INACTIVATION OF MICROORGANISMS ON WHEAT GRAIN BY USING INFRARED IRRADIATION

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ABSTRACT

Over the past few years, there has been a substantial new system called HACCP system. This new system has introduced to the food industry and a safety of food from raw material to the consumer has become strongly demanded. The propagation of microorganisms on a raw crop as wheat grain was regarded very small because their water activity was kept low by drying it to the safe moisture content. However, the drying can not inactivate the microorganisms sufficiently and they have a chance to proliferate in a process to final product of the grain crop. In this study we tried to inactivate the microorganisms on wheat surface by exposure to infrared irradiation that is safe for consumer and easy handling safely. Moreover, exposure the wheat grain by using infrared irradiation has an advantage of non-contact heating, rapid heating and a small deterioration of wheat grain by its weak penetration.

A cylindrical type device for a grain disinfection equipped with four infrared radiation tubes was used. Wheat grain of about 300 g was exposure by using infrared irradiated under various conditions. The survival rate was of about 0.02 for microorganisms irradiated two times continuously at 2.0 kW for 63 sec. This was the smallest survival rate value in all conditions. However, the quality of wheat grain treated in this condition was lower than the other. The most effective condition of radiation for inactivation of microorganisms in this study was the exposure of wheat grain by using infrared irradiation for two times intermittently at 2.0 kW for 37 sec.

Keywords: inactivation, wheat grain, infrared radiation, disinfection, microorganism, moisture content, germination rate

INTRODUCTION

In recent years there were problems of food safety such as poisoning by *E. coli* O-157, milk poisoning and BSE in Japan, so that the consumer has strongly demanded the safety of food. In addition, it is expected that the food safety from farm to table, since HACCP system was introduced to the food industries (Ropkins and Beck, 2000). Namely sterile processing for raw materials of foodstuff such as cereal grains is required. The propagation of microorganisms on the raw material was regarded very small because their water activity was kept low by drying it to the safe moisture content, however, actually the raw materials are heavily contaminated with various species of microorganisms (Filtenborg et al., 1996; Rabie et al., 1997; Sarrias et al., 2002). Methyl bromide fumigation has been applied to disinfection of agricultural produces; nevertheless it will be completely inhibited in advanced nations after 2005 by the resolution of the Montreal Protocol.

There is no appropriate technique for a disinfection of raw materials such as cereal grains and beans nowadays. The technique needs to have performances as follows; high effect of disinfection; short treatment time; easy handling; safety for consumer, operator and environment; low cost. Several methods of disinfection using chlorine (Andrew, 1996, Andrew et al., 1996), Gamma ray and electron beam (Byun et al., 1998; Molins et al., 2001; Sarrias et al., 2003), soft electron (Hayashi et al, 1998, 1999) and others (Tsukada, 1984; Ramakrishna et al., 1991; Ohisa et al., 1999; Tsuchido et al., 2001) have been tried and investigated, however, these methods did not sufficiently satisfy the performances described above.

Infrared radiation heating (IRH) draws attention as one of method of disinfections for foodstuff owing to its advantage (Hashimoto et al., 1993; Sawai et al., 2000). As IRH needs no heating media, it can rapidly and effectively heat the surface of object. And also infrared ray penetrates not so deeply into substance. Consequently, if it is applied to a disinfection of cereal grains, internal quality of the grain is not deteriorated. Moreover, it is a physical method so that an effect on environment is little and there is no dangerous residue on the grains.

The purpose of this study is to clarify the effect of infrared irradiation on inactivating microorganisms on the wheat grain surface and investigate the quality of wheat grain after irradiation of infrared ray. The final purpose is to develop a practical infrared disinfection system for raw materials as cereal grains.

* Materials and Method

Wheat (*Triticum aestivum,* cv. Chikugoizumi) harvested in Kyushu University farm was used. The wheat grains were dried to 16 %w.b. after harvest and stored at 15 C. The grains were added distilled water at the experiment to prepare four levels of moisture content (16, 18, 20, 22 %w.b.). The drum type disinfection device equipped with four infrared radiation (IR) tubes is shown in Fig.1. The power of an IR tube was 0.5 kW. Two and four tubes were turned on to obtain a power of 1.0 kW and 2.0 kW, respectively. The device consisted of a hopper, a body (cylinder), IR tubes, a gathering tray, stirring rods, an electric motor, a speed controller and so on. A 300 g of wheat grains were thrown into the hopper, and slid down in the chute into th e inside of cylinder covered with aluminum foil. The cylinder (length: 650 mm, inner diameter: 1605mm) was inclined toward the forward, and four IR tubes equipped in the cylinder irradiated wheat grains sliding down. The grains were agitated by the stirring rods to be uniformly irradiated and were finally received by gathering tray.

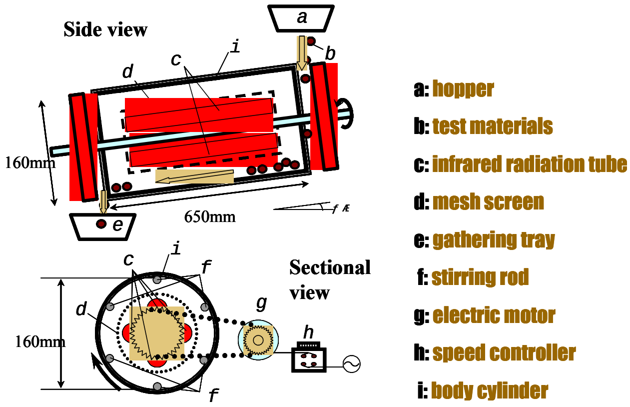

Fig. 1 Schematic diagram of the device for disinfection of wheat using infrared radiation

Table 1 Condition of irradiation

Irradiation	One time of pass	Two times of pass	
		Continuous*	Intermittent*
Power of IR tube (kW)	1.0 2.0	2.0	2.0
Irradiation time (s)	28, 37, 63	28, 37, 63**	28, 37, 63**
Number of exposure	1	2	2

* Second exposure of intermittent irradiation was conducted after cooling wheat grain exposed to first irradiation. That of continuous irradiation was just after first exposure without cooling.
** These values are the time for one pass.

Table 2 Medium composition

Medium	Composition	
Standard agar for general bacteria	Yeast extract	2.5 g
	Glucose	1 g
	Tryptone	5 g
	Agar powder	15 g
	Distilled water	1000 ml

The condition of irradiation is shown in Table 1. The revolution rate of cylinder was regulated so as to be 6.9, 15, 26.1 rpm and the irradiation time which is the pass time of wheat grains through the cylinder was 63, 37, 28 sec, respectively. Wheat grains passed to be exposed to irradiation through the cylinder one or two times. The treatment of passing one time was called “one pass treatment” and passing two times, “two passes treatment”. The total irradiation time of two passes treatment was 126, 74, 56 sec. Continuous and intermittent irradiation was carried out in two passes treatment. Second pass of the intermittent irradiation was conducted after cooling of wheat grain exposed to irradiation at first pass. That of the continuous irradiation was just after first pass without cooling.

Test grains were immediately cooled in refrigerator at 4 C after IRH disinfection treatment, and 10 g of them was rinsed out to get rid of the microorganisms with 5 min of stirring using 100 mL of sterile saline solution. The saline solution after rinsing was used as a microbial suspension. A 0.1 mL of the suspension appropriately diluted was spread on medium plates shown in Table 2. The plates were incubated at 25 C for 48 hr and the colonies appeared on the plate were counted. Subsequently, the survival rate (N/N_0) were calculated, where N is the number of surviving spores after treatment and N_0 is the initial number of spores.

Temperature of the wheat grain surface just after the treatment was measured with a radiation thermometer (Minolta, IR-0510). The temperature of the grain surface at intermittent irradiation was regarded same as that at one time pass because the temperature before the beginning of second pass of the intermittent irradiation became to the value before the first pass by cooling.

Moisture content of the wheat was measured by a single kernel moisture meter (Shizuokaseiki, CTR-800A). Germination rate of wheat was obtained as follows. One hundred of wheat grains were laid on a wet filter paper in a petridish and covered with upper dish put another wet filter paper. A small clearance between upper and lower dishes was opened for ventilation. When the filter papers was to be dry, water was added. The grains incubated at 25 C for 7 days and the seeds normally germinated were counted and the germination rate was calculated.

RESULTS

Fig. 2 shows the effect of power of IR tube and irradiation time on survival rate in one pass treatment. With increase of irradiation time, the survival rate decreased. Especially, the survival rate at 2.0 kW of irradiation was lower than that at 1.0 kW and was around 0.1 at 2.0 kW for 63 sec. Surface temperature of wheat after IR treatment is shown in Table 3. The temperatures at 1.0 kW is relatively low, however, that at 2.0 kW for 63 sec exceeded 75 C.

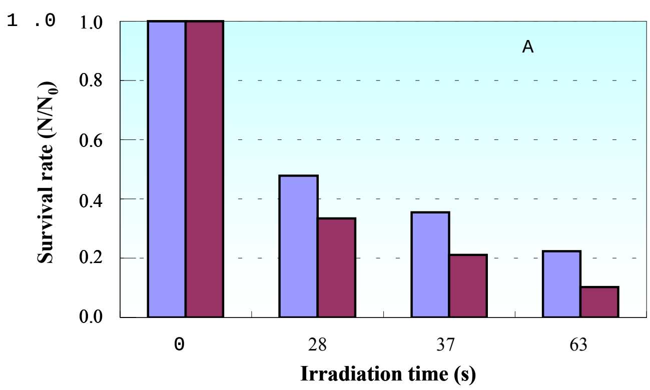

Fig. 2 Effect of power of IR tube and irradiation time on survival rate in one pass treatment
Left bar: 1.0 kW, Right bar: 2.0 kW.

Fig. 3 shows the survival rate, the moisture content and the germination rate at 2.0 kW of IR irradiation in two passes treatment. IR irradiation for 28 sec per pass inactivated the microorganisms on the wheat surface by more than 70 %.Though the survival rate was less than 0.02 in the condition of continuous irradiation for 63 sec per pass, the temperature of grain surface was 109.8 C (Table 4). Moisture content decreased with irradiation time and was 14.8 %w.b. in continuous irradiation for 63 sec per pass. Likewise germination rate was decreased with irradiation time and the reduction was rapid at continuous irradiation. The continuous irradiation for 37 and 63 sec. decreased germination rate to less than 80 % so that the quality of the grain might deteriorate.

Table 3 Surface temperature of wheat in one pass treatment (C)

Irradiation time	Power of IR tube 1.0kW	Power of IR tube 2.0kW
28 s	28.4	39.0
37 s	31.9	47.4
63 s	49.2	76.4

Effect of initial moisture content of wheat grain on the survival rate of microorganisms on the grain surface is shown in Fig.4. The survival rate decreased with the increase of irradiation time despite of the initial moisture content. The higher the initial moisture content, the lower the survival rate. The temperature rise of wheat with higher initial moisture content was smaller than that of wheat with lower initial moisture content as shown in Table 4 because of the latent heat of evaporation. Considering the quality of wheat, high initial moisture content is desirable, on the other hand, the inactivation of microorganisms is effective at low initial moisture content. The germination rate of the grain with higher moisture content is better than that with lower moisture content, nevertheless the difference in the rate was very small except in continuous irradiation for 37 and 63 sec per pass. The smallest survival rate was of about 0.02 in continuous irradiation at 16 % of initial condition for 63 sec per pass. However, the

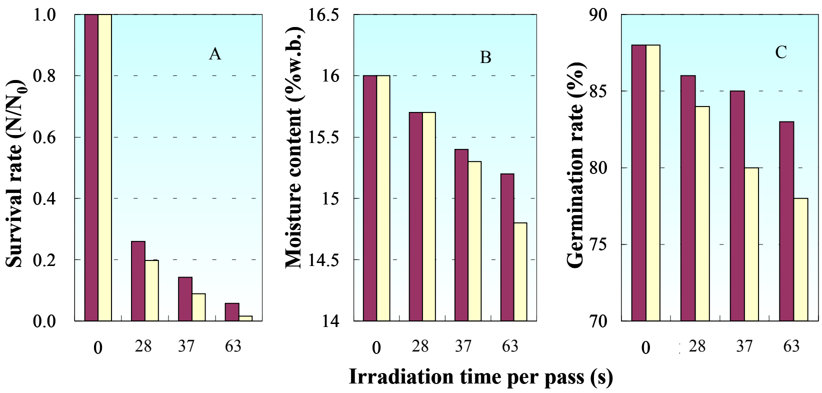

Fig. 3 Survival rate, moisture content and germination rate a 2.0 kW of IR irradiation in two passes treatment
A: Survival rate, B: Moisture content, C: Germination, Left bar: Intermittent, Right bar: Continuous.

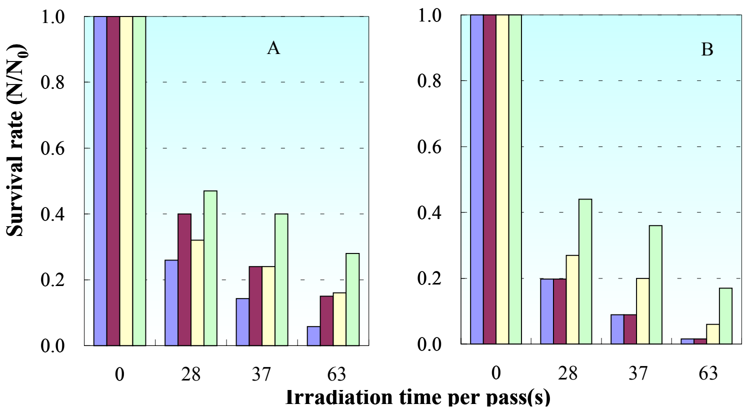

Fig. 4 Effect of initial moisture content of wheat grain on survival rate after 2.0 kW of IR irradiation in two passes treatment
A : intermittent, B : Continuous, Left bar: 16 %w.b., Middle left bar; 18 %w.b., Middle right bar; 20 %w.b., Right bar; 22%w.b.,

quality of wheat grain treated in this condition was lower than the other. When the intermittent irradiation was carried out, the germination rate was kept 85 % even if the

Table 4 Changes in temperature of wheat grain after 2.0 kW of IR irradiation (C)

	One pass				Two passes		
Initial M.C.	Irradiation time (s)				Irradiation time (s)		
(%)	0	28	37	63	28	37	63
16	20	39.0	47.4	76.4	56.0	80.9	109.8
18	20	39.1	46.8	75.5	58.1	81.3	108.4
20	20	37.8	43.5	74.2	52.3	77.4	105.5
22	20	36.0	42.8	72.2	50.1	68.2	89.3

Table 5 Changes in germination rate of wheat grain after 2.0 kW of IR irradiation in two pass treatment (%)

	Intermittent irradiation				Continuous irradiation		
Initial M.C.	Irradiation time per pass (s)				Irradiation time per pass (s)		
(%)	0	28	37	63	28	37	63
16	88	86	85	83	84	80	78
18	87	86	86	80	86	84	81
20	90	86	84	83	84	82	83
22	89	88	88	86	86	86	85

wheat grain with 16 % of initial moisture content was irradiated for 37 sec per pass (Table 5).

From these result it is concluded that the most effective condition of radiation for inactivation of microorganisms in this study was the exposure of wheat grain by using infrared irradiation for two times intermittently at 2.0 kW for 37 second.

CONCLUSION

To clarify the effect of infrared irradiation on inactivating microorganisms on the wheat grain surface, the cylindrical type device for a grain disinfection equipped with four infrared radiation tubes was made and the survival rate of microorganisms after infrared heating was measured.

With increases of the irradiation time, the power of irradiation tube and the number of passing through the device, the survival rate decreased. However, too strong irradiation caused the deterioration of the wheat quality. From these results the most effective condition of radiation for inactivation of microorganisms in this study was the exposure of wheat grain by using infrared irradiation for two times intermittently at 2.0 kW for 37 second.

REFERENCES

1. BYUN, M.W., YOOK, H.S., KANG, I.J. CHUNG, C.K. KWON, J.H. and CHOI, K.J., 1998. Comparative effects of gamma irradiation and ozone treatment on hygienic quality of Korean red ginseng powder. *Radiation Physics and Chemistry*, **52**, 95-99.
2. FILTENBORG, O., FRISVAD, J.C. and THRANE, U., 1996. Moulds in food spoilage. *Int. J. Food Microbiology*, **33**, 85-102.
3. HASHIMOTO, A., SAWAI, J., IGARAASHI, H. and SHIMIZU, M. 1993. Irradiation

power effect on IR pasteurization below lethal temperature of bacteria. *J. Chem. Eng. Japan*, **26**, 3311-333.

4. HAYASHI, T. OKADOME, H. TOYOSHIMA, H., TODOROKI, S. And OHTSUBO, K., 1998. Rheological properties and lipid oxidation of rice decontaminated with low-energy electrons. *J. Food Protection*, **61**, 73-77.
5. HAYASHI, T. and TODOROKI, S., 1999. Continuous grain rotator designed for soft-electron sterilization (in Japanese with English abstract). *J. Japanese Soc. for Food Sci. and Tech.* **46**, 422-427.
6. MOLINS, R.A., MOTARJEMI, Y. and KAFERSTEI, F.K., 2001. Irradiation: a critical control point in ensuring the microbiological safety of raw foods. *Food Control*, **12**, 347-356.
7. OHISA, N., SUGAWARA, M., MINE, H. And ISSHIKI, K., 1999. Killing *Bacillus* spores with calcined calcium (in Japanese with English abstract). *J. Japanese Soc. for Food Sci. and Tech.* **46**, 613-615.
8. RABIE, C.J., LUBBEN, A., MARAIS, G.J. and JANSEN VAN VUUREN, H., 1997. Enumeration of fungi in barley. *Int. J. Food Microbiology*, **35**,117-127.
9. RAMAKRISHNA, N., LACEY, and SMITH, J.E., 1991. Effect of surface sterilization, fumigation and gamma irradiation on the microflora and germination of barley seeds. *Int. J. Food Microbiology*, **12**, 47-54.
10. ROPKINS, K. and BECK, A.J., 2000. Evaluation of worldwide approaches to the use of HACCP to control safety. *Trends in Food Sci. and Tech.* **11**, 10-21.
11. SARRIAS, J.A., VALERO, M. and SALMERON, M.C., 2002. Enumeration, isolation and characterization of *Bacillus cereus* strains from Spanish raw rice. *Food Microbiology*, **19**, 589-595.
12. SARRIAS, J.A., VALERO, M. and SALMERON, M.C., 2003. Enumeration of *Bacillus cereus* contamination in raw rice by electron beam irradiation. *Food Microbiology*, **20**, 327-3325.
13. SAWAI, J., SAGARA, K., HASHIMOTO, A., IGARASHI, H. and SHIMIZU, M. 2003. Inactivation characteristics shown by enzymes and bacteria treated with far infrared radioactive heating. *Int. J. Food Sci. and Tech.* **38**, 661-667.
14. TSUCHIDO, T., HAYASHI, M., MATSUMURA, Y. And OHYA, S., 2001. Inactivation of bacteria found in solid particulate foods by using a continuous UV irradiation system (in Japanese with English abstract). *J. Antibacterial and Aantifungal Ag*ents, **29**, 305-309.
15. TSUKADA, N., 1984. Application of high pressure steam and superheated steam for food process (in Japanese). *J. Japanese Soc. for Food Sci. and Tech.*, **31**, 536- 545.