CONSUMER ACCEPTANCE, MARKET TEST AND MARKET DEVELOPMENT OF IRRADIATED RICE, DEHYDRATED VEGETABLES AND SPICES

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Abstract. Establishment of irradiation processing parameters, a quality assurance system, consumer acceptance, market test and market development of irradiated rice, dehydrated vegetables and spices were the activities carried out in this project by the Chinese Agricultural Irradiation Center. The results of the studies showed that the process dose for rice was 0.2–0.5 kGy when the non-uniformity was lower than 2.5, dose range for dehydrated vegetables was 5–7 kGy, dose for spices was 7–8 kGy. The system for quality assurance was established. The processing standards for several irradiated food items were set up. Market test showed that more than 70–80% of consumers accepted irradiated food. Industrial companies also accepted irradiated dehydrated vegetables and spices. The later were successfully introduced to the markets and successful commercialization of irradiated garlic was followed. The economic benefit of operating the Chinese Agricultural Irradiation Center was analyzed and found attractive especially for low dose irradiation of foods in sufficient supply.

1. INTRODUCTION

The Chinese Agricultural Irradiation Center joined the RPFI Phase IV on "Public Acceptance and Trade Development in Irradiated Food in Asia and the Pacific" in 1994. The work carried out in the Center focused on consumer acceptance, market test and market development of irradiated rice, dehydrated vegetables and spices. The activities carried out are described below:

(1) Irradiation processing of rice and dehydrated vegetables and major factors affecting the process.
(2) Establishment of a quality control system for industrial scale food irradiation following the ICGFI Code and Codex General Standard and considering the practice and the processing standards for food items in China.
(3) Investigation of consumer acceptance and dissemination of irradiation information to the public.
(4) Market development and commercialization of irradiated rice and dehydrated vegetables.

2. RESULTS OF RESEARCH WORK

2.1. Quantity of irradiated food

The quantities of irradiated rice, dehydrated vegetables and spices and other foods irradiated at the Chinese Agricultural Irradiation Center as well as in China are shown in Tables I and II respectively.

TABLE I. QUANTITY OF FOOD IRRADIATED AT THE CHINESE AGRICULTURAL IRRADIATION CENTER (1995–1998)

	Name and amount (tons) of products					
Year	Rice	Dehydrated Vegetables	Spices	Health Foods	Others	Total
1995–1996	1000	400				1400
1997	800	400	400	15	5	1620
1998	100	500	1500	20		2320

TABLE II. QUANTITY OF IRRADIATED FOODS COMMERCIALLY PRODUCED IN CHINA (1995–1998)

Food items	Quantity (tons)
Rice	2,800
Garlic	130,000
Spices	25,000
Dehydrated vegetables	8,000
Health Foods	200

2.2. Determination of processing parameters for rice, dehydrated vegetables and spices

To ensure quality of treated products, the related irradiation processing parameters for rice, dehydrated vegetables and spices were determined and are discussed below:

2.2.1. Rice

The objective was irradiation disinfestation

2.2.1.1. Doses for irradiation of rice

The color, smell and content of linear starch were not affected by irradiation under 1 kGy, but the taste quality (chew property, hardness) and the yield of cooked rice, starch iodine blue value and viscosity decreased with increase in irradiation dose. The viscosity was the most sensitive to irradiation followed by the starch iodine blue value, the yield of cooked rice and the taste quality. The taste quality was most affected at dosages between 500–600Gy. The results of measurements are shown in Table III.

2.2.1.2. Effect of irradiation on major storage pest in rice

The effect of irradiation on the emergence and survival of treated *Sitophilus zeamais* at different development stages is shown in Table IV. The data indicated that the egg and larvae were the most sensitive stages and the adults, the most tolerant to irradiation. The sensitivity to irradiation of the pupa was between the larvae and adults.

From the results above, good irradiation practice for rice on an industrial scale should follow the following guidelines:

(1) Wind selecting and polishing must be carried out before irradiation to take out the adults and pupae from the rice as otherwise the body of dead pupa and adults remain inside the rice.

(2) The period from egg stage to the pupae stage at different temperature was about 16–44 days. To be sure that there is no pupae of *S. zeamais* in the rice, the irradiation processing should be conducted within 20–30 days after packaging.

(3) The maximum dose should be the highest dose that will not affect the nutrition and sensory quality of treated rice, and the minimum dose should be the lowest dose that will be lethal to the pest in the rice. Considering the above, the dose and non-uniformity ratio is as follows: D_{max}/D_{min} = 500 Gy/200 Gy = 2.5.

(4) To avoid re-infestation the rice should be packaged in a plastic bag and sealed, then kept in a paper carton. The irradiated rice should be stored in a pest-free room.

TABLE III. EFFECTS OF DIFFERENT DOSES ON THE PHYSIOCHEMICAL CHARACTERISTICS AND SENSORY QUALITY OF RICE

Dose (Gy)		0	200	400	500	600	800	1000	Correlation coefficient	Correlation degree
Sensory	Color	7	7	7	7	7	7	7		
Quality	Smell	7	7	7	7	7	7	7		
	Tastes	5.7	5.6	4.8	4.4	2.9*	2.3*	2.2*	–0.945	1%
Yield of cooking rice (%)		359	354	350	347	345*	340*	335*	0.9979	1%
Starch iodide blue value (%)		22.0	20.4	19.2	18.5*	17.4*	16.5*	15.3*	–0.9859	1%
Viscosity		10.19	8.40*	7.40*	6.46	5.41*	4.68*	4.52*	–0.9812	1%
Content of linear chain starch (%)		20.62	20.61	20.63	20.62	20.64	20.61	20.61	–0.08	

*Significant difference at 1% level.

TABLE IV. EMERGING OR SURVIVAL RATE OF IMAGO AFTER IRRADIATION AT DIFFERENT DEVELOPMENT STAGES

Development Stage	Days after Irradiation	Dose(Gy)							
		0	30	60	120	200	400	600	800
Egg-larvae	Emergence rate (%)	100	7.7	0.3	0	–	–	–	–
Pupae	Emergence rate (%)	100	–	–	–	14.5	0	0	0
Imago	Survival rate (%)	86.3	–	–	–	40.6	0	0	0

TABLE V. IRRADIATION STERILIZATION ON DEHYDRATED VEGETABLES

Bacterium	Vegetable	Irradiation dose (kGy)					
		0	1	3	5	7	10
Total	Green bean sprout	44×10^4	33×10^3	26×10^2	83×10	–	–
(per gram)	Wild cabbage	160	66	50	–	–	–
Mold	Green bean sprout	93	7	14	6	–	–
(per gram)	Wild cabbage	31	15	20	–	–	–
Colon bacillus	Green bean sprout	72400	2400	200	–	–	–
(per gram)	Wild cabbage	–	–	–	–	–	–

2.2.2. Dehydrated vegetables

The objective of irradiation was sterilization. The suitable dose range and the change of nutrient components in treated dehydrated vegetables were investigated.

2.2.2.1. Irradiation sterilization

The effect of different irradiation doses on the microbiological quality of dehydrated vegetables is shown in Table V. The results show that unirradiated dehydrated green bean sprouts have a higher microbiological count than dehydrated wild cabbage. A dose of 5 kGy was adequate to reduce the microbiological count of dehydrated wild cabbage to zero. A dose of 7 kGy was required to achieve the same results for dehydrated green bean sprouts. Microbiological counts decreased with increasing irradiation dose.

2.2.2.2. Nutrient analysis of irradiated dehydrated vegetable

The results of amino acid and trace element analysis of dehydrated green bean sprouts and wild cabbage are shown in Table VI. The results indicate that irradiation doses of 5 kGy and 10 kGy did not induce changes on Cu, Zn, Fe, Mn, amino acids and protein.

2.2.2.3. Flavor, color and water-absorption capability

(1) Flavor evaluation

After half-year of storage, no color change could be observed for the irradiated dehydrated vegetables. Irradiated dehydrated green bean sprouts kept its original yellow color and irradiated dehydrated wild cabbage maintained its yellow green color and its good flavor. The color of unirradiated samples changed due to the growth of bacteria and insects.

TABLE VI. THE EFFECT OF DIFFERENT IRRADIATION DOSES ON AMINO ACID AND TRACE ELEMENT COMPOSITION OF DEHYDRATED VEGETABLES

Item	Green bean sprouts			Wild cabbage		
	Control	5 kGy	10 kGy	Control	5 kGy	10 kGy
Total Amino Acid	20.78	20.16	20.58	7.17	6.96	6.96
Aspartic acid	6.36	6.47	6.04	0.86	0.87	0.84
Threonine	0.84	0.78	0.84	0.37	0.34	0.36
Serine	0.91	0.80	0.92	0.40	0.41	0.41
Glutamic acid	1.67	1.48	1.80	1.52	1.45	1.45
Glycine	0.68	0.61	0.72	0.38	0.38	0.38
Alanine	0.92	0.87	0.95	0.41	0.42	0.42
Cystine	min.	min.	Min.	min.	min.	min.
Valine	1.59	1.59	1.55	0.42	0.43	0.43
Methionine	0.29	0.19	0.23	0.10	0.09	0.13
Isoleucine	1.05	1.07	1.08	0.31	0.30	0.31
Leucine	1.24	1.23	1.32	0.50	0.49	0.49
Tyrosine	0.50	0.52	0.53	0.20	0.20	0.21
Phenylalanine	1.03	1.11	1.11	0.25	0.25	0.25
Histidine	0.76	0.63	0.69	0.49	0.46	0.41
Lysine	1.23	1.16	1.16	0.48	0.42	0.39
Arginine	1.70	1.65	1.65	0.48	0.46	0.49
Cu	14.7	14.3	14.2	4.30	4.70	6.30
Zn	56.1	54.3	50.8	14.60	17.00	14.80
Fe	76.3	60.6	59.5	57.50	50.80	53.80
Mn	14.7	13.7	12.6	9.30	9.70	9.40
Crude protein	30.18	31.19	29.23	10.18	10.03	9.91

TABLE VII. EFFECT OF IRRADIATION DOSES ON WATER ABSORPTION CAPACITY OF DEHYDRATED VEGETABLES (Weight increase on immersion in water for 10 minutes)

Vegetable	Irradiation dose (kGy)					
	0	1	3	5	7	10
Dehydrated green bean sprouts	1:4.2	1:4.4	1:4.2	1:4.2	1:4.2	1:4.1
Dehydrated wild cabbage	1:4.5	1:4.0	1:4.3	1:4.3	1:4.3	1:4.1

(2) Water absorption capacity

Water absorption capacity as measured by weight of water absorbed by 48 grams of the irradiated dehydrated vegetables kept in water for 10 minutes was not affected by irradiation. The results are shown in Table VII.

The above results indicated that irradiation at 7–8 kGy was adequate to reduce the microbiological count of the above dehydrated vegetables to zero without obvious color and flavor changes and changes in amino acid and trace element composition.

2.2.3. Spices

The objective of irradiation was disinfestation. Irradiation processing parameters and irradiation doses were investigated following ICGFI recommendations (Document No. 5 [1]).

2.3. Establishment of a quality control system for industrial scale irradiation of food and agricultural products following the recommendation of ICGFI and Codex General Standard

A quality control system for assuring the quality of irradiated food was established. The key point of the system was to implement ICGFI and Codex recommendations for proper irradiation processing. The objective of the system was to ensure that the desired quality of treated products was achieved. Quality assurance involved dose mapping of the irradiation chamber, irradiation processing, control and inspection. The procedure for effective inspection to ensure that all required controls are implemented and described as follows:

Assurance of quality of agricultural products and irradiation treatment
Inspection of products' quality before irradiation. Selection of packaging material
Determination of processing dose. Irradiation of test sample

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Assurance of irradiation facility
Equipment documents. Test and calibration of equipment
Assurance of irradiator facility. Assurance of irradiation capacity

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Assurance of irradiation processing
Determination of product arrangement method. Determination of operation parameter.
Distribution of irradiation dose

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Daily irradiation control
Operation parameter. Supervision of irradiation dose. Evaluation of product quality after irradiation

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Storage control of product
Separate storage for irradiated and unirradiated products. Label for irradiated food

2.4. Consumer acceptance and market test for several irradiated foods

Studies on food irradiation started in China in the 1950's. Thirty years of research resulted in several achievements. In the 1980's exploratory activities for industrial production and commercial application began and as people gradually realized the advantages of food irradiation, the technology developed at an accelerated pace after 1990. With the support of the State Science and Technology Commission, China National Nuclear Corporation, the Ministry of Agriculture and the Ministry of Public Health, about 30 market tests and consumer acceptance investigations were carried out on different foods and at several cities during the past decade. The advantages of irradiated food were promoted and irradiation technologies were introduced to producers. Industrial production and commercial applications has developed rapidly in recent years.

TABLE VIII. THE PROCEDURE FOR ASSURANCE AND SUPERVISION OF IRRADIATED FOODS

(1) Assurance of products The supplied foods must be evaluated before irradiation. At first the food should be cleared for irradiation treatment by related authority of the government, and GMP documents should be verified. (2) Assurance of irradiation facility The irradiation facility for treatment of food should be examined and approved by related department of the government. The design of the facility should satisfy the requirements for wholesomeness of the food and effectiveness of irradiation processing. Trained employee and a detection laboratory (for dose measurement and microbiology) should be provided. (3) Assurance of irradiation processing Irradiation parameters for treatment of products, especially new products must provide assurance that the absorbed dose is adequate. (4) Daily irradiation control During the operation of the irradiation facility, the written record of the treatment procedure must be kept before, during and after irradiation for checking. The contents of records should include products geometry, condition during irradiation, key processing parameter and measurement of absorbed dose. (5) Storage control The objective of storage control is to avoid the mistake of repeat irradiation. Stick an irradiation label on product containers for the purpose. According to the requirement for industrial scale food irradiation of the Chinese government, irradiation processing standards for 30 food items were prepared by our institute. These standards will be submitted to the Chinese government at the end of the year for clearance. This will facilitate the development of food irradiation.

2.4.1. Market test and consumer acceptance

Two market tests and consumer acceptance investigations were conducted in Beijing. Irradiated rice, garlic, mushroom, pepper powder, braised chicken, healthy food, longan, cooked meat, refrigerated meat and others were put on display and sold.

The results of consumer acceptance investigations are shown in Tables IX and X. The results indicate that consumers were interested in the quality of products. More than 70 per cent of consumers investigated thought that a special marker should be used to help them identify the irradiated food and which could show that the food was strictly treated according to requirements. The results also showed that about 80% of producers and consumers like to try the new technology.

2.4.2. The promotion of irradiated food

A videotape titled “Irradiated Food In China” was broadcast on China Central Television (CCTV). A total 40 copies has been sold nationwide. In every kind of meeting, the advantages of irradiated food were introduced to factories and consumers. A new video entitled “Food Irradiation Processing and Commercial Application” will be completed this year for broadcast on CCTV.

TABLE IX. PUBLIC ACCEPTANCE QUESTIONNAIRE FOR IRRADIATED FOOD

No.	Questions
1	Do you know foods including grain are all treated by means, for example of chemical fumigation and insecticides, to prevent insect growth and putrefaction?
2	Do you have an idea that irradiation can be used for elimination of insects and bacteria, to keep food fresh and prevent putrefaction?
3	Do you know it is safe, reliable, economical and non-polluting to use irradiation for disinfestations of insects and inactivation of bacteria in foods ?
4	Do you know that hygienic standards for 18 irradiated foods have already been issued by government?
5	Which will you choose between chemical or antiseptic treated food and irradiated food?
6	Do you think irradiated food needs a special marker to show it was irradiated?
7	After our introduction, will you choose irradiated food in future?

Investigation place: Dianmen Market, Beijing. Date: February 1996.

TABLE X. RESULTS OF INVESTIGATION OF THE LEVEL OF PUBLIC ACCEPTANCE FOR IRRADIATED FOOD

Question number	Answer	Market Group	Institute Group
		Percentage	Percentage
1	Yes	74	88
	No	26	12
2	Yes	68	82
	No	32	18
3	Yes	65	74
	No	35	26
4	Yes	33	33
	No	67	67
5	Yes	28	15
	No	72	85
6	Yes	78	90
	No	22	10
7	Yes	81	91
	No	19	9

TABLE XI. QUANTITY OF SPICES IRRADIATED FROM 1995 TO 1998

Year	Total (tons)	Garlic Powder	Onion Powder	Red Pepper	Others*
1995	120				
1996	600	180	120	240	60
1997	2400	720	480	960	240
1998	5000	1500	750	2000	750

*Including ginger powder, black and white pepper powder, etc.

TABLE XII. COST PRICE, SELLING PRICE AND IRRADIATION FEE FOR IRRADIATED FOOD

Year	Name of products	Cost price (10,000 yuan/ton)	Selling price (10,000 yuan/ton)	Irradiation fee (yuan/ton)
1995	Garlic powder	0.6	0.8	480
	Onion powder	0.7	1	480
	Red pepper powder	2	2.2	480
1996	Garlic powder	0.6	0.8	480
	Onion powder	0.7	1	480
	Red pepper powder	2	2.2	480
1997	Garlic powder	1.2	1.4	500
	Onion powder	1.15	1.5	500
	Red pepper powder	0.75	0.9	500
	Chinese prickly ash	1.4	1.6	500
	Aniseed	2	2.4	500

TABLE XIII. QUANTITY OF MAJOR IRRADIATED DEHYDRATED VEGETABLES

Year	Name of Product	Amount irradiated (ton)	Cost price (10,000 yuan/ton)	Selling price (10,000 yuan/ton)	Irradiation fee (yuan/ton)
1997	Carrot granule	500	1.25	1.45	500
	Korea cabbage	250	1.25	1.6	250

2.4.3. Market development and economic benefit analysis of major irradiated foods

Along with consumer education, the market for major irradiated foods namely, rice, dehydrated vegetables and spices was developed. In cooperation with related factories in Beijing, the Chinese Agricultural Irradiation Center (which belongs to the Institute for Application of Atomic Energy, Chinese Academy of Agricultural Sciences) successfully developed the market for irradiated foods, and made great achievements in recent years.

We like to illustrate this by an example; the Beijing Meiquan Food Limited produced a variety of spices and dehydrated vegetables. The treated spices and dehydrated vegetables were supplied to instant noodle and quick-frozen food companies as materials and these companies required that the material must be treated by irradiation (1996–1998).

Income from irradiation fee for treated products (in 1997) was only 4% of total cost for garlic powder, 4.3% of total cost for onion powder and 6.7% of total cost for red pepper powder.

The products listed in above tables were supplied to following instant noodle companies in the following cities: Tianjin, Beijing, Wuhan, Guangzhou, Kunshan and Chengdu. The products of the Beijing Meiquan Food Limited were irradiated in four irradiators in Beijing, about 50% was treated in our irradiation facility.

The following results were obtained from an analysis of the economic benefit coefficient for above products according to the formula: $F = (I - C)/C$ [2] where I is income per hour, and C means operation fee per hour. The economic benefit coefficient is an indication of the rate of benefit from the irradiation of a certain food item. The higher the economic benefit coefficient, the higher the benefit rate. The factors affecting the economic benefit coefficient include irradiation dose, operation time per year, arrangement of products, etc.

Total operation cost should included depreciation of fixed capital, operating costs, cost (salary for employees, energy cost, management and maintenance cost, and others). The cost for the operation of the facility is shown in Table XIV.

TABLE XIV. COST FOR THE CHINESE AGRICULTURAL IRRADIATION CENTER

Items	Investment (10,000yuan)	Depreciation rate	Cost per year (10,000 yuan)
Construction	800	4.0%	32
Source	170	12.5%	21.5
Machinery	70	10.0%	7
Total	1040		60.5

TABLE XV. OPERATING COST FOR THE CHINESE AGRICULTURAL IRRADIATION CENTER

Items	Cost per year (10,000 yuan)
Salary	9.6
Pay for temporary workers	6
Electricity, water cost	7
Facility maintenance	1
Management cost	5
Others	2
Total	30.6

The total cost for the Chinese Agricultural Irradiation Center per year was 911,000 yuan RMB representing the sum of the operating cost and fixed capital cost.

The main food item irradiated in the Center was spices. Irradiation fee was 300 yuan RMB per hour (irradiation dose: 6–7 kGy), the cost for operation per hour was 130 yuan, so $F = (300 - 130)/130 = 1.31$.

For dehydrated vegetables, the irradiation fee was 400 yuan (irradiation dose 4 kGy), so $F = (400 - 130)/130 = 2.08$.

Comparing the calculated results of irradiated spices and dehydrated vegetables, economic benefit of low dose dehydrated vegetables irradiation was obviously higher than that of high dose spice irradiation in the 200 kCi capacity source of the Chinese Agricultural Irradiation Center.

Due to policy change and reform in the system for providing food in China in recent years, the amount of irradiated rice decreased yearly. To assure benefit from the irradiation of a product like grains, assurance of a sufficient supply of the commodity is necessary and the transportation must be considered.

3. EVALUATION OF RESEARCH PROGRAM

The research described above has been completed during the past four year. The original plan and objective of this program were to establish a system and standard for irradiation processing as well as a quality assurance system for irradiation of food. With wide publicity to factories and shops, about 70-80% consumers liked to try irradiated food. More and more food companies accepted this new food technology. This could be identified from the rapid increase in the amount of food irradiated at the Chinese Agricultural Irradiation Center. More than 95% of treated products in the Center were food items. This was also the objective of establishing the irradiation center. It was a good start for irradiation technology transfer from the laboratory to industrial and commercial application. With more and more interest from food companies, the application of irradiation technology should be supported and standardized by the government. Wholesomeness standards for six categories of irradiated food were promulgated by the Chinese government this year. This will surely facilitate the development of irradiation technology. For the irradiation company, food irradiation brings good economic benefits and significant social effects.

4. RESEARCH WORK IN THE FUTURE

The research and commercial application of irradiated food in the Chinese Agricultural Irradiation Center has been carried out for many years. The Chinese Agricultural Irradiation Center was also a major institute for the study of food irradiation application in China. The work plan for next few years is as follows:

(1) Follow the ICGFI Recommended Code and Codex, the Chinese standards for irradiation processing of food will be completed and promulgated by the government before 2000. These standards will ensure the processing quality of commercially irradiated food.
(2) Continue to develop new irradiated food items for commercial application.
(3) Complete the video on "Irradiation Processing and Commercial Application of Irradiated Food".
(4) Develop the regional and international trade test for selected irradiated food items, to investigate the problems that will occur in import and export trade of irradiated food. This work needs the support of IAEA and other international organizations.
(5) Carry out the feasibility research for irradiation as a quarantine treatment.

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