. Effectiveness of the process depends on uniformity of delivered surface dose. Low energy electron beam cannot be used for processes where whole volume of food must be irradiated like in phytosanitary treatment of sprouting inhibition.

In addition, Low energy electron accelerators can be used in - line, Lower cost of installation - installation doesn't need shielding.

References

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