PRELIMINARY ESTIMATES OF ECONOMIC IMPACT OF LIVER FLUKE INFECTION IN THAILAND AND THE FEASIBILITY OF IRRADIATION AS A CONTROL MEASURE

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Abstract. Liver fluke infection by *Opisthorchis viverrini* is the leading cause of food-borne parasitic disease in Thailand. Approximately one third of the population in the northeastern region of the country, ie, 6–7 million, are infected by this parasite through the habit of consuming raw or insufficiently cooked freshwater fish, especially those of cyprinoid family. A recent survey showed that 60% of the work force in the Northeast between the age of 15 and 60 is infected. The estimated wage loss of this population may be approximately Baht 1,620 million (US$65 million) per annum. The estimated direct cost of medical care may be as high as Baht 495 million (US$19.4 million) per annum. Thus, the total direct cost of the infected work force is estimated to be Baht 2115 million (US$84.6 million) per annum.

Irradiation of fish flesh infected by metacercaria of *O. viverrini* has been demonstrated as an effective method of control. A minimum dose of 0.1 kGy is effective without changing physiochemical properties of the fish flesh. This technology, therefore, shows promise as a method to control infection by *O. viverrini* acquired by the habit of consuming raw freshwater fish in the country. Preliminary economic analyses indicate that the public health benefit from preventing infection with this parasite could outweigh the investment cost of irradiation facilities. Detailed economic feasibility studies should be carried out to demonstrate the practical efficacy and cost-effectiveness of the treatment as a public health intervention measure in the country.

INTRODUCTION

While the world has witnessed tremendous technological development in recent years, basic primary health care has not kept up with this progress. For example, the incidence of food-borne disease continues to adversely affect the health and productivity of populations in most countries, particularly those in the developing world. The report of a Joint FAO/WHO Expert Committee on Food Safety (WHO, 1984) stated that "illness due to contaminated food is perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity".

Because food-borne disease is so widespread and a significant cause of morbidity, the social and economic impact is considerable in both developing and developed countries; more information is available concerning the latter. While the economics of food-borne disease is not clearly established, the estimate in North American and European countries shows that it can be enormous and represents a significant loss to national economies. For example, the United States Food and Drug Administration estimated the occurrence of food-borne diarrheal disease in the USA is as high as 24–81 million cases per year. The costs of medical care and lost productivity may amount to US$5–17 billion per year (Archer, 1986). Todd (1989) estimated the total number of cases of food-borne disease in Canada to be 2.2 billion cases per year of which 88% was caused by microbiological agents. The estimated economic loss was 1.3 billion Canadian dollars in 1985. In the Federal Republic of Germany, salmonellosis costs alone were estimated to be DM240 million per year (WHO, 1984). Costs of medical treatment and productivity lost alone for trichinosis, toxoplasmosis, salmonellosis, campylobacteriosis and beef tapeworm in the USA were estimated by the USDA to be over US$1 billion per year (Morrison and Roberts, 1985).

Little data are available on the estimated costs and economic impact of food-borne parasitic diseases, especially those commonly occurring in developing countries. Roberts (1985) estimated the costs of lost wages and medical treatment of 563 reported cases of trichinosis in the USA in 1985 as $1.4 million. This paper attempts to make preliminary analysis of economic impact of liver fluke infections caused by *Opisthorchis viverrini*, a common parasitic disease transmitted to man by the consumption of raw freshwater fish in Thailand. It will also attempt to analyze the feasibility of introducing irradiation technology to control the disease in the country.

LIVER FLUKE INFECTION

Liver fluke infection is widespread among populations in the northeastern region of Thailand. This region has a total population of approximately 18 million, one third of the entire country. According to the Thai Ministry of Public Health, the most common diseases of the population in this region are those of the respiratory tract and gastrointestinal tract, with infection rates of 89.6 and 64.7 per 1000 population, respectively (Anon , 1985). The populations in this region have a tradition, culture and habits which differ from those of other regions. For example, the habit of eating raw meat and fish allows parasites, such as tapeworms, round worms, liver flukes and other food-borne parasites, to gain access into their bodies. As freshwater fish is the most common source of animal protein for the population, the major causes of their gastrointestinal infections are intestinal parasites, especially the liver fluke. In addition, the habit of farmers of defecating in the field promotes the spread of this disease. The Ministry of Public Health estimated that one third of the population in the region, ie, 6 million are infected with liver flukes.

To improve economic productivity of the region, a number of water resource development projects have been put into operation to improve irrigation and increase fish production. Such projects have also contributed to the spread of parasites in fish and aquatic animals in the region.

Epidemiology of liver fluke infection

According to Sornmani (1988), *O. viverrini* is transmitted through consumption of raw or improperly cooked freshwater fish, especially of the cyprinoid family which is abundant in natural waters all over Thailand.

The popular dishes prepared from this fish are "koi pla" and "pla som". "Koi pla" is made by chopping raw fish into small pieces and mixing it with chili, lemon and other spices. It is then eaten immediately with glutinous rice. "Pla som" is also made from fresh cyprinoid fish but it is mixed with boiled rice and other spices and left to ferment overnight. Metacercariae in fish prepared by these methods can retain their infectivity.

Liver fluke infection is known throughout Thailand, but is much more prevalent in the northeastern region. It is a chronic liver disease and the common clinical symptoms are weakness, gastrointestinal disturbances and pain the right subcostal region. Jaundice and fever from the obstruction of bile ducts or cholangitis are also common. In prolonged and severe cases, the patients may develop biliary fibrosis or cholangiocarcinoma of the biliary system. An effective medicine to treat the infection became available recently. Praziquantel, an isoquinolin compound, has been found to be highly effective against the infection. The side effects of the treatment are mild and could be reduced or prevented by giving the drug after dinner. Although an effective drug is available to control the disease, there are still problems concerning the cost of the drug and the high reinfection rate.

Measures to control infection

The following measures have been considered and introduced for controlling liver fluke infection:

a. Control of intermediate hosts (snail, fish).
b. Health education and improvement of sanitation.
c. Prevention of reinfection.
d. Treatment.

The first measure was considered impractical and uneconomical. The second measure will take considerable time, especially changing the habit of the population from eating raw to cooked fish. The same is true for the third measure, as the only way to become reinfected is through ingestion of raw fish. Thus, the fourth measure is the only way to control this infection in Thailand at present.

Notwithstanding the difficulties facing the control of liver fluke infection, three pilot projects were carried out by Sornmani (1988) and his team between 1981 and 1986 in Khon-Kaen Province. The projects covered diagnosis, treatment, health education and sanitation improvement. The strategies included education of mothers, children in school, annual treatment to reduce reinfection, community participation in diagnosis and payment for the treatment, etc. The projects were quite successful as the number of infections was significantly reduced during this period. Close and constant monitoring of the infection is required, however, to evaluate the degree of reinfection of the parasite.

In principle, there are three defense mechanisms to control food-borne illness:

a. To produce food (eg, fish, meat, vegetables) free from agents which cause infectious diseases.
b. To process food to destroy target organisms (eg, pathogenic bacteria, parasites).
c. To educate consumers to properly handle and cook food.

With regard to liver fluke infection, it appears that only the last defense mechanism is applicable until now. While the practicability and economics would rule out the applicability of the first mechanism, it may be worthwhile exploring a technology which could control the infectivity of liver fluke without compromising the safety and quality of treated fish. Such a technology should be comparable to heat pasteurization of liquid food (eg, milk), which is effective in controlling milk-borne pathogens without significantly altering the nutritional value or quality of milk.

ECONOMIC IMPACT

In general, the economic impact of food-borne illnesses may be measured by:

a. The loss of business to the food producer, retailer or caterer.
b. Medical care and hospitalization of the patients.
c. Income lost because of illness or carrier state.
d. Cost of investigation of the outbreak.
e. Cost of recall of infected food from commercial channels, destruction of such food.
f. Law suits and prosecution.
g. Grief, pain, suffering and death.

In this preliminary analysis of economic impact of liver fluke infection in Thailand, attempts were made to estimate only the costs of medical care and hospitalization and income loss because of illness caused by liver fluke infection. A number of assumptions were made to arrive at reasonable estimates.

Based on a previous one year observation on morbidity of opisthorchiasis in a community in Khon Kaen Province conducted by Sornmani (1988), the following assumptions were made in making an economic analysis:

a. Total population infected by liver fluke in the northeastern part of Thailand: 6 million.
b. The percentage of the infected population at active working ages (15–60): 60% (a total of 3.6 million population infected).
c. Each infected person had an average of three days of illness during each episode.
d. Parasite treatment per person per treatment: 3 tablets of praziquantel at a cost of 25 Baht each ($3 \times 25 = 75$ Baht/person/annum).
e. Five per cent of infected persons required hospitalization on an average of 3 days/ person/year. The cost of hospitalization is approximately Baht 250/day ($300,000 \times 3 \times 250 = 225,000,000$).
f. Official minimum wage of Baht 50/day/person.

From these assumptions, the cost estimates of medical care and wage loss of liver fluke infection northeastern Thailand were as follows:

Loss of wages	**Cost/annum**
a. Income per capita in northeast: 50 Baht/day,	15,000 Baht (6×10^2 US$)

25 days/month

b. If 60% of work force is infected.	3.6×10^6 persons
c. Each infected person has 3 episodes per year of 3 days duration. each ($3.6\times10^6\times3\times3\times50$)	$1{,}620\times10^6$ Baht (65×10^6 US$)

Direct cost of medical care

a. Treatment (25 Baht/tab, 3 tab. of praziquantel/person)	270×10^6 Baht (10.4×10^6 US$)
b. If 5% of infected persons required hospitalization of 3 days at Baht 250/day ($0.3\times10^6\times3\times250$)	225×10^6 Baht (9×10^6 US$)
Total direct medical cost:	495×10^6 Baht (19.4×10^6 US$)
Total direct cost of infected work force of 3.6×10^6 persons	$2{,}115\times10^6$ Baht (84.6×10^6 US$)

Using the conservative scenario, wages lost from the infection may be as high as Baht 1,620 million (US$65 million) per annum. Together with the cost of medical care of Baht 495 million (US$19.4 million) the economic impact of wages lost and of medical care of infection caused by liver flukes in northeastern Thailand may be as high as Baht 2,115 million (US$84.6 million) per annum.

IRRADIATION TO CONTROL FOOD-BORNE PARASITES

Unlike thermal pasteurization of liquid food, there is no method to "pasteurize" solid foods from animal origin, such as meat, fish, chicken, etc, to ensure their hygienic quality and without changing their physical properties.

In the past decade, radiation treatment of food has been increasingly recognized by national authorities as an effective method to ensure hygienic quality of food, especially solid food, and to reduce post-harvest food losses. The safety of this treatment has been evaluated by several international expert committees appointed by FAO, IAEA and WHO since 1964. In its last session, the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Foods (WHO, 1981), convened in 1980, concluded that "irradiation of any food commodity up to an overall average dose of 10 kGy causes no toxicological hazard; hence, toxicological testing of food so treated is no longer required." The Committee also stated that such treatment introduces no special nutritional and microbiological problems in food. In 1983, the Codex Alimentarius Commission, an intergovernmental body dealing with worldwide food standards, and represented by 138 governments at present, adopted a Codex General Standard for Irradiated Food and Recommended International Code of Practice for Operation of Facilities Used for Treatment of Food.

Following these international recommendations, 37 governments have approved the use of irradiation for treating one or more food items. Twenty-four of these countries are using the technology for treating a number of food/food ingredients for commercial purposes. With regard to control of food-borne parasites, the US FDA has approved the use of the technology for controlling trichinosis in pork, with a minimum dose of 0.3 kGy. There is, however, no practical application for this purpose in the USA in view of the low incidence of trichinosis in the country. Small scale application of irradiation to control salmonellosis and trichinosis in "nham" (fermented pork sausages) has been successfully carried out in Thailand in the past 4 years (Prachasittisak *et al*, 1989).

What is food irradiation? What can it do?

Food irradiation is the treatment of food by a certain type of energy similar to heating, freezing and microwaving. The process involves exposing the food, either packaged or in bulk, to carefully controlled amounts of ionizing radiation for a specific time to achieve certain desirable objectives. Ionizing radiation which can be used for treating food include the following:

a. Gamma rays from the radionuclides ^{60}Co or ^{137}Cs.
b. X-rays generated from machine sources operated at or below an energy level of 5 MeV.
c. Electrons generated from machine sources operated at or below an energy level of 10 MeV.

These ionizing radiations cannot add radioactivity to the food regardless of the length of time the food is exposed or the amount of energy "dose" absorbed. In other words, these radiations are at levels too low to induce radioactivity in any material, including food.

Ionizing radiations act through changes in DNA molecules in living organisms, such as bacteria or sprouting cells, to prevent their division, or cause biochemical reactions in the physiological processes of plant tissues slowing down ripening or maturation of certain fruits and vegetables. The energy level used for irradiation of food to achieve any technological purpose is extremely low. At the maximum energy level (dose) of ionizing radiation recommended by the Codex Alimentarius Commission for treating food (10 kGy), the absorbed energy is equivalent to energy of heat which would increase the temperature of water by 2.4° C. Quite often, irradiation of food uses much lower doses (0.1 or 1 kGY) which would be equivalent to heat energy of 0.024° C or 0.24° C. Thus, irradiated food remains at the same natural state after treatment as it was originally.

Irradiation as a control method

The effect of irradiation on the destruction of food-borne parasites was recognized some 70 years ago (Schwartz, 1921). Gould *et al* (1955), Gomberg and Gould (1958), and Brake *et al* (1985) demonstrated the effect of irradiation at a minimum absorbed dose of 0.3 kGy against *Trichinella spiralis* in pork. Based on these data, the US FDA approved the use of irradiation for treating pork to control *T. spiralis* in 1985 (FDA, 1985) using a minimum absorbed dose of 0.3 kGy (maximum 1 kGy).

Taylor and Parfitt (1959) and van Kooij and Bobijns (1968) reported a dose of 6 kGy to control *Taenia solium* and *T. saginata* using evagination as a means to determine whether the treated tapeworms were still alive. Verster (1979), however, used the ability to grow and retain scolices as criteria to determine infectivity, and reported a dose between 0.2 and 0.6 kGy could be used to render carcasses infected with cysticerci fit for human consumption. Dubey *et al* (1986) reported a dose of 0.5 kGy as effective to prevent infectivity of *Toxoplasma gondii* using cats and mice for bioassay.

In the past three years, institutions in Argentina, Belgium, China, Japan, Republic of Korea, Kuwait, Mexico, Poland, Thailand, Turkey and USA have collaborated under the scope of a Coordinated Research Program on the Use of Irradiation to Control Infectivity of Food-Borne Parasites, sponsored by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. The results of this coordinated research program are summarized in Table 1.

Strategies

Thermal pasteurization of milk has been made mandatory by most governments in the past 50 years to protect consumers' health. As a result, milk-borne disease has been significantly reduced or virtually eliminated. Unfortunately, consumers are not yet given the same degree of protection from other foods of animal origin, especially those intended to be consumed in a raw or partially cooked state.

Radiation treatment of such foods against pathogenic microorganisms and parasites offers a unique opportunity to control infections from these biological agents. The liver fluke is sensitive to low dose irradiation. A minimum radiation dose of 0.10 kGy appears to be effective to control infectivity of this parasite. Treated fish will remain in its raw state and can be

Table 1

Minimum Effective Dose (MED) of radiation to control infectivity of certain food-borne parasites.

Parasite	MED (KGy)
Opisthorchis viverrini	0.1
Clonorchis sinensis	0.1
Angiostrongylus cantonensis	2.0*
Toxoplasma gondii	0.55
Taenia saginata	0.6*
Trichinella spiralis	0.3

* Preliminary results

used for traditional food preparation without significant changes in sensory properties. However, for the infection to be effectively controlled by this technology, the following parameters will have to be considered:

a. Logistics of treating fish soon after catching and distribution in the villages.
b. Population to be made well-aware of health risk from consuming raw cyprinoid fish.
c. Populations need to have neutral attitude to fish treated by irradiation.
d. Close cooperation among local health, food control and technical personnel in treating fish by this technology.

Thus, a feasibility study should be carried out to determining the volume of products to be treated, type of facility (whether stationary or mobile unit), its capacity, location and cost. Consumer attitudes will also have to be studied to ensure success of the project. Ideally, such a project should be carried out in a model village where the incidence of infection is already known and the local health authorities are constantly monitoring it. The impact of irradiation of local fish products on the incidence of infection could then be measured.

Once a small scale feasibility study produces positive conclusions, the government (central or provincial) has to decide in terms of investment about an irradiation facility. Irradiation, in this case, should be considered as an effective public health intervention measure rather than economic benefit to the investment. The cost of investment of irradiation facilities (approximately US$800,000 each) and the treatment cost should be borne by national authorities in exchange for the cost of medical care and lost productivity attributable to liver fluke infection. It would also be interesting to conduct a large scale economic feasibility study on installing a number of facilities in Thailand to treat all cyprinoid fish against this parasite. It may be possible that the public health benefit would far outweigh the investment cost of facilities.

An added benefit of an irradiation facility is that it can also be used for controlling the infectivity of other parasites in raw fish and for treating other types of food, such as rice and dried fish against insect infestation, onions, potatoes, garlic and ginger roots against sprouting, and "nham" against *Salmonella* contamination, and possibly *Trichinella*, etc.

CONCLUSIONS

Radiation treatment has been demonstrated as an effective method to ensure hygienic quality of food, especially solid food. It is similar to thermal pasteurization, which is effective for the same purpose in liquid food. Radiation treatment is unique as a method to control food-borne illness in solid food of animal origin (meat, fish) which is traditionally consumed raw or improperly cooked. The technology shows promise as a method to control liver fluke infectivity attributable to the habit of consuming raw freshwater fish in certain regions of Thailand. The estimated cost of medical care and lost wages from this illness is approximate Baht 2,115 million (US$84.6 million) per annum. Together with other costs, such as loss of jobs and productivity, possible reduction of life span, travel to and from clinics/hospitals, etc, the cost of this food-borne parasitic disease alone represents a significant loss to the economy of the country. Preliminary analysis indicates that the public health benefits from controlling infectivity of this parasite by irradiation would far outweigh the investment cost of irradiation facilities. Detailed feasibility studies would have to be conducted to demonstrate the practical efficacy and acceptability of the technology by the local population.

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