

*WORKING MATERIAL*

***The Coordinated Research Project on “Use of  
Irradiation to Ensure the Safety and Quality of  
Prepared Meals”***

*Proceedings of the 3rd FAO/IAEA Research  
Coordination Meeting (RCM)  
held in Beijing, People’s Republic of China  
22-26 May 2006*

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Vienna, Austria, 2006

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## 1. INTRODUCTION

The prepared convenience foods sector has become a significant part of the economy of many developed countries with a similar trend evolving in developing countries, where many types of ethnic foods are now also prepared as convenience foods. For example, the prepared convenience foods sector in Ireland is a significant part of the Irish economy. In 2001, just under half of the sector's total output was exported for a value of 841 million Euro, representing a 12% annual increase. The sector's strong growth both in exports and in total sales has made it one of the fastest growing sectors of the food industry in many countries.

Consumer studies carried out on convenience foods have shown that perceived time pressures contribute positively to the purchase of both prepared meals and take-away meals. Other reasons found to contribute positively to the purchase of prepared meals include not enjoying cooking for oneself, a value-for-money perception of convenience foods and different eating times of family members. With rapid urbanization and change in socio-economic status, and an ever increasing proportion of working women, the tendencies are similar in developing countries.

Traditionally prepared meals are retort-processed, or, more recently, stored frozen, whereas an increased demand exists for chilled commodities, partly due to their fresh appearance, which is more appealing to the consumer than canned or frozen meals. Freezing and retort processing are also more energy demanding. Chilled prepared foods, however, are non-sterile and potential survival of some pathogenic microorganisms and/or post-processing contamination before packaging create microbiological risks, and a considerable limitation of shelf-life. For example, in Germany a survey of prepared cooked meat products showed an incidence rate of 3.7% for *Listeria monocytogenes*. In the ethnic Korean food, Kimbab, *Salmonella* spp. [Noack and Joekel, 1993] were found in some instances especially in the summertime [Kang et al<sup>1</sup>, 2002].

Even frozen foods are not necessarily safe if already contaminated by pathogenic bacteria. This safety problem is even more aggravated in the case of chilled foods, which are more vulnerable to temperature abuse or instabilities of the "cold chain". This can result in the growth of psychrotrophic pathogens. In addition to this problem, chilled prepared meals have a limited shelf-life under chilling conditions, thereby limiting the geographical area in which they can be marketed. Therefore, technologies that will improve their microbiological safety, while extending the shelf-life, are required.

As a consequence of the increased national and international interest in the marketing of convenience and prepared foods, the food industry needs to be equipped with new ways for the production of safe and high quality prepared meals. One technology with a particular potential to achieve these objectives is food irradiation.

It is thought that research into the application of ionizing radiation to products such as prepared meals could be of ultimate benefit to consumers, industry and trade. This is particularly important for countries where the microbiological safety of many ethnic prepared meals is questionable and their shelf-life limited due to the conditions under which they are produced, stored and distributed. Food irradiation used on its own or in combination with other technologies could significantly enhance the microbial safety of such products as well as

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<sup>1</sup> Noack, D.J. and Joeckel, J. (1993). *Listeria monocytogenes*, occurrence and significance in meat and meat products and experience with recommendation for its detection and assessment. *Fleischwirtschaft* 73: 581-584.

extending shelf-life. This is of special importance for the most vulnerable individuals in society such as the immunocompromised. It is estimated that this group comprises 20% of the total world population, whether they are hospitalized or not.

Although extensive research has been carried out on the microbiological and sensorial effects of irradiating individual uncooked food items, little work has been reported on the irradiation of complex food systems such as prepared meals. In this Coordinated Research Project (CRP), the potential of using the irradiation technology for convenience foods has been investigated with regard to safety, shelf-life and overall quality, particularly in terms of sensory acceptance. A wide range of ethnic meals as well as meal components were investigated with the objective of meeting continual changes in consumer demands world-wide.

Other aspects of the CRP included the adoption of a Hazard Analysis Critical Control Point (HACCP) system for prepared meals and research into consumer willingness to purchase irradiated food at a premium price. The scope of the CRP was therefore wide-ranging.

The overall objective of this CRP was to evaluate the effectiveness of irradiation as a method to ensure the microbiological safety and extend the shelf-life of prepared meals, stored under ambient, chilled or frozen conditions, and to evaluate the sensory quality of the treated products.

The specific objective of the CRP was to use validated procedures for irradiation treatment and process control, and to use validated methods for assessing microbiological safety and quality as well as the sensory quality of prepared meals mainly of ethnic origin.

## 2. MEETING

The meeting was held at the Jia Yuan Hotel in Beijing and was attended by Research Contract/Agreement holders from China, Ghana, Hungary, India, Indonesia, Israel, Korea, Syria, South Africa, Thailand, United Kingdom and United States of America. The list of participants is attached as Annex II. Argentina is also a Research Contract holder but the investigator could not attend the meeting although a report was submitted and the abstract is included as part of this report's meeting.

The main objective of the meeting was to evaluate the achievements of the CRP since 2001.

The meeting was opened by Dr. Gong Xifeng, Deputy Directory General of the Department of International Cooperation, Chinese Academy of Agricultural Sciences (CAAS). It was also attended by Dr. Feng Dongxin, Deputy Division Chief, CAAS.

Dr. Tatiana Rubio-Cabello of the Food and Environmental Protection Section of the Joint FAO/IAEA Division for Nuclear Techniques in Food & Agriculture, Vienna, thanked Dr. Gong Xifeng for his welcome, and the CAAS for hosting the Research Coordination Meeting (RCM). In particular, she thanked Dr. Lu Daguang of Department of International Cooperation, CAAS, and his colleague Mr. Baozhong Sun for organising the meeting and for their excellent co-operation prior to the RCM. Dr. Rubio-Cabello emphasized the objectives of the meeting as well as the requirements of the Agency to publish the results of the CRP as an IAEA-TECDOC.

Dr. Amanda Minnaar and Dr. Eileen Stewart agreed to act as rapporteurs.



All participants presented a report on the work they had undertaken since 2001 with special emphasis on the research carried out since the 2<sup>nd</sup> RCM held in South Africa. The meeting agenda included an introduction of each participant followed by intensive presentations and discussion. The programme of the meeting is attached in Annex III.

### 3. ACHIEVEMENTS

The participants carried out research into more than 50 different prepared meals. Table 1 summarizes the list of the dishes investigated as well their composition, intrinsic qualities, and the analyses carried out in order to determine their overall safety and quality.

#### 3.1. General Achievements

##### 3.1.1. Predictive microbiological modelling

The investigators from Hungary used predictive microbiological modelling which could be used as an additional tool in product and process development. Its potential is obvious in predicting the growth of potential spoilage and pathogenic microorganisms as a function of processing and storage conditions. Among these tools establishment of the ComBase international database and computer programme (<http://wyndmoor.arserrc.gov/combase> and <http://www.ifr.ac.uk/combase>) is perhaps the most important. ComBase is the result of the wide cooperative effort, and it combines information on results of a very large number of microbiological studies on the growth, survival and inactivation of microorganisms, particularly pathogenic ones, forming an enormous database and offering predictive modeling softwares. Further progress in the field of this CRP and increasing efforts to invest into the automation of microbiological measurements and the development of systematically organized databases for the collected data is of great interest.

##### 3.1.2. HACCP

The objective of the work was to introduce a modified HACCP-based analysis for irradiated prepared meals that addresses potential safety hazards as well as sensorial failures, and economic risks, while pin-pointing failure modes specific to the radiation pasteurization aspects. The analysis covered all production inputs and stages, and all foreseen failure modes related to the physical, chemical and biological hazards of the prepared meals: raw materials, packaging and prepared meals. A practical 10-step approach to implement the suggested modified HACCP plan, from comprehensive analysis to validated protocol was further provided. At the final stage of this study, a collaborative HACCP was carried out on the ethnic foods of Indonesia as an example of this specific type of foods. Approaching the industrial stage of safe prepared meals was further assessed in this study. In view of the currently accelerating consumer demand and industrial production of prepared meals and convenience foods, the multi-stage approach to ingredients safety seems preferred, safety-wise, sensorial-wise, irradiation-wise and economic-wise. With proper orchestration of the radiation stages within the production chain, we can achieve better food quality and safety while practically using less radiation, yet at two or more stages.

##### 3.1.3. Consumer studies

The objective of the consumer studies was to assess and evaluate consumers' perceptions, acceptance and willingness to pay for irradiated ground beef patties. Determining consumers'

willingness to pay a premium for irradiated food products is important because this is a major factor that would determine the potential marketability and success of the product. In addition, food irradiation adds costs to the production of the product and these costs must be able to be covered by the price premium before any food manufacturer or retailer will consider selling the irradiated product. Studies carried out in the USA, using both survey and experimental economics methodologies, generally suggest that information about the nature of food irradiation technology increases consumer acceptance of irradiated prepared and processed ground beef. The research findings also indicated that consumers are willing to pay a premium for irradiated ground beef. Most of the participants also conducted consumer sensory evaluation tests to establish acceptability of irradiated prepared meals.

### **3.2. Specific achievements**

Table 1 summarizes the list of the prepared meals and their components investigated as well their composition, intrinsic qualities, and the analyses carried out in order to determine their overall safety and quality.

**Table 1:** List of prepared meals / meal components studied

<b>Participating Country</b>	<b>Animal-based Products</b>	<b>Vegetable / Fruit-based Products/Miscellaneous</b>
China	Chinese dumpling Wuxi chop	
Ghana	Poached chicken meal Jollof rice (rice cooked in tomato sauce) with beef tripe Waakye (co-boiled rice and cowpeas) with fried fish and vegetable salad	
Hungary	Cordon Bleu (reconstituted turkey meat with cheese & ham) Filled pasta products (Tortellini)	
India	Prawn masala Prawn pulao Mutton shammi kababs Chicken chilli Chicken biryani Prawn pulao Khichadi (cereal/legume gruel)	Poha Upma Mixed vegetables Rice Vegetable pulao
Indonesia	Black soup Ox-tail soup Chicken vegetable soup Chicken sweet-corn soup Yunan chicken	Croquette Risolle Spring rolls
Korea	Bulgogi (Cooked beef with vegetables) Galbi (Marinated beef ribs)	Kimbab (cooked rice rolled in dried seaweed) Kimchijumeokbab (cooked rice mixed with fermented vegetables and fried pork)
South Africa	Beef Biltong Ready-to-eat bovine tripe	
Syria	Kubba (spicy mince coated with ground wheat) Borak (lamb in dough/cheese in dough) Sheesh Tawoq (spicy, boneless chicken)	
Thailand	Thai spicy chicken basil rice (Kao Ka Pao Kai) Stir fried rice noodle with dried shrimp (Pad Thai) Steamed sticky rice with roasted chicken and papaya salad (Kao Neaw Som Tom)	
UK	Chicken Masala Minced beef patties Salmon meat patties	

### 3.2.1. Animal-based prepared meals

The efficacy of radiation processing for microbiological safety and quality of more than 30 prepared meals with beef, chicken, pork, mutton or prawns as a major component was investigated as shown in Table 1. The meals included cannelloni, empanadas, soups, Yunan chicken, Thai spicy chicken, poached chicken, chicken chilli, Chinese dumpling, Wuxi chop, Chicken Masala, Bulgogi, Galbi, Kubba, Borak, Sheesh Tawoq, Prawn pulao, and Khichadi. The optimum gamma radiation doses were found to be in the range of 2 to 4 kGy for a majority of the meals to achieve microbiological safety and desired sensory quality.

Challenge studies with pathogens such as *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Salmonella* spp., revealed that doses employed eliminated the test organisms thus demonstrating the improvement in microbiological safety of these products. In general, shelf-life of the meals was extended from one week to more than three weeks at chilled temperatures depending upon the characteristics of meals. No significant changes were observed with regard to physical and chemical properties such as pH, water activity, lipid peroxidation of the meals. There was no significant difference in the overall acceptability of the meals at the optimal doses of gamma radiation. In addition, it was found that using natural antioxidants such as vitamin C, vitamin E and flavonoids (quercetin, epicatechin and resveratrol) could enhance the quality of the meat component of irradiated meals by successfully reducing the occurrence of oxidative rancidity. Shelf-life studies conducted at abuse temperatures emphasised the importance of maintaining the “cold-chain” during production and storage of irradiated prepared meals.

### 3.2.2. Vegetable-/fruit-based prepared meals

Radiation processing of two of the most popular vegetarian meals consumed in India, namely vegetable pulao and mixed vegetables, was standardised. The initial bacterial load in the non-irradiated control samples was found to be 2.6 log<sub>10</sub> cfu/g and increased to 6.4 log<sub>10</sub> cfu/g during storage at 0 – 3°C. These samples were also found to be contaminated by potentially pathogenic bacteria such as *S. aureus* and spoiled within two weeks. Contrary to this, no viable bacterial growth was observed in samples treated with gamma radiation (2 kGy) up to 30 days of storage period. Malonaldehyde formation, a measure of lipid peroxidation, increased marginally on irradiation and on further storage. No significant difference in sensory acceptability was observed between the untreated samples and the irradiated ones. Shelf-life of the meals was extended by more than two weeks by gamma radiation treatment. Thus it can be concluded that microbiologically safe, convenient vegetable pulao and mixed vegetables with a shelf-life of a month could be prepared by radiation processing and be of advantage to the processor, retailer and consumer.

On the other hand, studies carried out showed that some of the vegetable-based preparations, including fruit salad, custard and bread pudding, could be decontaminated by radiation processing for immunocompromised patients.

### 3.2.3. Miscellaneous meals

The sensory quality of cooked rice irradiated at more than 2 kGy was found to be unacceptable in terms of texture and colour. For steamed sticky rice a dose of 3 kGy was enough to control *L. monocytogenes* and *E. coli* during chilled storage when stored for more than eight weeks. Doses of 4 kGy are recommended for stir fried rice noodles with sauces and dry shrimp.

Gamma irradiation with doses of 5 - 7 kGy of four frozen soups made of different basic materials, having moisture contents between 69 and 86%, could reduce microbial load by 2- 3 log cycles and extend the shelf-life to three months at  $5 \pm 2^{\circ}\text{C}$ , without impairing sensory quality. Soups were vacuum packaged with laminated pouch of polyester/aluminum foil/LLDPE. A challenge test result indicated that 5 - 7 kGy doses were sufficient to reduce population of *Clostridium sporogenes* by 6 - 7 log cycles.

A dessert composed of fresh apples and pear cubes mixed with strawberry flavoured gelatine jelly and soft white cheese, packaged in polypropylene recipes and refrigerated at  $5^{\circ}\text{C}$ , was successfully decontaminated by 1.5 kGy of gamma radiation, attaining a 3 log cycles reduction in total viable counts with acceptable sensory quality throughout a week of storage, which doubled its shelf-life. A *Salmonella enteritidis* challenge test showed that this dose was sufficient to reduce its counts by 6 log cycles, which assured a good security level.

Gamma radiation of a carrot, hard-boiled egg and tomato salad at a dose of 2 kGy, packaged in polypropylene, covered with PVC film and stored at  $5^{\circ}\text{C}$  was sufficient to attain a 6 log cycle reduction in *Salmonella enteritidis* counts. Total viable counts were reduced by 3 - 4 log cycles with few detrimental effects on sensory quality.

#### 4. SUMMARY OF RESULTS

A summary of the products studied, their composition, intrinsic qualities and analyses undertaken are given in Table 2 while an overall summary of the effect of irradiation on the safety, shelf-life and quality of the products listed in Tables 1 and 2 are presented in Table 3. Abstracts of the work carried out under this CRP are presented in Annex I.

The results of work carried out in Argentina are not included as the representative of this country was unable to attend the meeting; however, the abstract is included as part of this report.

**Table 2.** Summary of safety and quality parameters of products studied

Country	Prepared meal(s) studied	Composition of prepared meal(s)	Intrinsic parameters	Safety and Quality Parameters		
				Microbiological	Sensorial	Chemical/Physical
China	Chinese dumpling	Wheat flour, pork, onion, spices	Moisture <sup>1</sup> , a <sub>w</sub> <sup>1</sup> pH	Total Viable Count, <i>S. enteritidis</i> , <i>L. monocytogenes</i> , <i>S. aureus</i>	Scores based on colour, texture, taste, flavour; overall acceptability using a 5-point hedonic scale	POV <sup>2</sup> , TVBN <sup>2</sup> , acidity <sup>1</sup> , protein <sup>1</sup> , fat <sup>1</sup> TBARS <sup>2</sup> , Starch retrogradation, Vitamin B <sub>1</sub> Water holding capacity, amino acid composition, FFA <sup>1,2</sup>
	Wuxi chop	Spare ribs, soya sauce, sugar, spices		<i>E. coli</i> + all the above		
Ghana	Poached chicken meat	Chicken, rice, carrots	pH, a <sub>w</sub> <sup>1</sup>	Total Viable Count, <i>E. coli</i> , <i>S. aureus</i>	Triangle test, Overall acceptability using a 9-point hedonic scale	FFA <sup>1,2</sup>
	Jollof rice	Rice cooked in tomato sauce	As above	Total Viable Count, <i>Salmonella</i> spp, <i>S. aureus</i> , <i>E. coli</i> , Yeasts & Molds, <i>Shigella</i>	Descriptive sensory analyses	FFA <sup>1,2</sup> POV <sup>2</sup>
	Waakye	Co-boiled rice and cowpeas	As above	Total Viable Count, Coliforms, Yeasts & Molds		
	HACCP prepared ready-to-eat meals	14 different commercially available airline meals		Total Viable Counts, Total Coliforms, <i>Salmonella</i> / <i>Shigella</i> , Yeasts & Molds		
Hungary	Tortellini	Pasta filled with meat/vegetables	a <sub>w</sub> <sup>1</sup> pH	Total Viable Count, <i>S. aureus</i>	Hedonic scores, ranking tests	Thiamine
	Cordon Bleu	Pre-fried, irradiated breaded slices/steaks of reconstituted turkey meat filled with slices of ham and cheese	As above	Total Viable Count, Lactic Acid Bacteria, <i>L. monocytogenes</i> , Clostridia	As above	TBARS <sup>2</sup>

Country	Prepared meal(s) studied	Composition of prepared meal(s)	Intrinsic parameters	Safety and Quality Parameters		
				Microbiological	Sensorial	Chemical/Physical
Hungary (cont.)	Mechanically deboned turkey meat			Total Viable Count		TBARS <sup>2</sup> Cholesterol Oxidation Products
India	Prawn masala Prawn pulao Mutton shammi kababs Chicken Chilli Chicken biryani Prawn pulao Khichadi (cereal/legume gruel) Poha Upma Mixed vegetables Rice Vegetable pulao	Vegetables, chicken, rice, prawns, garlic, ginger paste	a <sub>w</sub> <sup>1</sup> pH	Total Viable Count, <i>S. aureus</i> , <i>B. cereus</i> , <i>L. monocytogenes</i> , Faecal coliforms, Yeasts & Molds, Aerobic Spore Count	Overall acceptability using a 10-point hedonic scale	TBARS <sup>2</sup>
Indonesia	Black soup  Oxtail soup  Chicken and vegetable soup  Chicken sweet corn soup	Beef meat, <i>Pangium edule</i> , shallot, garlic, roasted coriander, red chilli, ginger, lemon leaf, roasted fish paste, turmeric, ginger root, lemon grass, <i>Kaempferia galanga</i> , salt, palm sugar, bay leaf, palm oil, water  Oxtail, shallot, garlic, salt, palm oil, water, onion, ground nutmeg, cloves, white pepper, onion leaf, celery, margarine  Chicken, shallot, garlic, salt, water, nutmeg, white pepper, onion leaf, celery, margarine, sugar, carrot, green beans, broccoli, sugar peas  Chicken, salt, water, nutmeg, sweet corn, chicken sausage, carrot, egg, corn starch	pH	Total Viable Count Yeasts & Molds, Coliforms, <i>E. coli</i> , <i>Salmonella</i> spp., <i>S. aureus</i> , <i>Cl. perfringens</i>	Overall acceptability using a 5-point hedonic scale	Fat <sup>1</sup> , carbohydrate <sup>1</sup> , protein <sup>1</sup>

Country	Prepared meal(s) studied	Composition of prepared meal(s)	Intrinsic parameters	Safety and Quality Parameters		
				Microbiological	Sensorial	Chemical/Physical
Indonesia (cont.)	Springrolls	Wheat-based sheet filled with cooked shrimps and chicken meat as well as vegetables (including young bamboo shoots)	As above + a <sub>w</sub>			
	Risolle	Wheat-based sheet filled with cooked chicken, vegetables	As above + a <sub>w</sub>			
	Croquette	Potato-based sheet filled with beef and vegetables	As above + a <sub>w</sub>			
	Yunan chicken	Specially salted chicken, marinated in herbs and spices - cooked in a steamer	As above + a <sub>w</sub>			Thiamine, POV <sup>2</sup>
Israel	Black soup Oxtail soup Chicken and vegetable soup Chicken sweet corn soup Spring rolls Risolle Croquette Yunan chicken	As described above	HACCP parameters	HACCP parameters	HACCP parameters	HACCP parameters
Korea	Bulgogi Galbi Kimbab	Cooked rice rolled in a dried laver (seaweed)	pH, a <sub>w</sub> <sup>1</sup>	Thermophilic bacteria, Coliforms, <i>S. aureus</i> , <i>E. coli</i> , <i>S. typhimurium</i> , <i>B. cereus</i> , <i>L. ivanovii</i> Total Viable Counts	Overall acceptability using 9-point hedonic scale	TBARS <sup>2</sup> , DPPH <sup>2</sup> , protease activity <sup>1</sup>
	Kimchijumeokbab	Cooked rice mixed with fermented vegetables and fried pork		Total Viable Count		



Country	Prepared meal(s) studied	Composition of prepared meal(s)	Intrinsic parameters	Safety and Quality Parameters		
				Microbiological	Sensorial	Chemical/Physical
South Africa	Biltong  RTE - bovine tripe	Salted, dried, intermediate moisture meat product  Ready-to-eat cooked beef tripe	Moisture <sup>1</sup> , NaCl <sup>1</sup> a <sub>w</sub> <sup>1</sup> , fat <sup>1</sup> , pH	<i>S. aureus</i> , Total Viable Count, Yeasts & Molds  <i>Cl. perfringens</i> , Aerobic Spore Counts, Total Viable Count	Multiple difference testing Overall acceptability using a 9-point hedonic scale  9-point hedonic scale	TBARS <sup>2</sup>
Syria	Kubba  Borak Cheese borak Sheesh Tawoq	Ground wheat, beef, spices, lamb, onion, fat, pistachio  Dough, eggs, lamb, onion, spices Dough, eggs, cheese Spicy, boneless chicken	Moisture <sup>1</sup> , fat <sup>1</sup> , ash <sup>1</sup> , protein <sup>1</sup> , a <sub>w</sub> <sup>1</sup> , pH	Total Viable Count, Coliforms, Yeasts & Molds, <i>Salmonella</i> spp., <i>E. coli</i>	Overall acceptability using a 5-point hedonic scale	Lipid oxidation, TVBN <sup>1</sup> , total acidity <sup>2</sup> Proximate analyses <sup>1</sup>
Thailand	Kao Ka Pau Kai  Pad Thai  Kao Neaw Som Tom	Cooked rice, chicken, vegetable oil, chilli, fish sauce, water, Basil leaves  Stir fried rice noodle with dried shrimp  Sticky rice, roasted chicken and papaya salad	Moisture <sup>1</sup> , pH	<i>L. monocytogenes</i> , <i>E. coli</i> , <i>S. typhimurium</i> <i>L. monocytogenes</i> , <i>E. coli</i>  <i>L. monocytogenes</i> , <i>E. coli</i>	Overall acceptability using a 9-point hedonic scale	Instrumental texture analyses; Lab colour measurements
U.K.	Chicken Masala  Beef patties	Chicken, onion, tomato, water, yoghurt, coconut, red pepper, tomato puree, rapeseed, oil modified starch, ground coriander leaf, salt, ginger, cayenne pepper, malt extract, turmeric		Total Viable Count, <i>Pseudomonas</i> spp., Psychrotrophs, Lactic Acid Bacteria, Coliforms  Total Viable Count, <i>Pseudomonas</i> spp., Psychrotrophs, Anaerobic spores		TBARS <sup>2</sup> , Vitamins B <sub>1</sub> and E, Cyclobutanone (EN1786)  TBARS <sup>2</sup> CIELAB colour measurements Addition of natural antioxidants

Country	Prepared meal(s) studied	Composition of prepared meal(s)	Intrinsic parameters	Safety and Quality Parameters		
				Microbiological	Sensorial	Chemical/ Physical
U.K. (cont.)	Salmon meat patties					CIELAB colour measurements Addition of natural antioxidants
USA	Ground beef patties	Ground beef	Consumer demand and acceptance parameters		Consumer demand and acceptance parameters	

Abbreviations: <sup>1</sup>a<sub>w</sub>: water activity; <sup>2</sup>TBARS: Thiobarbituric Acid Reactive Substances, POV: Peroxide Value, TVBN: Total Volatile Basic Nitrogen, DPPH: 1,1-Diphenyl-2-Picrylhydrazyl, FFA: Free Fatty Acids

**Table 3.** Summary of the effect of irradiation on the safety, shelf-life and quality of products studied

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
China	Wuxi chop	6 kGy	Vacuum packaging (anaerobic)	0-4 °C  20 ± 2 °C	<i>E. coli</i> : D <sub>10</sub> = 0.46 kGy <i>S. aureus</i> : D <sub>10</sub> = 0.58 kGy <i>Salmonella</i> spp: D <sub>10</sub> = 0.41 kGy	From 5 days (control) to 30 days at 0-4 °C  From 2 days (control) to 15 days at 20 ± 2°C
	Chinese dumpling	3-4 kGy	Vacuum packaging (anaerobic)	0-4 °C	<i>L. monocytogenes</i> : D <sub>10</sub> = 0.45 kGy <i>S. aureus</i> : D <sub>10</sub> = 0.44 kGy <i>Salmonella</i> spp: D <sub>10</sub> = 0.31 kGy	From 5-7days (control) to 3 to 4 weeks at 0-4 °C
Ghana	Poached chicken meal	3 kGy	Aerobic	3-5 °C	<i>E. coli</i> : D <sub>10</sub> = 0.189 kGy <i>S. aureus</i> : D <sub>10</sub> = 0.271 kGy	Eliminated test pathogens From 7 days (control) to 21 days at 3-5 °C
	Jollof rice with beef tripe and sauce	3 kGy		3-5 °C	<i>E. coli</i> : D <sub>10</sub> = 0.173 kGy) <i>S. aureus</i> : D <sub>10</sub> = 0.260 kGy) <i>Salmonella</i> spp: D <sub>10</sub> = 0.285 kGy	Eliminated test pathogens From 7 days (control) to 21 days at 3-5 °C
	Waakye with fried fish, vegetable salad and tomato sauce	3 kGy		27-32 °C	<i>E. coli</i> : D <sub>10</sub> = 0.271 kGy <i>S. aureus</i> : D <sub>10</sub> = 0.325 kGy <i>Salmonella</i> spp: D <sub>10</sub> = 0.440 kGy	Shelf-life studies not conducted
Hungary	Cordon Bleu (a <sub>w</sub> =0.96; pH=6.2-6.3)	2 kGy	MAP (20% CO <sub>2</sub> + 80% N <sub>2</sub> )	5 °C  9°C	<i>L. monocytogenes</i> 4ab No.10: D <sub>10</sub> = approx. 0.80 kGy	From 2 weeks (control) to 4 weeks at 5 °C  From 1 week (control) to 2 weeks at 9 °C
	Tortellini (a <sub>w</sub> =0.96; pH=5.5-6.1)	3 kGy	MAP (20% CO <sub>2</sub> + 80% N <sub>2</sub> )	15 °C	<i>S. aureus</i> ATCC 6538: D <sub>10</sub> < 0.80 kGy	Less than 2 weeks (control) to 4 weeks at 15 °C

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
India	Prawn masala  Chicken Chilli  Mutton shammi kababs  Prawn pulao  Chicken biryani	3 kGy	Aerobic	0-3 °C	<i>S. aureus</i> ATCC 6538P: D <sub>10</sub> = 0.365 kGy <i>B. cereus</i> MTCC 470: D <sub>10</sub> = 0.466 kGy  <i>S. aureus</i> ATCC 6538P: D <sub>10</sub> = 0.365 kGy <i>B. cereus</i> MTCC 470: D <sub>10</sub> = 0.473 kGy	Pathogens eliminated ( <i>L. monocytogenes</i> ; <i>S. aureus</i> ; <i>E. coli</i> ; <i>Salmonella</i> ) Shelf-life extended to at least 2 weeks at 0-3°C
	Khichadi (cereal/legume gruel) Poha Upma Mixed vegetables Rice Vegetable pulao	2 kGy	Aerobic	0-3 °C		Pathogens eliminated ( <i>L. monocytogenes</i> ; <i>S. aureus</i> ; <i>E. coli</i> ; <i>Salmonella</i> ) Shelf-life extended to at least 4 weeks at 0-3 °C
Indonesia	Black soup Oxtail soup Chicken and vegetable soup Chicken sweet corn soup	5 - 7 kGy (irradiated under cryogenic conditions)	Vacuum packaged in laminated pouch (anaerobic)	5 ± 2 °C		Pathogens eliminated ( <i>E. coli</i> ; <i>Staphylococcus spp.</i> ; <i>Cl. perfringens</i> ) Irradiation extended the shelf-life up to 3 months at 5 ± 2 °C
	Spring rolls	7 kGy				Pathogens eliminated ( <i>E. coli</i> ; <i>Staphylococcus spp.</i> ; <i>Cl. perfringens</i> ) Microbiological shelf-life: 1 month at 5 ± 2 °C Sensory quality not acceptable after irradiation due to textural defect in young bamboo shoot

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
Indonesia (cont.)	Risolle	3 - 7 kGy				Pathogens eliminated ( <i>E coli</i> ; <i>Staphylococcus spp</i> ; <i>Cl. perfringens</i> ) Irradiation extended the shelf-life up to 3 months at 5 ± 2 °C
	Croquette	5 – 7 kGy				Pathogens eliminated ( <i>E coli</i> ; <i>Staphylococcus spp</i> ; <i>Cl. perfringens</i> ) Irradiation extended the shelf-life up to 3 months at 5 ± 2 °C
	Yunan chicken	3-5 kGy			<i>S. typhimurium</i> : D <sub>10</sub> = 0.28 kGy <i>Pseudomonas aeruginosa</i> : D <sub>10</sub> = 0.17 kGy <i>E.coli</i> 0157: D <sub>10</sub> = 0.12 kGy <i>Campylobacter</i> spp: D <sub>10</sub> = kGy <i>L. monocytogenes</i> : D <sub>10</sub> = kGy)	Test pathogens eliminated by irradiation From 6 weeks (control) to 9 weeks (3 and 5 kGy) at 5 ± 2 °C
Korea	Bulgogi	2.5 kGy	Aerobic	0-5 °C		Eliminated <i>B. cereus</i> , Coliforms From 2 weeks (control) to 4 weeks (2.5 kGy) at 0-5 °C
	Galbi	2.5 – 5 kGy	Aerobic (but vacuum recommended)	0-5 °C	<i>B. cereus</i> KCTC 1012: D <sub>10</sub> = 0.66 kGy <i>S. aureus</i> KCTC 1916: D <sub>10</sub> = 0.59 kGy <i>E.coli</i> KCTC 1682: D <sub>10</sub> = 0.54 kGy <i>S. typhimurium</i> KCTC: D <sub>10</sub> = 0.63 kGy	Eliminated all inoculated pathogens From 2 weeks (control) to 4 weeks (2.5 kGy) at 0-5 °C

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
Korea (cont.)	Kimbab	1 kGy	Aerobic	10 °C	<i>S. aureus</i> KCTC 1916: $D_{10} = 0.31$ kGy <i>E. coli</i> KCTC 1682: $D_{10} = 0.42$ kGy <i>S. typhimurium</i> KCTC: $D_{10} = 0.44$ kGy <i>L. ivanovii</i> KCTC 344: $D_{10} = 0.43$ kGy	Eliminated all inoculated pathogens From 12 h (control) to 36 h (1.0 kGy) at 10 °C
	Kimchijumeokbab	3 kGy	Aerobic	10 °C		From 12 h (control) to 36 h (3 kGy) at 10 °C
South Africa	Biltong ( $a_w=0.979$ ; pH=5.32)	4 kGy	Vacuum	Ambient	<i>S. aureus</i> ATCC 9441	Eliminated test pathogen
	RTE - bovine tripe	9 kGy	Aerobic (boil after packaging)	5 °C 15 °C	<i>Cl. perfringens</i> ATCC 13124	No <i>C. perfringens</i> after irradiation but survival of heat and irradiation resistant aerobic spore formers Extends shelf life to at least 2 weeks at both 5 and 15 °C Control sample spoils after 3 days at 15 °C
		9 kGy	Anaerobic (boil before vacuum packaging)	5 °C 15 °C		Elimination of test pathogen Shelf-life of irradiated samples at least 7 days at both 5 and 15 °C Control sample spoils after 4 days at 15 °C
Syria	Kubba	4 – 6 kGy	Aerobic	0-4 °C	<i>Salmonella spp</i> : $D_{10} = 0.465$ kGy <i>E. coli</i> : $D_{10} = 0.510$ kGy	From less than 1 week (control) to 3 weeks at 4 or 6 kGy
	Borak	do	do	do		Elimination of pathogens From less than 1 week (control) to 3 weeks at 4 kGy and to at least 5 weeks at 6 kGy

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
Syria (cont.)	Cheese borak	do	do	do	<i>Salmonella spp</i> : D <sub>10</sub> = 0.303 kGy <i>E. coli</i> : D <sub>10</sub> = 0.500 kGy	Elimination of pathogens From less than 1 week (control) to 2 weeks at 4 kGy and to at least 6 weeks at 6 kGy
	Sheesh Tawoq	do	do	do		From 12 weeks (control) to at least 20 weeks (4 and 6 kGy)
Thailand	Kao Ka Pau Kai - cooked rice	2 kGy	Aerobic	5°C	<i>L. monocytogenes</i> <i>E. coli</i>	Cooked rice: from 2 weeks (control) to at least 4 weeks at 5°C
	- cooked chicken	2 kGy			<i>L. monocytogenes</i> <i>S. typhimurium</i>	Cooked chicken: from 2 weeks (control) to at least 4 weeks at 5°C
	- basil leaf	1 kGy				Up to 2 weeks at 5°C after irradiation
	Pad Thai - cooked rice noodle	4 kGy		4°C	<i>L. monocytogenes</i> : D <sub>10</sub> = 0.29 kGy <i>E. coli</i> : D <sub>10</sub> = 0.69 kGy	From 2 weeks (control) to at least 4 weeks
	- sauce and dry shrimp				<i>L. monocytogenes</i> : D <sub>10</sub> = 0.49 kGy <i>E. coli</i> : D <sub>10</sub> = 0.68 kGy	
	Kao Neaw Som Tom - sticky rice	3 kGy			<i>L. monocytogenes</i> : D <sub>10</sub> = 0.33 kGy <i>E. coli</i> : D <sub>10</sub> =0.15 kGy	From 2 weeks (control) to at least 8 weeks
- roasted chicken		<i>L. monocytogenes</i> : D <sub>10</sub> = 0.51 kGy <i>E. coli</i> : D <sub>10</sub> = 0.52 kGy				
- papaya salad		<i>L. monocytogenes</i> : D <sub>10</sub> = 0.23 kGy <i>E. coli</i> : D <sub>10</sub> = 0.44 kGy				
U.K.	Chicken Masala	2 – 3 kGy	???	3°C		Shelf-life of 14 days achieved with no adverse effect on vitamins B <sub>1</sub> or E. Irradiation easily detectable using 2-alkylcyclobutanone method (EN1786)

Country	Prepared meal(s) studied	Effective irradiation dose (kGy)	Packaging conditions	Temperature of storage	Inoculated pathogens / Surrogates	Improvement in safety/shelf-life
U.K. (cont.)	Beef patties	2.5 kGy	Vacuum packed in polyethylene bags	3°C		During the 21 days post-irradiation, total viable counts were reduced / maintained at low levels in vacuum packs. Oxidative rancidity maintained at acceptable levels for sensory quality although appearance is poor until patties are allowed to 'bloom up' in an oxygen atmosphere prior to use.
		2.5 kGy	Overwrapped with cling film	3°C		Total viable counts reduced to below limit of detection by irradiation over 21 day storage period. Oxidative rancidity increased with storage but maintained at acceptable levels for sensory quality by 2.5 kGy up to 21 days.  Addition of the flavonoid antioxidants quercetin, epicatechin and reveratrol can reduce oxidative rancidity throughout shelf-life
	Salmon meat patties	2.5 kGy		3°C		Addition of the flavonoid antioxidants quercetin, epicatechin and reveratrol can reduce oxidative rancidity throughout shelf-life.



## 5. CONCLUSIONS

- a. The CRP demonstrated that radiation processing of prepared meals results in safer food by eliminating pathogens and extends the shelf-life by decreasing the number of spoilage organisms without significantly jeopardising the overall quality. Radiation treatment thereby offers the opportunity of a wider utilisation and marketing of such high quality meals including many ethnic food products.
- b. The safety of radiation processed products was demonstrated using challenge tests / inoculated pack studies with various pathogenic test organisms or their surrogates. Such products could satisfy or fulfil several niche markets. However, proper storage temperature and maintenance of the “cold chain” is a crucial factor of food safety and stability. Oxidative changes are sometimes enhanced by radiation treatment but counteracting such changes by proper packaging conditions and using efficient antioxidant additives has been demonstrated.
- c. Strict hygienic practices during the manufacture of prepared meals are a prerequisite for the successful application of irradiation in order to ensure product safety, quality and extended shelf-life.
- d. In view of the insight gained about the quality changes that occur in the irradiated foods investigated under this CRP and emerging needs of consumers, e.g. functional qualities of foods in relation to nutrition and health, further research activities are necessary.
- e. This technology could potentially be advantageous for consumers, food manufacturers, and traders world-wide as the foods are safer, have an extended shelf-life and high quality.
- f. In view of the increasing trend in consumer demand for safe prepared foods, the importance in the use of radiation pasteurization is likely to increase in the future. This was confirmed by the consumer studies carried out in the USA, the results of which were reported during the course of this CRP. Provision of information about the nature of food irradiation increases consumer acceptance and willingness to pay a premium for enhanced product safety and quality.
- g. As a result of extensive predictive microbiological modeling activities during the last two decades several computer programmes and softwares became available recently for facilitating microbiological risk assessment. After validation of their sufficient predictability, such softwares would be worthwhile to use because they offer an efficient tool for risk estimation for selected marketing scenarios and microbiological ecological parameters/stress factors in foods, decreasing thereby the necessity for very costly challenge tests.
- h. Although this CRP demonstrated that radiation processing can facilitate the production of safer and extended shelf-life products, the work also highlighted the complexity and technological challenges of using radiation processing for multi-component food systems such as prepared meals.

## 6. RECOMMENDATIONS

- When using any new food processing technology for complex food systems such as prepared meals it is important to consider the requirements in terms of both product

and process parameters to obtain the desired safety and quality effects. The oversimplified attitude to employ ionizing radiation as a technology to pasteurize an existing industrial meal-product is often inadequate to meet the goal of extended shelf-life and improved safety. The meal should be modified first, to extend its sensorial shelf-life (e.g. texture), regardless of bacterial growth, and then pasteurized by irradiation. In particular, shelf-life changes relating to conversion of bound-water into free-water adversely affect the sensorial quality of high-moisture foods (e.g. dumplings). These ageing effects should be minimized by the use of appropriate additives for that purpose.

- Radiation pasteurization is particularly advantageous as the final processing step, applied on the packed and sealed prepared meal. Nonetheless, the bio-burden of the ingredients at early stages of preparing the meal can most often be reduced by alternative methods, which may be advantageous to specific foods. This attitude includes a pre-treatment or radiation-disinfection of specific ingredients of high bio-burden. Thus, the radiation dose at the final stage, which affects all the ingredients, can be substantially lowered, resulting in improved sensorial quality and as important - economic profitability.
- The efficacy of radiation treatment should be tested / validated under real commercial conditions since microbial growth might be greatly facilitated under more or less abusive temperature conditions which may frequently occur in the food chain and home storage before consumption.
- Suitable packaging material and processes as well as adequate storage conditions are prerequisites for successful deployment of this technology.
- Regulatory approval for new radiation-pasteurized prepared meal products is crucial, legally and economically alike, since it is important to allow their market testing and consequent marketing as soon as their development is complete. Hence, it is most recommended to take care of all legal aspects of the petitions for new products, as soon as completion of their development seems viable. New concepts such as multi-stage irradiation (raw-material decontamination and end-product treatment) should receive proper consideration by the regulatory authorities.
- In conjunction with technology development, market and economic studies are crucial to successful commercialization of irradiated prepared meals.
- Along with the continuing research and development in this field, relevant agencies, particularly, the Joint Division FAO/IAEA, should disseminate information and assist technology transfer to facilitate the proper utilization of the critical mass of multi-disciplinary knowledge gathered during CRPs. They could also offer neutral and pre-competitive support of such knowledge for the common sake of all the relevant stakeholders, including regulators of food irradiation. In such meaningful technology transfer, comparisons of relative advantages and / or disadvantages of alternative technologies should always be considered.
- It is essential to provide a solid scientific foundation for a wider application of the knowledge gained from this CRP. Hence international cooperative research efforts are needed for further implementing the technology.

## 7. PUBLICATIONS

A list of the publications to date resulting from the research work carried out under this CRP are given in Annex IV.

## ANNEX I -ABSTRACTS OF COUNTRY REPORTS

### ARGENTINA – Narvaiz, P.

Ready-to-eat meals are common place nowadays in urban life. Many of them, minimally processed, could convey food borne pathogens likely to cause diseases to the consumer, which is of concern to the normal population and even more to the immunocompromised. The feasibility of attaining microbiological decontamination at pasteurization levels of such foods by gamma irradiation was studied. Typical Argentine dishes were chosen after market surveys: caneloni in tomato sauce, tomato and carrot salad with boiled egg, “empanadas”, fruit salad in gelatin jelly with white cheese, ham and cheese sandwich, chicken and vegetables pie, custard, and bread pudding, in different packagings.

Microbiological profiles of the meals were obtained; challenge tests with *Listeria* or *Salmonella* were performed to determine the minimum radiation dose to be applied in each food so as to attain a 6 log cycles reduction of eventual pathogen counts. Preliminary sensory evaluation, out of panel, was carried out to evaluate possible unacceptable sensory alterations due to the irradiation treatment. Then a greater amount of samples were irradiated at the minimum radiation dose and at a maximum dose equal or less than twice the minimum, at the cobalt-60 semi industrial facility of the *Ezeiza Atomic Center*. Microbiological and sensory analysis by consumer panel were performed on control and irradiated samples throughout storage life at refrigeration temperatures.

A whole irradiated lunch, composed of the salad, “empanadas”, and the fruit salad, was tasted by 44 immunocompromised patients at a hospital. The composition and adequateness of this lunch was designed by nutritionists.

Results showed that it was feasible to attain the proposed decontamination goal , without impairing significantly the sensory quality. Shelf life was almost triplicate in irradiated samples.

Immunocompromised patients liked very much the irradiated lunch, and asked for it and other dishes alike to be commercially available.

### CHINA – Sun, B.

The effect of gamma irradiation for microbiological safety improvement and shelf life extension of Chinese traditional prepared meals including Chinese dumpling and Wuxi Chop were investigated. *Bacillus polymyxa*, *Bacillus cereus*, *Enterococcus gallinarum*, *Propionibacterium acnes* were the main type of bacteria exist in Chinese Dumpling, while Gram-negative and positive bacillus, cocci could be found in Wuxi Chop. The D<sub>10</sub> and D values of irradiation for *Salmonella enteritidis* inoculated in cooked and chilled dumpling vacuum packed were 0.31kGy and 1.63kGy, the D<sub>10</sub> values and D value for *staphylococcus aureus* were 0.44 kGy and 2.55 kGy. the D<sub>10</sub> and D value for the *Lister monocytogenes* are 0.45kGy and 2.74 kGy, 3 kGy could ensure the microbial safety of the cooked and chilled dumpling. The D10 value and D value of irradiation for *Salmonella enteritidis* inoculated in Wuxi Chop are 0.41 kGy and 1.91 kGy, the D10 value and D value of irradiation for *staphylococcus aureus* are 0.58 kGy and 2.69 kGy. 3 kGy irradiation also could ensure the microbial safety of the Wuxi Chop. The D10 value and D value of irradiation for visual bacteria in he D<sub>10</sub> values and D value of irradiation for the microbial population in cooked and chilled dumpling were 2.04kGy and 4.00kGy, so the 4.00kGy irradiation should be regarded

as the appreciated dose for the shelf life of cooked and chilled dumpling. The  $D_{10}$  values and  $D$  value of irradiation for the aerobic bacteria existed in Wuxi chop 4.66 and 5.88 kGy, the 6 kGy was thought to be the suitable irradiation dose for the shelf life extension of Wuxi Chop.

In the project, we also found that the irradiation dose during 0~5 kGy and storage time during 0~28 d had significant effects on the moist content, fat content,  $A_w$ , pH, total acidity, volatile basic nitrogen, POV, TVBN value of the cooked and chilled dumpling, the evaluated score for the color, texture, taste and flavor of the chilled cooked dumpling non-irradiated and irradiated with different dose and stored at different time also showed irregular difference, the sensory quality except the shape tended to decrease with the irradiation dose and storage time. The addition of antioxidant mainly contained Ve had the effect on the reduction of TBA value, however it did not show significant effect on the improvement of sensory acceptance. The addition of complex phosphate did not show both the water capacity of filling and the sensory acceptance of the chilled cooked dumpling. For the nutritive quality, the selected irradiated dose and storage had significant influences on fat content and vitamin B1 and a few kind of amino acid and fatty acid. The selected irradiation dose had non significant influences on the shape, color appearance acceptability of the dumpling products, However, the consumers gave the irradiated dumpling products a significant lower evaluation on the items of oral flavor, taste, texture, oral acceptability and whole acceptability above the acceptable level except the texture.

The results showed that the irradiation has significant effect on the lipid oxidation of Wuxi Chop. The POV value of Wuxi Chop irradiated with 0, 2, 3, 4 and 6 kGy had showed evident differences, it showed increase with the increase of irradiation dose. Storage also had the significant effect on the POV value of irradiated and non-irradiated Wuxi chop. The TBA value of Wuxi Chop irradiated with different dose had showed evident differences, it showed increase with the increase of irradiation dose. Storage also had the significant effect on the TBA value of irradiated and non-irradiated Wuxi chop. Both the irradiation and storage had non significant influences on the water activity and pH of Wuxi chop, but they influence the color, texture, odor and taste of Wuxi chop. The content of VB1, the content of a few kind of amino acid and fatty acid of Wuxi Chop irradiated with 6 kGy had shown significant difference with the non-irradiated one at 0 d and 21 d storage. The 6 kGy could be extend the shelf life of Wuxi Chop to four weeks under chilled condition with the qualified microbiological safety and acceptable sensory quality.

#### **GHANA - Nketsia-Tabiri, J.**

Fourteen international ready meals prepared under approved HACCP plan and two Ghanaian ready meals (Waakye and Jollof rice) were investigated with the view to enhancing microbiological safety and extending shelf-life under chilled conditions. The microbiological count of the complete Waakye meal exceeded the microbiological standard. The microbiological counts on meals prepared under HACCP plan or the Jollof rice meals were within the microbiological standards although some potential pathogens from Waakye and its accompaniments were also present on some of the meals prepared under HACCP. The  $D_{10}$  values for potential pathogens on Waakye were 0.271 kGy for *E. coli*, 0.325 kGy for *S. aureus* and 0.440 kGy for *Salmonella* spp while values on Jollof rice meal were respectively 0.173 kGy, 0.260 kGy and 0.285 kGy. Challenge tests with the pathogens on one of the HACCP meals (poached chicken meal) or Jollof rice suggested that the 3 kGy dose was sufficient for the elimination of the pathogens to ensure the microbiological safety of the meals. Doses of 1 and 2 kGy did not affect the sensory quality of rice and chicken/gravy but boiled carrots were unable to withstand >1 kGy dose. Treatment of poached chicken and gravy or Jollof rice meal

with 3 kGy dose extended their shelf-life under chilled storage for 28 days without significant effects on their sensory quality.

#### **HUNGARY – Farkas, J.**

Experimental batches of a stuffed pasta product, „Tortellini” and slightly pre-fried breaded reconstituted turkey meat steaks with cheese and ham filling, „Cordon Bleu”, were prepared according to commercial recipes then inoculated to  $10^4$  CFU/g with *Staphylococcus aureus* (in case of Tortellini) and to  $10^6$  CFU/g with *Listeria monocytogenes* (in case of Cordon Bleu) prior to packaging in plastic pouches under a gas atmosphere of 20 % CO<sub>2</sub> and 80 % N<sub>2</sub>. The inoculated packages were irradiated at 3 kGy (Tortellini) and 2 kGy (Cordon Bleu) by a <sup>60</sup>Co radiation source. The applied radiation doses were sensorically acceptable with these products. The experimental batches of Tortellini were stored at 15°C, while the Cordon Bleu samples were stored at 5 and 9 °C, resp. Unirradiated samples were kept together with the respective irradiated ones. Storage was continued for four weeks and microbiological testings were performed before and after irradiation, and subsequently after every seven days. Besides selective estimation of the counts of the test organisms, total aerobic counts, and in case of Cordon Bleu, also colony counts of lactic acid bacteria, Enterobacteriaceae, sulphite reducing clostridia, yeasts and moulds were also selectively estimated. The 3 kGy dose reduced the *Staph. aureus* count in Tortellini below the detection limit ( $\log_{10}$  CFU/g = 0.26), and it remained undetectably low in the irradiated samples during the whole 28 days of storage, while the *Staph. aureus* count in the unirradiated samples increased up to  $10^8$  CFU/g for the 8th day. The *Listeria* count in Cordon Bleu was reduced by irradiation from the initial  $\log$  CFU/g = 6.1 to  $\log$  CFU/g = 3.5. At 5°C storage, this residual count remained stagnant up to 3-4 weeks, but started to increase at 9°C after one week. In the unirradiated samples, the *Listeria* count increased hundred-fold during 4 weeks at 5°C, and during 2 weeks at 9°C. Sulphite reducing clostridia were and remained undetectable ( $\log$  CFU/g < 0.48) in all samples even at 9°C. The limiting factor of the shelf-life of the unirradiated poultry product was the growth of lactic acid bacteria at 9°C, whereas enhanced lipid oxidation was an unwanted side-effect of radiation treatment. One can conclude from these studies that the potential risk posed by the investigated non-sporeforming pathogenic bacteria could be considerably reduced by gamma irradiation, however, storage temperature remains a crucial factor of safety and methods should be developed to counteract the lipid-oxidative effect of the radiation processing.

Pasteurising effect of 2 kGy radiation dose in nonfrozen mechanically deboned turkey meat (MDM) was achieved without increase of cholesterol oxidation products (COPs) and increases of TBARs values (thiobarbituric acid-reactive substances) during 15 days of chilled storage following the treatments, while untreated samples were spoiled. Addition of antioxidants, such as thyme-oil or  $\alpha$ -tocopherol inhibited significantly the oxidative changes of cholesterol and lipids during 3 kGy treatment.

As a result of intensive predictive microbiological modelling activities, several computer programmes and softwares became available recently for facilitating microbiological risk assessment. Among these tools, the establishment of the ComBase, an international database and its predictive modelling softwares of the Pathogen Modelling Program (PMP) set up by the USDA Eastern Regional Research Center, Wyndmore, PA, and the Food Micromodel/Growth Predictor by the UK MAFF Food Research Institute, Norwich, are most important. We have used the PMP 6.0 software version of ComBase as a preliminary trial to compare observed growth of selected test organisms in relation to our food irradiation work during the recent years within the FAO/IAEA Coordinated Food Irradiation Research Projects

D61023 and D62007 with their predicted growth on the basis of growth models available in ComBase for the same species as those of our test organisms. Results of challenge tests with *Listeria monocytogenes* inoculum in untreated or irradiated experimental batches of a semi-prepared breaded turkey meat steaks („Cordon Bleu”), sliced tomatoes, sliced watermelon, sliced cantaloup, and sous-vide processed mixed vegetables, as well as *Staphylococcus aureus* inoculum of a pasta product, Tortellini, were compared with their respective growth models under relevant environmental conditions. This comparison showed good fits in case of unirradiated and high moisture food samples, whereas growth of radiation survivors lagged behind the predicted values.

#### **INDIA – Sharma, A.K.**

The effect of gamma irradiation on microbiological, chemical and sensory qualities of some Indian ethnic preparations including items from breakfast menu, meal components and complete meals as well as some commercially available traditional Indian ready-to-eat (RTE) meat products were investigated. Initial total viable counts (TVC) were in the range of 1-3 log CFU/g in case of samples prepared in the laboratory while the counts were higher (3.5 – 5 log CFU/g) in the commercial meat products. TVC increased rapidly during storage at 0-3°C in non-irradiated samples. Radiation processing resulted in dose dependent reduction in total bacterial counts. *Staphylococcus spp* were completely eliminated by irradiation (1-2 kGy). A dose of 3 kGy was found to be optimal for extending the shelf life of the commercial products by more than two weeks at 0-3°C compared to the corresponding non-irradiated controls. Lipid peroxidation monitored in terms of TBARS content increased marginally on irradiation and with storage. However, sensory attributes of products were not significantly affected.

The safety of irradiated chilled products was demonstrated by inoculated pack studies with *S. aureus* and *B. cereus*. The radiation sensitivity of *S. aureus* and *B. cereus* in the commercial meat products were initially investigated. D<sub>10</sub> values of *S. aureus* in mutton shammi kabbabs and chicken chilly were 330 ± 32 and 365 ± 28 Gy, respectively. D<sub>10</sub> values of *B. cereus* in mutton shammi kabbabs and chicken chilly were 473 ± 65 and 466 ± 80 Gy, respectively. *S. aureus* (inoculated 10<sup>6</sup> CFU/g) was eliminated at a dose of 2.5 kGy in both the products, whereas, for *B. cereus* was eliminated at 3 kGy. The growth of both the test organisms inoculated into these products during storage at chilled temperature (0-3°C and 10°C) was studied. No growth of the test organisms was observed at 0-3°C. However, at higher temperatures such as 10°C the organisms could multiply. These results indicated that temperature abuse during storage of irradiated products should not be allowed. Radiation processing in combination with low temperature (0-3°C) storage thus resulted in microbiologically safe RTE products with extended shelf life.

#### **INDONESIA – Koenari, Z.I.**

There are growing trends in Indonesia to market frozen prepared meals and intended to microwaving or conventional way prior to consumption while *Yunan* chicken is one of functional food-prepared meals, has very short shelf-life either at room or chilled temperatures.

Different type of 4 semi-concentrated soups, three different types of pre-cooked snacks e.g., springrolls, risolles, croquette, and *Yunan* chicken were individually packed in a dry laminate pouch of PET 12μ /LDPE adh.2μ/Al-foil 7μ /LDPE adh/LLDPE (C<sub>4</sub>) 50μ under vacuum followed by freezing over night at -18 °C prior to irradiation with doses of 3-7 kGy at cryogenic condition (-79 °C) along the process. Both the unirradiated and irradiated soups and snacks were stored in refrigerator at 5 ± 2°C up to 3 months, and up to 9 weeks for

Yunan chicken. Irradiation at doses of 5-7 kGy could significantly reduce some potential pathogenic microorganisms in the soups and snacks. Microbiological assessments of *Yunan* chicken such as Total Plate Count in the unirradiated sample showed an increase during storage up to 6 weeks,  $23 \times 10^6$  cfu/g into  $9.4 \times 10^9$  cfu/g, then slightly reduced into  $7.5 \times 10^7$  cfu/g at 9 weeks of storage, but no microbial growth found in all irradiated samples before and after storage. Coliforms and *Escherichia coli* (*E. coli*) did not grow in all the tested samples.  $D_{10}$  values of *Salmonella typhimurium*, *Pseudomonas aeruginosa*, and *E. coli* O157 were 0.28; 0.17; and 0.12 kGy, respectively. Both irradiation and storage did not show any significant effects on moisture content, water activity ( $a_w$ ), pH value, salt, protein nor fatty acid contents respectively. The chicken at doses up to 5 kGy could slightly reduce vitamin B<sub>1</sub> and fat contents, either before or after storage. Irradiation treatment with doses 5-7 kGy did not affect significantly any sensoric attributes such as colour, texture, aroma, taste and general appearance. Yunan chicken packed in a laminate pouch of PET/Al-foil/LLDPE then irradiated with the dose of 3 kGy at cryogenic condition along the process could be kept until nine weeks of storage at  $5 \pm 2^\circ \text{C}$  without affecting the overall quality.

### **ISRAEL – Haruvy, Y.F.**

The classical methodology of hazard analysis critical control points (HACCP) focuses on hazards and related implications. A new methodology is suggested herein, that attempts at a systematic simultaneous assessment of safety hazards, sensorial failures and economic disasters, and the critical control points necessary for their early detection and/or prevention of their implications. The new methodology attempts also at combining the three parameters to form a qualitative prioritization of the numerous control points, to screen those that can be cost-effective for implementation.

The new methodology is demonstrated in this paper for a complex product, namely - Radiation Sterilized Ready-to-Eat Meals. Hence, a fourth parameter specific to this product - the radiation-specific pitfalls - is also assessed. The advantages and drawbacks of the combined assessment methodology are described and their overall possible impact is discussed.

The suggested combined assessment and control system, for assuring the safety and quality of food, can provide a more structured and critical approach control identified hazards, compared to that achievable by traditional inspection and quality control procedures. It has the potential to identify areas of concern where failure has not yet been experienced, making it particularly useful for new operations and products thereafter.

For numerous ethnic foods, the list of ingredients is apparently too long for utilizing the detailed ingredient-by-ingredient assessment. For this type of foods, a group-by-group assessment methodology has been further developed. The primary assessment groups are: Animal source ingredients, at which the major hazard is bacterial and health-compromise thereafter; Fat-rich ingredients, including frying oils, the primary hazard for which is rancidization and sensorial degradation thereby; Anti-bacterial ingredients/spices, the primary concern related to those is uncontrolled concentration of active materials, and uncontrolled bacterial and sensorial quality; All other groups are of minor related hazards. The primary conclusion of the group-assessment methodology is that TWO-STAGE irradiation seems greatly beneficial: The high bacterial loads in the animal-source ingredients should be eradicated foremost, at the very first stage, allowing a lower dose Pasteurization of the prepared meal at the last stage and apparently a better preservation of the sensorial quality of



the food. This two-stage principle seems economically advantageous as well, especially in cases where meat is irradiated by the supplier as part of his production route.

The rancidization effected hazard seems economically alarming in view of its manifestation at the final product at the end of storage, whereas our capability to predict it is currently poor. Running our updated modified HACCP on all ethnic foods investigated in this CRP demonstrates the complexity of this issue, and the insufficient knowledge of the interplay of radiation, oxygen, and antioxidants on the final level of rancidization and off-flavours thereafter.

Approaching the industrial stage of safe ready-to-eat meals was further assessed in this study. In view of the currently accelerating consumer demand and industrial production of ready-to-eat meals and convenience foods, the multi-stage approach to ingredients' safety seems preferred, safety-wise, sensorial-wise, irradiation-wise and economic-wise. With proper orchestration of the radiation stages within the production chain, we can achieve better food quality and safety while practically using less radiation, yet at two or more stages. Special regulatory effort is needed in this regard, as well as a future R&D endeavour, since the superstitious belief that reirradiation brings forth a hidden potential risk has already been discredited by the Geneva IAEA/WHO work-team.

#### **KOREA, Republic of – Jo, C.**

The effect of gamma irradiation for microbial inactivation and shelf-life extension of Korean traditional prepared meals including *bulgogi*, marinated beef rib and *Kimbab* were investigated. Raw vegetables, fruits and soy sauce for *bulgogi* sauce making were highly contaminated by *Bacillus* spp. and *coliform* bacteria at the initial stage. Irradiation at 10 kGy eliminated *coliforms* in the *bulgogi* sauce and no growth was found during storage at 20°C. Sensory evaluation of *bulgogi* sauce and cooked *bulgogi* showed that the irradiation was better in color than nonirradiated control or heat-treated sample. The total aerobic acteria and coliform bacteria of marinated beef rib were 5.68 and 3.68 log cfu/g, respectively. The growth of four test organisms inoculated (about 10<sup>6</sup>-10<sup>7</sup> CFU/g) into the marinated beef rib and *Kimbab* were sustained by an irradiation treatment during 3-9 day or 36 hrs at different temperatures. All the four pathogens inoculated on marinated beef rib were eliminated at 4 kGy. D<sub>10</sub>-values of *Bacillus cereus*, *Staphylococcus aureus*, *Salmonella* Typhimurium and *Escherichia coli* on inoculated marinated beef rib were 0.663±0.01, 0.594±0.05, 0.636±0.02, and 0.538±0.01 kGy, respectively. *E. coli* was the most radiation-sensitive in the raw marinated beef rib among the pathogens tested. The four pathogens inoculated into *Kimbab* decreased 2-3 log CFU/g by 1 kGy treatment and was not detected after 3 kGy. The D<sub>10</sub> value of pathogens inoculated into the *Kimbab* were 0.31-0.44 kGy among the four organisms. This study indicated that low dose irradiation is effective to ensure safety of the Korean traditional prepared meals including *bulgogi* sauce, *bulgogi*, marinated beef ribs, and *Kimbab* with acceptable sensory quality. *Kimchijumeokbab* was applied for irradiation with abusive temperature (30°C) and 5 kGy of irradiation maintained the total aerobic bacteria below 10<sup>6</sup> CFU/g. However, in terms of sensory point of view, the irradiation dose should not be exceeded 3 kGy with a lower storage temperature.

#### **SOUTH AFRICA - Minnaar, A.**

South Africa is a multi-cultural country with different eating habits and food preferences. Traditional African foods such as bovine tripe form a part of the diet of black South Africans. These foods are laborious to prepare, not generally available commercially, and have a limited

shelf-life. Other popular ethnic foods in South Africa include meat products such as “biltong”, an intermediate moisture dried meat). Moist beef biltong has the potential to cause food poisoning. The application of irradiation (alone) or in combination with other technologies can help solve these problems.

Lean moist beef biltong (47% moisture; 3.7% NaCl; 1.5% crude fat;  $a_w$  0.92) can be irradiated to doses up to 10 kGy without adversely affecting sensory acceptability provided that irradiation is performed under vacuum conditions and that the biltong is exposed to aerobic conditions after irradiation to dissipate off-odour volatiles. However, low dose irradiation ( $\leq 4$  kGy) was perceived to be more acceptable and preferable by consumers. Gamma-irradiation of moist beef biltong (53.6% moisture; 1.91 % NaCl;  $a_w$  0.979) at doses between 4 and 5 kGy was adequate to ensure safety from *Staphylococcus aureus* even if contamination levels as high as  $10^7$  cfu/g were initially present. However, doses up to 5 kGy were insufficient to prevent yeast and mould spoilage if initial fungal contamination levels were high ( $>10^3$  cfu/g). Casein-whey protein edible coatings did not inhibit microbial growth on moist beef biltong, probably due to diminished oxygen barrier properties as a result of the very high moisture content of the biltong.

RTE-bovine tripe can be irradiated up to 9.3 kGy without affecting the consumer acceptance adversely. Gamma-irradiation at a target dose of 9 kGy significantly reduced Aerobic Plate Counts (APC) and Aerobic Spore Counts (ASC) and extended the shelf-life of RTE-bovine tripe to at least 14 days at both 5 and 15 °C when aerobic conditions prevail. However, this dose may not be sufficient to assure safety of the product if surviving aerobic spores are pathogenic *B. cereus* spores. When anaerobic conditions prevail during processing of RTE-beef tripe, the use of boiling in combination with gamma-irradiation at a dose of 9 kGy and chilling at 5 °C can be used to produce safe RTE-bovine tripe from a *C. sporogenes* perspective with an extended shelf-life.

#### **SYRIA - Al-Bachir, M.**

Locally prepared meal (Kubba, Borak, Cheese Borak and Sheesh Tawoq) was treated with 0, 2, 4 or 6 kGy doses of gamma irradiation. Treated and untreated samples were kept in a refrigerator (1-4°C). Microbiological and chemical analyses were performed on each treated sample immediately after processing, and weekly throughout storage period which lasted for 3 weeks for Kubba, 6 weeks for Borak and Cheese Borak and 20 weeks for Sheesh Tawoq. Sensory evaluation and proximate analysis were done within one week after irradiation. Results of the proximate analysis of Borak, Cheese Borak and Sheesh Tawoq showed that irradiation doses did not have a significant effect on moisture, protein and fat content of meals. Whereas, irradiation decreased the major constituents of Kubba moisture, protein and fats. Used doses of gamma irradiation decreased the microorganisms load and increased the shelf-life of Kubba, Borak, Cheese Borak and Sheesh Tawoq. The radiation doses required to reduce the microorganisms load one log cycle ( $D_{10}$ ) in Borak were 456 and 510 Gy and in cheese Borak 303 and 500 Gy for the *Salmonella* and *E. coli* respectively. The three chemical parameters, total acidity, lipid peroxide and volatile basic nitrogen, which were chosen as the indices of freshness, were all well within the acceptable limit for up to 3 weeks for Kubba, 6 weeks for Borak and Cheese Borak and 20 weeks for Sheesh Tawoq treated with 6 kGy. Sensory evaluation showed no significant differences between irradiated and non-irradiated samples.

## **THAILAND - Noomhorm, A.**

Gamma irradiation was applied to extend the shelf life of selected Thai prepared meals, which composed of rice, meats and vegetables) and kept under chilled condition. For Thai spicy chicken basil rice (Kao Ka Pao Kai), cooked rice was prepared to obtain quite harder texture and irradiated at 2 kGy. Three components (cooked chicken, sauce, and blanched basil leaf) were separately packed and irradiated at 2 kGy and 0.1 kGy for basil leaves. Shelf life of irradiated spicy chicken separately packed (>4 weeks) was much more than control sample (2 weeks) considering sensory quality. Dose of 2 kGy, however, was not enough to kill entire inoculated *L. monocytogenes* in spicy cooked chicken. Likewise there is a need to preserve basil leaf due to it was microbiologically spoiled at the 2<sup>nd</sup> week of storage. For stir fried rice noodle with dried shrimp (Pad Thai), dose of 4 kGy was recommended because product was free from *L. monocytogenes* and *E. coli*, safe from microbial spoilage and had acceptable sensory quality. Irradiation at 4 kGy could extend shelf life of chilled Pad Thai to more than 4 weeks compared to normal chilled ready meal, which has shelf life 5-7 days. For steamed sticky rice, roasted chicken and papaya salad (Kao Neaw Som Tom), dose at 3 kGy was enough to control *L. monocytogenes* and *E. coli* during chilled storage. Product irradiated at 3 kGy upwards was microbiologically safe after 8 weeks of chilled storage whereas non-irradiated sample was spoiled since the 2<sup>nd</sup> week. Panelists accepted irradiated steamed sticky rice and roasted chicken, which kept under chilled condition for 8 weeks but they rejected irradiated papaya salad due to the soft texture and worse taste

## **UNITED KINGDOM – Stewart, E.**

The studies reported focus on a Chicken Masala ready-to-eat meal, and on the meat components of such meals, looking at the effects of ionizing radiation on the quality attributes of the meals of importance to the consumer. Chicken Masala meals were given doses of 1, 2 and 3 kGy, and stored for 0, 7, 11 or 14 days at 3°C. They were analysed for vitamins B<sub>1</sub> and E, oxidative rancidity (TBARS), cyclobutanones, in order to determine if irradiation treatment of the samples could be detected, and for microbiological quality. Results showed that TBA values decreased with increasing irradiation dose, while irradiation dose, storage and re-heating all significantly reduced concentration of vitamin B<sub>1</sub> and E, although not too a level that would be detrimental from a nutritional point of view. Cyclobutanones were detected in the meals. With regard to microbiological quality in all cases, irradiation significantly reduced the levels of bacteria in the prepared meals thereby extending shelf-life.

Looking at potential components of ready meals, fresh minced beef was used to prepare burgers which were subsequently vacuum packaged. The samples were irradiated with doses of 2.5 or 5.0 kGy at 5°C or 20°C or left unirradiated, followed by storage for up to 8 weeks at 3°C. The samples were analysed for oxidative rancidity using TBARS. There was a significant reduction in TBA values of the patties upon irradiation, the values being lower for samples irradiated at the higher temperature of 20°C compared to those treated at 5°C.

In a further experiment freshly minced beef was used to produce more vacuum packed patties which were irradiated with 2.5, 5.0, 7.5 or 10.0 kGy or left unirradiated. Following irradiation some samples were retained within the vacuum packages or transferred to sterile containers and overwrapped in cling film. Samples were either analysed immediately or after 1, 2, 5, 7, 14 or 21 days at 3°C for microbiological quality or after 1, 2, 5, 7, 14 or 21 days at 3°C for oxidative rancidity. Irradiation did not have a significant effect on the TBA values for vacuum packed patties although storage did result in an increase in values. Unlike the vacuum packed samples, it can be seen that the TBA values of the over-wrapped samples increased

with increasing irradiation dose and storage time, although it was noted that little change occurred over the first two days of storage and for a dose of 2.5 kGy Both irradiation and storage significantly improved the microbiological quality of both the over-wrapped and vacuum packaged beef patties.

A further series of experiments were undertaken to determine the effect of the addition of the 'natural' antioxidants vitamin E ( $\alpha$ -tocopherol), quercetin, epicatechin and resveratrol on the oxidative rancidity in minced beef and salmon meat patties. Initially, fresh minced beef patties were prepared containing the antioxidants mentioned at concentrations of 110 and 550  $\mu\text{mol/kg}$  or with no antioxidant added. Following preparation, each pattie was placed in a plastic container and overwrapped with cling film and irradiated with 2.5 and 5 kGy or left unirradiated. The samples were analysed for oxidative rancidity following storage for up to 28 days at 4°C. It was found that inclusion of antioxidants into the patties significantly reduced oxidation of the product and that resveratrol was the most effective antioxidant. Quercetin and epicatechin produced similar effects with oxidation levels being significantly lower than those of the controls but higher than samples containing resveratrol. Following on from this work further patties were made from fresh minced beef and also fresh salmon meat with the same antioxidants included at concentrations of 25, 50, 100, 250, 500 and 700  $\mu\text{mol/kg}$  whilst other patties were prepared with no antioxidant included. Samples were irradiated at 2.5 kGy or left unirradiated and stored at 4°C. In the case of the beef patties it was again found that resveratrol was the most effective antioxidant while for salmon meat epicatechin was most effective. In both cases the TBA values for samples containing  $\alpha$ -tocopherol were not significantly less than those of the untreated controls. Overall, concentration had a significant effect on the TBA values with lower values being obtained with inclusion of higher levels of a antioxidant.

#### **UNITED STATES – Nayga, R.**

This paper focuses on estimating willingness to pay for reducing risk of getting food-borne illness using a non-hypothetical experiment utilizing real food products (i.e., prepared ground beef), real cash, and actual exchange in a market setting. Respondents were given information about the nature of food irradiation. Single-bounded and one and one-half bounded models are developed using dichotomous choice experiments. Our results indicate that individuals are willing to pay for a reduction in the risk of food-borne illness once informed about the nature of food irradiation. Our respondents are willing to pay a premium of about \$0.77 for a pound of irradiated ground beef, which is higher than the cost to irradiate the product.

## ANNEX II

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## **ANNEX III**

### **Programme**

#### **Monday 22 May**

09:00 - 09:30	Inaugural Session: Dr. Gong Xifeng (Deputy Directory General of the Department of International Cooperation - Chinese Academy of Agricultural Sciences, CAAS) Dr. T. Rubio-Cabello (FAO/IAEA)
09:30 - 10:00	Objectives of the RCM: Dr. Tatiana Rubio-Cabello
10:30 - 11:00	Break
11:00 - 12:00	Publication of results- IAEA-TECDOC Administrative matters
12:00 - 13:00	Lunch
13:00 - 14:00	Use of irradiation to ensure the safety and quality of Chinese dumpling B. Sun (China)
14:00 - 15:00	Irradiation of prepared meals for microbiological safety and shelf-life extension J. Nketsia-Tabiri (Ghana)
15:00 - 15:30	Break
15:30 - 16:30	Improvement of the microbiological safety and shelf-life of selected chilled meals by gamma irradiation J. Farkas (Hungary)
18:00	Banquet for participants

#### **Tuesday 23 May**

09:00 - 10:00	Radiation processing to ensure the safety and quality of ethnic prepared meals A. Sharma (India)
10:00 - 11:00	Irradiation to ensure the safety and quality of home style frozen food and prepared meals Z.I. Koenari (Indonesia)
11:00 - 11:30	Break
11:30 - 12:30	Consumer acceptance of irradiated prepared and processed food R. Nayga (USA)
12:30 - 13:30	Lunch
13:30 - 14:30	HACCP protocols for ready-to-eat meals pasteurised with ionising irradiation Y.F. Haruvy (Israel)



- 14:30 - 15:30 Irradiation application on ready-to-eat Kimbab, Korean traditional meal product for safety and extending shelf-life  
C. Jo (Korea)
- 15:30 - 16:00 Break
- 16:00 - 17:00 Use of irradiation to improve the safety and quality of ethnic South African foods  
A. Minnaar (South Africa)

### **Wednesday 24 May**

- 09:00 - 10:00 Effect of gamma irradiation on the microbial load, chemical, and sensory characteristics of locally prepared meals  
M. Al-Bachir (Syria)
- 10:00 - 11:00 Effect of gamma-radiation on the quality of prepared meals and their components  
E. M. Stewart (UK)
- 11:00 - 11:30 Break
- 11:30 - 12:30 Working groups
- 12:30 - 13:30 Lunch
- 13:30 - 15:30 Working groups
- 15:30 - 16:00 Break
- 16:00 - 17:00 Working report

### **Thursday 25 May**

- 09:00 - 10:00 Use of irradiation to improve the safety and quality of Thai prepared meals  
A. Noomhorm (Thailand)
- 10:00 - 10:30 Conclusions and recommendations
- 10:30 - 11:00 Break
- 11:00 - 12:30 Final draft and revision of the written report
- 12:30 - 14:00 Lunch
- 14:00 - 17:00 Visit to irradiation facility

### **Friday 26 May**

- 09:00 - 11:00 Approval of the report
- 11:00 - 11:30 Break
- 11:30 - 12:00 Closing ceremony

## ANNEX IV

### PUBLICATIONS TO-DATE – resulting from research of this CRP

- Aiew, W., Nayga, Jr. R.M., Nichols, J.P.: The promise of food irradiation: Will consumers accept it”, *Choices*, Third Quarter pp. 31-34. 2003.
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- Farkas, J., Andrásy, É., Polyák-Fehér, K.: Improvement of the microbiological safety of two chilled semi-prepared meals by gamma irradiation. In: *Book of Abstracts, The 19th International ICFMH Symposium, Food Micro 2004: New Tools for Improving Microbial Food Safety and Quality, 12-16 September 2004, Portoroz, Slovenia. (P. Raspor et al., eds.)*, Slovenian Microbiological Society, 2004. ISBN 961-90346-3.5. pp. 271.
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