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Concept Paper

Long Term Research Grant Scheme (LRGS) 2012

Ministry of Higher Education Malaysia (MOHE)

Institution : Multimedia University (MMU)

Program Title : Versatile Fiber Dosimeter Technology for Managing Food Irradiation Safety

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Executive Summary

In order to provide for food safety, radiation dosimetry in irradiated food is required. However, modern dosimeters and methods have poor sensitivity and complex measurement process. Fibre dosimeters are suitable candidates to overcome such shortcomings. Nonetheless, there are still unanswered fundamental questions relating to fibre dosimeters.

Recently, the Food Irradiation Regulations 2011 under the Food Act 1983 has been introduced. However, no provision is available on the measurement of absorbed dose in irradiated food. Furthermore, the absence of such provision may erode the public and market acceptance towards irradiated food. This may subsequently affect agricultural produce exports and the National Key Economic Area (NKEA).

This proposal entails a research program that will embark on a collective and interdisciplinary effort to accomplish the **fundamental study of fiber dosimetry including fabrication (MCVD) and characterization (TL and OSL).** The new fiber dosimeters will be used for measuring radiation dosage in irradiated food. A project will also be dedicated at developing a novel and versatile **fiber dosimeter reader**. Besides dosimetry, **irradiated food nutrition studies** will also be carried out. Subsequently, the program proposes to **assess the public and market acceptance on irradiated food**, particularly with and without radiation dosimetry procedures, interleaved with **multimedia based public awareness programs**. Finally, the program will recommend **revised regulations in measuring absorbed dose in irradiated food** to the Ministry of Health.

The outcome of the proposed program leads to a simple and effective method for radiation dosimetry using portable, cost-effective, rapid, reliable and reproducible fiber dosimetry system, with proposed revised food irradiation regulations, that enhances public and market safety and confidence on irradiated food.

Background & Rationale

Food irradiation is the process of exposing food to ionizing radiation to destroy microorganisms, bacteria, viruses, or insects that might be present in the food. Irradiated food does not become radioactive, but in some cases there may be subtle chemical changes leading to the need for radiation dosimetry. Modern dosimeters are made of a range of materials, such as alanine pellets, perspex (PMMA) blocks, radiochromic films, high-purity Germanium detector (HPGe), as well as special solutions like Ceric Cerous. However, these methods are costly, required complex measurement process and time consuming. Fibre dosimeters are suitable candidates to overcome such shortcomings. However, more studies on doped silica fiber and photonic crystal fiber (PCF) as radiation dosimeter are required in order to understand and answer fundamental research questions, such as:

1. What are Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) characteristics of irradiated fiber with different dopants and dopant concentrations? How about PCF with different configuration?
2. What is the dynamic range offered by possible combinations of dopant concentration/ PCF type?
3. What is the origin of TL and OSL in amorphous/ crystalline doped silica fiber/ PCF?

The Food Irradiation Regulations 2011 under the Food Act 1983 has recently been introduced. The provisions under the regulations enforced by the Ministry of Health include operations of irradiation premises and irradiation sources which contain mandatory requirements to be observed when treating food with ionizing radiation. However, no provision is available on the measurement of absorbed dose in such irradiated food. Furthermore, the absence of such provision may erode the public and market acceptance towards irradiated food. Formulation of regulation on radiation measurements for irradiated food will be an important tool to assess conformity with the requirements on food irradiation.

Nevertheless, the U.S. Food and Drug Administration (USDA) and other health organizations over the world have studied the effects of irradiated food and declared it safe for consumption. Although irradiation process may leave macronutrients unaffected such as protein, fats and carbohydrates as well as minerals; the same is not true for vitamins. Therefore, it is crucial to assess the nutritional content of the irradiated food after irradiation process.

Description of the Research Program

This proposal entails a program that will embark on a collective and interdisciplinary collaboration to accomplish the following objectives:

1. To design, fabricate and characterize optical fiber dosimeters
2. To characterize and analyze the dosimetry characteristics of the fabricated fiber dosimeters

3. To design, develop and deploy an irradiated food database and intelligent early warning system
4. To review provisions of radiation measurement in food irradiation regulations
5. To assess the consumer acceptance and market potential of irradiated foods
6. To assess the influence of radiation dose on nutrition in irradiated food

In order to achieve the objectives, the program will be divided into several projects as shown in **Figure 1** in the domains of fiber dosimetry, food nutrition, socio-economy and regulatory. The project titles and project leader(s)/ member(s), with their respective research track records, are provided in **Table 1**.

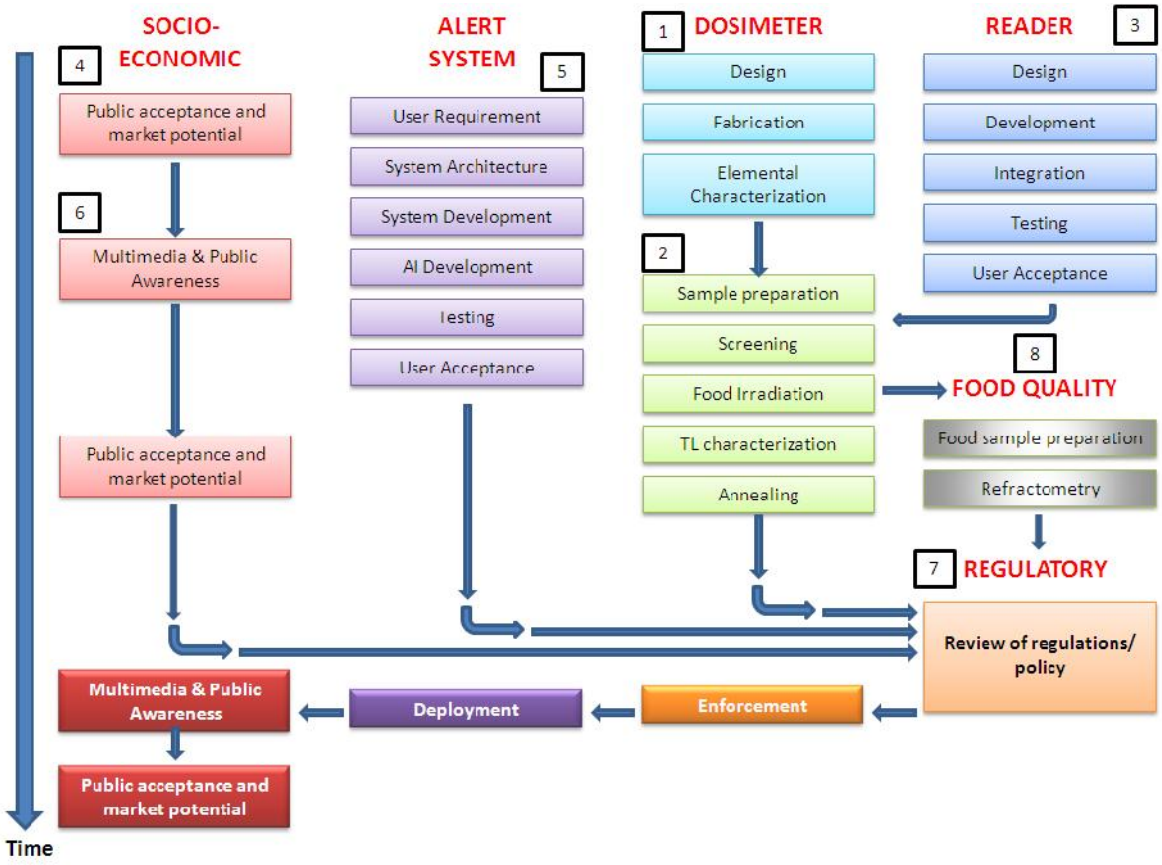

Figure 1: Overview of the proposed program

NO	PROJECT TITLE	LEADER/ MEMBER	FUNDING RECEIVED RM ('000)	H-INDEX	CITATION	JOURNAL PUBLICATION	INSTITUTION
1	**Design, fabrication and elemental characterization of fiber dosimeters (Doped Fiber and PCF)**	**Prof. Dr. Hairul A. Abdul-Rashid (L)**	**3,120**	**8**	**201**	**62**	**MMU**
		Khairul Anuar Mat Shariff					TMR&D
		Mohd. Imran Zulkifli					TMR&D
		Shahrin Zen Muhammad Yasin					TMR&D
		Alawiah Ariffin					MMU
		Assoc. Prof. Dr. Faisal Rafiq M. Adikan					UM
		Dr. Ghafour Amouzad					UM
		Dr. Nizam Tamchek					UPM
		Assoc. Prof. Dr. Zulfadzli Yusoff					MMU
		Assoc. Prof. Dr. Ridzuan Mokhtar					MMU
		Dr. Mukul C. Paul					CGCRI

		Prof. Dr. Raphael Phan					MMU
2	**Irradiation and Optically Stimulated Luminescence (OSL) and TL characterization**	**Prof. David A. Bradley (L)**	**10,000**	**22**	**1319**	**200**	**UM/ Univ. Of Surrey**
		Prof. Dr. Yusoff M. Amin					UM
		Prof. Dato' Dr. Mohd Jamil Maah					UM
		Assoc Prof. Faizal Mohamed					UKM
		Dr. Suhairul Hashim					UTM
		Dr Wan Saffiey Wan Abdullah					NMA
		Dr. Ahmad Taufek Abdul Rahman					UiTM
		Assoc. Prof. Dr. Faizal Mohamed					UKM
		Assoc. Prof Dr. Noranizan Mohd Adzahan					UPM
		Dr. Norhayati Hussain					UPM
		En. Taiman Kadni					ANM
		Dr. Noramaliza Mohd Noor					UPM
		Alawiah Ariffin					MMU
		Assoc. Prof. Dr. M. Iqbal Saripan					UPM
		Assoc. Prof Roslan Md Nor					UM
		Assoc. Prof. Rosli Mahat					UM
		Dr Muhamad Samudi Yasir					UKM
		Dr. V. Vijayakumar					MMU
		Dr. Yang Ping					NUS
3	**Design and Development of versatile TL and OSL dosimeter reader**	**Dr. Nizam Tamchek (L)**	**2,500**	**7**	**152**	**35**	**UPM**
		Dr. Suhairul Hashim					UTM
		Dr. Ahmad Taufek Abdul Rahman					UiTM
		Dr Wan Saffiey Wan Abdullah					NMA
		Assoc. Prof. Faizal Mohamed					UKM
		Assoc. Prof. Dr. Zulfadzli Yusoff					MMU
		Assoc. Prof. Dr. Ridzuan Mokhtar					MMU
		Prof. Dr. Hairul A. Abdul-Rashid					MMU
4	**Assessment of consumer acceptance and market potential of irradiated food products**	**Assoc. Prof. Mohhidin Othman(L)**	**500**	**-**	**-**	**7**	**UPM**
		Dr. Normazalila Abu Bakar @ Harun					MMU
		Dr. Hazrina Ghazali					UPM
		Dr. Wan Melissa Wan Hassan					UPM
5	**Regulated irradiated food database and intelligent early warning system**	**Assoc. Prof. Dr. Ho Chin Kuan (L)**	**3,495**	**6**	**120**	**58**	**MMU**
		Prof. Dr. Raphael Phan					MMU
		Dr. Khairil Imran Ghauth					MMU
		Linda Chua Sook Ling					MMU
6	**Effectiveness of public awareness and education on irradiated food through media**	**Assoc. Prof. Neo Tse Kian (L)**	**475**	**6**	**206**	**111**	**MMU**
		Assoc.Prof. Neo Mai					MMU
		Kwok Wai Jing					MMU
		Heidi Tan Ju-Yeen					MMU
7	**Review of Food Regulations on Irradiated Food**	**Dr. Haniff Ahamat (L)**	**200**	**-**	**-**	**3**	**UIAM**
		Assoc. Prof Noranizan Mohd Adzahan					UPM
		Dr. Ahmad Faizal Abdull Razis					UPM
		Dr. Nasarudin Abd. Rahman					UIAM
		Dr Muhamad Samudi Yasir					UKM
8	**Nutritional content assessment of irradiated food**	**Dr. Ahmad Faizal Abdull Razis (L)**	**200**	**4**	**27**	**11**	**UPM**
		Dr. Norhayati Hussain					UPM
		Assoc. Prof Noranizan Mohd Adzahan					UPM

Table 1: Project Information

Research Program Duration, Budget, Preparedness and Commercialization

Proposed program duration is **4 years**, with total budget requested of **RM11.9 million** for GRA, travelling, research material, equipments and special services.

The program is set based on a strong research track record of the group of researchers as reflected in Table 1. As such, quite a number of **major equipments and facilities are already available** such as:

1. irradiation sources (e.g. Cobalt-60, LINAC, Synchrotron, Gamma, Beta)
2. fabrication facilities (e.g. MCVD, Drawing Tower, Furnace, Solution Doping Station)
3. characterization facilities (e.g. Desktop TLD Reader, SEM, EDX, EXAFS, ESCAR, TOFSIM, Refractometer)

Funding wise, support from the industrial parter, Telekom R&D Sdn. Bhd. has pumped in RM2 million worth of funding on the fabrication facilities, while MOHE has granted RM 115,000 to MMU for the study of doped fiber dosimeters through FRGS. The research team has strong track record with total **funding for past related projects worth RM20 million**.

The outcome of the project can be **commercialized** through a consortium including our industrial partner, namely Telekom R&D Sdn. Bhd. to provide both food irradiation safety products and services. Recently, Global Industry Analysts, Inc. Reported that the global irradiated food market is expected to **grow beyond USD2.3 Billion by 2012 (http://www.prweb.com/releases/food_irradiation/gamma_radiation/prweb1530744.htm).**

Research Approach

The 8 projects proposed in this program, will run in parallel while being highly dependent on one another as portrayed in Figure 1. Description of each project is as follows:

Project 1

Design, fabrication and elemental characterization of fiber dosimeters (Doped Fiber and PCF)

Research question: How do different dopants influence energy traps in fiber dosimeters?, How different microstructure fiber geometries influence on dose response?
How deep are the traps/vacancy created in photonic crystal fiber dosimeter

Hypotheses: High energy/mass of incident particle creates multiple displacement/Frenkel-pair

Solution: Fabricate and characterize fiber dosimeters. Find relation/coefficient of trap number and depth with dopant type and concentration

Synthesis: Fabrication using MCVD and solution doping, elemental characterization using SEM, EDX, WDS, ESR, XANES

Expected outcome: Analysis of bonding structure of dopants in glass matrix leading to understanding of energy trap formation in fiber dosimeters, Understand the effect of fiber size, geometry, and micron size holes in fiber with different uniform structures, on dose response of fiber dosimeters.

Project 2

Irradiation and Optically Stimulated Luminescence (OSL) and TL characterization

Research question: What is the luminescence intensity and wavelength for different fiber dosimeters?

Hypotheses: Luminescence intensity/wavelength depend on incident particle energy and doses, traps type and amount of traps created in the dosimeter

Solution: Find relation/coefficient of incident particle energy and doses, trap number and depth with dopant type and concentration

Method: Radiate dosimeter with different energy and doses (X-ray, gamma, electron, alpha, neutron) and measure TL and OSL.

Expected outcome: Analysis of luminescence intensity and wavelength leading to understand of luminescence coefficient and efficiency

Project 3

Design and Development of versatile TL and OSL dosimeter reader

Problem statement: Luminescence intensity is very small due to ionization quenching. Furthermore, current readers are not portable.

Hypotheses: Low atomic number atom capable to produce higher intensity, use high sensitivity photon-counting detector

Solution: Increase the radiation doses and dopant concentration, develop high sensitivity photon-counting detector

Expected outcome: Prototype of versatile TLD and OSLD reader for rapid analysis of radiation doses

Project 4

Assessment of consumer acceptance and market potential of irradiated food products

Problem statement: Contemporary attitude, awareness and acceptance of consumers towards irradiated foods both from the general public and industry perspective is not known.

Method: Data of interest for this research will be collected using a multi-method methodological approach. A combination of qualitative and quantitative techniques will be employed in assessing consumer acceptance and market potential of irradiated food products which include observations, focus group, face to face and in depth interviews as well as survey questionnaires will be carried out accordingly, in meeting the respective research objectives.
Expected Outcome: Documentation of consumer acceptance, compilation of consumer profile, development of marketing strategies towards irradiated food

Project 5
Regulated irradiated food database and intelligent early warning system
Problem statement: Need for alert when crisis due to safety of irradiated food occurs
Solution: A database of irradiated food, dosage and the relevant metadata with intelligent system (AI) to alert in the case of crisis, with incorporation of privacy mechanisms.
Method/ Synthesis: Database is populated from the enforcement and regulatory departments. The development of mechanisms that enable health related data to be stored and processed without compromising privacy will be done. An artificial intelligence algorithm will be employed to assert the necessary alarm in case of crisis.
Expected outcome: A novel intelligent early warning system, regulated irradiated food database with privacy protection.

Project 6
Effectiveness of public awareness and education on irradiated food through media
Problem statement: Public inadequate knowledge on food irradiation creating misconception
Research question: How do we educate the public on irradiated food and its usefulness? How effective?
Solution: Using social and multimedia technology effectively
Method: Using multi method research approach by using qualitative and quantitative methods
Expected outcome: Documents on effectiveness of the media in enhancing public knowledge and awareness on irradiated food.

Project 7
Review of Food Regulations on Irradiated Food
Problem statement/ question: The Food Irradiation Regulations 2011 prescribe mandatory requirements on doses etc for food irradiation but do not provide procedures to assess conformity with such requirements.
Hypotheses/ Solution: Insert provisions stipulating mechanism to measure and assess conformity with the mandatory requirements on food irradiation.
Method/ Synthesis: (1) Content analysis of Food Irradiation Regulations 2011, (2) Comparative legal analysis with laws and regulations in other countries, (3) Doctrinal analysis on principles relating food safety.
Expected outcome: Propose amendments to the regulations on food irradiation that assess compliance with the requirements for the operation of food irradiation.

Project 8
Nutritional content assessment of irradiated food
Problem statement: The irradiation process affects vitamins.
Hypotheses: The micronutrients of irradiated food are expected to be reduced after radiation at high dose.
Method/ Synthesis: The nutritional content of irradiated food will be assessed using refractometer .
Expected outcome: A suitable dose can be employed in food irradiation to ensure the quality of food and its nutritional value.

Program Outcome

At the end of this program, the outcomes include:

1. Contribute directly to the enhancement of food safety level in Malaysia
2. Contribute indirectly to increase in GDP and strengthening of NKEA: Agriculture
3. 18 PhD students, 27 Masters students
4. 120 conference papers, 80 journal publications
5. 7 patents
6. Market ready prototype development of TL and OSL reader
7. New technologies on food safety using fiber dosimetry
8. New knowledge on mechanism in OSL and TL in fiber
9. New understanding on public and market acceptance and market potential towards irradiated food
10. Proposed new regulations and policy on radiation measurement of irradiated food for both imports and exports