



# Soft electron (low energy electron) processing of foods for microbial control

Setsuko Todoriki<sup>a,\*</sup>, Olivia Kimiko Kikuchi<sup>b</sup>, Motoko Nakaoka<sup>c</sup>,  
Mika Miike<sup>c</sup>, Toru Hayashi<sup>d</sup>

<sup>a</sup> National Food Research Institute, 2-1-12 Kannondai Tsukuba, Ibaraki, 305-8642, Japan

<sup>b</sup> IPEN/CNEN-SP, Travessa R, No. 400 Cid. University Saõ-Paul, CEP.05508-910, Brazil

<sup>c</sup> RyokokuShoji Co. Ltd., 5-7-5 Shoko-center, Nishi-ku, Hiroshima, 733-0833, Japan

<sup>d</sup> JIRCAS, 1-2 Ohwashi, Tsukuba, Ibaraki, 305-8686, Japan

---

## Abstract

“Soft-electron” is a new term we have created referring to electrons with energies of 300 kV or lower. Homogenous irradiation of surfaces with soft electrons can decontaminate dry food ingredients such as grains, pulses, spices, dehydrated vegetables and tealeaves without detrimental effects. Treatment of soybeans with electrons of acceleration voltages at 170 kV reduced their microbial count to an undetectable level. Pre-treatment of soybeans with soft electrons enabled the extension of soymilk without sterilization process at a high temperature (120°C). The gelatinized property of soymilk from soft electron-treated beans was better than that of high-temperature sterilized soymilks. These results indicate that soft-electron sterilization improved the quality of soybeans for the processing of soymilk and Tofu(soymilk curd). © 2002 Elsevier Science Ltd. All rights reserved.

*Keywords:* Soybeans; Low-energy electron (soft-electron); Decontamination; Soymilk; Tofu

---

## 1. Introduction

“Soft-electron”, new term we have created means an electron with energy of 300 kV or lower. Soft-electrons with an extremely small penetration capacity do not reach inside the edible part of cereals and grains, but irradiate their surface layers, where most of microorganisms reside. Therefore, homogenous irradiation of surfaces with soft-electrons can decontaminate dry food ingredients such as grains, pulses, spices, dehydrated vegetables and tealeaves without detrimental effects (Todoriki and Hayashi, 2000; Hayashi, 1998; Hayashi et al., 1998, 1997).

Soybeans have been utilized in many kinds of foods, including soybean curd (tofu) and soymilk, which are

digestible and nutritive protein products (Liener, 1972). Ingredient soybeans are naturally contaminated with microorganisms and heat sterilization is essential in the soymilk processing. However, heating at high temperature reduces the nutritive and processing quality of soymilks. It is expected that decontamination of ingredient soybean with soft electrons can extend shelf life of soybean product and improve their quality.

In the present study we treated soybean with electrons of acceleration voltage at 170 kV, and evaluated their sterility and quality for processing.

## 2. Materials and methods

### 2.1. Soybeans

Soybeans (*Glycine max*), variety Vinton, harvested in USA were used in this experiment.

---

\*Corresponding author. Tel.: +81-298-38-8047; fax: +81-298-39-1552.

E-mail address: setsuko@nfri.affrc.go.jp (S. Todoriki).

## 2.2. Treatment with electrons

Twenty-five grams of soybeans was placed under the window of Van de Graaff electron accelerator (Nissin High Voltage Engineering Co. Ltd., Kyoto, Japan) and treated with electrons at acceleration voltage of 170 kV under rotation. The distance between the window of the electron accelerator and the sample tray was 15 cm. The energy of electrons irradiating the samples was estimated to be 60 kV based on the mass stopping power of air and titanium (ICRU, 1984), and the current was 4  $\mu$ A.

## 2.3. Preparation of soymilks and soybean curds

Soybeans were ground with a Wiley type soybean grinder and mixed with six volumes of distilled water. After keeping at 60°C for 30 min, the mixture was filtrated through nylon cloth. The concentration of soymilk was measured with Digital Refractometer (PR-100 ATAGO), and diluted with distilled water at a concentration of 5%. Ten millilitres of 5% soymilk were put in a spit tube and heated at 92°C for 5 min. After cooling on ice water, the soymilk was gelatinized with 0.3 ml of 10% CaCl<sub>2</sub>: $\delta$ -gluconolactone (1:1) solution at 85°C for 5 min.

## 2.4. Evaluation of soybean curd

Gelatinized soymilk (soybean curd) in a spit tube was cooled to 10°C and centrifuged at a speed of 1200 rpm for 2 min, then the volume of gel layer was determined. Gel property index of soybean curd (gelatinized soymilk) were calculated as follows:

$$\text{Gel property Index} = A \times B / 10,$$

Where *A* is the concentration of soymilk after filtration (%) and *B* is the volume of the 5% soymilk gel after centrifugation (ml).

## 2.5. Microbial test

Five grams of samples were homogenized in 45 ml of 0.85% NaCl for 5 min at 3000 rpm. The homogenate was diluted with 0.85% NaCl and 1 ml of each dilution was mixed with 20 ml of nutrient agar and poured in a petri-dish. The colonies formed after incubation for 48 h at 35°C were counted. For detection of coliform bacteria, 1 ml of homogenate was mixed with 20 ml of deoxycholate agar, and red colonies formed after incubation for 48 h at 35°C were counted. BGLB test was carried out as follows: 1 ml of homogenate was mixed with BGLB culture broth in test tube with Durham tube. After the incubation of the broth at 35°C for 48 h, the gas evolved was detected.

The numbers of microorganisms in soymilks were determined after heating at 92°C for 5 min according to the same procedures mentioned above.

## 3. Results and discussion

### 3.1. Sterility of soybeans and soymilks

Total microbial count of untreated ingredient soybeans was  $1.1 \times 10^3$ , while coliform bacteria were not detected in the sample. Treatment of soybeans with electrons at acceleration voltages of 170 kV for 10 min resulted in extremely low levels of microbial contamination (Table 1).

Table 2 gives the microbial counts of soymilk just after preparation and those stored for 5 days at 35°C. When the soymilk was heated at 92°C, 10 cfu/g of microorganisms were detected in the soymilks prepared from untreated ingredient, and the number of microorganisms increased to  $10^8$  level during the storage for 5 days at 35°C. Therefore, this heating temperature (92°C) is insufficient for complete sterilization. Pre-treatment of soybeans with soft-electrons (170 kV) reduced microbial count of soymilks to an undetectable level, and this sterility was kept during the storage. When the soymilks

Table 1  
Sterility of soybeans (ingredients) treated with soft-electrons

Treatment	Total microbial count (CFU/g)	Coli form	
		Deoxycholate plate count	BGLB method
Untreated control	$1.1 \times 10^3$	— <sup>a</sup>	—
170 keV, 3.3 min (2.5 kGy)	$6.0 \times 10$	—	—
170 keV, 5 min (3.75 kGy)	$3.0 \times 10$	—	—
170 keV, 10 min (7.5 kGy)	<10	—	—

<sup>a</sup> —: not detected.

Table 2  
Total microbial count of soymilk prepared from soft-electron treated soybeans

Treatment of soybeans	Heating condition for soymilk processing (°C)	Total microbial count (0 days) (CFU/g)	Total microbial count (5 days 35°C) (CFU/g)
Untreated	92	11	$1.3 \times 10^8$
170 keV, 5 min	92	<10	<10
170 keV, 10 min	92	<10	<10
Untreated	120	<10	<10

Table 3  
Gel property index of soymilks prepared from soft-electron treated soybeans

Treatment of soybeans	Heating condition for soymilk processing (°C)	Gel property index <sup>a</sup>
Untreated	92	5.24
170 keV, 5 min	92	5.18
170 keV, 10 min	92	5.24
Untreated	120	3.52

<sup>a</sup>5.5 ≤ I: excellent quality, 4.5 ≤ I < 5.5: high quality, 3.0 ≤ I < 4.5: good quality, 3.0 > I: poor quality.

were heated at high temperature (120°C), the microbial count was reduced to an undetectable level without soft-electron treatment of ingredients. These results indicated that pre-treatment of soybeans with soft-electron enabled extension of the shelf life of soymilk without sterilization process at a high temperature (120°C).

### 3.2. Gel property of soymilk prepared from soft-electron treated soybeans

Table 3 gives the gelatinized property index of soybean curd. The index reflects the yield of soymilk and the water holding capacity of the gels. Without regard to soft electron treatment, the gel index scores of soymilks heated at 92°C were higher than 5.0, which mean these soymilks have a high quality for tofu

processing. The gelatinized property of soymilk heated at high temperature (120°C) was 3.52, which indicates good quality. These results indicate that soft-electron sterilization of soybeans enabled to reduce the heating temperature of soymilks, which improved their gelatinized property.

In conclusion soft-electron sterilization improved the quality of soybeans for the processing of soymilk and Tofu (soymilk curd).

### References

- Hayashi, T., 1998. Decontamination of dry food ingredients and seeds with soft-electrons (low energy electrons). *Food Sci. Technol. Int. Tokyo* 4 (2), 114–120.
- Hayashi, T., Takahashi, Y., Todoriki, S., 1997. Low energy electron effects on the sterility and viscosity of grains. *J. Food Sci.* 62 (4), 858–860.
- Hayashi, T., Okadome, H., Toyoshima, H., Todoriki, S., Ohtsubo, K., 1998. Rheological properties and lipid oxidation of rice decontaminated with low energy electrons. *J. Food Prot.* 61 (1), 73–77.
- ICRU, 1984. Stopping powers for electrons and positrons. ICRU Report 37. International Commission on Radiation Units and Measurements, Bethesda, USA.
- Liener, I.E., 1972. Nutritional value of foodprotein products. In: Smith, A.K., Circles, A.J. (Eds.), *The Soybeans: Chemistry and Technology*, (Vol. 1). AVI Publishing Co Inc., Westport, CT, USA.
- Todoriki, S., Hayashi, T., 2000. Disinfection of seeds and sprout inhibition of potatoes with low energy electrons. *Radiat. Phys. Chem.* 57, 253–255.