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THE POTENTIAL USE OF IONISING ENERGY TREATMENT IN QUEENSLAND'S HORTICULTURAL INDUSTRIES

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THE POTENTIAL USE OF IONISING ENERGY TREATMENT IN QUEENSLAND'S HORTICULTURAL INDUSTRIES

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SUMMARY AND CONCLUSIONS

The potential application of ionising energy treatment (IET) technology in Queensland falls into three categories viz. insect disinfestation, disease control and quality improvement, of which insect disinfestation is the most important and would be the governing factor in any commercial irradiation programme.

IET fulfils the requirements of a disinfestation treatment against Queensland fruit fly and other pests of quarantine importance in respect to efficacy, absence of phytotoxicity, absence of residues and, on technical considerations would be an ideal replacement for the fumigant EDB. In Queensland the two insect problems for which the technology is most applicable are fruit flies and the mango seed weevil. For individual commodities into certain markets, additional pests are also involved.

Uneconomically low throughput is estimated to preclude commercial feasibility of any form of IET in the short term (2 to 5 years). In the medium term (5 to 10 years) it is judged that an IET plant would need the support of other usage (for example, medical sterilisation) with fresh foods providing only supplementary throughput. In the longer term, an installation specifically for fruit and vegetable treatment could only be viable in Queensland if export markets develop quite substantially and marketing and logistical constraints can be overcome.

Ionising energy is a well established technology in use throughout the world principally for the sterilisation of medical equipment. The use of this technology on foodstuffs has been limited to date due to previous concerns over consumer safety. These concerns have been largely waylaid by the July 1983 FAO/WHO approval to treat food by ionising energy at doses up to 10kGy. This approval has, and will continue to, lead to an acceleration in the treatment of foodstuffs with ionising energy.

The technology of generation of ionising energy is in a highly dynamic phase with major developments in electrical generation even during the term of our study. It is not possible to predict the state of technology when production of crops in the developmental phase reaches full production but the current technology of Cobalt-60 sourced facilities could well be phased out in favour of electrically generated X-rays.

Benefits for disease control and quality improvement do not justify introduction of the technology at present but advantageous effects of this nature would accrue from disinfestation treatments for some commodities. The potential for disease control usage lies with multiple component treatments (for example, in combination with hot water treatments) with IET contributing in a synergistic role where the combined effects are greater than the sum of the independent effects of the individual component treatments.

There is potential for user-disappointment if it is not realised that other fruit handling techniques must be retained at existing standards. These techniques are in the post-harvest handling area of packaging, transportation and storage.

Further demand for ionising energy would be for quarantine treatment of imported fruit, vegetables and flowers which would assist the economic viability of an IET facility. Increased throughput could also come from the beekeeping industry for voluntary disease control in apiaries if conveniently located IET facilities became available.

The constraints to the commercialisation of food irradiation in Australia are fourfold, entailing legal approval, fulfilment of research needs, economic viability and consumer acceptance.

The approval of health authorities is expected in 1985 given the recommendation of the NHMRC early in 1985.

A significant research input will be needed: to prove treatments by commodities for pest species; to optimise IET dosage for maximum bonus disease and quality effects; to solve fruit damage problems arising in individual crops; and to generally facilitate the adoption of the technology by the industry. Maximum interaction of insect and disease control and quality improvement research is essential.

The early acquisition of a research irradiator is judged to be the best alternative to cope with perceived research needs.

Study tours should be undertaken within 2 years by researchers in the areas of commodity treatment research and market planning involving the transfer of the technology to industry.

Because of the high capital cost of a commercial facility and the related high economic threshold for throughput, initial market development should be undertaken with existing facilities in Sydney and Melbourne until an installation in Queensland can be sustained with an economic throughput. The alternative of subsidisation of a Queensland-based IET plant could be very costly with operating costs of such a plant in the vicinity of $600 000 per annum.

In the absence of subsidisation, the construction of an IET facility will remain a purely commercial decision. However, priority research will enable the identification of the most appropriate type, location and timing of construction of an IET plant, thereby facilitating some industry input into the construction of a commercial facility.

Consumer acceptance should not be a significant problem within Australia once the appropriate health clearances are approved and provided incorrect treatments, leading to adverse physiological effects in fruits, can be prevented. There may, however, remain some 'anti-nuclear' opposition which could favour the construction of electrically-sourced X-ray plants.

Once an IET facility becomes available, crops most likely to provide high volume throughput are mangoes, citrus, avocados, tomatoes, cut flowers and possibly bananas. Those likely to expand as a result of availability of the technology include green ginger, broccoli, papaw and lychees.

INTRODUCTION

The potential for ionising energy as a postharvest treatment for fruit and vegetables has been recognised for more than 20 years. The purposes of such treatments have been to improve quality or extend shelf life through delayed ripening, to prevent deterioration caused by micro-organisms, or to serve as a disinfestation treatment against insects for quarantine or related purposes. Despite extensive research activity this process has not been implemented commercially, arguably due to problems of high capital costs, associated logistical complexities, health clearances and public acceptance.

Bans implemented by US authorities on the use of the fruit fly disinfestation fumigant ethylene dibromide (EDB), precipitated a critical situation for trade in tropical and temperate fruits throughout the world. Ionising energy treatment is a favoured candidate replacement for EDB, with even greater versatility. It is used commercially in Australia for sterilisation of medical products and a range of industrial purposes. Overseas, it is used additionally for prevention of sprouting in stored onions and potatoes and, possibly uniquely, in South Africa on a quasi-commercial scale for the extension of shelf life, insect disinfestation and disease control in fruit.

In Australia, as in many other countries, the process is not yet approved for fresh foods for human consumption. However, a recent decision by the Codex Alimentarius Commission of the United Nations World Health Organisation adopted a maximum safe irradiation dose of 10 kilograys (kGy) for foodstuffs for human consumption. Acceptance of this WHO limit in Australia is anticipated and the way would then be open for implementation of IET technology across a wide range of foodstuffs in Australia. The 10kGy limit is many times that required for the treatment of fresh fruit as the usual limit before damage is caused to fresh fruit is 1kGy.

The origin of this Working Group predated the bans on EDB. It was initiated with a view to establishing a disinfestation treatment against the mango seed weevil. This insect is a major factor in the exclusion of Queensland mangoes from mainland USA, Japan, the Middle East and other markets, and is not sufficiently susceptible to any of the fumigants or insecticides currently used. IET was judged to be the only treatment likely to be effective against the weevil while having the added advantage of being highly effective against fruit flies and other mango pests of quarantine importance.

This Working Group was convened to investigate all aspects of IET technology, its potential application to the Queensland fruit and vegetable industry, and the feasibility of establishing a pilot installation. It brought together expertise in entomology, plant pathology, plant physiology, marketing and economics, as they related to the adoption of IET technology. This report addresses these aspects and provides conclusions on IET as it relates to Queensland's horticultural industries. Detailed technical contributions on each of these aspects are appended.

BACKGROUND

Ionising energy treatment entails the use of radiation energy at levels which momentarily reduce the molecular structure of plant or animal tissues to their component ions. At low doses it affects reproduction of insects and plants resulting in sterility, while at high doses it causes death of all organisms and tissue changes in fresh food. The energy involved is many levels below that which could impart radioactivity to the food or other commodities treated in this way.

The dosage which irradiated matter receives is a function of the strength of the source of the ionising energy, the length of time of exposure, and the distance/depth/density of the matter relative to the source. Dosages are measured in kilograys (kGy).[1]

There are three types of radiation sources which could be used for treating food, viz:

- radioisotopic (nuclear) sources (for example, Cobalt-60): this is currently the most commonly used source-type;
- electrically-sourced electron accelerators (electron beams): although widely used in industry (for example, for polymerization) this source-type does not produce sufficient penetration to be of general application in the food industry;
- electrically-sourced X-rays (converted from electron beams): although this technology has been available for many years, its use in food irradiation is yet to be put into practical application (an X-ray sourced plant is expected to be operational in the U.S. by 1986).

The uses of IET to date have largely been restricted to high dosage sterilisation of medical equipment. However, a diverse range of applications to food products have been developed over the years. These uses can be broadly divided into three categories, viz:

- High dosage (up to 50kGy): long-term preservation of meat and poultry, via total sterilization and elimination of viruses;
- Medium dosage (up to 10kGy): reduction of microbial loads (disease control) for a variety of foodstuffs (for example, spices, poultry, game meats, seafood);
- Low dosage (up to 1kGy): sprout inhibition and delay in ripening in fresh fruit and vegetables and insect disinfestation in grains and fresh fruit and vegetables .

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1 Grays have replaced the former unit, rads (100 rads = 1 Gy)

The practical application of food irradiation has not been extensive to date. Major examples are:

. Soviet Union	: insect disinfestation of imported grains (other uses probably also occur).
. Japan	: inhibition of sprouting in potatoes
. Netherlands	: reduction in microbial loads for spices and various frozen produce
. Belgium	: similar to uses employed in Netherlands
. South Africa	: insect disinfestation, extension of shelf-life and disease control in fresh fruit and vegetables
. Hungary	: inhibition of sprouting in onions
. Norway	: reduction in microbial loads for spices
. United Kingdom	: sterilisation of meals for immune-deficient hospital patients;
. USA	: reduction in microbial loads for spices.

The restricted application of food irradiation to date has largely been due to concerns over safety for human consumption - concerns which were alleviated by the 1980 recommendations of JECFI.[2] The principal recommendation of JECFI was that foods irradiated at doses up to 10kGy be considered safe for human consumption. This recommendation was accepted by the Codex Alimentarius Commission in July, 1983. This Commission is an international organisation established to implement the joint FAO/WHO Food Standards Program by recommending the adoption of approved food standards in member countries.

With the removal of doubts about the safety of irradiated foods to consumers, it is expected that most countries will remove the legal barriers to food irradiation. In the United States, an FDA (Food and Drug Administration) proposal currently in place will permit food to be irradiated to inhibit the growth and maturation of fresh fruits and fresh vegetables, and to disinfest food of insects at doses not to exceed 1kGy and to disinfect spices of microbes at doses not to exceed 30kGy. It is expected that this proposal will be approved early in 1985. The FDA has notified an intention that approval for food irradiation at higher doses will be considered upon the completion of further research.

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2 Joint FAO/IAEA/WHO Expert Committee on Wholesomeness of Irradiated Food.

In Australia, the legislative responsibility for the approval of food irradiation rests with the various State Departments of Health. However, where health matters are of general concern to all States, the NHMRC (National Health and Medical Research Council) is empowered to consider such matters and recommend the appropriate legislative action to the States. The NHMRC has considered the introduction of food irradiation in Australia and it is expected that a recommendation could be made early in 1985 to approve the irradiation of food at doses up to 10kGy. If the States accept this recommendation the remaining constraints to the introduction of food irradiation in Australia will be:

- economic viability
- consumer acceptance
- the need for detailed research to ascertain optimal doses and verify efficacy

These matters are addressed further in this report.

The co-ordination of the introduction of food irradiation in Australia is the responsibility of the newly-formed Advisory Group on Application of Irradiation Technology to Foodstuffs. This Committee, formed under the auspices of the Standing Committee on Agriculture, comprises representatives from Government, Agriculture and Health Authorities, and is responsible for advice on technical and regulatory aspects of food irradiation, monitoring of overseas developments, co-ordination of research and development in Australia and liaison with Government and consumer organisations on consumer education. The convenor of this Working Group is currently the Queensland representative on the Advisory Group.

PURPOSES OF IONISING ENERGY TREATMENT

General

For the purposes of insect disinfestation, disease control or quality improvement, three essential features are required of treatments.

- Demonstrated efficacy
- No detrimental effects to the commodity
- Ability to meet health and safety requirements for both producer and buyer countries.

Ionising energy treatment appears to meet these as well as, and possibly better than, any other treatment. It is by no means entirely free of problems and could prove unsuitable for some commodities or require special modifications such as precooling or treatment in a controlled atmosphere.

A further problem with ionising energy treatment is that it could raise unfulfillable expectations for quality improvement. Clearly, fruit which is less than prime quality is unlikely to become so following irradiation. Similarly, fruit must continue to be protected from mechanical damage by good packaging and transport practices, and refrigeration will continue to be needed in most instances. Insect disinfestation treatments confer no residual protection and care will be necessary to segregate treated from untreated fruit and ensure that reinfestation cannot occur. Similar requirements apply to an even greater extent for disease control.

Insect disinfestation

This use is judged to be potentially the most advantageous application of ionising energy treatment to fruit and vegetables in Australia. The method is widely effective as a quarantine treatment. Such treatment is normally applied to fruit before export but can be equally appropriate for imported commodities for which treatment might be ordered following inspection. A further usage is to reduce insect numbers to an infestation threshold or tolerance which might be required in a commodity by a market, on grounds other than quarantine.

Throughout the world, fruit flies are arguably the most important pests necessitating quarantine treatment of fruit and vegetables. In Australia the most important is the Queensland fruit fly **Dacus tryoni** (See Appendix 1). However, there are 14 other endemic species of economic importance of which at least two, the cucumber fly, **D.cucumis** and Jarvis' fruit fly, **D.jarvisi** warrant separate consideration. Other pests for which ionising energy treatment is appropriate include the mango seed weevil **Sternochaetus (Cryptorhynchus) mangiferae**, lightbrown apple moth **Epiphyas postvittana**, potato moth, **Phthorimaea operculella** and numerous scale insects, mealy bugs, thrips, and other plant feeding larvae of moths.

Historically, the most widely used quarantine treatment for fruit flies was fumigation with ethylene dibromide, although Australian species were found to be more difficult to kill than other species and required higher concentrations of gas, often leading to fruit damage and excessive bromide residues. This treatment was the subject of EPA (Environmental Protection Agency) bans in the USA, operative from 1 September, 1984 for all fruit and vegetables except imported mangoes and exported grapefruit, for which the effective date has been extended. Consequent action in Australia has involved elevation of the compound in the poisons schedule; thus involving more stringent controls on operator exposure and a lowering of permissable residues by a factor of 10.

The best approved alternative is cold treatment at $-0.5^{\circ} \pm 0.5^{\circ}C$ for 14 days. This treatment can be used on apple, pear, grape, orange, kiwifruit, persimmon and pomegranate but is unsuitable for highly perishable commodities such as berries and stone fruits or for chill-sensitive cultivars including grapefruit, lemon, avocado, papaw, bananas, tomato and capsicum. Other alternatives include heating in a saturated atmosphere which appears not to be satisfactory against Australian pest species. The insecticides dimethoate and fenthion, with few exceptions, do not meet the high levels of quarantine efficacy demanded by many overseas and interstate markets except Victoria.

Quarantine treatments are required to meet demonstrated levels of efficacy. The highest of these is 'Probit 9' or 99.9968% mortality at P=0.05. In practice, this translates as no survivors in 100 000 treated insects at each relevant stage of the life cycle. Within Australia requirements are currently 99.99% mortality demonstrated as no survivors in 30 000, or 99.5%, demonstrated as no survivors in 1 500. For fruit flies the Probit 9 level can be met with ionising energy treatment at a dose of 0.075 kGy if the criterion for effect is "no viable pupae". Should mortality of eggs or larvae be a requirement, the dose would need to be increased to 0.2 kGy. If sterile offspring were an acceptable criterion the dose could be as low as 0.025 kGy.

For insects other than fruit flies the dose also varies. About 0.3 kGy will give sterilisation of the mango seed weevil and about 0.6 kGy will produce larval mortality. Some moth adults however, can survive 1 kGy, the most common threshold for effects on fruit tissues, although the progeny of such moths would be sterile.

A summary of advantages and disadvantages of ionising energy treatment and the most common alternatives for insect disinfestation are shown in Table 1.

Table 1. Advantages and disadvantages of commonly used commodity treatment..

* signifies 'yes' X signifies 'yes conditionally'

Advantages	EDB	MeBr[1]	Cold	Heat	Insecticides	IET[2]
Wide spectrum	*				*	*
Effectiveness (QFF[3])	*		*		X	*
No residues			*	*		*
Simple dosimetry	*	*			*	*
Low cost					*	

Disadvantages	EDB	MeBr[1]	Cold	Heat	Insecticides	IET[2]
Operator restrictions	*	*				*
Fruit damage	X	*	*	*		*
High capital			*			*
Health approvals	*	*			*	*

1. Methyl bromide, a fumigant of limited usefulness for fruit against Queensland fruit fly
2. Ionising energy treatment
3. Queensland fruit fly

Disease control

Postharvest disease control is a major factor in the marketing of fruit and vegetables, because it is the most important single factor, apart from ripening, affecting the shelf life of commodities. However, the prospects for using ionising energy treatment to control these diseases are not as optimistic as they are for insect disinfestation. The causal moulds and bacteria generally require high doses of irradiation for control (see Appendix 2). A minimum dose for disease control approximates 1.75 kGy. This is approaching levels at which serious damage can occur to fruit[3] by way of loss of firmness, abnormal ripening, altered flavour and increased susceptibility to mechanical injury.

Few fruits or green vegetables can withstand the high doses of ionising energy needed for total control of disease. Of those that can, strawberries are the example most often quoted, and possibly the only one with commercial potential. Nevertheless the overall effect of low doses of ionising energy used for other purposes could be expected to be mildly beneficial.

The most promising application of ionising energy for disease control in fruit appears to be in combination with other methods. For example a hot water dip followed by a moderate dose of ionising energy treatment can show a synergistic effect greater than the sum of each treatment applied alone. Such treatments are likely to be specific to particular disease - crop combinations and should not be expected to have universal application.

A summary of general effects on potentially exportable fruits and vegetables is shown in Table 2.

Table 2. Tolerance to IET and dosage required for disease control on selected fruit and vegetables.

Crop	Tolerance to IET (kGy)	Dose required (kGy)	Potential for usage
Avocado	0.1	> 1.75	probably nil
Mango	< 1.0	1.6-2.1	combination only
Orange	0.3-3	1.4-2.0	varies with variety
Tomato	> 1.0	1.0-3.0	degree of control possible
Strawberry	> 4.0	1.9-4.0	good

3 Anon. Irradiation of fruit products. Comments from CAST 1984-1. Council for Agricultural Science and Technology, USA.

Quality improvement.

Apart from insect disinfestation and postharvest disease control, outright improvement to the shelf life or marketability of fruit and vegetables can accrue from ionising energy treatment (see Appendix 3). Across the world the most commercially viable use is inhibition of sprouting in potatoes and onions, and installations have been set up for this specific purpose in Europe, Japan and other countries. The dosage required is in the same range as fruit fly treatments. However, potato and onion treatments are largely unnecessary in Australia where these crops can be produced throughout the year. Chemicals are currently available for this purpose but they attract little use in Queensland.

Another possible purpose for ionising energy treatment, in the category of quality improvement, is to delay ripening. Effects vary with the dose, the variety of fruit or vegetable and the stage of maturity at the time of treatment. Although such effects are usually beneficial we do not judge them to be of sufficient value to justify treatments of any fruit or vegetables solely for this purpose. Therefore any advantages of this nature are likely to accrue solely as a bonus from treatments for insect disinfestation (for example, a delay in ripening of export mangoes treated against the mango seed weevil) or for disease control.

ECONOMIC AND MARKETING ASPECTS OF IONISING ENERGY TREATMENT

For the technical advantages of ionising energy to be translated into commercial use, it must be proved to be economically viable and the produce subjected to treatment must be acceptable in the marketplace.

Economic constraints

The principal economic constraint on the commercialisation of ionising energy is the high capital cost associated with the construction of an IET plant. The requirement for an ionising energy source (usually Cobalt-60), a carriage mechanism for produce being treated, protective shielding around the installation, remote handling equipment, buildings and other ancillary equipment incur costs of at least $2m (Refer Appendix, p 69). The recently proposed use of X-rays to irradiate foods will incur similar capital costs.[4] These high capital costs, together with (in the case of Cobalt-60 sourced plants) the need to annually replace the decaying radiation source (12% loss p.a), demand that plant utilisation be at very high capacity levels. It is normal practice for IET plants to operate 24 hours per day for 50 weeks of the year (96% capacity) - with the break in operation needed only for repairs and maintenance and replacement of source. In order to satisfy this high capacity requirement, plant throughput must be planned days or weeks in advance.

For these reasons, the construction of an IET plant will only be feasible if a base load throughput for the majority, or all, of the capacity requirements can be guaranteed prior to construction. To date, the most common base load for IET plants overseas (and in Australia) has been for the sterilisation of medical equipment. The few plants that treat horticultural produce do so on a quasi-commercial basis.

Demand for ionising energy treatment

There are essentially two economic options for IET of fruit and vegetables in Queensland, viz:

- constructing a plant to utilise fruit and vegetables as a base load;
- utilising a 'service' plant which operates with some other commodity as a base load.

In order to assess the feasibility of these options, the demand for ionising energy from the horticultural sector needs to be assessed. This assessment will attempt to estimate projected demand over the next 5 to 10 years. Beyond this time, structural changes in the horticultural industry and the anticipated acceleration of IET technology make projections inappropriate.

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4 Dr M.C. Lagunas - Solar <u>Radiation Sources for Food Irradiation. A Technical Overview</u>. University of California, USA, 1984.

The principal demand for ionising energy will come from the following areas:

- disinfestation of fresh fruit and vegetables (FFD) for export;
- disinfestation of fresh fruit and vegetables (FFD) for sale to southern markets;
- extension of shelf-life of horticultural produce;
- disease control in horticultural produce;
- disinfestation of imported horticultural production, for quarantine purposes.

FFD - export

The most pressing demand for ionising energy is for the disinfestation of fresh fruit and vegetables for export overseas. This demand comes from two sources, viz:

- the US ban (from 1 September, 1984) on the use of EDB to disinfest fruit and vegetables, and likely flow-on bans which could be imposed by other countries;
- the absence of any other disinfestation treatment for mango seed weevil in mangoes, the increased production of which will require development of export markets which may prohibit importation of fruit infested with the weevil.

The current use of EDB fumigation for this purpose in Queensland is relatively insignificant. In 1982/83, 13 566 packages of produce (approx. 270 tonnes) were fumigated for export (refer Appendix, p 73). Fumigations were mainly required for oranges (10 776 packages). This low proportion of EDB fumigations is commensurate with the low percentage of horticultural produce exported (approx. 3% of annual production) and the even lower percentage that is exported to countries requiring disinfestation prior to export. This in itself is a reflection of the difficulty experienced in exporting to countries with rigid quarantine laws.

The use of IET alone will not gain access to these markets - for many crops, ionising energy is no more effective as a disinfestation treatment than was EDB. It is evident that there are other barriers (for example, market competitiveness) that must be overcome. However, the use of chemical treatments for disinfestation of produce entering in world trade is undoubtedly being rapidly phased out due to undesirable chemical residues, and ionising energy offers the most comprehensive alternative treatment. The development of export markets in quarantine-strict countries (for example, USA, Japan) will be difficult with ionising energy - but will almost certainly be impossible without it, in the absence of marked changes in quarantine protocol.

The disinfestation of mango seed weevil from mangoes is a particular case in point. In short, quarantine-strict countries will not accept mangoes unless they have been disinfested of the mango seed weevil - and IET is the only available treatment which can achieve this. This need is given greater urgency by the anticipated expansion in mango production which could lead to a domestic surplus of approx. 10 000 tonnes by 1991 (refer Appendix, pp 57-61). The marketing of this tonnage will be fraught with many difficulties, including entry into quarantine-strict countries. The introduction of IET should at least overcome one of these barriers.

A further export crop which has the potential to utilise an IET plant is cut flowers. The many surface insects that infest cut flowers need to be disinfested from the host produce prior to export, and such disinfestation could be achieved by ionising energy treatment. In addition to disinfesting the produce, there are also reports that IET could extend the vase-life of cut flowers. Exports of cut flowers from Queensland are currently very low (refer Appendix p 64), however there appears to be an export market potential for various native wildflowers and if this potential is realised it could provide a proportion of the throughput of an IET plant.

Specific markets for which potential demand for ionising energy is currently evident, are New Zealand (for winter vegetables) and Japan (for oranges). However, in the next 5 to 10 years the demand potential in these markets will be limited (in the case of New Zealand) and uncertain (in the case of Japan).

Growth in the New Zealand market will be limited over the next 10 years by the phase-out provisions of the Closer Economic Relations Agreement with New Zealand (CER). Under CER, New Zealand's import licencing system will be gradually phased-out by 1995. Based on the current phase-out provisions (which are, along with the rest of CER, subject to a general review in 1988), and on current prices and exchange rates, Australia's 1984/85 access will be approximately 250 tonnes per annum[5] - most of which will be filled by Queensland's winter vegetables. This access will gradually increase to approximately 1 000 tonnes by 1994/95, after which time the import licensing system will be abolished.

Growth potential in the Japanese market can best be described as uncertain. Following on from the US ban on EDB, it is not unlikely that the Japanese will follow suit. This will cut-short the fledgling orange market being developed in Japan. (In June 1984, 180 tonnes of navels were shipped to Japan from the Central Burnett with a further 600 tonnes of valencias due for shipment in September.) The likelihood of Japan accepting IET fruit in the short term cannot be viewed optimistically, given that it took over 20 years for them to accept EDB treated fruit.

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5 SOURCE: Committee of Direction of Fruit Marketing (C.O.D.)

FFD - interstate trade

The continuing concern over chemical residues on fruit and vegetables will lead to greater pressure to ban EDB as a disinfestation treatment within Australia. However, as with exported produce, the use of EDB fumigation is relatively insignificant. In 1982/83, 19 539 packages (approx. 400 tonnes) were fumigated for interstate sales (refer Appendix V). Currently, quarantine regulations in South Australia, Western Australia and Tasmania require, for most months of the year, that most fruit fly susceptible produce be fumigated with EDB prior to entry into each State. Victoria had a similar requirement up until September 1982. The Victorian requirements have now been relaxed and EDB fumigation is no longer mandatory and Western Australia has now commenced to negotiate less stringent requirements.

Prior to the Victorian relaxation of quarantine requirements, the quantity of produce fumigated was significantly higher. In 1981/82 approximately 2 500 tonnes of produce would have been EDB fumigated (refer Appendix I). Much of this produce is now treated by dimethoate dips or sprays. In the event of an IET facility becoming available it is likely that a proportion of this produce would be treated with ionising energy by preference. The extent of this usage will depend on its cost effectiveness vis a vis dimethoate treatments and the southern states' future quarantine policies. As indicated previously IET has the significant advantage of freedom from undesirable chemical residues.

Extension of shelf-life

Research to date has established that ionising energy can achieve an extension of post-harvest shelf-life of a number of days for a variety of horticultural commodities. However, ionising energy alone will not maximise post-harvest shelf-life. This is achieved by a combination of many factors including fruit maturity and quality at harvest, the control of disease, effective disinfestation and appropriate packaging, handling and storage. Benefits to post-harvest shelf-life from ionising energy are likely to be marginal and would not create a strong demand for ionising energy in itself. If ionising energy is developed for disinfestation purposes, then any extension of shelf-life could be considered an added 'bonus' to the disinfestation process as discussed previously under 'Quality improvement' (p 11).

The inhibition of sprouting in potatoes and onions is not perceived as an industry problem. Potatoes can be produced year round in Australia and are generally marketed soon after harvest. Sprouting in onions does not usually occur unless crops are harvested too late. Sprout inhibition, and the elimination of rots and moulds in green ginger could expand overseas sales of this product as these are major problems encountered during the long marketing lag involved in shipping green ginger overseas. Last year a few hundred tonnes were exported (principally to Arabian Gulf countries). However, export markets for green ginger are very unstable and it would be impossible to identify a stable level of demand for ionising energy from this source. Were an IET plant available, it is likely that it could be used for this purpose.

Disease Control

The demand for ionising energy for this purpose is very limited for the reasons outlined in already under 'Disease control' (p 10). The only significant demand is likely to come from use of the combined treatments shown to be effective for some fruit (esp. mango and papaw). The use of ionising energy for disease control will be of secondary importance to its use for insect disinfestation. Once dose levels for disinfestation have been established, the use of combined treatments for disease control could be considered.

Disinfestation of imported produce (Quarantine)

Imports of fruit and vegetables fall into four inspection categories:- inspection on arrival; treatment with hot water (for diseases) or fumigation with methyl bromide or with EDB. Most produce falls within the first category, which requires EDB fumigation only if living insects are detected on inspection. Very little fruit in this category requires fumigation (mainly some US citrus with scale and New Zealand produce with thrips etc.). Similarly very little fruit requires mandatory EDB fumigation. In 1983, only 1 500 trays of mangoes were imported into Brisbane under this category (refer Appendix V). Of 11 442 cartons of cut flowers imported into Brisbane in 1983, 583 required EDB fumigation.

There is not, therefore, a substantial demand for ionising energy for horticultural quarantine purposes on incoming produce.

<u>Utilising horticultural produce as a base-load for an IET plant</u>

It is evident that the principal demand for ionising energy from the horticultural sector will be for disinfestation purposes, primarily to replace EDB as a disinfestation treatment for export and interstate trade and to eradicate mango seed weevil from export mangoes.

Lesser demand will come for shelf-life extension purposes and as a quarantine measure. It is also possible that supplementary demand may come from the wider agriculture sector, for example, sterilisation of bee boxes (estimated to be up to 10 000 supers (boxes) per annum) and disinfestation of other agricultural produce for quarantine purposes.

In many respects, the requirements of an IET plant are not suited to the typical traits of the horticultural industries. IET plants require a high volume of throughput throughout the year, which needs to be planned days or weeks in advance. This is in contrast to the fluctuations in supply and quality, seasonality of production and widely dispersed production districts that typifies the horticultural industries. These factors will always militate against the viability of an IET plant based on horticultural produce.

It is very difficult to estimate the minimum annual throughput required to operate a horticulture-based IET plant viably, due to the absence of any such (commercially operated) plant in the world and the lack of knowledge of the particular requirements of the produce to be treated. It is important to note however, that there are significant economies of scale associated with IET plants and hence 'per unit' treatment costs tend to decrease as maximum available throughput increases and vice versa. This is important to the horticultural industries as any horticulture-based IET plant is likely to operate at the lower end of the throughput range.

Agricultural economists in NSW estimated that a plant built to treat citrus in Australia could operate at 87 500 tonnes p.a. at a cost of $7.00 per tonne (14c per carton). (refer Appendix V). For this treatment cost to be equivalent to that of EDB fumigation (approx. 35c per carton) a throughput of around 35 000 tonnes would be required.

In Tzaneen, South Africa, an IET plant currently operates to treat fruit and vegetables. This plant operates at only 7 000 tonnes p.a. at an estimated operating cost of $20 per tonne.[6] However this plant continues to operate in a developmental phase and the capital outlay to construct the facility ($300 000) was well below commercial levels. The type of plant in operation, an AECL JS-8200 batch irradiator, has a maximum design capacity of approx. 36 000 tonnes (assuming a max. dosage of 1kGy) if operated at 96% capacity with the maximum cobalt loading of 400kCi.[7] (The Tzaneen plant currently operates on only 70kCi).[8]

An IET plant currently operating in Hokkaido, Japan to inhibit sprouting in potatoes treats 20 000 tonnes of potatoes annually. This plant operates as part of a Government-supported price stabilisation scheme and the true economic viability of the plant is masked by this.

There is a further proposal to treat 25 000 tonnes of onions, garlic and shallots in Italy each year. This plant is to be constructed with a Government grant of $US3m.

It is evident from these indicative throughtput levels and the preceding section on the demand for ionising energy, that there is currently insufficient demand for ionising energy to justify the construction in Queensland of a plant utilising horticultural produce as a base load. Further, it is unlikely that this situation will change in the next 5 to 10 years.

Beyond this time, mangoes may be able to provide the throughput required for an IET plant. However there are a number of issues that would need to be resolved before an assessment of economic viability can be made. These issues can be categorised under three broad headings, viz:

- technical requirements;
- technological developments; and
- marketing and logistical constraints.

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6 Van der Linde, H.J. (1983). Marketing Experience with radurised products in South Africa Proc. Ionising Energy Treatment of Foods. National Symposium, Sydney 1983, P96

7 Gay H.G. (1983) Design and Operation of Radiation Facilities ibid p109

8 kCi = 1,000 curies (unit of radioactivity)

Technical requirements

In order to determine the appropriate type of plant to be used, the technical requirements of treating mangoes would need to be determined. These include the optimal required dosage, the need for combined treatments to extend shelf-life or enhance disease control, the optimal cobalt strength and the most appropriate carriage mechanism (for example, palletised versus tote box). In relation to the latter, it must be noted that palletised plants are probably unsuitable for fruit and vegetables due to the associated high cobalt strength required and the problem of unacceptably high maximum-minimum dosage variation through the pallet at the low dosage levels required for fruit and vegetables. In any case pallets used in IET plants are smaller than the standard transport pallet and hence economies in handling by utilising a palletised plant would be minimal.

These technical issues will need to be the subject of future IET research.

Technological developments

With the increasing interest in food irradiation, it can be reasonably expected that major advancements will occur in IET technology over the next 5 to 10 years. These advancements could significantly affect the viability of a horticulture-based IET plant. The use of X-rays may prove a more viable and cost-efficient technology in the future, especially in view of the anticipated increase in the cost of Cobalt-60. Close watch will also need to be kept on other technological innovations such as the use of mobile IET plants and the possibility of 'leasing' the energy source (for example, Cobalt-60) for the length of a harvesting season.

Marketing and logistical constraints

Ensuring that a level of throughput can be maintained to treat produce at an economical cost is perhaps the most crucial economic constraint to be considered. For mangoes, the basic requirement will be for throughput of fresh fruit destined for quarantine-strict export markets. It is also likely that this fruit will need to be of a high quality standard to prevent adverse physiological effects from ionising energy. For the same reason, fruit to be treated will need to be at the optimum stage of ripeness. In addition, throughput will need to be assessed, not only on a seasonal basis, but on a weekly and even daily basis. The short highly-peaked mango season could present problems in this regard. The logistical problems of co-ordinating harvesting, transportation, treatment and exporting produce will also be a major problem. The cost of the necessary cool store facilities at the IET plant will also need to be assessed, as will the optimal location of the plant.

These issues will need to be more closely investigated.

Utilising a "service" plant with another commodity as a base load

Given the absence of sufficient demand to justify an IET plant for horticultural produce alone, the horticultural industry will have to utilise a service plant which has another commodity as a base load. The problem with using such a plant is that it would be constructed to optimally treat the base-load commodity and is unlikely to meet the optimal requirements for treating fruit and vegetables. These requirements include timing of construction (which will be a commercial decision based largely on the attainment of the minimum required throughput of the base-load commodity), location of plant, source strength, and type of carriage mechanism.

Due to its perishability, horticultural produce would also need to be treated as a matter of priority once it arrived at a plant and cool storage facilities would need to be provided at the plant site.

It is essential that research be undertaken promptly so that the particular requirements of horticultural produce can be identified. If this is done it may then be possible for the industry to have some input into the timing, construction and design of a commercial IET plant.

The actual cost of treatment of horticultural produce in a 'service' plant is likely to be quite low and compare favourably with the cost, for example, of EDB fumigation. Preliminary cost estimates (based on the costs of a plant operating in Melbourne) for citrus and mangoes are 30c per citrus pack and 15c per tray respectively. By comparison, the current cost of EDB fumigation for citrus is 30c-40c per citrus pack. (refer Appendix V).

Consumer acceptance

Consumer acceptance is the final hurdle to be overcome before commercialisation of food irradiation can become a reality in Australia. To some extent any consumer concern over the safety of consuming foods treated with ionising energy will be dissipated by the anticipated approvals of the appropriate health authorities.

However, such approvals are aimed at a technical/legal level and consumer awareness campaigns may be required to overcome concerns at the emotive level.

A more valid concern relates to possible adverse physiological effects on treated fruits. If fruits are not treated correctly, these effects may be chemical (which may adversely affect the nutritional value of the fruit), physical (for example, textural degradation, anomalous ripening, pigment changes), or physiological (for example, changes in odour or flavour). Overseas research has demonstrated that only fruit of outstanding quality should be treated; stage of ripeness has a critical effect on the fruits' response to treatment; and post-treatment handling, storage and marketing-time will be crucial in maintaining fruit quality.

Inappropriate treatment, especially in the early stages of market development, could seriously damage the acceptability of irradiated fruit. It is therefore essential that priority research define the exact parameters of treating fruit with ionising energy and that commercialisation of treated fruit not take place till such parameters are so defined. Once the process has been confirmed, commercial promotion of IET fruit, both in Australia and overseas will be required to ensure maximum market penetration. Market acceptance overseas will, of course, require the appropriate health authority approvals in the first instance. In addition to overseas health authority approvals, confirmation of minimum-maximum dosages received, by the use of tamper proof radio-sensitive stickers on packages of exported fruit, will be required when exporting produce to quarantine-strict countries.

In a broader sense, public acceptance of irradiated foods may be hampered by the activities of variously motivated 'anti-nuclear' pressure groups. These activities would centre on issues such as worker safety, potential source leakage and disposal of radio-active waste. It will be important that these concerns be treated seriously and ideally, forestalled, if Cobalt 60 sourced food irradiation is to become viable in Australia. Alternatively, the use of electrically-sourced X-ray food irradiation might negate these activities. Subject to the practical success of this form of ionising energy, X-ray sourced treatment may prove the more viable option in the long-term. Action by groups concerned with the wholesomeness of irradiated food may also hamper public acceptance of this technology.

RESEARCH NEEDS

General

Implementation of a programme to adopt ionising energy treatment into the fruit and vegetable industry raises a plethora of research needs. Although research has been undertaken on the method to show its general applicability, specific needs remain. Some of these are:

- Establishment of the required dose for each relevant insect pest in each fruit.

  To date only a few key species have been researched, for example, only one of the 14 Australian pest species of fruit flies; and a similar situation can be expected for native species of moths and other pests. Additional problems will become apparent as negotiations are undertaken for the export of new crops. Even where full testing is not required it can be expected that the comparative susceptibility of each pest species will need to be adequately demonstrated. For many of these species there is not yet a laboratory culture method to obtain the numbers needed for testing.

- Demonstration of the efficacy of specific proposed doses against each problem species in pertinent commodities.

  This may not need to be tested as widely as for ethylene dibromide where the Australian species were more difficult to disinfest than similar species from other parts of the world. In fact it depends on the point above. However, importing countries can ask for extensive supporting data for a treatment schedule and if past experience is a guide they will do so more often than not.

- Optimisation of dosages for the best balance of advantageous effects of insect disinfestation, disease control and quality improvement.

  Ionising energy costs are related to the time taken for treatment. The optimum dose must satisfy a number of criteria some mandatory, some economic. A major problem with fruit is that production is seasonal and high treatment throughputs will be required over relatively short production periods.

- Economic and marketing research.

  These two factors are highly important in a system with high capital input and consequent servicing costs. Sound research in this area must be undertaken on the requirements of the Queensland industry and must continue as production and export potentials develop. Computer modelling is envisaged as a means of clarifying some of the problems involved.

- Research on disease control and quality improvement problems of local and general importance.

Although we judged that disease control and quality improvement could not justify the implementation of ionising energy treatment in Queensland at this time, significant problems need to be resolved, particularly in relation to optimising the effects of disinfestation with disease control and quality improvement.

These relate both to the local production scene (for example, diseases, varieties, production) as well as to problems of a more basic nature and could be expected to repay research costs many times over.

Research facilities

The nearest full scale research facility for ionising energy treatment is at the Lucas Heights Atomic Energy Establishment, Sydney. Locally, samples of insects, but not fruit in quantity, can be subjected to experimentation using the 'Gammacell' of the University of Queensland Department of Entomology at St Lucia (capacity 3.6 litres).

Our existing Departmental research programmes involve disinfestation of fruit with insecticides, control of disease pathogens with fungicides and hot water dips, particularly in mangoes and avocados, and quality improvement, also with particular emphasis on mangoes. Comprehensive research facilities are available for this type of work and would be readily adaptable to ionising energy treatment studies. In New South Wales similar facilities are available at the Gosford laboratory on a smaller scale and, in a more limited way again, in Perth. Since all three are fully committed to the present programmes it is unlikely that one could cope alone with the needs of our industry for ionising energy treatment research.

The co-ordination of research into disinfestation of fresh fruit, including the use of ionising energy, is undertaken through the Fresh Fruit Disinfestation Sub-Committee of SCA.

Irradiation facilities of increased capacity are essential in Queensland if appropriate research is to be undertaken within the time available before fruit production, especially of mangoes, reaches critical levels for export - estimated to be in the next 5 to 10 years (refer Appendix IV). The alternative to a local facility would be to work with those in Sydney. This is estimated to cost up to $1,000 per treatment for transport of fruit and travelling costs of staff involved. Up to 100 treatments could be necessary in a development programme - possibly more if unforeseen problems arise.

If this work were to be placed in the hands of another organisation, totally or in part, costs would be expected to be similar, or greater. Problems of priority would inevitably arise and the logistical problems of transport of fruit would still exist. This presupposes spare capacity in another organisation to undertake the work.

It is therefore considered that a research irradiator with the capacity to treat sample quantities of fruit should be acquired and located at Indooroopilly. A suitable unit would be the Atomic Energy of Canada 'Gammabeam 150'; cost of such a unit is unavailable; or an open pool irradiator of 40kCi similar to that at the University of Hawaii estimated to cost $150,000. Whilst this is seen to be a very high cost for research on fruit and vegetables it could also service a number of other experimental areas in Animal and Meat Industries and should attract hire revenue from other research and industry bodies, including hospitals. It could also be developed to serve as a small pilot facility for public acceptance trials.

Consideration was given initially to the feasibility of a commercial pilot scale irradiation facility for Queensland. This is now seen to be impracticable due to the low levels of production of relevant commodities for at least another 5 years. On this basis the smaller scale facility described above would be more appropriate.

Overseas study tours to study recent developments in treatment of commodities, marketing research and commercial operation are seen as essential if we are to make full use of developments overseas.

Acknowledgements

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APPENDICES

CONTRIBUTED PAPERS

I A REVIEW OF POTENTIAL USAGE OF IONISING ENERGY TREATMENTS FOR INSECT DISINFESTATION OF FRUIT, VEGETABLES AND OTHER COMMODITIES IN QUEENSLAND
N.W. Heather, Entomology Branch

II POTENTIAL USE OF IONISING ENERGY FOR POSTHARVEST DISEASE CONTROL
I.F. Muirhead, Plant Pathology Branch

III POSTHARVEST PHYSIOLOGICAL ASPECTS OF IONISING ENERGY TREATMENT
B.I. Brown, Horticulture Branch

IV EXPORT MARKET POTENTIAL FOR SELECTED HORTICULTURAL CROPS
P.T. Sheehy, Marketing Services Branch

V ECONOMIC FEASIBILITY OF USING AN IONISING ENERGY TREATMENT PLANT FOR DISINFESTATION OF FRUIT AND VEGETABLES IN QUEENSLAND
R.N. Hassall, Economic Services Branch

VI SCOPE OF DESIGNS AND OPERATION OF IONISING RADIATION FACILITIES
N.W. Heather, Entomology Branch

I A REVIEW OF POTENTIAL USAGE OF IONISING ENERGY TREATMENTS FOR INSECT DISINFESTATION OF FRUIT, VEGETABLES AND OTHER COMMODITIES IN QUEENSLAND

N.W. Heather, Supervising Entomologist,
Entomology Branch.

Introduction

World trade in fruit, vegetables, flowers and other similar commodities relies heavily on effective insect disinfestation treatments to meet the quarantine requirements of importing countries, states and regions. For Australia the single most important insect pest in fruit is the Queensland fruit fly, (Dacus tryoni), (QFF).

Quarantine requirements have been met in a large measure for some decades by fumigation with ethylene dibromide, (EDB) and to a much lesser extent methyl bromide, (MeBr). Cold and heat treatments have limited usefulness alone or in combination with a fumigant. Dips or sprays with appropriate insecticides are sometimes satisfactory but generally lack the high levels of efficacy needed.

Ionising energy treatment by irradiation can also fulfil these requirements and is probably more effective against more pest species than any other treatment.

For at least a decade there have been doubts about the usage of EDB fumigation, that chemical having been shown to have carcinogenic, teratogenic and other undesirable properties. Recently (1983) the US Enivornmental Protection Authority issued a proclamation which banned the use of EDB for certain agricultural purposes, effective immediately, and for fumigation of fruit and vegetables from 1 September 1984 although this date was extended for imported mangoes and exported grapefruit with more stringent health tolerances.

This will have a major effect on usage of the fumigant in world trade and can be expected to flow on to Australia. Information from USA (Australian Embassy Sources) indicated that a major programme could be under way to implement ionising energy treatments as one of the alternatives to EDB for disinfestation of fruit, vegetables and like commodities.

Disinfestation treatments are required to meet security levels set by quarantine Authorities of importing countries or states. The highest security level is 'probit 9' which in effect means that under test conditions a mortality of 99.9968% must be demonstrated at a statistical probability $P = 0.05$. This requires trials against 93 617 individuals of one or more stages without survivors, usually stated as no survivors in 100 000. This level of security is currently required by the US Department of Agriculture Plant Quarantine Service (APHIS) for fruit imports from Australia. For fruit fly it applies to both eggs and larvae.

Within Australia, the security level against QFF required by Tasmania, South Australia, and Western Australia is 'probit 8.719' or 99.99% mortality in trials requiring treatment of 30 000 individuals of both eggs and larvae without any survivors. Recently, Victoria reduced their security level to 99.5% mortality, requiring tests against 1 500 individuals of each stage without survivors.

Security levels attainable vary between treatments as well as with the insect species and the variety of fruit or vegetables.

When safe controllable sources of irradiation for ionising energy treatments became available in the 1950s, extensive ongoing research commenced on its usefulness for disinfestation treatments. This included studies undertaken in Hawaii on the Oriental fruit fly, **Dacus dorsalis** (OFF), the melon fly (**Dacus cucurbitae**) the Mediterranean fruit fly (**Ceratitis capitata**) (Med fly) and the mango seed weevil (**Sternochaetus (Cryptorhynchus)** mangiferae)[3]. In Australia[4] the method was shown to be similarly effective as a quarantine treatment against QFF. In South Africa[5] and Hawaii[3] it was extensively researched for control of the mango seed weevil. This work showed that the method could be used at low doses to induce sterility or at moderate doses to kill outright, the various developmental stages which could be present in fruit.

Although the method was not adopted widely for fruit disinfestation purposes it has been extensively utilised for other purposes, especially at low doses to inhibit sprouting in stored potatoes and onions and at high doses to sterilise medical disposables. This has resulted in a degree of public acceptance in many countries, including Spain, USA, Germany, Hungary, India, The Netherlands and Japan.

For this review I have examined the insect species in Queensland for which disinfestation treatments are required and the produce they may infest; the types and sources of ionising energy appropriate for the purpose and the doses needed to meet market requirements; the stage of development of ionising energy disinfestation treatments likely to be needed for Queensland export requirements; and the likely need for research together with priorities

Insect species requiring disinfestation

Most requirements for disinfestation treatments in export fruit relate to the Queensland fruit fly **Dacus tryoni** (Froggatt). However, there are more than 15 economic pest species of closely related Dacine fruit fly genera which occur in Australia viz. the genus Callantra (1 species) and the sub-genera **Afrodacus** (2 species), **Austrodacus** (1 species), **Bactrocera** (formerly **Strumeta**) (10 species), **Paratridacus** (1 species), and **Zeugodacus** (1 species). These pest species occur in the coastal tropical and subtropical parts of Australia. From a national viewpoint there is also the important introduced Med fly present in Western Australia.

Fruit Flies

Although the main pest species is D. (Bactrocera) tryoni there are other serious pest species viz. D. (Afrodacus) jarvisi, D. (Austrodacus) cucumis, D. (B.) melas, D. (B.) neohumeralis and D. (B.) musae all of which occur in commercial fruits to a sufficient extent to represent a risk of introduction for importing countries.

Each of these species could need to be considered individually when treatment schedules are developed and tested. However, in most instances the assumption has been permitted that treatments which eliminate D. tryoni will eliminate the other species equally effectively. This is reasonable for field control measures as any atypical species would otherwise have increased in prevalence; it is almost certainly so for all postharvest disinfestation treatments but corroborative evidence for ionising energy treatment would be valuable when dealing with sensitive markets.

Susceptible fruit and vegetables include all commercial fruit and many vegetables, especially cucurbit and solanaceous types. The level of susceptibility varies from extreme to rarely attacked but this is not generally relevant from a quarantine viewpoint where introduction in many cases is a chance event of low probability.

A full listing of Australian economic fruit fly species and susceptible fruit and vegetables is appended. (Appendix IA)

Historically, these fruits were treated with EDB, although from 1981 onwards fruit for the Victorian market began to switch to dimethoate dipping. This trend is shown in Table 1.1, but it seems likely that the potential volume for treatment by one method or another would be about 200 000 to 250 000 packs (3 000 to 4 000 tonnes). Of the 1982-83 total less than half was treated for export (Table 1.2). Since only the export market and three states (Western Australia, South Australia and Tasmania) needs treatments of the security standard afforded by IET the mandatory usage for the treatment could be as low as 200 tonnes plus market increases in citrus and mangoes.

Table 1.1. Total Fruit and Vegetables fumigated with ethylene dibromide in Queensland (unit packages) as a postharvest pre-export disinfestation treatment for the years 1977-83.

FRUIT/VEGETABLES	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
FRUIT						
Grapefruit	8 922	2 098	4 070	9 704	2 944	Nil
Lemons	3 585	385	3 652	5 220	900	870
Mandarins	89 818	64 836	160 368	134 148	59 659	16 406
Mangoes	42 433	23 465	34 084	45 459	1 256	1 352
Oranges	29 190	38 832	46 036	15 026	4 854	11 976
Rockmelons	Nil	Nil	Nil	56	94	620
Sub Total	173 948	129 616	248 210	209 613	69 707	31 224
VEGETABLES						
Capsicums	Nil	43 543	43 954	29 727	74 785	150
Cucumbers	Nil	Nil	Nil	Nil	325	Nil
Eggfruit	Nil	Nil	Nil	Nil	27	150
Zucchinis	Nil	Nil	Nil	Nil	218	Nil
Sub Total	Nil	43 543	43 954	29 727	75 355	300
Total	173 948	173 159	292 164	239 340	145 062	31 524

Prepared by J.D. Wedemeyer (Standards Branch)
19.03.84

Table 1.2. Records of postharvest ethylene dibromide fumigation in Queensland for the years 1982-83 and 1983-84 (part).

1982-83

Commodity	Interstate (No. of packages)	Export (No. of packages)
Lemons	870	-
Mandarins	16 406	-
Mangoes	627	1 352
Oranges	1 200	10 776
Rockmelons	-	670
Capsciums	140	684
Zucchini	96	-
Eggfruit	150	70
Cucumbers	50	14
TOTAL	19 539	13 566

1983-84 (until 11 Nov. 83)

Commodity	Interstate (No. of packages)	Export (No. of packages)
Mangoes	120	10
Rockmelons	95	408
Oranges	-	2 550
Capsicums	1 390	110
Zucchini	32	37
Cucumbers	-	30
Eggfruit	-	30
TOTAL	1 637	3 175

Prepared by Standards Branch Officers

Mango seed weevil

This introduced insect (Sternochaetus (Cryptorhynchus) mangiferae) infests only mangoes. However, mango production is on the verge of a massive increase which will require the export of the majority of production if mango is to remain a high return crop.

On current standards the mango seed weevil will exclude Queensland mangoes from the US mainland and Japanese markets unless an acceptable treatment can be found. At present no treatment other than ionising energy has the potential to meet required USDA treatment security levels. Even for ionising energy treatment there could be significant problems in achieving insect mortality without irradiation damage to fruit. At present the alternatives seem to include only (1) develop and gain acceptance of irradiation treatments (2) restrict exports to less demanding (and less lucrative) markets or (3) negotiate reduced security levels. Our studies indicate that the levels of security attainable with other methods such as fumigation are unlikely to be acceptable.

Other pests

Further pests requiring disinfestation treatment of fruit include red scale Aonidiella aurantii and other scales on citrus, and lightbrown apple moth Epiphyas postvittana on pome and stone fruits. For vegetables, a recent example is cabbage moth in broccoli. In practice there are a range of coccids, thrips, moths and other pests which may be nominated by specific countries. Even where the insects occur in the importing country there is often a requirement to reduce numbers in imported produce to nominated low or even nil tolerance levels.

Quarantine

Australia, also, has stringent insect quarantine standards which can be met either by disinfestation in the country of origin or in some instances by treatment after arrival. Such treatment may be mandatory. Again, a wide range of pest species is involved, although the quarantine schedules are mostly blanket treatments listed by commodities.

Appropriate types, sources, and dosages of ionising energy

For practical purposes, only nonparticulate electromagnetic radiation as gamma or X-rays and accelerated electrons need be considered. Whereas the ionising effect produced by gamma or X-rays occurs throughout the material (allowing for loss of energy as it travels through a material) accelerated electrons penetrate only a relatively short distance. This means that for deep seated infestations in fruit, only gamma or X-ray treatment is effective. Both fruit fly and mango seed weevil come into this category. Therefore accelerated electron generators could have only limited usefulness such as for thrips on flowers or scale insects on fruit. For maximum utility only gamma irradiation plants warrant consideration at this time; appropriate X-ray generators are still in the developmental phase but commercial units could be available by mid 1986. In terms of end point efficacy it is judged not to be important how the ionising energy is generated, although there could be advantages for consumer acceptance with the electrically generated method.

Units

Dose levels are currently expressed as 'Grays' (Gy). These replaced 'rads' which had earlier replaced roentgens.

Equivalents are:-

1 roentgen approximates 1 rad (derived units: kilorad (krad) 1 x 10^3; megarad (mrad) 1 x 10^6).

100 rad = 1 Gy (derived units: kGy, mGy).

Thus 1 krad = 0.01 kGy.

The dosage of irradiation required to disinfest fruit depends on (1) the security level required, (2) the criteria for effectiveness, and (3) the fruit species or variety. Security levels have been discussed. Effectiveness of irradiation can be measured as sterility or mortality and hence the method differs from fumigants, insecticides and physical treatments. Although sterilisation of insects should be adequate for quarantine purposes there may be no practical way a quarantine inspector can tell with certainty whether a treatment has been applied effectively. Telltale stickers, which change colour when irradiated, are available however and with adequate tamper-proofing may prove useful in this role. The influence of fruit species or variety occurs when some varieties are more susceptible to treatment damage than others for example, 'common' mangoes are more readily damaged than the low fibre varieties such as Kensington Special ('Bowen Special'). Fruit species influences packaging and handling which in turn influences treatment schedules and the ripening characteristics and stage of ripeness at treatment also influences treatment schedules.

For treatment of commodities traded within Australia, where treatment standards can be accepted with confidence, sterilisation doses should prove adequate. The same applies to disinfestation treatments of incoming commodities applied after arrival in Australia. However, some overseas markets could be expected to require treatment at levels producing mortality before inspection. For fruit flies 'no viable pupae' i.e. 'no adult emergence' constitutes an appropriate compromise.

Dosage levels do not appear to have been precisely determined for Australian species of fruit flies. A dose of 0.075 kGy has been put forward (C. Rigney, pers com) to prevent adult emergence of QFF in fruit. Another earlier report[4] concluded that 0.05 kGy would prevent adult emergence but 0.8 KGy was required for a quick kill. Our preliminary studies show the LD$^{99.9}$ for eggs of **D. tryoni** and D. jarvisi based on adult emergence to be near 0.1 kGy. It is likely that the practical doses will approximate 0.1 kGy for interstate markets and up to 0.8 kGy for overseas markets requiring no live survivors. The dosages for mango seed weevil [3, 5, 12] are likely to be 0.3 kGy for interstate and some overseas markets and again 0.8 KGy for high security overseas markets. These dosages all lie below levels at which fruit damage or detectable flavour change could be expected. There is no possibility of residual radiation in treated fruit or other foodstuffs[13].

Alternative disinfestation treatments

Apart from irradiation, disinfestation for fruit flies and other pests except mango seed weevil can be achieved by fumigation, dips or sprays with insecticides, cold or heat treatments, or a combination of two or more of these treatments. No one treatment is suitable to all situations.

Fumigants

The most versatile postharvest disinfestation treatment has proved to be fumigation with ethylene dibromide (EDB). Other fumigants for example, methyl bromide (CH_3Br) or phosphine (PH_3) have very restricted application. The criteria which a fumigant treatment must meet are (1) efficacy (2) no phytotoxicity (3) acceptable residue levels and (4) low cost. With some exceptions EDB has met these until recently but with new more stringent tolerances it can be expected to be phased out world wide. It is unlikely that world quarantine standards will be relaxed to the point where treatments having lower efficacy could replace EDB. However, in the interim before it is phased out, more stringent operator safety requirements and lower residue limits will apply, with consequent increase of treatment costs. For fruit fly, MeBr is usually less effective, has residue problems because it must be used at higher dosages to compensate, and frequently causes phytotoxic damage at these levels. PH_3 also has been found to be phytotoxic at the levels required to control Queensland fruit fly and additionally works much more slowly - to the point of impracticability for some fruits.

During 1982-83, 33 000 packages of fruit were treated with EDB as a postharvest fumigation treatment for overseas and interstate exports (very approximately 330 tonnes or $412.5m^3$). Totals for recent years are shown in Table 1.1. These reflect reduced need for fumigation treatments for interstate trade following acceptance of insecticides by Victoria.

Insecticide treatments

These treatments are becoming increasingly used in Queensland for fruit and vegetables exported to Victoria. Approved treatments are applied on the farm, either in the field preharvest as a spray, or during packing, postharvest, as a dip or a spray. Most approvals relate to dimethoate or fenthion. With rare exceptions these treatments do not meet the probit 9(99.9968% at P = 0.5) mortality level of security. They were introduced to met the lowered Victorian standard of 99.5% mortality which they do adequately for most fruit. In many instances they meet the Australian requirement of 99.99% (no survivors from 30 000). Apart from the lower levels of security offered by these treatments compared with fumigants they pose problems for certifying authorities as regards (1) observation of application of the treatment and (2) monitoring the amount of insecticide applied.

Insecticide treatments of this type are therefore unlikely to gain acceptance readily for produce traded overseas and have yet to gain acceptance for produce traded into two Australian states with 'area freedom' status for QFF. (Tasmania and Soutn Australia) i.e. where overseas authorities accept that Queensland fruit fly does not occur.

Cold and heat treatments

These treatments are based on cooling or heating fruit to the lethal temperature limits for the insect concerned. For Queensland fruit fly a temperature of $-0.5^{o}\pm0.5^{o}C$ for 14 days will provide probit 9 levels of security. This treatment can be used for citrus (with some varietal exceptions) and pome fruits, but not stone fruits or the tropical fruits, mangoes, avocados, or bananas the latter of which have threshold temperatures of around 9 to $12^{o}C$ for cold damage. High temperature treatments have not been established for any fruits as they are believed to be above damage thresholds for fruit fly species tested, even in saturated vapour atmospheres.

Stage of development of IET

Ionising energy treatment systems are currently available which would meet Queensland's needs for disinfestation of fruit and vegetables for interstate and overseas export trade. Within Australia there is construction and operating expertise at least with Ansell International at Dandenong Victoria. This company is about to commence construction of a multipurpose contract treatment facility in Sydney and would put an additional one or two into Queensland if profitability were established. In south Queensland there is sufficient potential throughput of medical goods to bolster significantly the viability of a facility primarily intended for the treatment of locally produced fruit, vegetables, cut flowers and specific Plant Quarantine disinfestation tasks. If the installation were located in North Queensland supplementary loading could prove difficult. This would not necessarily preclude establishment of a facility there.

The design of a facility suited to our needs is almost certain to be available from amongst the 130 gamma irradiation plants operating in the world, but especially those in South Africa, Holland and the USA. In the longer term X-ray units currently under development in USA could replace cobalt-60 sourced facilities.

Research needs and priorities

It will be necessary to demonstrate that all Australian pest species of fruit flies are equally or more susceptible to the disinfestation doses established for QFF. This can probably be done satisfactorily in the small irradiation facility available at the University of Queensland. However, should it prove necessary to demonstrate efficacy of treatment against these species at the probit 9 level in fruit, this would have to be done in a larger irradiator such as that available at Lucas Heights Sydney (Australian Atomic Energy Commission) or at Dandenong (Ansell International). Logistics of such an arrangement would prove complex.

Optimisation of dosage levels would need to be undertaken as a means of minimising cost of treatment. This could mean considerable testing at the levels of (1) mortality of the stage treated (2) prevention of emergence of adults and (3) sterilisation.

It is anticipated that some commodities will not fit the general schedule either through phytotoxicity or other physiological reasons. Development of special schedules involving combinations with other methods for example, cold, heat, would then prove necessary. Some adjustment of schedules could also be involved to accommodate plant disease control or quality enhancement requirements.

In terms of priorities it is seen that establishment of comparative susceptibility of pest species is most important, and should be undertaken as soon as practicable. Refinement of dosage levels could possibly wait until the method is in operation. Other scheduling problems could not be determined until operations commenced at least on a pilot trial scale.

Of the other pest species, disinfestation of the mango seed weevil might need to be demonstrated to probit 9 or lesser security. However, the pest occurs widely and work in both Hawaii and South Africa has established the necessary schedules. It is not anticipated that Australia would need to demonstrate these mortalities. However, there would be considerable testing necessary to ensure that the overseas schedules were compatible with our fruit varieties and shipment times. Should modification be required the new schedules could need to be tested to probit 9 standard.

The multiplicity of pest species which occur on cut flowers and surface pests of fruit and vegetables makes it difficult to predict what work would be necessary. Much would depend on the levels of security required. However, it seems likely that sizeable research needs might occur here, and also for quarantine treatments against pests on flowers and fruit entering Australia. Again, the problem of two levels of effect - mortality or sterilisation-arises.

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APPENDIX IA

Economic fruit flies of Australia and their commercial hosts.

Species of fruit fly	Commercial hosts (pp 37,38)
A. Callantra aequalis (Coquillet)	37
B. Dacus (Afrodacus) jarvisi (Tryon)	1, 2, 4, 24, 31, 35, 41, 42, 43, 45, 48.
C. Dacus (Austrodacus) cucumis French	12, 15, 32, 38, 47, 49, 50, 51.
D. Dacus (Bactrocera) aquilonis (May)	22, 24, 41.
E. Dacus (Bactrocera) breviaculeus Hardy	24
F. Dacus (Bactrocera) bryoniae (Tryon)	7, 31, 39.
G. Dacus (Bactrocera) cacuminatus (Hering)	7, 11, 51.
H. Dacus (Bactrocera) frauenfeldi Schiner	Distribution Aurukun north only. Bred from 24 and 31.
I. Dacus (Bactrocera) halfordiae Tryon	22, 23, 25, 27,30, 37
J. Dacus (Bactrocera) mayi Hardy	2
K. Dacus (Bactrocera) melas (Perkins & May)	1, 17, 18, 22, 24, 25 27, 37, 39, 41, 42, 44.
L. Dacus (Bactrocera) musae (Tryon)	4, 5
M. Dacus (Bactrocera) mutabilis (May)	25
N. Dacus (Bactrocera) neohumeralis Hardy	1, 2, 3, 11, 14, 16, 18, 21, 22, 24, 25, 26, 27, 30, 31, 33, 37, 39, 40, 41, 42, 44, 46, 51, 52.
O. Dacus (Bactrocera) tryoni (Froggatt)	1, 2, 3, 4, 6, 7, 8, 9, 10, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 51, 53.

Commercial hosts	Fruit fly pests (p 36)
1. APPLE - Malus sylvestius Mill.	K N O (B in lab only)
2. APRICOT - Prunus armeniaca L.	B J N O
3. AVOCADO - Persia gratissima Gaertn. f.	N O
4. BANANA - Musa nana Lour.	B L O
5. BANANA - Musa paradisiaca L. var sapientum (L.) Kuntze	L
6. BULLOCK'S HEART - Annona reticulata L.	O
7. CAPSICUM, GIANT - Capsicums frutescens L. var grossum L.H. Bail	F G O
8. CARAMBOLA - Averrhoa carambola L.	O
9. CASHEW - Anarcardium occidentale L.	O
10. CHERRY - Prunus avium L.	O
11. CHILI - Capsicum frutescens L.	G N
12. CHOKO - Sechium edule Siv.	C
13. CITRON - Citrus medica L.	O
14. COFFEE - Coffea arabica L.	N O
15. CUCUMBER - Cucumis sativus L.	C
16. CUSTARD APPLE - Annona squamosa L.	N O
17. DATE - Phoenix dactylifera L.	K O
18. FIG - Ficus carica L.	K N O
19. GRANADILLA - Passiflora quadrangularis L.	O
20. GRAPE, EUROPEAN CULTIVATED & WINE - Vitus vinifera L.	O
21. GRAPE, ISABELLA - Vitus labruscana L.H. Bail	N O
22. GRAPEFRUIT - Citrus paradisi Macf.	D I K N O
23. GOOSEBERRY, CAPE - Physalis peruviana L.	I O
24. GUAVA - Psidium guajava L.	B D E H N O
25. KUMQUAT - Fortunella japonica (Thunb.) Swingle	I K M N O
26. LEMON - Citrus limon Burm. f.	N O
27. LOQUAT - Eriobotrya japonica (Thunb.) Lindl.	I K N O
28. LYCHEE - Litchi chinensis Sonn.	O
29. MACADAMIA - Macadamia sp.	O
30. MANDARIN - Citrus reticulata Blanco	I N O
31. MANGO - Mangifera indica L.	B F H N O
32. MARROW - Curcurbita pepo L. var.	C

32.	MARROW - Curcurbita pepo L. var. medullosa Alef.	C
33.	MULBERRY, BLACK - Morus nigra L.	N O
34.	MULBERRY, WHITE - Morus alba L.	O
35.	NECTARINE - Prunus persica (L.) Batsch var. nectarina (Ait.) Maxim	B O
36.	OLIVE - Olea europaea L.	O
37.	ORANGE - Citrus sinensis Osbeck	I K N O (A in lab only)
38.	PAPAW - Carica papaya L.	C L O
39.	PASSIONFRUIT - Passiflora edulis Sims	F K N O
40.	PASSIONFRUIT, WHITE - Passiflora alba Link & Otto	N O
41.	PEACH, - Prunus persica (L.) Batsch	B D K N O
42.	PEAR - Pyrus communis L.	B K N O
43.	PERSIMMON - Diospyros kaki L. f.	B O
44.	PLUM - Prunus domestica L.	K N O
45.	POMEGRANATE - Punica granatum L.	B O
46.	POMELO - Citrus grandis Osbeck	N O
47.	PUMPKIN - Curcurbita pepo L.	C
48.	QUINCE - Cydonia oblonga Mill.	B O
49.	ROCKMELON - Cucumis melo L.	C
50.	SQUASH - Curcurbita pepo L. var melopepo	C
51.	TOMATO - Lycopersicon esculentum Mill.	C G N O
52.	TREE TOMATO - Cyphomandra betacea Sendt.	N
53.	WALNUT - Juglans regia L.	O

II POTENTIAL USE OF IONISING ENERGY FOR POSTHARVEST DISEASE CONTROL

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General

The ionising energy working group has recognised three potential benefits or irradiating fresh fruit and vegetables:

- insect disinfestation
- disease control
- extension of shelf life by delaying ripening or senescence.

This report deals with the second aspect, postharvest disease control. Use of ionising radiation for this purpose has been studied for at least 25 years. Early optimistic reports indicating potential benefits were followed by more cautious statements which higlighted problems which had come to light. Recent reviews indicate considerable promise for some crops and apparently insurmountable problems for others. Each crop must therefore be considered on its merits. This is the approach adopted in this report.

Many published reports on irradiation do not distinguish benefits conferred by controlling diseases from those conferred by delaying senescence or ripening. We are fortunate that a recent review by Moy (1983) concentrates on disease control or 'radurisation' which he defines as 'exposure of a fruit or vegetable to limited doses of ionising radiation to effect a reduction in spoilage and disease-causing micro-organisms'. Many crops considered in Moy's review are those nominated by the Working Group for special attention.

A brief examination of broad principles of disease control by irradiation will assist in interpreting specific information relating to particular crops. These principles include:

Dose rates

Dose rates required for disease control generally fall in the range 2-3 kGy (200-300 krad) but may be as low as 1 kGy (100 krad) or as high as 6 kGy (600 krad). These rates often exceed tolerance levels in host tissue and are far higher than those which kill insects or delay ripening and senescence.

Doses which give disease control are defined less precisely than those which kill or inactivate insects because the effect depends on:

- the amount of inoculum present (more fungal cells require higher doses);
- stage of disease development at treatment (active lesions are harder to control than early infections);
- handling methods (if refrigeration is used after irradiation, a lower dose may be acceptable);

- differences between host varieties and the state of the host when treated.

These factors are important in practice and account, in part, for variations between published results.

Interactions with other treatments

There is clear evidence in at least two crops (mangoes and papaws) that disease control by irradiation in conjunction with another curative treatment (hot water) exceeds that given by either treatment alone. There is thus a synergistic effect.

Production of mutants

It is possible that irradiation will give fungal or bacterial mutants with an enhanced capacity to cause disease. This is considered unlikely because the association between host and pathogens is relatively unspecific in postharvest diseases (Moy 1983).

Individual crops

The following crops, with the exception of papaw, were selected by the Working Group for particular attention. Papaw has been included because of the vast amount of research effort devoted to it in Hawaii and because it demonstrates the principle of synergism.

Mango

Diseases: Anthracnose (Glomerella cingulata var. minor).

Stem-end rot (**Dothiorella dominicana** and other species, **Botryodiplidia theobromae** and several other fungi).

Disease risk ...... high.

Current treatment: 5 min dip in hot water (52°C) plus benomyl (1 g product/L). Gives good disease control but is inconvenient, may damage fruit if used incorrectly, may advance ripening slightly and increase shrivelling during latter stages of ripening. Widely used in Queensland.

Dose required for control: 1.57 - 2.1 kGy (157-210 krad) or above.

Host damage: High risk at 1 kGy (100 krad). Tolerance variable - in India 0.75 kGy (75 krad), in Florida 0.1 kGy (10 krad), in Hawaii 1 kGy (100 krad). Depends on cultivar, stage of ripeness when treated.

Comments: Doses required for primary disease control will damage fruit. Lower doses which kill insects will not give primary disease control. However, there is a good chance that low doses combined with hot water (with or without benomyl) may act synergistically. Such combinations are used commercially in South Africa and rated highly in Hawaii. Waxing to reduce shrivelling should be considered.

References: Moy (1983), Akamine and Moy (1983), Akamine and Goo (1979), Dennison and Ahmed (1971), Jacobs et.al. (1973).

Avocado

Diseases: Anthracnose (Glomerella cingulata var. minor).

Stem-end rot (Dothiorella aromatica, Botryodiplodia theobromae and other fungi).

Disease risk ...... high.

Current treatment: No fungicides registered. Prochloraz under consideration. Temperature management recommended.

Dose required for control: 1.75 kGy (175 krad) and above.

Host damage: May occur as low as 0.1 kGy (10 krad). Avocados are very sensitive.

Comments: Because of the sensitivity of avocados to irradiation, there is little chance of primary disease control. However, a South American report which I have not seen yet apparently reports a beneficial effect of hot water combined with irradiation. The possibility of synergism should therefore be evaluated.

References: Moy (1983), Akamine and Moy (1983), Kamali, Maxie and Rae (1972).

Tomatoes

Diseases: Alternaria rot (A. alternata)

Rhizopus rot (R. stolonifer)

Sour rot (Geotrichum candidum)

Grey mould (Botrytis cinerea)

Disease risk ...... low to moderate. Risk increased by prolonged storage at low temperatures and by wet weather.

Dose required for disease control: 1-3 kGy (100-300 krad).

Host damage: Doses given for disease control caused mottled ripening. The fruit should be pink or riper to avoid injury. High doses increase disease levels.

Current treatments: Sanitisation with chlorine and other compounds used in packing sheds. Nabam sometimes used for Alternaria rot. Benomyl, guazatine and chlorine under consideration.

Comments: Rated by Akamine and Moy as beneficial for disease control. Effects on ripening would need careful study.

References: Moy (1983), Akamine and Moy (1983), Bramlage and Lipton (1965), Mathur (1968), Abdel-Kadir, et.al. (1968).

Citrus

Diseases: Blue and green moulds (Penicillium italicum and P. digitatum).

Stem-end rots (Alternaria citri, Phomopsis citri, Botrydiplodia theobromae).

Sour rot (*Geotrichum candidum*).

Disease risk ...... moderate on domestic market, high for export.

Current treatments: Wide range of fungicides including benomyl, imazalil, guazatine, SOPP, diphenyl, 2 amino-butane. 2,4-D required for export for stem-end rot.

Dose required for control: 1.4-2 kGy (140-200 krad) for mould. Variable. Depends on time of harvest, maturity, inoculum level, application of wax. These doses may increase stem-end rot (A. citri).

Host damage: Depends on host. Oranges more tolerant than grapefruit, tangerines. Peel injury can occur at 0.3-3 kGy (30-300 krad).

Comments: May be a synergistic effect with hot water (53°C for 5 min) which could be exploited.

References: Moy (1983), Akamine and Moy (1983), Beraha et.al. (1959), Bramlage and Covey (1975), Dennison and Ahmed (1971).

Broccoli

No information on diseases of broccoli was found. However, bacterial soft rot, a likely cause of disease in this crop, was not controlled in potatoes by 0.18-4.8 kGy (18-480 krad). Other leafy vegetables were damaged at 2 kGy (200 krad). See Moy (1983).

Lychees

Diseases: A complex of fungi which darken the pericarp soon after harvest.

Disease risk .... high when storage is attempted.

Current treatment: 2 min dip in hot water (52°C) plus benomyl (1 g/l). Should be used in association with p.v.c. cling wraps over small packages.

Dose required for disease control: Information limited. 0.5-1 kGy (50-100 krad) did not injure the tissue and decay was apparently reduced. Effects of storage temperature and other factors are described by Akamine and Goo (1977).

Bananas

Diseases: Anthracnose, crown rot, blackend (Colletotrichum musae and other fungi).

Disease risk ...... normally low, higher when storage attempted.

Current treatment: Treatment with benomyl or related fungicides. Prochloraz a possibility in future.

Doses required for control: 2-3 kGy (200-300 krad).

Host damage: 0.2-0.5 kGy (20-50 krad) applied when the fruit are pre-climacteric, apparently causes no damage in the ripe fruit.

References: Moy (1983), Ferguson et.al. (1966).

Papaya

Diseases: Anthracnose (Glomerella cingulata vars. cingulata and minor and various Colletotrichum species).

Other surface rots (includes Phomopsis caricae-papayae, Alternaria sp. and others).

Stem-end rot (mainly Phoma caricae).

Disease risk ...... high. A limiting factor during storage.

Current treatment: Controlled ripening limits wastage. No fungicides used, but prochloraz is under consideration. In Hawaii, hot water (49°C for 20 min) is used routinely.

Dose required for disease control: Up to 6 kGy (600 krad).

Host damage: 1 kGy (100 krad) and above.

Comments: Papaws (papayas) are regarded in Hawaii as the crop most likely to benefit from irradiation. Doses which give primary disease control damage fruit but there is clearly a synergistic effect between the hot water treatment and irradiation. The combination most likely to be used commercially is 49°C for 20 min, 0.25-0.75 kGy (25-75 krad) followed by storage at 15.6°C.

References: Moy (1983), Akamine and Moy (1983).

Other Crops

Other crops which could benefit from irradiation for disease control but which were not high on the Working Group's priority list include strawberries, and figs.

CONCLUSIONS

- Doses required for disease control are nearly always in the range which causes host damage. Prospects for effective postharvest disease control by ionising energy treatments alone are therefore severely limited.
- Synergism between irradiation and other curative treatments (mainly hot water) could be useful commercially. Crops most likely to benefit from synergism include mango, papaw, and to a lesser extent, citrus.
- Doses selected for semi-commercial testing should be those required to achieve insect disinfestation (and perhaps delayed ripening or senescence) without host damage. The possibility of employing synergism to improve disease control by other treatments should be a secondary consideration.
- Where possible, fungicides should be avoided to exploit the commercial advantage of a 'no residue' ionising energy treatment.

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III POSTHARVEST PHYSIOLOGICAL ASPECTS OF IONISING ENERGY TREATMENT

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General

Tropical and subtropical fruits are difficult products to manage because of variation in crop maturity and quality at harvest, susceptibility to preharvest insect infestation, postharvest bruising and disease, and they have a short postharvest shelf life.

No single process can be expected to maintain postharvest quality by itself. Every step in the production, harvesting, handling and selling should be carefully monitored and controlled. If this is not done, confusion, misinformation and negative responses from producer to consumer are likely, especially if a new process such as ionising energy is used as one additional technological means of protecting fresh fruit quality.

This will apply to domestic and export marketing, but particularly to distant Australian markets and for export which will be of major importance to Queensland fruit and vegetable crops.

It should be emphasised that the effect of ionising energy on the marketable quality of fresh produce includes not only longer physical survival of the produce but also the appearance, aroma, flavour and texture of the produce, right up to final consumption. Only a few fruits and vegetables appear to show potential for the practical application of irradiation as a protective technology.

In studying the effects of ionising energy on fruits, it is imperative that the physiological state of the fruits be determined before treatments are applied. Preclimacteric fruits show a different response from ripening and postclimacteric fruits. Also, different preclimacteric fruits when irradiated do not show a consistent response during ripening. Irradiation is likely to intensify most, if not all postharvest physiological disorders of fruits such as chilling injury, high temperature injury and storage disorders. Therefore the environmental conditions of fruit after irradiation will be critical to storage life and eating quality.

Physiological breakdown attributable to irradiation treatment may occur to varying degrees of severity depending on the post-treatment conditions of storage. Apart from entomological and pathological effects, changes included in fruits and vegetables by irradiation may be:

<u>Chemical</u>

(a) immediate effects, for example, effects on pigments, pectins and ethylene production.

(b) during storage, for example, reduction in ascorbic acid but an increased citric acid content.

Ascorbic acid is one of the more radiosensitive vitamins. This may be an important consideration nutritionally in fruits such as citrus, tomato and capsicum.

Physical

Textural degradation (cellulose, pectin, starch) may occur immediately after treatment and subsequently at a slower rate during post treatment storage, particularly in fruits such as tomato, apple, pear, strawberry.

It seems likely that with most fresh fruits, adverse effects such as textural changes (cellulose, pectin, starch), anomalous ripening and pigment changes will limit irradiation to doses well below those which result in significant loss of vitamins.

Of all the physiological effects of irradiation of fruit and vegetable tissue, loss of tissue structure (texture) is the most important. This effect can be direct (and immediate) or there may also be a delayed secondary effect during subsequent fruit ripening and storage before consumption.

Physiological

Irradiation effects have been observed on respiration during ripening. Fruit maturity at harvest has an influence on the irradiation effects.

In the climacteric fruits, the production of odour and flavour components is closely related to the physiological state of the fruit. Irradiation applied to preclimacteric (unripe) fruit may inhibit the normal ripening processes and thereby reduce the eating quality of ripe fruit.

Treatments applied during ripening would involve radiolytic alteration of odour and flavour compounds as well as their rate of production.

Considerable recent work has been done in South Africa on tropical and subtropical fruits, particularly mango, papaya and lychee.

The following points arose from the experimental and pilot scale commercial trials:

- Only fruit of outstanding quality should be treated by ionising energy (and so labelled) for the fresh market.

- Maxmimum storage benefits were achieved by treating fruit with a hot water dip (55°C for 5 min for mango) plus ionising energy (average dose 0.75 kGy) within 1 day after harvest.

  Fruit had to be dry before irradiation to avoid skin injury.

- Irradiation of immature fruit (particularly early season) resulted in poor ripe fruit quality.

- Irradiation of ripe fruit gave inadequate control of disease and seed weevil and fruit developed 'jelly seed' pulp.

- Post-treatment handling, storage and time before sale, were critical factors in maintaining fruit quality.

Three recommendations were made before actual commercialisation of the process:

1. Results of laboratory experiments should be tested with limited commercial trials.

2. The exact parameters of a combined heat treatment/irradiation process should be established to ensure maximum benefit. These parameters (fruit maturity, handling, treatment procedure, packaging, storage, transport) will influence the optimal siting of an irradiation facility.

3. Co-ordinated test marketing should be carried out and include wholesale/retail markets, government agencies and consumers. Control of treated products should be at a national level.

Mango

According to reports from South Africa on experimental and limited commercial scale work, a combined treatment of a hot-water dip at 55°C for 5 minutes, followed by Cobalt-60 radurisation at an average dose of 0.75 kGy, effectively controlled fungal disease and seed weevil and delayed physiological ripening processes.

In Hawaii, it has been reported that the only technique available for effective disinfestation against both fruit fly and seed weevil is gamma radiation. Control of both pests has been achieved in several varieties of mango at a minimum absorbed dose of 0.33 kGy with an extension of shelf life of 3 to 8 days.

In India, treatment of mangoes in a nitrogen atmosphere with an average dose of 0.25 kGy, up to a 6 day extension of postharvest shelf life of Alphonso mangoes has been reported, with an improvement in fruit firmness. However adverse physiological effects have also been noted, such as retention of green skin colour, lack of pulp colour and poor flavour with a retention of acidity.

Therefore a combined hot dip/irradiation treatment would appear to be beneficial as a disinfestation treatment (against fruit fly and seed weevil) and as a means of controlling postharvest disease (although the effectiveness is not known against stem end rots which are a problem in Queensland mangoes and heat damage to fruit could be significant).

There would also appear to be a possible minor extension of the short postharvest life of mangoes by a purely physiological effect of irradiation. However, it is anticipated that in practice the extension of shelf life achieved would be mainly due to fruit maturity and quality at harvest, effective disinfestation, absence of postharvest rotting, and correct packaging, handling and temperature management of the fruit.

Although an average dose of 0.75 kGy is reported, dosages levels from 0.5 kGy to 1.5 kGy have also been mentioned on mangoes. At levels greater than 0.75 kGy, which may be necessary for seed weevil disinfestation, one might expect undesirable physiological effects to occur such as skin and pulp blemish, off-odours and off-flavours. Further, these may develop in the post-treatment marketing stage before final retailing and consumption of the fruit.

Papaya

In terms of tolerance and responses to achieving an intended technical effect commensurate with fruit quality after treatment, papaya is the most promising fruit to be gamma radiated.

In Hawaii, a combined hot water treatment (47.8°C for 20 min) with 0.75 kGy irradiation dosage resulted in an effective disinfestation and control of anthracnose, as well as an extension of shelf life of 3 to 4 days.

Avocado

In Israel, several avocado varieties have been treated with doses up to 1 kGy and marked varietal effects were noted. The earliest variety Ettinger had a delay in ripening after a dosage of 350 Gy of 24 days for early season fruit and 14 days for late season fruit. However early season Fuerte fruit treated with 350 Gy had only 3 to 8 day extension of shelf life. In some cases, late season Fuerte fruit even ripened faster after a dosage of 0.35 kGy.

All doses up to 0.50 kGy on Hass avocado caused more rapid ripening. In general the more mature the fruit the less effect irradiation had in delayed ripening.

Most irradiation treatments caused some type of discolouration of the skin and pulp when the fruit were ripe.

None of the doses tested controlled anthracnose.

Citrus

In Israel, mature Shamouti and Valencia oranges irradiated with dosages of 0.14 kGy to 2.8 kGy suffered mild to severe skin pitting although internal quality of the fruit was not affected.

No single radiation dose can be given that will be the minimum required for protecting citrus fruits from the various types of spoilage organisms, especially established infections (stem end rots, green and blue moulds).

Irradiation at dosages up to 2 kGy does not appreciably affect the eating quality of oranges and grapefruit. However irradiation causes changes in the pectic components of fruits which can increase juice viscosity, affect texture and cause peel injury which increases with storage.

Tomato

In The Netherlands, it has been shown that the respiration rate of mature green tomatoes increased with increasing gamma dosages with 2 kGy being an optimal level.

The ripening of mature green tomatoes would be delayed by up to about 5 days with a dose of 0.2 to 0.25 kGy.

However, the colour development of tomatoes treated with 2 kGy was irregular.

Lychee

Recent experimental work in South Africa indicates that dosages of 0.5 - 1.5 kGy are suitable for controlling postharvest disease. However, no details are available on the level of post-treatment control of the complex of organisms present, or on the effects (if any) of ionising energy on the discolouration (browning) of lychee skin. This disorder can be caused by several different but interrelated factors and it seriously detracts from the postharvest quality of this brightly coloured fruit. Also, in Australia the rapidly expanding lychee industry will need to consider different marketing (domestic, export) for particular varieties from the wide range now being grown.

Nevertheless, ionising energy treatment of lychees could well complement recent and continuing developments on the Australian postharvest technology for this crop. Such a treatment would also be useful for certain quarantine purposes on introduced plant material and on off-season fresh fruit imports from South East Asia.

Vegetables - heavy produce

A promising application of ionising energy treatment is the inhibition of sprouting of onions and vegetables. A single dosage of 0.15 kGy will produce this effect.

Such a treatment might be beneficial on green ginger, a Queensland grown crop. Export markets in Japan might become available by gamma radiation of green ginger to inhibit sprouting and reduce potential wastage through spoilage organisms and dehydration.

Leafy vegetables

Difficulties were experienced in The Netherlands when irradiating leafy vegetables. Dosages from 0.5 to 2.0 kGy gave no advantages in reducing spoilage or extending postharvest life. Lesions and discolouration were found in leaves at the higher dosages.

Irradiation of red cabbage also gave only minor advantages over untreated controls. Again, discolouration of leaf was a problem.

Quarantine uses

In November 1983, a FAO/IAEA consultant group reported on the possible use of irradiation as a quarantine treatment of agriculture commodities. This report emphasised the need for a co-ordinated research program on the use of ionising energy for quarantine purposes.

There would appear to be potential for the use of ionising energy treatment (IET) as a quarantine treatment, this being an alternative to normal holding periods or the use of chemicals.

IET might be used for devitalising cut flowers, treatment of decorative plant material such as geraldton wax, treatment of prohibited imports etc. Its use on introduced horticultural plant material for example, wood or rooted plants may be limited because of the effect of IET on vegetative growth.

IET would be a viable alternative to chemicals as a quarantine treatment on imports of fresh produce to Australia.

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IV EXPORT MARKET POTENTIAL FOR SELECTED HORTICULTURAL CROPS

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Introduction

At the inaugural meeting of the ionising energy working group a number of horticultural crops were selected with a view to more closely examining their potential for ionising energy treatment. The crops selected were:

mangoes, tomatoes, broccoli, citrus, avocados, papaws, lychees, bananas, cut flowers.

The main thrust of the investigation is to ascertain the feasibility of utilising an irradiation plant to disinfest fresh fruit and vegetables destined for export markets. As such, this paper addresses the export market potential of the selected crops with the prime view of estimating likely trends in export markets in the future. These trends will have a significant bearing on throughput levels, and hence on the economic viability of an ionising energy plant.

Barriers to the development of overseas markets

The export market for Queensland's horticultural produce accounts for only a minor proportion of annual production. In 1982-83, $8.5m of horticultural produce was exported from Queensland[1]. This represents only 3.0 percent of the estimated gross value of horticultural produce in that year of $279.6m[2].

The reasons for this lack of emphasis on exports can be traced to a combination of factors which have acted as barriers to the development of overseas markets for most horticultural products. These factors include:

- the approach of producers/exporters to marketing overseas;
- competitive pressures on world markets;
- quarantine and institutional barriers imposed by importing countries; and
- the perishability of much horticultural produce.

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1. Refer Appendix IVA; 'Queensland Exports of Fresh Fruit and Vegetables: 1980-81 to 1982-83'

2. Source: Australian Bureau of Statistics (ABS)

Approach of producers/exporters to marketing overseas

The approach to overseas marketing of horticultural produce has often been typified by its unco-ordinated nature. This is a reflection of the disaggregation inherent in the horticultural industry from the point of production through the marketing chain. The lack of co-ordinated export marketing puts Queensland exports at a considerable disadvantage in their ability to penetrate and sustain export market outlets. This principally occurs through the inability to project a single positive product image in importing countries. Such an image is readily conducive to reinforcement by promotional activities. A unified approach to marketing could also aid in overcoming other deficiencies in export market performance, such as inadequate market research, poor packaging and presentation, financial inflexibility and difficulties in the areas of quality control and irregularity of supply. The gains to be made by a unified approach to export marketing are exemplified by New Zealand kiwifruit, which stands as a world marketing success story for New Zealand. The ability of other countries to successfully co-ordinate export marketing exacerbates Queensland's competitive disadvantage in this area.

Competitive pressures on world markets

Queensland horticultural produce is, in many areas, at a competitive disadvantage on world markets. Primary amongst these is Australia's geographic isolation from the major developed export markets in the Northern Hemisphere. This has necessitated a phasing in emphasis away from these markets to the nearer South-east Asian, Pacific and Middle-Eastern markets. Even when exporting to these markets, Queensland's competitiveness is hampered by high domestic handling costs. These costs are amplified where consignments are not amenable to automation of handling, as is often the case with horticultural products, which generally require careful handling and where the small size of consignments or commodity perishability makes bulk handling unfeasible.

To some extent Queensland can off-set this disadvantage by concentrating exports on the high value-to-weight commodities, such as many of the tropical fruits. This has the effect of reducing relative transport costs. Queensland can also take advantage of producing and marketing certain crops at times when they are out of season in Northern hemisphere producing countries. Mangoes are an example of one commodity that has the potential to take advantage of contra-seasonal production on Northern hemisphere markets.

Queensland also faces price undercutting on international markets by the low wage-cost countries in Central and South America and Asia. This makes many commodities, (bananas, for example) grossly uncompetitive on world markets. Competitive pricing can also be brought about by the subsidisation of exports by the exporting country.

Quarantine and institutional barriers imposed by importing countries

Import restrictions based on domestic quarantine standards pervade world agricultural trade - and horticultural trade is no exception. Japan's long-standing ban on Australian citrus imports, and the current prohibition on importing Queensland's mangoes into a number of overseas countries are but two examples of this. However, perhaps more damaging than this are the institutional barriers placed in force for political and/or economic reasons. Quarantine enforcement is often used as a convenient rationale for these barriers which are put in place to fulfil domestic policies such as self-sufficiency/import-replacement goals, preserving valuable foreign exchange or maintaining preferential trading dealings between countries (often within the same region). China and the Philippines, for example, are aiming at self-sufficiency/import replacement in horticulture (to preserve foreign exchange for higher valued imports), whilst the European Economic Community is pursuing preferential trade arrangements in favour of member countries. Tariffs and import quotas are also effective barriers against imports, and can be used either across the board or on a preferred country (or countries) basis.

The perishability of much horticultural produce

A major deterrent to the export of many horticultural products is their perishability. This has the effect of limiting the marketing time and/or increasing marketing costs through more sophisticated storage and handling methods. This factor reduces the attractiveness of the export market vis a vis the domestic market as an outlet for many horticultural products.

Regional market prospects

The following section analyses particular markets and groups of markets as potential importers of Australian horticultural produce. This section draws largely on part of a recent paper by the Bureau of Agricultural Economics[1].

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1. B.A.E. Economic Potential for Selected Horticultural Crops in Australia: (Attachment II Domestic and Export Market Prospects), AGPS, Canberra, January 1984 pp 16 - 33.

Asia

There is a wide variation of demand characteristics within this region, however the general economic growth and proximity of this region to Australia favours it as an export market outlet. The best prospects appear to lie in the Hong Kong and Singapore markets and more particularly in the hotel/tourist sector of these markets. Other countries in this region have poorer prospects due to Government pursuance of self-sufficiency/import replacement objectives (for example, Indonesia, Philippines), whilst others are major exporters in their own right (for example, Thailand). The Japanese market, although having apparently enormous potential, is largely self-sufficient in fruit and vegetables[1] and has imposed stringent quarantine laws against the importation of products which may carry harmful insect pests and diseases. Imports into Japan are dominated by supplies from the United States. Australia is an insignificant supplier to this market, and will remain so unless the complex quarantine and institutional barriers can be overcome.

The Middle East

There is considerable potential for horticultural exports to the Arabian Peninsula countries of the Middle East. The development of this potential will depend largely on the size of the expatriate population whose purchasing power makes them the largest consumers of non-traditional products. The potential in the mass market is limited as eating habits remain traditional and the distribution of wealth is heavily concentrated in a small elite. Export market prospects elsewhere in the Middle East are negligible or non-existent.

Europe

Horticultural trade prospects to Europe are uncertain and are largely dependent on future policies within the European Economic Community and, to a lesser extent, the Eastern bloc countries. The preferential trade arrangements within the EEC has seen an expansion of horticultural trade within member countries - to the detriment of external suppliers. Australia is a distant supplier to European markets and future market propsects for this region will depend largely on exporters' ability to contain freight and handling costs to remain competitive with nearer suppliers (for example, South Africa, Israel). Australia's best prospects appear to be in Western Europe, with the maintenance of traditional export lines, such as citrus and pome fruit, and also with exotic fruit if price and quality are competitive. Prospects in the Meditteranean countries are very limited as these countries are major suppliers to the EEC themselves and are in the process of pushing for even greater access into the EEC markets. The preferential trade and self-sufficiency policies of the Eastern European countries rule out any significant export market potential in these countries.

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1. In 1980, Japan's self-sufficiency was estimated at 81 percent for fruit and 97 percent for vegetables (Dept. of Trade, 'Overseas Market Report; Fruit and Vegetables - Japan'; March 1984 p. 1)

The Americas

With the important exception of Queensland mandarins exported to Canada, very little Australian (and Queensland) horticultural produce is exported to the North American continent. The United States, (like Japan) while having an apparently enormous export market potential, is a very difficult market to enter. Strong preference is given to other countries in this region, particularly Central America, the Caribbean and Canada. The United States' plant quarantine regulations are also a major barrier to exports of horticultural produce into that country. Exporters must overcome these significant barriers (in addition to any competitive constraints) before the United States can become a significant export market outlet. The other major North American market, Canada, is the largest single export market outlet for Queensland's major horticultural export, mandarins[1]. The extent to which this market can be further penetrated by other horticultural produce will depend on the ability of Queensland produce to compete with United States' exports, which currently dominate imports into Canada[2]. Central and South American countries offer no real trade prospects due to the presence of preferential tariff arrangements, the attainment of self-sufficiency in many products, and the political instability and/or severe financial difficulties experienced in many of these countries.

The Pacific Region

Australia is a significant supplier to this small, regional market. Given this region's proximity, exports should be sustainable in the future. One factor limiting growth in this market is the desire of many countries to encourage local production to replace imported produce. New Guinea, for example, has placed quotas on imported fruit and vegetables to achieve this goal. The signing of the Closer Economic Relations Agreement with New Zealand has opened up prospects for further horticultural exports to this country. This is especially true for Queensland's winter vegetables (including tomatoes) which will continue to gain greater access to New Zealand as that country's import licencing system is phased out.

Africa

There is little prospect for export market growth in this region, with many countries lacking the financial resources or political stability to establish significant import demand. The notable exception is South Africa, but as this country has a similar range and seasonality of production as Australia, export potential to this market is limited.

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1. In 1982-83, mandarin exports to Canada were valued at $1.28m.

2. Imports of fresh fruit and vegetables from the United States accounted for 89% and 95% respectively of all fresh fruit and vegetables imports into Canada in 1981, (USDA, Foreign Agricultural Circular: Horticultural Products, August 1982, p.p. 8-10)

Commodity Analysis

The following section examines, on a commodity-by-commodity basis, the export market potential for the nine selected commodities, with particular emphasis being placed on mangoes, for the reasons specified below. This analysis essentially applies the general considerations and regional market prospects detailed in the preceding sections to the specific commodities under review.

Wherever possible, export statistics used are sourced from the Australian Bureau of Statistics[1]. However, where these have not been disaggregated to the required level, statistics from the Commonwealth Department of Primary Industry Export Inspection Service are cited[2].

Mangoes

EXPORTS (1982-83)*:- 217 850 kg.

The Working Group has placed considerable emphasis on mangoes as the horticultural product which may be most suitable to ionising energy treatment. This is due to the unavailability of any alternate technology to effectively disinfest the mango seed weevil which has caused Queensland mangoes to be a prohibited import into Saudi Arabia, the United Arab Emirates and potentially other countries. These prohibitions could severely restrict exports in the face of the anticipated expansion in mango production.

Currently, mango production in Queensland is probably in excess of 5 000 tonnes per annum[3]. The majority of this is sold to domestic fresh market outlets with exports accounting for only around 200 tonnes. Mango processing, primarily into pulp and concentrate, also takes up a proportion of the domestic production. The extent of such processing is difficult to ascertain. However, a 1982 estimate put production at 500 tonnes of raw fruit equivalent[4]. Given this, it is likely that the domestic fresh market absorbs some 4500 tonnes of mangoes per annum.

There are a number of factors which place export markets for mangoes in a favourable light. Primary amongst these is its high value to weight ratio and its generally high quality vis a vis its Asian counterparts. Queensland produce also has the distinct advantage of being available in the Northern Hemisphere 'off-season', a factor which gives Queensland mangoes a considerable market advantage in the November-January period. Supplies are generally geared towards specialist market outlets, such as the hotel/tourist trade for which premium prices have been obtained.

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1. Refer Attachment: Queensland - Exports of Fruit and Vegetables -1980/81 to 1982/83.

2. E.I.S. data will be marked with an asterisk (*).

3. Refer Table 1

4. D.C.I.D., D.P.I., C.O.D., <u>Prospects for Horticultural Development in the Burdekin/Bowen Region of North Queensland</u>, 1982, p. 78.

Whilst export market prospects for mangoes appear promising in the short term, the medium to long term growth prospects cannot be viewed in the same light. As stated previously, some 200 tonnes of mangoes are currently exported from Queensland annually. If the expansion in mango plantings in North Queensland continues as proposed, exports will have to increase up to one-hundred fold for the anticipated production to be absorbed.

This prognosis is based on a 1981 Departmental survey of the North Queensland mango industry[1]. This survey conservatively concluded that if all intended mango plantings were carried out, North Queensland mango production would be in excess of 30 000 tonnes by 1996. Table 1 (below) summarises the production projections of that survey.

Table 1. Regional production forecasts

Region	Trees		Production (tonnes)			
	Current Age	Number	1981	1986	1991	1996
BOWEN	0 - 5	5 075	0	76	508	761
	5 - 10	6 418	96	642	963	1 284
	10 - 20	5 956	596	893	1 191	1 489
	20 +	5 058	1 014	1 267	1 267	1 267
	Proposed	14 973	0	0	222	1 479
		TOTAL	1 706	2 878	4 151	6 280
BURDEKIN/ TOWNSVILLE	0 - 5	36 240	0	544	3 642	5 436
	5 - 10	3 707	56	371	556	741
	10 - 20	7 950	795	1 193	1 590	1 988
	20 +	1 197	239	299	299	299
	Proposed	107 060	0	0	1 606	10 706
		TOTAL	1 090	2 407	7 675	19 170

1 S. Luxton, Mango Survey Report, Queensland Dept. of Primary Industries, 1982.

ATHERTON TABLELAND	0 - 5	12 445	0	187	1 245	1 867
	5 - 10	1 789	27	179	268	358
	10 - 20	611	61	92	122	153
	20 +	39	8	10	10	10
	Proposed	20 090	0	0	301	2 009
		TOTAL	96	468	1 948	4 397
MACKAY	0 - 5	1 613	0	24	161	242
	5 - 10	1 072	16	107	161	214
	10 - 20	1 261	126	189	252	315
	20 +	686	137	172	172	172
	Proposed	5 942	0	0	89	594
		TOTAL	279	492	835	1 537
TOTAL	100% proposed plantings		3 171	6 245	14 607	31 384
	50% proposed plantings		3 171	6 245	13 498	22 990
	0% proposed plantings		3 171	6 245	12 389	15 596

Assumptions

1. Trees are all aged at the younger limit of age class: for example, all trees in 10 to 20 year age class are 10 year.

2. Production levels:

Tree age	Level
5 year	15kg
10 year	100kg
15 year	150kg
20 year	200kg
25 year	250kg

3. Proposed tree plantings do not occur until 1986.

It is likely that this increased production will be partially absorbed by increased domestic fresh market consumption, especially in view of Victoria's recent relaxation of its fruit fly fumigation requirements. Increased processing could also absorb greater quantities of lower quality fruit. However, even allowing for a very generous expansion in domestic fresh market and processing demand, production surplus to domestic requirements will be in excess of 20 000 tonnes by 1996. This surplus will be even greater if the Northern Territory proceeds with its proposed planting of 70 000 trees[1] or if credence is given to North Queensland Development's literature which claims that its Horseshoe Lagoon and Laudham Park developments will 'boast' 283 000 trees by 1988[2]. These latter plantings are apparently not fully recorded in the 1981 survey.

The daunting potential mango surplus may well discourage future plantings in which case the survey's projected production would be lower. However, even if only 50% of proposed plantings are undertaken, North Queensland production is estimated to reach 22 990 tonnes by 1996 - producing a likely domestic surplus of some 15 000 tonnes.

The prospects for establishing export markets for this volume of produce cannot be viewed optimistically. It is evident that the very limited nature of the high-priced specialist export market outlets in South-east Asia and the Middle East offer only limited market growth prospects. There are already indications that market growth in South-east Asia is easing off and considerable price cutting may soon be required to maintain market shares. Potential in the Middle Eastern markets is further hampered by the presence of the mango seed weevil and/or possible adverse reaction to irradiated fruit.

Potential in the Japanese and North American markets is severely limited by those countries' complex quarantine and institutional barriers. Mangoes are not permitted into either market due to the presence of fruit fly and mango seed weevil and the current controversy over E.D.B. treatments against fruit fly makes future entry of E.D.B. - disinfested mangoes extremely unlikely. If these quarantine barriers can be overcome, market competitiveness will become the over-riding constraint on the development of these markets.

The Western European market remains the only other potential export outlet of any major consequence. However, consumption in these countries is typically low, especially in the Northern Hemisphere mid-winter months when Queensland mangoes are available. High transport costs and likely future EEC trade policies are further impediments to market penetration in Europe.

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1 B.A.E. op:cit. (Attachment 1 Situation and Profitability) p. 19. (It is understood, however, that this production will be mostly mechanically harvested and pulped).

2 North Queensland Developments Pty. Ltd., An Agricultural Revolution in North Queensland, 1983, p. 2, 3.

It is likely that the small export markets in New Zealand and the Pacific region will be sustained in the future.

Tomatoes

EXPORTS (1982-83) 330 822 kg $477 656

Queensland is the largest producer of fresh market tomatoes in Australia. Tomato production has steadily increased over recent years as the Bowen and Bundaberg regions respond to their climatic and production cost advantages. Queensland tomatoes are almost exclusively marketed to fresh domestic outlets with (fresh) exports probably accounting for less than 1 per cent of production.

With the recent expansion in production, alternative outlets, such as exports, will be given greater attention. Queensland can produce high quality firm tomatoes, but their relatively low value to weight ratio incurs transport disadvantages which rule out market prospects in nearly all but the closer South-east Asia and South Pacific markets. One market in this region, New Zealand, has shown considerable growth potential of late following the signing of the CER Agreement and the development and acceptance of an effective post-harvest treatment against Queensland fruit fly. This market will continue to expand moderately over the next 5 to 10 years as New Zealand's import licencing system is gradually phased out.

Broccoli

EXPORTS (1982-83)* 464 850 kg

Production of broccoli has expanded markedly in Queensland in recent years. This rapid expansion has been largely due to increasing consumer demand for high quality pre-cooled broccoli. The same can be said of export markets (principally in South-east Asia) where Queensland broccoli has the reputation of being prime quality produce. In these markets, this produce is directed at the more affluent market segments including the hotel and restaurant trade, the expatriate community and the more wealthy of the local population. A major barrier to expanding export market outlets for broccoli is the highly perishable nature of the product. Broccoli has a very short post-harvest life and immediate post-harvest cooling, refrigerated transportation and top-icing have become essential features of post-harvest handling. These added costs make broccoli a relatively high priced vegetable and limits its market potential, especially to more distant markets. Despite this, market prospects should remain sound in the South-east Asia markets while some market potential is likely to exist in New Zealand and the wealthier segments of the Arabian Peninsula.

Citrus

EXPORTS (1982-83)

	kg	$
Oranges	991 943	494 742
Mandarins	3 359 590	2 083 230
Lemons & Limes	79 896	42 062
Grapefruit	1 819	1 362
Other	-	-
	4 432 348kg	$2 621 396

As a product group, citrus is by far Queensland's major horticultural export, representing nearly 40 per cent of all horticultural exports in 1982/83. Within this product group, mandarins are predominant, accounting for some 75% to 80% of citrus exports.

Other market outlets for citrus are the domestic fresh market (the major market outlet), and processing (mainly oranges) into juice and juice concentrates.

Queensland citrus has established export markets in all parts of the world, more particularly in South-east Asia (Singapore, Hong Kong and Indonesia), Canada, the Arabian Peninsula (esp. Saudi Arabia) and Europe. Potentials in these export markets vary. Prospects in the European markets are not good as increased production from the Mediterranean countries (particularly Spain and Greece) will increasingly replace imports from outside the EEC bloc. Counteracting this, however is the likely expansion in demand in South-east Asia. Export market growth in this area is possible if Queensland exporters actively compete to maintain (or increase) their market shares against the strong competition from the United States. The potential of the Japanese citrus market remains uncertain. Quarantine prohibitions have prevented the export of Queensland citrus to Japan until very recently, when in September 1983, a trial shipment of around 30 tonnes of Valencia oranges was exported. This was followed by a further shipment of around 180 tonnes of navel oranges in June 1984. However the prospects of Japan becoming a significant outlet for Queensland citrus should be viewed with caution. It is a long-held belief that Japan's quarantine restrictions go well beyond what is necessary for biological protection of domestic industries and is in effect a de facto trade barrier put in place to protect Japan's domestic industries. It is likely that Japan's influential citrus industry lobby will continue to push for the continuation of this protection. In addition to this, Queensland exporters face strong competition from United States citrus (which dominates Japanese citrus imports). The anticipated concern over the use of EDB (and possibly ionising energy) will be further barriers to market penetration in Japan.

Avocados

EXPORTS (1982-83)* 4 020 kg

High prices and strong consumer demand has stimulated increased production of avocados over the past decade. This trend is likely to continue, given the high proportion of non-bearing trees currently existent in the industry.

Avocados are almost exclusively sold to domestic fresh market outlets with export markets accounting for a very minor proportion of production. Export market prospects for avocados are very limited at current price levels. This is primarily due to the high production costs in Queensland (and Australia) - costs which are significantly higher than in most competing countries. When this is combined with Australia's freight cost disadvantage, prospects appear limited to South-east Asian markets and possibly the Arabian Peninsula markets. Limited sales will probably also continue to the Pacific Islands and Papua New Guinea. Supplies to South-east Asia are directed primarily at the high-priced hotel/restaurant trade with consumers being tourists, expatriates and the wealthy local residents. This market, albeit limited, offers some potential for Queensland avocados. However, a wider expansion into this market is severely restricted by the competition from the United States which can land avocados into this region at a significantly lower price. Queensland producers/exporters must be prepared to accept lower returns for their produce if they are to match this competition. There are currently indications that domestic market prices for avocados are falling and this trend should continue over the next few years as significantly increased supplies come onto the market.

Papaws

EXPORTS (1982-83)* 4 820 kg

The production difficulties that have beset the Queensland papaw industry have limited that industry's growth in Queensland. The papaw is susceptible to disease outbreaks (for example, dieback), to damage from adverse seasonal conditions (for example, cyclonic conditions in North Queensland), and to fruit damage during and after harvesting. These factors, whilst limiting the industry's growth potential, also limit its market potential, especially on the export market. Currently the majority of papaws are sold on domestic fresh markets, with a small percentage processed for use in tropical fruit salads and other products, and a very minor amount exported. Exports market prospects for papaws are poor, due primarily to the product's high perishability and variability in both quality and supply. It is unlikely that the current low level of exports will improve in the foreseeable future.

Lychees

EXPORTS (1982-83)* 2 440 kg

Production of lychees in Australia is expected to expand markedly in the near future as the current high proportion of non-bearing trees come into production[1]. Lychee production is marketed primarily on the domestic fresh market with a small proportion being exported, primarily to Papua New Guinea. As production expands there is a possibility of exporting lychees to the large traditional markets in South-east Asia, especially as Australian production occurs during the South-east Asia off-season. However, the development of these markets is likely to be limited and will depend on the correct choice of varieties and the ability of exporters to supply consistently high quality produce.

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1. Non-bearing trees currently account for approximately 91 per cent of all lychee trees (D. Franklin, 'Tropical Fruit', Commercial Horticulture, October 1983, p. 19).

Bananas

EXPORTS (1982-1983) 66 710 kg $11,030

The banana industry is the most important fruit crop industry in Queensland. Geographically, the industry is divided into two distinct locations, one in North Queensland (centred around the Tully-Innisfail area) and the other in the South-East Queensland coastal strip from the New South Wales border north to Bundaberg. The North Queensland crop is marketed primarily on the interstate fresh markets whilst the South-East Queensland crop is mainly supplied to the local fresh market. Only minor quantities are processed (for example, pureeing and drying) or exported. Export market prospects for bananas are poor. This is principally due to our high domestic labour costs which make exports unable to compete with the low labour-cost countries of South-east Asia (especially the Philippines), the South Pacific and South America (especially Ecuador). The possibility of exporting significant quantities of bananas in competition with these countries is extremely remote.

Cut Flowers

EXPORTS (1982-83)[1] $36 445

Production of cut flowers in Queensland is centred on the more traditional flowers, such as gladiolis, chrysanthemums, carnations and roses. These are principally marketed locally, with some flowers (mainly gladiolis) being sent to southern markets. A small market also exists in New Zealand for Queensland gladiolis. Australia exports over $2m worth of cut flowers each year. However, these exports are principally orchids from New South Wales and native wildflowers from Western Australia. The orchids are produced from a substantial industry in the Sydney region, while the Western Australian wildflowers are supplied almost exclusively from natural stands with limited commercial plantings beginning in that State and elsewhere in Australia. There appears to be substantial demand for Australian wildflowers overseas and it is in this area (rather than in the more traditional lines) that export market potential is greater. A substantial planting of geraldton wax in the West Moreton region has recently been undertaken. It is understood that production from this planting will begin in late 1984 and will be destined for export markets.

Concluding comments

Whilst there are many problems associated with the development of export markets for horticultural products, these problems are by no means insurmountable. What is required is the identification of barriers to export market development, as has been broadly addressed in this paper, followed by the initiation of the appropriate remedial action.

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1 ABS: SITC ITEM NO. 292.71

A fundamental change in attitude is required by producers/exporter who consider the export market as a 'spillover' market which will take produce surplus to domestic requirements - regardless of price, quality, presentation etc. Quite to the contrary, export markets are highly competitive and have specialised market requirements which must be met by exporting countries if they are to remain viable in the marketplace. If the Queensland horticultural industry is to improve its export market performance, greater attention needs to be given to 'targeting' particular markets for particular commodities for particular times of year - and then producing specifically for that particular target market.

Target marketing will require a greater understanding of each market's demand characteristics, price and quality of competing supplies and knowledge of any quarantine and/or institutional barriers imposed on imports, and the reasons for the imposition of such barriers. In order for this need for improved market knowledge to be met, concerted efforts will be required by producers, exporters and Governments.

Summary

Queensland is not a major exporter of horticultural produce, exporting around 15 000 tonnes of produce in 1982-83 valued at $8.5m. This represents a very small proportion of Queensland's annual fruit and vegetable production. The reasons for this include producers' and exporters' approach to marketing overseas, the inability of many crops to compete on world markets, the imposition of trade barriers in many countries and the perishable nature of many fruit and vegetables.

Regional market prospects are very much determined by the demand characteristics within each region, the price and quality of competing supplies and the extent of quarantine and institutional barriers to imports.

Some of the horticultural products under review do have reasonable export market prospects, providing some of the aforementioned problems can be overcome. These products include mangoes, broccoli, tomatoes and cut flowers (native wildflowers). The more traditional cut flowers should be able to maintain their small export market outlets, as should avocados. The export market potential for lychees is difficult to assess while the industry remains in an early stage of development. Export market prospects for bananas and papaws remain poor. Citrus (principally mandarins) is likely to retain its position as Queensland's major horticultural export in the near future.

The extent to which the potential for export market development can be realised will rely on greater efforts being put into export marketing by producers, exporters and Governments.

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APPENDIX IVA

QUEENSLAND - EXPORTS OF FRESH FRUIT[1] AND VEGETABLES: 1980/81 TO 1982/1983[2]

COMMODITY	1980/81		1981/82		1982/83	
	QUANTITY ('000 kg)	VALUE ($'000)	QUANTITY ('000 kg)	VALUE ($'000)	QUANTITY ('000 kg)	VALUE ($'000)
1. FRUIT						
(i) FRESH (OR CHILLED)[3]						
ORANGES	2 210	824	1 361	509	991	495
MANDARINS	5 833	2 928	3 251	1 860	3 360	2 083
LEMONS & LIMES	125	57	104	43	80	42
GRAPEFRUIT	307	121	101	43	2	1
OTHER CITRUS	1	(b)	-	-	-	-
BANANAS	13	9	13	8	67	11
APPLES	1 244	648	690	508	700	548
GRAPES	180	231	215	420	81	109
FIGS	4	7	(a)	(b)	-	-
PINEAPPLES, DATES, AVOCADOS, MANGOES, GUAVAS & MANGOSTEENS[4]	260	197	113	52	272	273
PEARS AND QUINCES	280	148	459	275	296	199
STONEFRUIT	14	48	7	19	10	13
BERRIES[4]	6	23	5	13	2	14
OTHER[4]	56	77	56	57	142	130
	10 470	5 317	6 366	3 807	6 003	3 922
(ii) OTHER						
DRIED GRAPES	21	34	30	44	18	41
NUTS	96	374	66	265	89	372
OTHER DRIED FRUIT	4	5	2	4	10	37
	121	414	98	313	117	449
2. VEGETABLES						
(i) FRESH (OR CHILLED)						
POTATOES	794	316	609	271	885	255
TOMATOES	148	180	174	170	381	478
ONIONS	379	138	536	254	147	47
SHALLOTS, GARLIC, LEEKS, etc.	41	67	133	238	316	407
CAULIFLOWERS	21	27	18	26	38	33
LETTUCE	113	101	59	60	44	46
CARROTS	69	47	123	75	94	55
OTHER	343	263	224	168	264	218
	1 908	1 138	1 876	1 262	2 169	1 538
(ii) OTHER						
BEANS, PEAS, LENTILS, etc., dried or shelled	2 047	644	1 260	620	6 363	2 352
VEGETABLES, preserved by freezing	35	37	12	19	2?6	182
VEGETABLES, provisionally preserved in brine, sulphur water etc.	123	88	27	23	51	39
VEGETABLES PRODUCTS	13	29	29	72	13	30
	2 219	797	1 328	734	6 633	2 603
	14 717	7 666	9 668	6 115	14 922	8 512

(SOURCE: ABS OVERSEAS TRADE: EXPORT STATISTICS)

1 INCLUDING NUTS

2 INCLUDES CHILLED, DRIED AND PROVISIONALLY PRESERVED PRODUCE

3 EXCEPT CITRUS WHICH IS FRESH OR DRIED AND BANANAS AND FIGS AND PINEAPPLES etc. WHICH ARE FRESH, CHILLED OR DRIED

V ECONOMIC FEASIBILITY OF USING AN IONISING ENERGY TREATMENT PLANT FOR DISINFESTATION OF FRUIT AND VEGETABLES IN QUEENSLAND

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Introduction

Countries and States importing horticultural crops impose protective quarantine requirements, particularly against insect pests. The most important insect pest in Queensland fruit is the Queensland fruit fly (Dacus tryoni).

The quarantine requirements of countries and States importing Queensland fruit have been met mainly by fumigation of fruit with EDB.

It appears that IET by irradiation can meet these quarantine requirements. EDB has been banned in United States of America for fumigation of fruit and vegetables from September, 1984, but will probably remain in use until an effective alternative is found.

This working group has been formed by the Department of Primary Industries 'to investigate the feasibility of the establishment of a pilot irradiation plant primarily for fresh fruit disinfestation purposes' in Queensland.

This paper considers the economic feasibility of using IET for disinfestation of fruit and vegetables in Queensland.

Crops selected by the Working Group for further investigation were:

mangoes, tomatoes, broccoli, citrus, avocados, papaws, lychees, bananas and cut flowers.

IET plant function, location, ownership

There are several possible functions, locations and forms of ownership for an IET plant in Queensland.

Function

An IET plant would be used either for fruit only or for fruit in addition to other goods.

Location

An IET plant could be located in fruit growing areas, at markets and shipping ports, or on a transport route.

Treatment should occur as soon as possible after harvest, but an IET plant at a centralised market or distribution point would attract more use and so increase efficiency.

It may be possible to have a temporary or seasonal plant established near areas of production. This would improve effectiveness of treatment, but could increase capital investment required and would require movement of the irradiation source.

Ownership

An IET plant could be owned, financed and controlled by private enterprise, Government, an industry organization such as the C.O.D. or by some combination of these.

Costs of IET

Australian situation

Beattie and Wiblin calculated a cost of $7.00 per tonne (or $0.14 per carton) under the following assumptions.

Capital cost of $2M for buildings, source plaque, tank, control equipment, concrete work for the shielding and materials handling systems.

Annual costs

	$
Depreciation over 15 years	133 000
Interest rate 14 per cent	280 000
Labour	150 000
Power, water, repairs and maintenance, renewal of source, other costs	50 000
Total annual cost	613 000
Total annual cost, per week (50 weeks)	12 260
Throughput (tonnes) per year	87 500
per week	1 750

Beattie and Wiblin conclude that: 'The fruit and vegetable industries in Australia are unlikely to provide the high throughput needed for an IRT (i.e. IET) facility'.

Queensland situation - estimated costs

The following preliminary cost estimates are based on costs of a plant operating in Melbourne and of one being built in Sydney.

Capital cost $M2.5

IET cost ($/carton)

mangoes	$0.14 - $C [illegible]
citrus	$0.30
capsicum	$0.15
melons	$0.30

These costs per carton compare favourably with approximate cost of EDB fumigation by the COD., e.g. citrus \$0.35 - \$0.40 and capsicums \$0.26 - \$0.3[illegible] EDB fumigation of citrus in the South Burnett region costs approximately \$0.30 per carton.

If fruit cannot be treated on pallets, unloading and reloading of pallets may add 5 cents to 10 cents per carton to the cost of IET.

Throughput levels

Export, interstate

The problem of insufficient throughput by Australia highlighted by Beattie and Wiblin is emphasised further by Queensland levels of production.

In 1982-83 total exports of fruit and vegetables from Queensland amounted to 14 922 tonnes, of which only 8 172 tonnes were fresh or chilled. The largest export fruit and vegetable crop was citrus (4 433 tonnes) followed by potatoes (885 tonnes). (See Appendix A).

From 'Records of post-harvest EDB fumigation, Queensland, 1982-83' (Appendix B), 19 539 packages were fumigated for interstate and 13 566 for export, i.e. approximately 400 tonnes and 270 tonnes respectively.

Mango is one crop on which IET could be required. Apart from problems of harvesting and marketing the suggested increased production, another problem is that the level of production will not support an IET plant until at least 1991.

Projected mango production, Queensland

Percentage of proposed plantings	Production per week* (t)		
	1986	1991	1996
100	625	1461	3138
50	625	1350	2299
0	625	1239	1560

* Assuming a 10-week harvest period.

Imports

It is possible that IET could replace EDB as a treatment for goods imported into Queensland, but the quantity of imports requiring treatment does not appear sufficient to make an IET plant viable. (See Appendix C).

Harvesting seasons

The economic performance of an irradiation plant will improve as throughput rises. Appendix D displays the harvesting seasons of some horticultural crops in the dry tropics. Very few crops are harvested in the period January to March, most crops being harvested from May to November. Mangoes are harvested during November, December and January.

Even if production increased to the capacity of an IET plant, the plant would not be required all year.

Citrus harvesting in the State's major production region, Central Burnett, extends from March to October.

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APPENDIX VA

Queensland - Export of Fruit & Vegetables 1982-83

Commodity	Value ($'000)	Quantity (t)
1. Fruit		
(i) Fresh (or chilled)		
Citrus	2 621	4 433
Bananas	11	67
Apples	548	700
Grapes	109	81
Pineapples, Avocados, Mangoes, et al	273	272
Pears, Quinces	199	296
Stonefruit	18	10
Berries	14	2
Other	130	142
	3 922	6 003
(ii) Other		
Dried grapes, nuts	449	117
2. Vegetables		
(i) Fresh (or chilled)		
Potatoes	255	885
Tomatoes	478	381
Onions	47	147
Schallots, etc.	407	316
Cauliflower	33	38
Lettuce	46	44
Carrots	55	94
Other	218	264
	1 538	2 169
(ii) Other		
Beans, peas (dried, shelled)	2 352	6 363
Other	251	270
	2 603	6 633
	8 512	14 922
3. Summary		
Fruit and Vegetables		
Fresh or chilled	5 460	8 172
Other	3 052	6 750
Total	8 512	14 922

APPENDIX VB

Records of Post-harvest EDB Fumigation - Queensland

1982-83

Commodity	Interstate (No. of packages)	Export (No. of packages)
Lemons	870	-
Mandarins	16 406	-
Mangoes	627	1 352
Oranges	1 200	10 776
Rockmelons	-	670
Capsicums	140	684
Zucchini	96	-
Eggfruit	150	70
Cucumbers	50	14
Total	19 539	13 566

APPENDIX VC

Fruit, Vegetable & Cut Flower Imports into Brisbane

A. Fruit and Vegetables

Group 1

Commodities in this group are subject to inspection on arrival. Fruit from California must be accompanied by a phytosanitary certificate stating that no species of fruit fly which attacks that fruit has been trapped within an 80km radius of the area of production within the previous 12 months. Alternatively the shipment is to be fumigated with EDB at $18 g/m^3$ for 2 hours at $21^{\circ}C$.

Little if any of the fruit imported in this category in 1983 would have been EDB treated. There is a percentage which requires treatment following quarantine detection of living insects. The most common are container loads of USA citrus with scale and NZ fruit and vegetables with thrips etc.

Commodity	trays	cartons/bags
Artichokes	261	55 bags
Asparagus	6 831	128 bags
Avocado	2 823	-
Babaco	399	-
Blackcurrants	99	-
Blueberries	662	-
Boysenberries	477	-
Brussel Sprouts	-	110 bags
Carrots		220 bags
Cherries	366	-
Cucumbers	300	-
Figs	-	175 ctns
Feijoas	1 584	-
Gooseberries	201	-
Grapefruit	-	504 ctns
Herbs	-	26 ctns
Kiwifruit	48 420	-
Lemons	-	2 016 ctns
Lettuce	-	74 bags
Melons	381	40 ctns
Minneolos	-	700 ctns
Mushrooms	92 739	-
Nectarines	46 587	-
Onions	-	6 980 bags
Oranges	-	3 528 ctns
Parsley	18	-
Passionfruit	6	-
Peaches	17 265	-
Pepinos	6	39 ctns.
Strawberries	11 025	-
Swedes	-	220 bags

Tamarillos	2 109	1 135 ctns
Tangelos	2 307	-
Tomatoes	549	2 ctns
Whitlof	-	127 ctns/ 14 bags

Group 2

Commodities in this Group require a hot water treatment for disease.
Chestnuts 9 cartons

Group 3

Commodities in this Group require a mandatory methyl bromide treatment of 48g per cubic metre for 3 hours.
Garlic 624 cartons

Group 4

Commodities in this Group require EDB fumigation on arrival.
Mangoes 660 trays 250 cartons

(In addition to these commodities, 1 carton of potatoes was imported under special permit)

B. Cut flowers

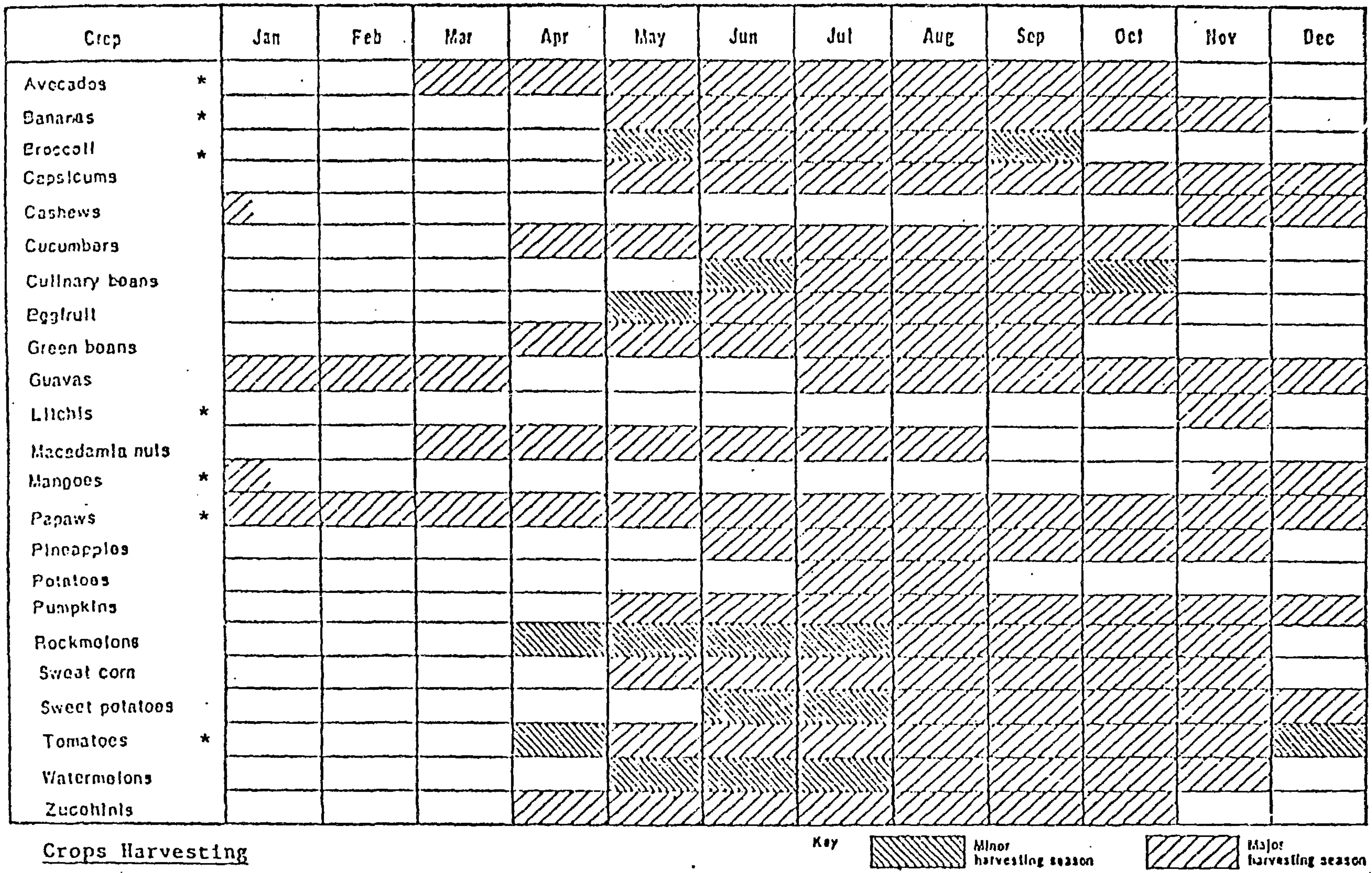
Imports of cut flowers are inspected on arrival. If living insects are detected, (e.g. aphids, mites) produce is fumigated with methyl bromide at $32gm/m^3$ for 2 hours at 21^oC..

IMPORTS:- 11 442 cartons
QUANTITY
FUMIGATED:- 583 cartons

(SOURCE: Plant Quarantine, Eagle Farm)

Figure 1. Dry Tropics Production Seasons

Source: Prospects for Horticultural Development in Burdekin/Bowen Region D.P.I. 1982



Crops Harvesting

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All Crops:	4	2	4	8	15	18	20	20	18	16	14	8
Selected Crops*:	2	1	2	3	5	5	5	5	5	4	5	3

APPENDIX VD

VI SCOPE OF DESIGNS AND OPERATION OF IONISING RADIATION FACILITIES

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Introduction

The largest manufacturer of irradiators[1] claims, with justification, that: 'The design, manufacture and operation of Cobalt-60 radiation processing facilities is a well established technology'. Design parameters of importance include permissible maximum and minimum dosages, physical features of the product to be irradiated (as they affect handling) and required throughputs. All of these parameters directly affect the economics of construction and operation.

In 1983 there were more than 130 industrial installations in more than 40 countries throughout the world. Most were primarily for the sterilisation of medical products, but several were food irradiation facilities or for other special applications. For the processing of fruit, the best source of design experience is South Africa[2] where there is a small semi-commercial facility (HEPRO at Tzaneen) which was designed to handle those tropical fruit varieties which are highly relevant to Queensland.

Electron accelerator irradiation units lack the capability to disinfest fruit for deep seated pests [3], and will not be further considered here because it is judged that they do not have the operational flexibility to serve the whole horticultural export industry. However, the technology exists to use accelerated electrons to generate X-rays which are identical to gamma irradiation and may be superior to radiation from a radioactive source because they can be focussed and selected for wavelength characteristics[4].

Designs

Cobalt-60 Source

In commercial designs the Cobalt-60 source is enclosed in stainless steel 'pencils' arranged in a rack which is safely held in a deep tank of water when the plant is not in use or during maintenance. The rack normally has provision for the addition of further pencils both to replace activity strength lost through decay (the half life of Cobalt-60 is 5.26 yrs) or to increase the capacity of the facility as throughput is increased. Caesium-137 is an alternative to Cobalt-60 but less efficient and is not used in any commercial facility in Australia.

The radioactive source can be manipulated safely under water with remote tools. For example, rearrangement for even distribution of radiation is usually undertaken once a year. This source handling flexibility means that it would be feasible to remove the pencils and transport them in the special shielded containers in which they are supplied to the site of another facility which might only be needed on a seasonal basis.

In terms of costs, the Cobalt Source is believed to be 40% of the initial capital cost of a commercial treatment facility and, operationally, with a half life of 5.26 years is more important than labour costs.

Cobalt sources are measured in units of 'curies' (Ci). Ansell's commercial multipurpose contract facility to be constructed in Sydney, will have a designed capacity of 2 million Ci. Their Dandenong facility has a capacity of 1 million Ci but was initially operated at 0.5 million and subsequently increased as the contract business grew so that at present its strength is 940 000 Ci. Designed throughput capacities are 40 000 and 14 000m^3 respectively, at 2.5 megarads.

The South African (HEPRO) facility for fruit currently operates at a mere 70 000 Ci but probably has considerably greater potential capacity. The relatively low doses of radiation required to disinfest fruit mean that good throughput can be achieved with a relatively low strength source, e.g. 1/2 to 1 tonne per hour for the 70 000 Ci strength HEPRO unit for an average 7 000 tonnes per year at 0.01 megarads (1kGy).

Small research irradiators have been built in which the source remains in the water tank (pond) and items to be irradiated are lowered beside the source in a waterproof container. Such units are safe to use and economical to construct but are inefficient in utilisation of the output of the source because the radiation is rapidly attenuated in water. They are impractical for commercial operations but excellent for research purposes.

Source pass mechanisms

Some form of mechanical facility is needed to carry the product to and from the source. These have devolved to:

- tote box systems, and
- carrier systems

Tote boxes: In the tote box systems a series of boxes are loaded and placed onto a conveyor bed system which moves a set distance in unit time. Movement is not continuous but contains 'dwell' periods which are varied according to the dose required for the product. Tote box systems are said to make most efficient use of the source.

The route taken by the conveyor system is designed to make best use of radiation from the source and may actually pass it 2 or 4 times to ensure that all of the product is administered the minimum dose but that neither side is overdosed. The maximum-minimum doses should be in a ratio not exceeding 2:1.

Use of tote boxes means that the product must be broken down to appropriate unit loads and reassembled later e.g. the tote boxes of the Dandenong facility are 900 x 500 x 450 mm but for a fruit treatment plant they could be made to a size which would accept standard fruit packs most economically. Ansell operate their Dandenong facility on a 24 hour basis with a staff of 3 to 7 each shift.

Carriers: These systems make use of palletised products which are loaded into a 2 pallet high frame. The pallets must be smaller than our standard transport pallet for effective dosage at the centre. The carriers are routed past the source on an overhead rail. This system is obviously most suited to large capacity facilities.

For both types of systems, greater or lesser degrees of movement, programming, and automation can be designed.

X-ray Source

Ionising energy generated as X-rays has not yet been implemented for commercial food treatment irradiators. Current research in the USA[4] could lead to this as soon as 1986. The generation of X-rays for use in medicine has been available as a commercial technology for some years and a number of systems are available. The system under development for food irradiation is said to involve a linear acceleration or induction generator with 10 MeV beam energy and average beam of 500 kW for a pulsed continuous wave type of beam. Output is limited by legislation in the USA[5].

The directional properties of the X-rays produced in this way are said to make for more efficient usage of the radiation than is possible for gamma radiation from a radioactive source. An installation of this nature could be most compatible with existing batch systems using tote boxes but sufficient design flexibility probably exists to fit either continuous or dwell systems.

Blockhouse construction

All commercial systems require a blockhouse above or underground to prevent escape of irradiation during treatment. Concrete is the usual construction material but some use earth fill. Entry for the products to be irradiated is via a maze.

For Cobalt-60 a hoist mechanism is needed to raise the source from the water tank (pond). These are usually compressed air operated for fail-safe operation. Other ancillary facilities are a deioniser for the water, drive and timing devices for the conveyor system, and sensors and locks to safeguard against accidental entry and exposure.

The blockhouse needs to be part of a warehouse type facility having a layout for efficient handling and segregation of products. For fruit, cool room facilities would be needed and for multiple treatments such as those involving hot water pretreatment or irradiation in a nitrogen atmosphere, appropriate ancillary equipment.

Site requirements

There appear to be few special site requirements apart from a well drained site for the 6m deep well for a radioactive source. There are no noise problems nor pollutants.

Location

Where a plant is located would be influenced by:

- Transport and handling patterns for produce, i.e. whether the major products are to be shipped by air or sea or utilised locally (for example medical products).
- Product quality requirements i.e. in some instances increased shelf life advantages for fruit would be expected to be greatest where the product is treated immediately after harvest.
- Access to import facilities, i.e. international airports or shipping terminals.

Costs

The estimated cost of the Ansell facility to be constructed in Sydney by 1985 is said to be A$2.1 million plus land ($400 000).

This facility is relatively large with an annual throughput capacity of 40 000 m^3 at a standard medical dose of 25 kGy - fruit requires 0.003 to 0.04 of the medical dose (up to 1 kGy).

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