The Application of Electron Beam Irradiation on Fruits Preservation

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Abstract: Food irradiation with high-energy electron from accelerator is a new type technique for storing and refreshing food. This paper reviewed the fresh-keeping mechanism and characteristics of electron beam irradiation in fruits preservation application recently. Electron beam irradiation can especially inhibit germination, delay maturate, sterilize and improve quality and so on. At last, we combined with other packaging technologies such as modified atmosphere packaging for fresh-keeping.

Keywords: electron beam irradiation; fruit; fresh-keeping; modified atmosphere packaging

1. Introduction

Fruits have an obvious seasonal character in growth and harvest, and a series of changes of biochemical and physiological processes will continue after harvest. During these processes, many nutrients have being consumed. The main causes boil down to two things: a series of changes of biochemical and physiological processes were mainly attributable to Enzymes and environmental factors; and the diseases and putrefaction caused by microbes. Respiration-inhibiting and mold-killing is very important to fruits preservation.

There are many preserving methods in the market. Their common characteristic is that they prevent spoilage and maintain the fruits quality by controlling one or several key points [1]. Traditional methods cannot be controlled artificially because of environment factors. MAP or cold preservation needs large cold storage or machine equipment.

In recent years, electron beam irradiation technology in China is booming. Because of its sterilization, safety and environmental protection advantages, this technology is widely used in food preservation. Xie Zhongchuan [2] used electron beam irradiation technology to restrain the respiration rate of Ginkgo Biloba. Rahman R A [3] extended the shelf life of bananas by electron beam irradiation combined with hot water. Electron beam irradiation plays an important role in fresh keeping technology of farm products.

2. The preservation methods of electron beam irradiation

2.1. The principle of electron beam irradiation

Low or high-energy electron beam radiation generated by electron accelerator (usually 10MeV) can damage DNA in living cells directly or get -H、-OH from radiolysis of water or small molecules indirectly by high energy pulse. Living radical with nuclear material can initiate cross-slink [4]. Thus we can kill pets, postpone fruit and vegetable ripening and senescence and also extend shelf life of the farm products.

2.2. Characteristics of electron beam irradiation preservation

1) *Energy conserving and Environment protecting: Electron beam irradiation of the generation and disappearance can be controlled by power switch without radiation, no pollution, no harm to the operator.*[5].

2) *Convenient and deep penetration： Electron beam has strong penetrability.*

3) *The ability of keeping fresh：Irradiation method is cold pasteurization, which can be carried out at room or low temperature* [3].

4) *Good effect of disinfection：In the appropriate radiation dose, 99.9 % of common bacteria, such as: Salmonella, Escherichia coli, Listeria can be killed* [6].

5) *Suitable for large-scale processing：Irradiation method is easy to operate and carried out fast* [7].

3. Influencing Factors of effect of electron beam irradiation preservation

3.1. Irradiation dose

Dose affects the effect of preservation directly. When radiation dosage was added to 0.1~1kGy, it showed the inhibition of microbial growth and reproduction. Jiang Yuqing [8] found that if the dosage is too low, it can only inhibit after-ripening of farm products and cannot inhibit the growth of microbes. Researches also showed that radiation dosage was too high to be harmful to farm products. Shi Jianxin [9] found that if the record of peaches storage was about 0.2kGy can extend the shelf life. But when the dosage was high to 0.5kGy, it can be harmful to the peaches.

3.2. Storage temperature

Storage temperature has obvious effect on fruit preservation after irradiation treatment. If storage temperature is too high, the microbial grow more easily and fruit respiration rate or water evaporation rate will increase. Zhao Yongfu [10] stored strawberry at 0℃ after irradiation treatment which shelf life can be extended to 30d. If the storage temperature was 4℃, the shelf life of strawberry can only be 15d; when it was stored at 25℃, all fruit had already rotten.

3.3. Different kinds of fruit

Different kinds of fruit or the same types of species will affect the effect of irradiation preservation. This is mainly due to the different fruit of the sensitivity of electron beam irradiation, and different tolerance. Table 1 shows the different tolerance of fruits.

Table 1. The Tolerance of Fruit on The Radiation [2]

Tolerance	Tolerated dose	Fruit
Strong	>1.0KGy	Mango, Longan, Strawberry, Papaya.
medium	0.3~1.0KGy	Bananas, oranges, lychees, figs, pineapple, strawberry, guava, melon, raspberry, cherry, apple.
weak	<0.3KGy	Pear, grape, lemon, peach, plum, loquat, olive, nectarine.

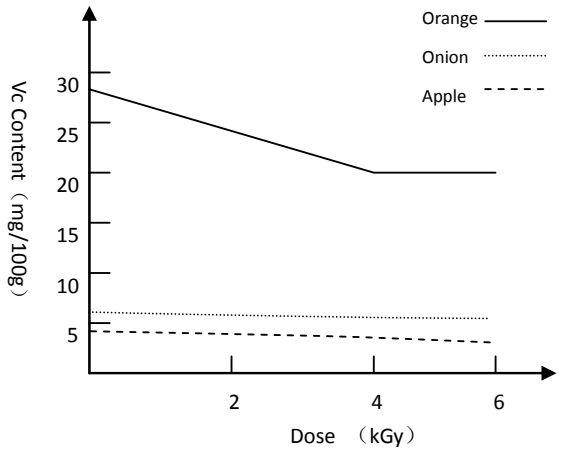

Figure 1. The effect of radiation dose on different fruits about VC content [11].

3.4 Others

Requirements of radiation dose are different from fresh degree of fruit. Generally high dose of fresh degree demands smaller radiation dose. The water content of different fruit will also affect the effect of irradiation preservation, and lower water content of fresh fruit is more beneficial to preservation.

4. The effect of electron beam irradiation preservation on fruit

4.1. The effect of electron beam irradiation on Vitamins

Vitamins are sensitive to the irradiation; the loss depends on the radiation dose, temperature, and oxygen or food type. In general, irradiation can reduce the loss of vitamins in low oxygen conditions, and fruit can also reduce vitamin loss at low temperature sealing state. There is different influence of irradiation on different types of vitamins. Figure 1 is the effect of radiation dose on different fruits about VC content.

4.2 The effect of electron beam irradiation on Carbohydrate

Carbohydrate molecules by irradiation treatment are relatively stable, and only after large doses of radiation, oxidize reaction and decomposition can be caused. For example, the sugar will release more carbon dioxide and other gases. In general, carbohydrate is very stable against irradiation.

4.3 The effect of electron beam irradiation on fruit firmness

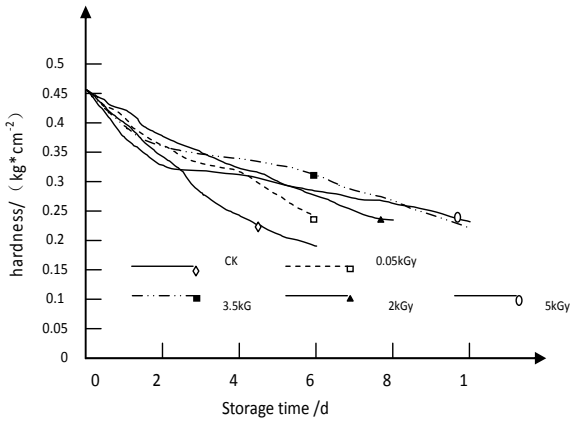

Figure 2. The trends of irradiation on fruit firmness of strawberry [13].

Changes in hardness to some extent reflect the characteristics and changes of pectin content. According to reports, due to the effect of after-ripening the degradation of pectin slowed down and less by irradiation, and thus it can be good for maintain the firmness of strawberry [12]. Figure 2 is the trends of irradiation on fruit firmness of strawberry.

4.4 The effect of electron beam irradiation on fruit Microorganisms

Inhibition and sterilization effect of irradiation has been

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widely recognized by the public. Table 2 shows that the total number of bacteria and fungi of strawberry which treated by irradiation were lower than total control. And the higher radiation dose, the fewer the number of bacteria and mold, the slower growth rate during storage.

5 Electron beam irradiation in the application of fresh fruit

In the aspect of fruit storage, it mainly adopts controlled temperature storage, controlled atmosphere storage, chemical storage and radiation preservation at home and abroad. From the sides of cost, convenience, security and storage effects, electron beam irradiation treatment can extend the preservation time and ensure the fruit quality. There has begun a large number of research applications in electron beam irradiation in fruit storage. Table 3 is about the dose of electron beam irradiation commonly used and its effect.

Table 2. Determination Results of The Number of Microbiological on Strawberry Treated by Electron Beam Irradiation [13]

Irradiation dose /kGy	0d			3d			6d		
	coliform group /[MPN • (100g)$^{-1}$]	*bacteria/ (CFU • g^{-1})*	*mold / (CFU • g^{-1})*	*Coliform group /[MPN • (100g)$^{-1}$]*	*bacteria / (CFU • g^{-1})*	*mold / (CFU • g^{-1})*	*Coliform group /[MPN • (100g)$^{-1}$]*	*bacteria / (CFU • g^{-1})*	*mold / (CFU • g^{-1})*
0	430	$1.38*10^{3a}$	$5.73*10^{2a}$	270	$1.14*10^{4a}$	$3.67*10^{4a}$	110	$1.60*10^{6a}$	$1.37*10^{6a}$
0.5	<30	$1.15*10^{2b}$	$5.63*10^{2a}$	<30	$6.03*10^{2b}$	$9.50*10^{3b}$	<30	$4.33*10^{2b}$	$2.36*10^{5b}$
2.0	<30	$5.87*10^{1bc}$	$2.07*10^{2b}$	<30	$3.48*10^{2c}$	$5.47*10^{3c}$	<30	$2.20*10^{2b}$	$9.33*10^{4c}$
3.5	<30	$3.33*10^{1bc}$	$1.39*10^{2c}$	<30	$2.50*10^{2d}$	$3.53*10^{3d}$	<30	$2.00*10^{2b}$	$2.05*10^{4d}$
5.0	<30	$1.00*10^{1c}$	$<1*10^{d}$	<30	$1.50*10^{2e}$	$4.33*10^{2e}$	<30	$1.67*10^{2b}$	$3.33*10^{3e}$

Table 3. The Dose of Electron Beam Irradiation Commonly Used and Its Effect [14]

category	dose（kGy）	effect
Irradiation inhibition	0.05~0.15	Germination inhibition；
（low dose）	0.15~1.0	Its maturing can be postponed for 16-20 days;
Irradiation disinsection	1.0~3.0	Shelf-life can be extended;
（moderate dose）	1.0~7.0	Killing pests and parasites deep in fruit and seeds.

5.1 Inhibition of physiological growth

Inhibit physiological growth by electron beam irradiation can keep fruit fresh. 1kGy dose of radiation can inhibit the activity of enzymes in fruits and decrease vitality in plants. Thus irradiation treatment significantly delayed maturity, inhibited fruit rot and flesh browning, kept firmness and fruit color, and prolonged the storage life of fruit. Qiu Quanfa [15] reported that low dose irradiation can delay maturity of fresh litchi 5~7days.

5.2 Extending Shelf Life

The irradiation preservation could restrain the activity of enzyme and respiration rate. Irradiation has no effect on quality of fruit such as VC content, acidity, sugar, aroma and taste. Table 4 is the electron beam irradiation dose and effect on fresh fruit.

5.3 The application of the degradation of harmful residues

Electron beam irradiation has strong degradation effect on chemical pollutants degradation. Tsinghua University found that electron beam irradiation has degradation effect on Hydrochloride, furazolidone, nitrofurantoin and some metabolites solution. Among them, the degradation rate of clenbuterol hydrochloric solution can be 95% [22]. Switzerland, Zhejiang and Jiangsu academy of agricultural studied the irradiation degradation of chloramphenicol in chloramphenicol solutions or aquatic products. The possibility of irradiation degradation of chloramphenicol was verified [23].

5.4 Sterilization, disinsection and quarantine treatment

Irradiation can kill microorganism, insect and parasite.The safety of international trade law often require safe disposal of imported fruits (especially tropical and subtropical fruit) to kill flies and other infectious diseases. The irradiation dose of killing drosophila (0.15kGy) does not change physicochemical properties of fruits and 0.1kGy irradiation can prevent drosophila egg to grow.

Table 4. The Preservation of Electron Beam Irradiation Dose and the Effect of Fresh Fruit [16]-[21]

Fruit name	Treatment and dose	effect
strawberry	0.1~2kGy	Soluble pectin decreases slightly The hardness decreased with increasing radiation dose;
Sweet cherry	0.15~0.90kGy >0.3kGy	No effect on soluble substances, acidity and flavor Brightness is variable low on surface, and red is increased;
melon	Combination of controlled atmosphere （4%O^2，10%CO^2） 1.0kGy	Respiratory rate is more stable It can be stored 20ds at 3℃;
cantaloupe	1.0kGy~1.5kGy	It can be stored 12ds at 10℃;
Green berry	0.25、0.15、0.75、1kGy	No effect on hardness at 1℃ for 3ds The hardness decreased when the dose is above the 0.75 kGy for 7ds;
mango	1.0kGy 1.5kGy、3.1kGy	Can be stored 21ds at 12℃ Flesh will be soften at the high dose

Table 5. The Comprehensive Fresh Keeping Process of Irradiation and Modified Atmosphere Storage

process	characteristics	Purpose and effect
1 Post-harvest selection , cleaning and grading	Manual measuring mechanical grade selection(size, weight, color)	Remove the damage , pests
2 Pre-cooling and warehousing	shade、ventilation or cold storage	Lower fruit transpiration, respiration and fruit physiological disease
3 packaging	Inner packing materials should be food grad, high radiation and protective.	Easy storage, transportation and sale
4 irradiation treatment	Appropriate dose electron beam irradiation at a certain temperature	Sterilization, biological growth inhibition, inhibition of enzyme activity, extend the ripening period
5 MAP	Regulate the ratio of CO_2,O_2	Decreasing respiration, and inhibiting microbial growth
6 storage, transportation and sale	Low temperature	Avoid the temperature effect of the respiration and microbial growth in transportation of sale process

6. Comprehensive applications of codified atmosphere packaging technology and electron beam irradiation

Since the factors affecting fruit storage not only fruit quality but also environmental factors, a single method such as irradiation cannot meet their storage requirements. Radiation dose increased had a marked effect of inhibition of microbes and bacteria, but a bad effect of fruit quality. Modified Atmosphere Packaging (MAP) reduces respiration, inhibited the enzyme activity, thus it can delay fruit ripening and has a useful role on VC content, soluble solids and fruit flavors.

Screening effective irradiation dose and combined with scientific storage methods (such as modified atmosphere packaging, frozen) can significantly extend the storage period of fruits. Table 5 is the comprehensive fresh keeping process of irradiation and modified atmosphere storage.

7 Conclusions

Electron beam irradiation preservation technique is efficient, safe, no pollution, no residue, and keeping the original color, flavor and so on. If combined the irradiation treatment and other methods, we can get good results. For example, USA, South Africa and Chile combined with irradiation and heat treatment method to storage fresh papaya, mango and so on. Shanghai china combined irradiation with cold storage method can effectively control postharvest corruption of apple and strawberry. Synergistic effect of combined treatment can reduce the amount of reagent and irradiation dose, both to extent the shelf life and ensures the safety of the food. With the development of the science technology, electron beam irradiation processing agricultural and sideline products, especially fruits can further improve people's living standards and is of great significance in the commercial production.

References

[1] Bao Shili, "Research on Storage Technology for Fruit and Vegetable", The Light & Textile Industries of Fujian, vol. 5, pp.8-13, May 2003.

[2] Xie Zhongchuan, Xing Xiaohei, "Combined Technique for Gingko Preservation", Acta Agriculturae Nucleare Sinica, vol.13, pp.159-162, 1999.

[3] Rahman R A .et al. Australian Centre for international Agricul-

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tural Research. 1994,378

[4] Li Mu, Xing Zengtao, “The application of electron beam irradiation on agri-foods preservation”, Acta Laser Biology Sinica, vol.16, pp.640-645, October 2007.

[5] Gu Kefei, Zhao Zhihui, “The Application of Electron Beam Irradiation Technology in Food Safety Control System”, Food and Nutrition in China, vol.3, pp.11-14, March, 2008.

[6] Ha Yiming, Shi Huidong, “Application and Characteristics of Food Irradiation by Electron Beam”, Journal of Nuclear Agricultural Sciences, vol. 21, pp. 61-64, 2007.

[7] Shi Peixin, Food Hygiene Safety- Principles and Techniques of Food Irradiation Processing. Bei Jin: China Agricultural Science and Technology Publishing House, 2004.

[8] Jiang Yuqin, “Comprehensive Preservation of Chinese Chestnut”, Acta Agriculturae Nucleare Sinica, vol.14, pp. 85-87, 2000.

[9] Shi Jianxin, “ The Studies on Physiological and Biochemical Indexes of Peach Fruit During Storage by 60Co- γ Irradiation”, Acta Laser Bilogy Sinica, vol.14, pp. 161-199, 1993.

[10] Zhao Yongfu, Xie Zongchuan, “Effect of Irradiation on Freshkeeping of Strawberry Stored at Room Temperature”, Acta Laser Biology Sinica, vol.13, pp. 23-26, 1999.

[11] Yang Bao’an, Huang Lunji, “Effect of Radiation and Storage Condition on VC Content in Food”, Henan Science, vol.24, pp.508-511, August 2006.

[12] Gu Chongguang, “The Studies on Effect of Pectin Content and Pectinase Activity of Strawberry by Irradiation”, Acta Agriculturae Nucleare Sinica, vol.4, pp.59-60, 1985.

[13] Yang Junli, “Effect of High Energy Electron Beam Irradiation on Normal Temperature Storage Quality of Strawberry”, Food and Fermentation Industries, vol.36, pp.191-195, 2010.

[14] Xu Hongqing, “The Present Situation and Prospect of Food Irradiation”, Service of Agricultral Technology, vol.24, pp.113-114, 2007.

[15] Qiu Quanfa, “Effect of Irradiation on The Preservation of Litchi”, Journal of Nuclear Agricultural Sciences, vol.10, pp.6-8, 1989.

[16] Miller W.R. et al. A Publication of the American Society for Horticultural Science (USA), vol.30, pp.306-308, 1995.

[17] Yu, L. et al. J. of food science (USA), vol.64, pp.844-816, 1996.

[18] Drake, S.R. et al. J. Of Food Processing and Preservation (USA), vol.21, pp.345-351, 1997.

[19] E CASTELL-PEREZ, MMOR, RGM, “Electron Beam Irradiation Treatment of Cantaloupes”, Journal of Food Science and Technology International, vol.10, pp.383-390, 2004.

[20] MARIA MORENO, MELENA CASTELL-PEREZ, CARMEN GOMES, et al., “Effects of Electron Beam Irradiation on Physical, Textural, and Micro structural Properties of ‘Tommy A skins’ Mangoes(Mangifera indica L.)”, J of Food Science, vol.71, pp.80-86, 2006.

[21] BRYAN BB, BRUCEAW, CHARLESA SMS, et al Effects of Low-dose Electron Beam Irradiation on Respiration.

[22] Yang Chengdui, “Mass Spectrum Detection of Nitrofurazone Metabolite’s Degraded by Electronic Beam Irradiation”, Journal of Instrumental Analysis, vol.24, pp.96-98, November 2005.

[23] Song Lihui, “Study of Clenbuterol Degrading by Electronic Beam Irradiation”, Chinese Journal of Analytical Chemistry, vol.33, pp.1007-1009, July 2005.