TEST MARKETING AND CONSUMER ACCEPTANCE OF IRRADIATED MEAT PRODUCTS

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Abstract. This study consists of two parts: irradiation processing of cooked meat and irradiation preservation of prepackaged chilled fresh cut meats. Irradiation of prepackaged pickled meat products dipped in grains stillage+ at a dose 6–8 kGy eliminated common food-borne microorganisms, such as *E. Coli* and other microbial pathogens and extended the shelf life of the product to 10 days at 5°C. Test marketing of 40,000 bags (about 10,000 kg) of the product in more than 100 supermarkets in the city of Shanghai showed no untoward problem with consumer acceptance. Irradiation of prepackaged chilled fresh cut pork at a dose 3 kGy led to inactivation of microbial pathogens and parasites with a concomitant reduction in numbers of common spoilage microorganisms and extension of shelf life of the product for 30 days at 5°C. The cost benefit and marketing applications were evaluated.

Grain stillage is the mixture of Chinese yellow wine distilled from grain and spices squeezed into the wine. The mixture is held in the pottery vessel for about a year followed by addition of boiled water with spices in the vessel.
Pickled boiled pork, poultry or organs are then soaked in the extract and stored at 2^0C for 4–6 hours before consumption.

1. INTRODUCTION

Food irradiation is an extremely promising technique that could substantially increase the supply of safe food and contribute to improving public health throughout the world. Over the years, special research efforts have been put into two important applications of food irradiation namely, the reduction of food losses and the incidence of food-borne diseases. Food-borne disease has been a major factor adversely affecting human health and productivity in many parts of the world. Foods, especially of animal origin, which are contaminated with microorganisms, particularly pathogenic non-spore-forming bacteria, or infected with parasitic holminthes and protozoa, have been a cause of human suffering and malnutrition.

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According to WHO, up to 70% of diarrheal diseases which cause about 25% of all deaths in developing countries, have food as the transmission vehicle for the causative agents. In the United States of America, there are between 24 and 81 million cases of food-borne diseases every year, and some 10,000 cases lead to death. Salmonellosis alone accounts for about 2 million of these cases and is estimated to cost at least US $1,500 million annually [1].

USDA agricultural economists and parasitologists recently estimated that the total annual cost, which includes income losses, medical cost, and over a lifetime of disability, due

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to congenital toxoplasmosis in the USA is of the order of US $5 billion. About half of the cases are estimated to be related to pork consumption, compared to 781,578 due to trichinellosis. Medical and productivity loss attributable to toxoplasmosis from meat and poultry consumption costs over US $2.6 billion. This far exceeds that for individual microbial pathogens as well as for other parasites of concern [1].

It has been demonstrated that ionizing radiation can eliminate or greatly reduce the population of microbial pathogens in food products and extend shelf life while preserving the desired nutritional and sensory properties. In fact, food irradiation is now recognized as an important post-harvest technique for food industries and the technology may become a viable alternative to hazardous chemical treatment. The Shanghai Irradiation Center has conducted R&D projects on irradiated prepackaged meat products for many years. The projects have been carried out in collaboration with the Shanghai Institute of Food Hygiene and Supervision and supported by the Science and Technology Commission of the Shanghai Municipality.

The Center took part in the Research Agreement No. 8167/CF of the FAO/IAEA Co-ordinated Research Programme on Public Acceptance and Market Development of Irradiated Food in Asia and the Pacific. This Research Agreement No. 8167/CF is entitled "Test Marketing and Consumers Acceptance of Irradiated Meat Products". It includes two sub-projects: Irradiation pasteurization of prepackaged cooked meat products and Irradiation processing of prepackaged fresh chilled/refrigerated cut pork.

2. STUDY OF IRRADIATION PASTEURIZATION AND TEST MARKETING OF PICKLED MEAT PRODUCTS WITH GRAIN STILLAGE

2.1. Irradiation of cooked meat products

Cooked meat products are important ready-to-eat food in China and constitute a large portion of China's meat consumption. The meat products are processed by cooking or boiling. However, they could be contaminated by microorganisms in the course of storage, transportation, selling, cutting and packaging. Without an effective means to disinfect the product after packaging, the hygienic quality of the meat products is still an open question. High temperatures and pressures cannot be used for Chinese dishes, especially Chinese meat products with a special color, flavour and taste. Therefore, food irradiation processing through "cold disinfection" has been welcomed by the food industry in China and in 1994, a national standard on this type of food "Hygienic Standard for Irradiated Cooked Meat Food" (G B 14891.10) was established by the Ministry of Public Hygiene. Since then, the number of food factories that use food irradiation for this purpose has increased gradually.

Pickled meat products are special type of meat products prepared by dipping boiled pork, poultry and organs (e.g. tongue, belly, gizzard, etc.) in rice wine, salt and spice berry (grain stillage). This kind of food has a special flavor and is especially popular in the summer. Every year, hundreds of tons of such pickled meat products are consumed in Shanghai. A process has to be developed that can replace high temperature sterilization used to ensure the hygienic quality of the prepackaged pickled meat products with grain stillage and extend shelf-life, while maintaining the special color, flavor and taste of the product. Based on these requirements, the Shanghai Irradiation Center and Shanghai Institute of Food Hygiene Supervision and Inspection jointly conducted studies on irradiation pasteurization, test marketing and consumer acceptance of the irradiated pickled meat product.

2.2. Study on irradiation pasteurization of prepackaged pickled meat products with grain stillage [2]

2.2.1. Materials and method

Pickled chicken or pork with grain stillage were vacuum-packaged with OPP/PET film bag. The samples were divided into four groups namely, 1) the control, 2) 6 kGy irradiation, 3) 8 kGy irradiation, and 4) the microbial test group. Each group had 90 bags of product. The groups were further divided into three subgroups. The products of subgroups of Group 1, 2 and 3 were stored at <10°C, 23°C and 35°C respectively, after irradiation. The products of the subgroups of Group 4, were inoculated with 1×10^3 cfu/g of *E. Coli*, and the treatments repeated on Group 1, 2 and 3. Regular observations were made to monitor changes of the samples in Group 1, 2 and 3 in terms of color, flavor and taste. Group 4 was used for microbial tests, which were performed as stipulated in China's National Standard, with every single test being done on two parallels.

2.2.2. Results of the sensory tests

The samples irradiated with 6 kGy and stored at <10°C lasted for 10days without change in color and flavor. The samples irradiated at 8 kGy and stored at <10°C did not change in color, flavor and taste for the entire experimental period of 15days. However, the control group changed color on the 10^{th} day, whereas the flavor and taste changed on the 11^{th} day. Statistical calculations on the results showed $x^2 = 8.13$ and $P < 0.05$, which indicated that there were notable differences in sample observations between the control and irradiated group. There were also notable differences between the two irradiation groups. The statistical results for the latter were $x^2 = 3.84$ and $P < 0.05$.

2.2.3. Shelf life of the samples under different storage temperatures

Shelf lives of the samples under different storage temperatures are shown in Table I. Statistical calculations of the shelf lives indicated $x^2 = 3.84$ and $P < 0.05$ between the two irradiation groups. All the differences were notable.

TABLE I. SHELF LIFE OF IRRADIATED PICKLED MEAT PRODUCTS WITH GRAINS STILLAGE AT DIFFERENT STORAGE TEMPERATURES AND IRRADIATION DOSES

Storage	Control			6 kGy			8 kGy		
Day	<10°C	23°C	35°C	<10°C	23°C	35°C	<10°C	23°C	35°C
2	-[a]	+[b]	+	-	-	-	-	-	-
3	-	+	+	-	+	+	-	-	-
4	-	+	+	-	+	+	-	+	+
5	-	+	+	-	+	+	-	+	+
6	-	+	+	-	+	+	-	+	+
7	-	+	+	-	+	+	-	+	+
8	-	+	+	-	+	+	-	+	+
9	-	+	+	-	+	+	-	+	+
10	+	+	+	-	+	+	-	+	+
11	+	+	+	+	+	+	-	+	+
15	+	+	+	+	+	+	-	+	+

[a]Mark (-) means that the sensory results and microorganisms in the samples conform to the National Hygienic Standard.

[b]Mark (+) means that the sensory results and microorganisms in the sample do not conform to National Hygienic Standard.

[c]Between control and irradiation groups, $x^2 = 7.46$, $P<0.05$.

[d]Between the 6 and 8 kGy groups, $x^2 = 3.84$, $P<0.05$.

2.2.4. Results of microbial tests of the contaminated group

E. coli, 1×10^3 cells/g, was added to group 4 of the samples. The subgroups 2 and 3 were irradiated to 6 and 8 kGy, respectively. The subgroup I was the control. Ten samples in the subgroups were stored at <10°C, 23°C and 35°C, respectively. Microbial tests on the samples were done everyday during the experimental period. The results are shown in Table II.

TABLE II. RESULTS OF MICROBIAL TESTS ON GROUP 4 OF THE SAMPLE (CFU/g)

Storage	Control			6 kGy			8 kGy		
Day	<10°C	23°C	35°C	<10°C	23°C	35°C	<10°C	23°C	35°C
2	0	1.4×10^5	1.4×10^5	40	20	<10	30	<10	120
3	2.3×10^3	3×10^4	3×10^5	<10	3×10^6	3×10^6	<10	90	1.2×10^5
4	1.2×10^3	U.C.	U.C.	<10	3×10^6	3×10^6	100	3×10^6	3×10^6
9	1.4×10^4	U.C.	U.C.	<10	U.C.	U.C.	<10	5.3×10^6	U.C.
10	3.4×10^4	U.C.	U.C.	1.9×10^5	U.C.	U.C.	400	U.C.	U.C.
11	9×10^6	U.C.	U.C.	2.8×10^6	U.C.	U.C.	<100	U.C.	U.C.
15	U.C.[a]	U.C.	U.C.	6×10^6	U.C.	U.C.	80	U.C.	U.C.

[a] U.C. means unable to count.

[b] Compare the rate of qualified and unqualified samples between the control and irradiated groups, $x^2 = 7.96$, $P < 0.05$.

The results showed that irradiation pasteurization can effectively prevent the growth of microorganisms. The results of *E. coli* tests are similar to these results. Bacterial pathogens of the samples were not studied.

2.3. Test marketing and consumer acceptance of the irradiated products

The irradiation pasteurized prepackaged pickled meat products with grain stillage that had been used in industrial production (the irradiation dose 8 kGy), had a shelf life of 10 days under 5°C.

For test marketing, a laser viscose label was placed on the top side of bag. It was marked with the terms "Irradiated Pasteurized Food", "Chinese Food Hygiene Inspection" and the international logo for food irradiation. A total of 40,000 bags (about 10,000 kg) of irradiated products with the above label were sold for about 1 month (from July to Aug. 1996) in more than one hundred supermarkets in the city of Shanghai. The sale was normal in the entire period and no opposing views were received.

Data on consumer acceptance had been carried out many times before. In visiting consumers, the following remarks were obtained:

"These irradiated products are cleared by the government, we believe that these foods are hygienic and safe."

"This laser label is a label of a high quality product."

"On the label had been marked Chinese Food Hygiene Inspection, means this product is reliable."

"I had tasted these products, the quality and flavor are all nice, so that I buy these products many times."

The above consumer remarks indicate that the test marketing of irradiated products with the irradiated food label was successful and that consumers can accept irradiated food.

3. STUDY OF IRRADIATION PRESERVATION OF PREPACKAGED FRESH CHILLED PORK

3.1. Fresh chilled meat consumption in Chinese cities

China is a big country for raising hogs and consuming pork. According to statistics, the output of pork reached 37 million tons in 1995, almost a half of the world's output. Per capita consumption has reached about 31 kg/man year, making pork the chief source of meat for Chinese people.

Prepackaged fresh chilled pork has been widely sold in supermarkets in large Chinese cities with a higher standard of living and where more goods are sold in supermarkets. There is high consumer demand today and even more in the next century, for natural, nutritious, convenient and good-tasting food that is fresh or fresh-like, preferably non-frozen, with extended shelf life.

Several interrelated factors such as storage temperature, gaseous environment, pH, water activity, light, indigenous enzymes and the presence of microorganisms affect meat stability (shelf life) and keeping quality. Microbial growth is, by far, the most important factor in the shelf life and keeping quality of fresh meat and is influenced by many of the above factors. Losses of up to 20 million pounds of meat due to microbial spoilage have been reported in the United States [3], and 90% of these losses could be accounted at slaughter, fabrication and in the retail area. Losses due to spoilage of unprocessed meat could account for higher figures than those mentioned, particularly in markets with a lack of an appropriate cold food chain. Current practices for the production and distribution of fresh meat are inadequate to protect consumers. For these reasons, prepackaged fresh chilled meat were developed and used, which have the following advantages:

- Holding of product at low temperature (0–5°C), from slaughter to retail;
- Protection of products from second contamination in the course of transportation, storage and retail;
- The meat finishes the "post-ripening course " under low temperature, resulting in better taste and flavor than the non-chilled fresh meat and frozen meat;
- The use of vacuum packaging or a vacuum-protective atmosphere package to prevent growth of spoilage microorganisms helps in extension of shelf life;
- Prepackaging is convenient for consumption.

Prepackaged fresh chilled meats are thus popularly consumed in the big Chinese cities. However, the shelf life of prepackaged fresh chilled meat is limited to about 7–10 days. Moreover, infectious parasites and microbial pathogens are not all eliminated. For this reason investigations on the use of irradiation processing were considered.

The primary purpose of irradiating meat is to eliminate microbial pathogens (e.g. *Camphlobacter jejuni*, *Escherichia coli* 0157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, the *Salmonellae*, and *Yersinia enlerocolitica*) and infections parasites (e.g. *Trichinella spiralis*, *Toxoplasma gondii* and *Taenia solim*), thereby reducing related incidence of foodborne illness and loss of life. In addition to realizing this public health objective, the technology can also provide economic benefits by extending the non-frozen (i.e. fresh and defrosted) edible-marketable life (shelf life) of meat.

In Shanghai, the daily consumption of pork is about 700 tons (1997), a greater part of these is fresh pork. From slaughter to retail or cooked, the time may be less than 24 hr under the non chilled/refrigerated condition. To ensure hygienic quality and to extend shelf life of fresh pork, the study of irradiated fresh pork is important. Shanghai Irradiation Center and Shanghai Institute of Food Hygiene Supervision and Inspection had combined to study this aspect under the support of the Science Technology Committee of Shanghai Municipality.

3.2. Irradiation preservation for prepackaged fresh chilled pork

The purposes of irradiation processing of prepackaged fresh chilled pork are the following:

- inactivitation of pork-borne parasites;
- elimination of bacterial pathogens from fresh pork;
- destruction of spoilage microorganisms in order to extend shelf life.

Our study included establishment of irradiation processing techniques, test of shelf life and test of quality (sensory test, physical–chemical test and microorganism test)

3.2.1. Test of irradiation dose

Fresh leg meat of pork (with the fat discarded) was purchased, washed by water, cut to 100g/piece, and vacuum-packed by OPP/PET film bag. These samples were used for the test.

Irradiation doses of 3 kGy and 6 kGy were tried. Ten (10) bags of control and irradiated samples were used for the test. After irradiation the samples were stored at 2–4°C in a refrigerator. Test of microbial counts and sensory characteristics were carried out on days 1, 20 and 40 after irradiation. The results are shown in Table III.

TABLE III. MICROBIAL COUNTS OF FRESH CHILLED CUT PORK AT DIFFERENT IRRADIATION DOSES AND STORAGE TIME AT 2–4°C (CFU/g)

Storage days	Control	2 kGy	6 kGy
1	3×10^5	<10	<10
20	U.C.[a]	830	<30
40	U.C.[a]	780	<30

[a] U.C means unable to count.

Results of sensory analysis indicated that the color of control samples changed to dark red after the seventh day and to grey white after the 30th day, but the color of irradiated samples (3 kGy and 6 kGy) were normal fresh-red up to the 40th day.

According to reports of Urbain, the D_{10} value of spoilage microorganisms in pork is only 01 kGy [4]. Many authors report the same conclusions. On this basis, the dose for the irradiation preservation of pork was fixed at 3 kGy.

3.2.2. Shelf life test of irradiated prepackaged fresh chilled pork

Fresh leg meat of pork (with fat discarded), was washed by water, cut in 100 g or 200 g per piece per bag, than vacuum-packed by OPP/PET film bag and irradiated by gamma ray. The samples were packed in a cardboard box and stored in a refrigerated warehouse (2–4°C, R.H.85%). Evaluation of samples were carried out at the Shanghai Institute of Food Hygiene,

Supervision and Inspection after 1, 10, 20, 30, 40, 60 days. The results are shown in Tables IV and V.

TABLE IV. THE COUNTS OF *E. COLI* AND BACTERIAL PATHOGENS AT DIFFERENT STORAGE TIMES (cells/100g)

	E. coli		Bacterial Pathogens	
Storage days	Control	Irradiated	Control	Irradiated
1st	2400	<30	no[b]	no
30th	-[a]	<30	-	no
60th	-	<30	-	no

a. Mark (-) means determination was not made because microbial counts were more than 10^7 CFU/g after the 10th day.
b. Mark (no) means bacterial pathogens in samples were not detected.

TABLE V. THE TVBN VALUE OF SAMPLES DURING STORAGE (mg/100 g)

Storage Days	Control	Irradiated
1st	5.31	5.26
20th	16.6	8.03
60th	-[a]	12.9

[a] Mark (-) means TVBN of sample was not tested.

Based on above-mentioned test results, the shelf life of prepackaged fresh chilled pork at a dose of 3 kGy was 30 days at <5°C. Quality was in accordance with National Hygienic Standard GB 2704

3.3. Inactivation of meat-borne parasites and elimination of bacterial pathogens from fresh meats [21, 22]

3.3.1. Inactivation of meat-borne parasites

Studies on the inactivation of meat-borne parasites were presented in Table VI.

3.3.2. Elimination of bacterial pathogens from fresh meats

Results on this subject are shown in Table VII.

TABLE VI. INACTIVATION DOSE FOR MEAT-BORNE PARASITES

Object	Inactivation dose (kGy)	Authors	Ref.
Trichinella spinalis	0.3 - 0.6	Kasprzak	[5]
	0.15 - 0.3	Brake	[6]
Toxoplasma gondii		Dubey	[7]
		Murrell	[8]
Taenia spp.	0.6 - 0.7	Smith	[9,10]
			[11]

TABLE VII. D_{10} VALUE FOR THE IRRADIATION OF BACTERIAL PATHOGENS

Object	D_{10} value (kGy)	Condition	Authors	Ref.
A. Vegetable pathogens				
Aeromonas hydrophia	0.14–0.19	beef	Palumbo	[12]
Yersinia enleroclitica	0.20	beef	El-Iawahry	[13]
Campy lobacter spp.	0.18	refrigerated	Clavero	[14]
Salmonella spp.	0.51	5°C, pork	Thayer	[15]
Listeria monocytogenes	0.47	beef, pork	Thayer	[15]
Escherichia coli 0157:H7	0.25	3–5°C	Thayer	[16]
Staphlococcus aureus	0.45	beef	Beuchat	[17]
B. Spore forming pathogens				
Bacillus spp	0.18/2.56[a]	4°C	Thayer	[18]
Clostridium perfringes	0.586/[b]	4°C	Grant	[19]
Clostridium botulinumA	3.73–3.85	0°C	Grecz	[20]

[a] left is D_{10} of vegetative cell, right is D_{10} of spore.
[b] D_{10} of spore has not been reported.

3.4. Simulated production of irradiated prepackaged fresh chilled pork

Tests simulating commercial operations (production, irradiation, transportation and storage), were carried out. The samples of commercial prepackaged fresh chilled cut pork (vacuum-protective atmospheres package) was produced by the Shanghai Long Hui Meat Products Co., where fresh cut pork are all held under 5°C after slaughter. Transportation time from factory to our Center was about one hour and irradiation (dynamic irradiation by chain) time was about 6 hours, at a room temperature of about 15-25°C. Irradiated samples were stored at 2–4°C in a refrigerated warehouse. After irradiation, samples were tested after 35 days. The results of microbial and TVBN tests are shown in Table VIII.

TABLE VIII. QUALITY TEST ON IRRADIATED PORK AFTER 35 DAYS

Item	Results
Microbial counts, cfu/g	<30
E. coli,cells/100 g	<30
Bacterial pathogens	None
TVBN, mg/100 g	19.6

According to above results, a shelf life of 30 days can be achieved for irradiated commercial prepackaged fresh chilled pork. This will bring many benefits and convenience to the consumer in the production, transportation, storage, sale and consumption of the product.

Sensory test of irradiated pork (stored for 25 days) was carried out at the Shanghai Mei Long Zheng Restaurant. The color, taste, flavor and smell after cooking were all the same as when fresh pork was used for cooking as concluded by cooks of this Restaurant.

3.5. Market application of irradiated prepackaged fresh chilled cut pork

The marketing test of irradiated pork had not progressed due to lack funds and co-operation from a company or factory. These marketing tests may progress with the support of government or a big group of company. The application of irradiation processing can be wider. The cost-benefit analysis was analyzed and discussed below.

Using a gamma ray irradiator, and an irradiation dose of 3 kGy and a considering a throughput per hour of hundreds of kg for a $1\text{-}2\times10^5$ Ci source, the cost of irradiation is about 0.3-0.4 yuan R.M.B/kg. The irradiation service price will be about 0.60 yuan R.M.B/kg. The cost analysis is shown in Table IX.

TABLE IX. COST ANALYSIS FOR THE GAMMA IRRADIATION OF PORK (R.M.B yuan/kg)

Item	Results
Pork, material	10.60
Package	0.50
Transportation	0.40
Irradiated	0.60
Storage	0.30
Total	12.40
Wholesale price	12.80[a]

[a] The wholesale price is same as fresh cut pork (unpacked).

Based on the above results, application of gamma irradiation processing for prepackaged pork poses some questions which affect the cost benefit of the process.

(1) Throughput per hour is too little and cannot satisfy the need for commercial operation.
(2) Irradiated cost and irradiated service price is high and will influence economic benefit of irradiating this type of product.

The high energy (8–10 MeV) linear electron accelerator has a big application in food irradiation and could have the following advantages:

(3) Processing speeds are very fast.
(4) Processing throughput in tons per hours that can satisfy commercial scale application needs can be achieved. Irradiation cost can drop along with throughput.

For example, for a 10 MeV 10 kW linear accelerator (e.g. LINAC), the scanner width is 60 cm. With this electron energy, maximum practical penetration thickness is about 8 cm of unit density material (irradiated on both sides) which is enough to satisfy irradiation needs of cut pork. According to count, the throughput per hour is about 3 tons/hour. If an electron accelerator were used, the cost-benefit analysis is shown in Table X.

TABLE X. COST BENEFIT ANALYSIS FOR THE IRRADIATION OF PORK BY LINEAR ACCELERATOR

Item	Price, R.M.B. yuan/kg
Pork, material	10.60
Package	0.50
Transportation	0.20
Irradiated	0.10
Storage	0.30
Total	11.70
Wholesale price	12.80

Based on above analysis, the commercial application of irradiated pork by linear accelerator is feasible. The economic benefit is remarkable, the social benefit for reducing food-borne diseases, extending shelf life and reducing losses of pork, is also remarkable.

4. CONCLUSIONS

The study of irradiation pasteurization of pickled meat products with grains stillage had progressed satisfactorily. Results of study showed that irradiation pasteurization was useful for enhancing hygiene quality and extending shelf life of the products. Shelf life of irradiated products was 10 days at 5°C. Irradiation pasteurization was carried out in large scale and achieved a success.

The test marketing and consumer acceptance of irradiated pickled meat products with grain stillage was also carried out. A total of 40,000 bags products (near 10,000 kg) of irradiated product was labeled and sold in more than one hundred supermarkets in Shanghai city. The consumer acceptance was better.

The study of irradiation preservation of prepackaged fresh chilled pork was carried out. A dose of 3 kGy inactivated infectious parasites and bacterial pathogens and extended shelf life up to 30 days at <5°C. Irradiated products satisfied the needs of production, storage, transportation and sales.

The cost analysis of irradiated prepackaged fresh chilled cut pork was discussed. If a 10 MeV linear electron accelerator is used for industrial irradiation, the economic benefit and social benefit are remarkable. The potential for application of this preservation technique is bright.

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