CONTROL OF NEWCASTLE DISEASE IN VILLAGE CHICKENS

ACIAR Projects 8334, 8717 and 93/222

Centre for International Economics
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1. Summary

Between 1983 and 1992, the Australian Centre for International Agricultural Research (ACIAR) invested A$3 million in research to find a vaccine that could provide protection from Newcastle disease in chickens and be applied in village environments in developing countries. A further $160 000 was invested in follow up projects which ended in 1996. Village chickens often provide the only source of protein to poor villagers living in remote areas and Newcastle disease frequently devastates unvaccinated village flocks.

The ACIAR-sponsored research was highly successful in developing a heat resistant vaccine (HRV4) which could be readily used in the field by coating it onto chicken feed. The vaccine was commercialised by an Australian company which subsequently was taken over by an American firm. Uptake of that technology has been somewhat limited to date. The capacity of poor villagers to pay for vaccine is limited, and logistical problems have been encountered in transporting and storing large quantities of vaccine-coated grain.

Having perceived these problems, ACIAR sponsored further research which led to the production of a new, uncommercialised vaccine, I_2. Quantities of the seed of this vaccine are now being sent to many countries, particularly in Africa. From this seed vaccine the heat resistant vaccine can be made locally and applied to chickens in drinking water or by eye drops.

The results of this analysis indicate that on the basis of conservative assumptions, the benefits from the research have already outweighed the costs. In the longer term, the discounted net present value of the research is estimated at $211 million. Malaysia and Vietnam have been the major beneficiaries to date, but large benefits are also expected in Africa.

2. Introduction

Newcastle disease (NCD) is a highly virulent disease in poultry and outbreaks can devastate village chicken populations in developing countries. Over an eight year period ending in 1992, the Australian Centre for International Agricultural Research (ACIAR) funded two major projects aimed at controlling NCD in village chickens in Malaysia and

other participating countries, including the Philippines, Sri Lanka, Indonesia, and Thailand. This was to be accomplished by developing a vaccine (HRV4) that could remain active in tropical climates without cooling facilities and be coated onto chicken feed. Conventional vaccines require a 'cooling chain' and are impractical for the conditions under which village chickens are run in developing countries.

This report presents the findings of a benefit–cost assessment of the outcomes from these projects. The focus is on two projects (8334 and 8717), and a subsequent project (93/222) that developed an alternative vaccine, I_2, aimed at spreading the technology in Vietnam and African countries. The vaccine parent seed stock is being made readily available and training is being provided for the local production and use of the vaccine.

Earlier reviews of projects 8334 and 8717 were undertaken before and shortly after their completion. The general conclusions (Johnston and Cumming 1991; ACIAR 1992) were that the research provided the potential for substantial benefits relative to the costs involved. Several issues requiring further attention were identified.

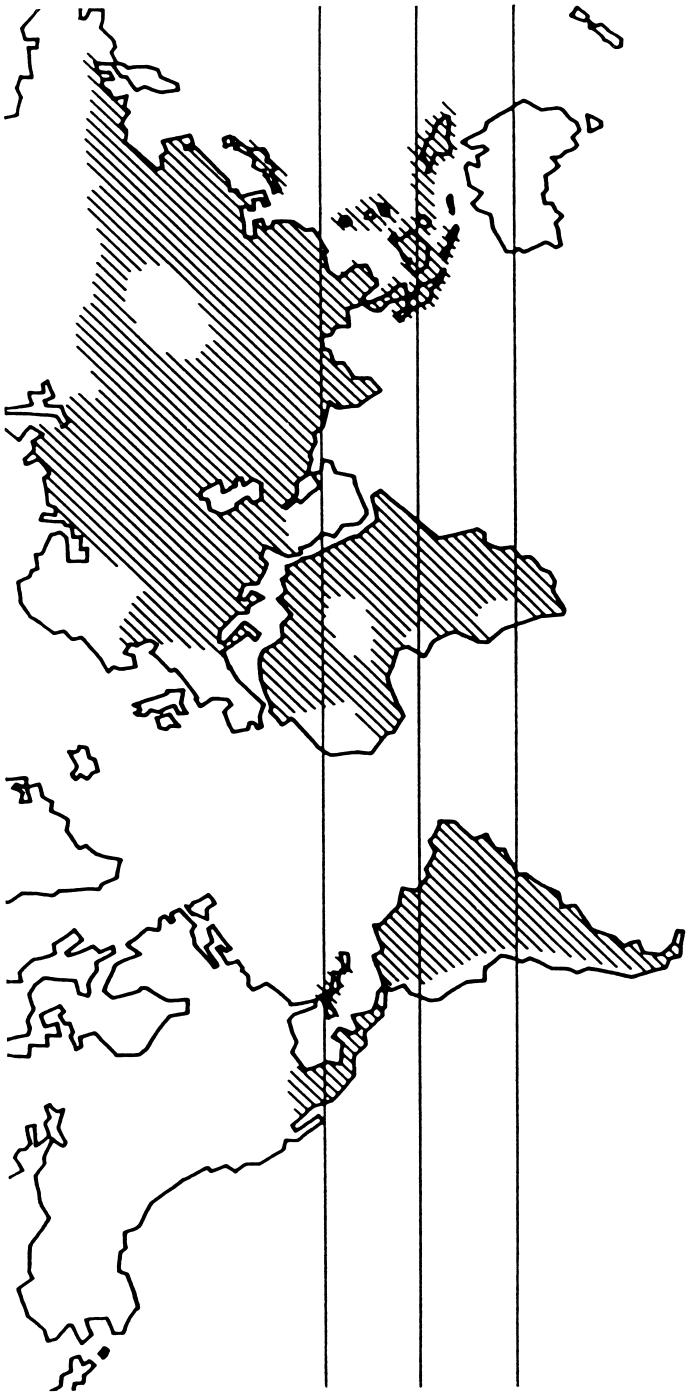
As the projects were completed several years ago, it is of particular interest to find out what has actually happened in the target countries and to revisit some of the assumptions made in the light of actual outcomes.

3. The ACIAR Projects

3.2 Background

The virus that causes NCD in poultry is very widely distributed throughout most developing countries (Figure 1). The disease is particularly serious in countries of Asia and Africa. The virus is a paramyxovirus that has several strains. The velogenic strains cause high mortality in chicken flocks, attacking the central nervous system (nerotropic) or other vital organs, particularly the intestines (viscerotropic). It is the latter that causes most chicken deaths in Asia (Spradbrow 1987). Other strains of the virus cause lower rates of mortality or production losses. An avirulent strain of the virus is present in Australia. This is commonly referred to as the V4 strain.

Figure 1. World distribution of Newcastle disease.



Source: Food and Agriculture Organisation of the United Nations (FAO)/World Health Organisation (WHO)/International Office of Epizootics (OIE) Animal Health Yearbook 1985, FAO Animal and Production Health Series.

3.2 The Significance of Village Chickens

For many people living in villages in developing countries, chickens provide the only cheap source of protein (through chicken meat and eggs) in their diets. Spradbrow (1994) presents a detailed review of NCD in village chickens. The chickens are free ranging and there is normally a complete absence of any husbandry practices. Each family may run a few chickens, which mostly scavenge on food scraps. A study in northern Thailand found that, on average, village families harvest about 13 birds a year for consumption and, in addition to the eggs produced, this was their only source of animal protein (Javiriyasopak et al. 1989). Another study involving Malaysian villages found that the average household ran nearly 19 birds with three eggs produced per hen per month, of which 55 per cent were brooded, with 67 per cent hatchability (Johnston 1990, as cited in Spradbrow 1994). In Indonesia, one study indicated an average flock of only 10 scavenging chickens, in the absence of NCD, provided 25 per cent of the family's monthly expenditure. Table 1 provides data on the relative importance of village chickens in several countries. In countries such as the Philippines, Malaysia and Vietnam there has been substantial growth in total poultry numbers, particularly commercial poultry.

Village chickens have an important social value as well as their value to supplementing village family income and consumption. Women and children mostly look after chicken flocks which provides them with a direct—albeit small—source of income. Village chickens and eggs mostly command a premium over commercial chickens in the local markets because of their perceived better taste. Also, chickens are frequently used or consumed during various social or religious occasions, creating increased demand for short periods. Village chickens mostly scavenge food scraps, and are a means of keeping villages clean and minimising the incidence of some human diseases (Johnston and Cumming 1991).

As countries progress in their economic development, large commercial poultry industries develop. This trend has been observed in Malaysia, for example, where village chickens are now a relativity minor source of national chicken meat and egg consumption. But village chicken production continues in remote areas and remains important to the villagers in those areas.

Table 1 Village chickens in some developing countries

Country/Region	Number of village or rural chickens (million)	Village poultry numbers as a proportion of the national flock (%)
Africa	1 500.0	70
Ethiopia	53.2	99
Kenya	16.0	70
Lesotho	1.6	
Nigeria	120.0	80
Tanzania	20.1	97
Nganda	16.0	80
Zimbabwe		30
China	2 000.0	50
Indonesia	187.0	60
Malaysia	6.5	13
Mganmar	23.2	85
Philippines	43.0	72
Thailand	120.0	80
Vietnam	196.0	98
Nepal		90
Pakistan	55.5	42
Sri Lanka	2.5	25

Source: Awan (1993)

3.3 Losses Due to Newcastle Disease

Productivity in village chickens is very low. Johnston and Cumming (1991) suggest that on average, slightly less than one chicken is consumed by the family or sold in a year for each chicken kept. NCD is not the only reason for low productivity, but it is certainly one of the major causes. In the absence of husbandry, brooding losses are great and other diseases such as fowl cholera also cause losses. A serious outbreak of NCD may devastate the village chicken flock but normally lesser outbreaks occur at certain times of the year—especially the beginning and end of the rainy season. One study of the global problem of NCD suggested that in most developing countries there are annual regional outbreaks of the disease that kill 70–80 per cent of unvaccinated village chickens (Spradbrow 1994).

Control of NCD in many areas would provide the potential for adoption of simple changes in husbandry practices to improve productivity. Without this control, there is little incentive for villagers to invest in even basic

husbandry practices. In the absence of control of NCD, egg production and chicken harvesting is limited because of the need to replenish flocks after an outbreak of the disease.

3.4 Development of the V4 Vaccine

Australia is one country that is free of the virulent or velogenic strains of the NCD, but the avirulent strain (V4) is present. This V4 strain was originally isolated by Simmons (1967) in Queensland and was found to create antibodies in chickens. Strict quarantine regulations in Australia have prevented the introduction of live velogenic strains of NCD for experimental purposes. The problem addressed in the early work on developing a vaccine for NCD was to see if the avirulent V4 strain, when given to chickens, could generate enough antibodies to give protection from challenge by the velogenic strains that cause NCD. Under laboratory conditions this proved highly successful and vaccines based on the Australian V4 strain started to be developed. Much of the initial research was done in the early 1980s at the Universiti Pertanian Malaysia (UPM) with support from the Australian Poultry Research Fund and the International Foundation for Science. The vaccine company Arthur Webster (based in Sydney) also became involved in the research and development of V4 as a commercial vaccine against NCD. The Australian poultry industry was keen to support Webster's efforts and to maintain stocks of the V4 vaccine because of the importance it placed on having the means to control NCD should there ever be an outbreak in Australia.

3.5 Objectives and Description of the Projects

Most vaccines are heat sensitive. They can be successfully applied under commercial conditions where there is complete control over the birds and each bird can be inoculated with relative ease. This is not the case for chickens in village environments in developing countries, where birds are largely free ranging and uncontrolled.

The ACIAR projects (8334 and 8717) set about tackling the task of developing heat resistant strains of the V4 vaccine (HRV4) which could be coated on to various chicken feeds. These could then be fed to village chickens, which are often largely feral. The heat resistant characteristics were essential to allow the live vaccine to remain active in the tropical heat conditions in the absence of 'cold chain' distribution systems and given that it is coated on feed and fed out to chickens in rudimentary ways (see ACIAR 1987a,b).

The first ACIAR project (8334) was entitled *Vaccination of Malaysian Village Poultry with an Avirulent Australian Newcastle Disease Virus* and commenced in early 1984. This project had four key objectives.

- To establish a cheap and effective method of protecting Malaysian village poultry against Newcastle disease.
- To examine the potential of the V4 virus as a potential vaccine against Newcastle disease.
- To establish a simple delivery system of the vaccine via its incorporation into feeds, such as pellets, rice or other local feeds.
- To determine the usefulness of the oral vaccine under village conditions to control Newcastle disease outbreaks.

This project involved a collaborative effort between scientists at the University of Queensland, led by Professor Peter Spradbrow, and at the UPM led by Professor Latif Ibrahim. Heat resistant strains of the V4 virus were developed (HRV4) and various methods were investigated for incorporating this onto various chicken feeds and evaluating the protection against NCD in laboratory experiments and under village conditions (see ACIAR 1990).

Following the success of the first project in meeting its objectives, the second ACIAR project (8717) embarked on further field testing on a more ambitious scale. Collaborators from the first project were joined by other colleagues in Australia, Thailand, the Philippines, Indonesia and Sri Lanka. Further work in Australia and Malaysia investigated various methods of coating feed pellets and use of other feed carriers. Large scale village trials were undertaken in Malaysia and also the Philippines, and laboratory efficiency trials and pilot village trials were initiated in the other countries. The laboratory work involved looking at how well the avirulent virus in the vaccine survives on different feed carriers and the mechanisms of immune reactions both within and between birds. The project also involved the collection of epidemiological, productivity and economic data and a detailed benefit–cost analysis of the research work (Johnston and Cumming 1991). This project was completed in early 1992.

The HRV4 vaccine was commercialised by Webster's in Sydney. Subsequently, this Australian company was taken over by the American Home Products company and became known as Cyanamid-Webster's. The name was then changed to New Fort Dodge Pty. Ltd. In Malaysia, the

Malaysian Technology Development Corporation finally took over Webster's.

At present there are three sources of the master seed stock for HRV4 vaccine: Pan African Veterinary Vaccine (PANVAC), New Fort Dodge and the Malaysian Technology Development Corporation. Thus, all supplies of the HRV4 vaccine are through commercial arrangements.

A consequence of these changes and the commercialisation process was that the vaccine became available at a low price only in relatively large quantities—1 000 doses at a time. Availability in smaller quantities substantially increased the cost to users. This limited the use of HRV4 for village chicken applications, as many villages are unable to afford the vaccine. This led Professor Spradbrow to apply for a third ACIAR project—to develop a new avirulent vaccine, I_2, which could be produced locally at very little cost. This was the objective of a small project (93/222), which was completed in December 1996. This project also aimed at developing training methods for people in developing countries to develop the I_2 vaccine from seed stocks of the vaccine supplied from Australia free of charge.

4. Project Outputs and Short Term Outcomes

4.1 Project 8334 Successfully Developed a Thermostable Vaccine

The initial project was highly successful in meeting its objectives. A thermostable vaccine (HRV4) was developed that was capable of being coated onto several feed carriers, and some feeds were found to be more effective than others as carriers for the avirulent virus. The HRV4 vaccine proved to be effective in providing a high degree of protection to chickens against virulent NCD attack under laboratory conditions and in the pilot village trials.

The project also achieved adoption of the vaccination procedures by the pilot village communities. At the conclusion of this project ACIAR sponsored an international workshop in Kuala Lumpur. This highlighted the importance of village chickens in rural communities of developing countries, emphasised the devastating impact of NCD and alerted the

international community to the potential benefits of thermostable vaccines for NCD based on HRV4.

4.2 Project 8717 Successfully Extended the Trials to Other Countries

Following the Kuala Lumpur workshop in 1987, delegates from several countries indicated an interest in future collaborative work. The second project further demonstrated the effectiveness of the HRV4 vaccine in providing protection to chickens under village conditions in the participating countries. This feed vaccine was officially adopted by the Malaysian Government as the vaccine for a national NCD control strategy. The feed vaccine was shown be safe, cheap, have a moderate shelf life without refrigeration and provide protection to vaccinated chickens against attack from virulent NCD (Ibrahim et al. 1992). Protection was in some cases more effective when the vaccine was applied to drinking water rather than on feed.

Considerable advances were made in understanding the epidemiology of the HRV4 virus in chickens and its transmission between birds but the research did not provide complete answers to all questions. A conclusion was that any transmission between birds was more a 'bonus' than a dependable way of providing protection—flocks periodically needed to be provided with the vaccine on feed or in drinking water and preferably as an eye drop, if possible, for protection to be effective.

Overall, this research showed that thermostable NCD vaccines can be produced and can protect chickens in village environments when administered as oral vaccine on coated chicken feed or applied to drinking water. A review of these projects (Geering et al. 1990) concluded that this work had been of considerable benefit to Australia and the other participating countries. The key findings of the review were that, for work completed to that point:

- it had yet to be conclusively demonstrated that there is protection against field challenge under village conditions; and
- it had yet to be determined whether control of the NCD is translated into productivity and economic gains in vaccinated village chickens.

The review team recommended that the momentum of the project should continue with extension of field trials and focus on issues such as feed

vaccine delivery systems, natural transmission under village conditions, basic epidemiology and economic evaluation.

Subsequent trial work demonstrated that the HRV4 vaccine does provide a high degree of protection under village conditions but the degree of protection depends on the type of feed carrier used.

Benefit–cost analysis showed potential gains

As part of project 8717, a detailed benefit–cost assessment of both projects was undertaken. Taking a twenty year time horizon and on the basis of various assumptions regarding increased productivity through vaccine use, the study concluded that adoption of the vaccine by the participating countries (Thailand, Malaysia, Sri Lanka, Indonesia and the Philippines) should give rise to net research benefits of A$144 million in present value (1990$A) terms (Johnston and Cumming 1991).

Estimated benefits exceeded the research costs by a factor of forty. But a high degree of adoption of the technology was assumed. A key focus in the present review is the extent of adoption since these trials were completed in 1992.

4.3 Project 93/222 Developed the I_2 Vaccine

As noted previously, commercialisation of the HRV4 vaccine led to limitations on its use by poor rural villagers. Project 93/222 was designed to develop a vaccine that could be produced cheaply at the local village level. This project was successful in developing a new strain of avirulent thermostable NCD virus (I_2) suitable for use in the production of vaccine for village flocks. Sufficiently large quantities of the I_2 master seed culture were made in Queensland to enable small quantities of seed culture to be sent to laboratories in developing countries interested in developing working seed. From this, the required quantities of the vaccine could then be made in local villages. The working seed is produced to standards less exacting than those required for commercial vaccines, but the costs of the final vaccine product are minimal. This I_2 vaccine is now being developed in Vietnam and there is considerable interest in several African countries. A workshop in Onderstepoorf, South Africa, in December 1995 enabled promotion of the idea among African delegates. Some training workshops have been held and trials are proceeding in several African countries.

This vaccine is more effective when administered by eye drop, which can limit its application and adoption in uncontrolled chickens. Much testing

remains to be done in Africa. In some cases there are delays in getting the necessary government approvals for the vaccine seed to be imported.

5. Long Term Project Outcomes

The underlying impetus to the research was to improve the welfare of villagers in developing countries by controlling NCD in village chickens. This section examines the developments which have occurred since the end of the main ACIAR projects (8334 and 8717) in the countries involved with these projects. In addition we look at developments in Vietnam and in African countries which are the focus of ACIAR-funded projects on the I_2 strain.

5.1 Malaysia

At the end of the ACIAR projects the following conclusions were drawn (Ibrahim et al. 1992).

> "It has now been established that village chickens vaccinated with the food-based vaccine are protected against virulent NCD virus. The food-based NCD vaccine will undoubtedly revolutionise the vaccination of village chickens against NCD in Malaysia. The benefits to the rural farmers in terms of increased survival of chickens, improved nutrition of rural poor villagers and an increased income to the farmers, could be enormous."

The poultry industry in Malaysia is now highly commercialised. Village chickens kept in small numbers no longer contribute significantly to overall poultry production in Malaysia, but they are still an important source of protein and supplementary income for many poor villagers, particularly in remote areas.

A recent trend has been the development of semi-intensive systems of producing 'village chickens' involving 20 000 birds per farm. Such farms do not appear to be using the V4 vaccine (Department of Veterinary Services, Malaysia, pers. comm.). There are about 6.5 million village chickens out of a total poultry population of 50 million. Given the recent trend towards semi-intensive rearing of 'village' chickens it is likely that the number of traditional village chickens in small flocks may have declined and will probably continue to decline.

The technology developed by the ACIAR projects was handed over to Webster's in Malaysia and is now controlled by the Malaysian Technology Development Corporation (MTDC). UPM was very active in commercialising the vaccine. The vaccine is no longer supplied on feed but rather in freeze-dried form. MTDC sells the vaccine to agents who then distribute it to villagers. At the village level, the vaccine can then be added to drinking water or mixed with feed. There has been no monitoring of the use and effectiveness of the vaccine since the end of the ACIAR projects and information on village chickens is scarce.

NCD is not yet eradicated in Malaysia but there have been no reports of major outbreaks of the disease since the early 1990s. It is difficult to relate this to the introduction of the HRV4 vaccine in any precise way. Up to 40 different types of imported vaccines are used to control NCD in commercial chickens, and the control of the disease in these flocks may have reduced the incidence of NCD in village environments. Also, there are continuing developments in vaccine research and development which, over time, will dilute the influence of the original research on HRV4 vaccine. For example, scientists at UPM are now working on recombinant vaccines, and the development of freeze-dried vaccines has already been mentioned.

5.2 Thailand

NCD is still a major problem in Thailand but some protection against the disease in village chickens has been achieved with conventional vaccines, unlike in many other Asian countries. Therefore the main focus of the ACIAR-sponsored trials was on the comparison of the HRV4 vaccine adminstered orally through various feed carriers and drinking water, with conventional vaccination (Tantaswasdi et al. 1992). Field trials gave variable results with protection from HRV4 to challenge ranging from 28 per cent to 85 per cent for oral vaccine. It was concluded that oral vaccination based on HRV4 would be only practiced if the aim was to provide protection to feral chickens in some remote parts of Thailand.

At the completion of the trials, the Department of Livestock Development planned to use the HRV4 strain in the control of NCD in native chickens. However, no further action was taken as the Department was told that the HRV4 belonged to a company and could not be provided.

The National Institute of Animal Health became involved in laboratory trials and developed a heat resistance seed vaccine based on local strains,

but limited funds and other priorities of the Institute prevented this work from progressing to field trials.

5.3 Philippines

There has been a substantial growth of poultry numbers in the Philippines from 81.5 million in 1992 to 135 million in 1997 (Food and Agriculture Organisation of the United Nations [FAO] database). Of the latter, 76.6 million or 54 per cent were village chickens. This compares with about 43 million village chickens in the early 1990s (Johnson et al. 1992, as cited in Spradbrow 1994).

Newcastle disease is still a major problem among village chickens, especially in remote rural areas. During outbreaks of the disease mortality rates of 80–90 per cent still occur (B.C. Fontanilla, pers. comm.). The oral HRV4 vaccine, when applied correctly and at the right time can increase survival rates to around 65–85 per cent.

Despite the success of the ACIAR trials, large scale vaccination of village chickens has not developed in the Philippines. Lakpue Drug Inc. is the exclusive distributor of Webster products in the Philippines and carries stocks of the HRV4 vaccine, but the product has not sold well and supplies of the vaccine have practically ceased (Fontanilla, pers. comm.). The company is seeking assistance to establish a network of vaccinators throughout the country to teach villagers how to vaccinate their flocks with the HRV4 vaccine.

5.4 Indonesia, Myanmar and Sri Lanka

These countries, although initially included in the participating countries for project 8717, either did not proceed with the cooperative trials or did not progress beyond some initial trials. There has been little adoption of the HRV4 vaccine technology in Sri Lanka. There was little cooperation in the case of Myanmar because of political difficulties and in Indonesia researchers concentrated on developing a heat resistant vaccine based on an Indonesian strain of avirulent virus.

5.5 Vietnam

NCD is still a big problem in village chickens in Vietnam. Each family has an average flock of around 10 chickens which are kept for home

consumption and occasionally additional income from sale in the local market. These sales help spread the disease.

The Department of Animal Health controls the distribution of vaccines and over the past decade, several thermostable strains have been tried—including the La Sota strain in the north and the I_2 vaccine from Australia—and developed commercially by Navetco in the south. There are approximately 120 million chickens in Vietnam of which about 75 per cent could be classified as traditional village chickens.

Navetco produces about 30 million doses of vaccine a year. The vaccination program involves giving two primary vaccinations at intervals of three weeks, starting when chicks are one week old. This is followed by a booster at 4–6 months of age. Thus, around 15 million chickens are vaccinated annually. The I_2 vaccine is the latest to be developed at Navetco and has received approval from the Ministry of Agriculture and Rural Development. Field trials for I_2 were completed in 1996 and in 1997 three million doses of I_2 were produced and distributed to provinces in southern Vietnam. The aim of the company is to sell the vaccine throughout Vietnam. Indications are that the I_2 vaccine will be adopted as the main vaccine of choice.

5.6 African Countries

The number of village chickens in Africa has been estimated at about 1.5 billion, accounting for 70 per cent of the combined national poultry flocks (Awan 1993). At present very few chickens are vaccinated and the potential for adoption of the technology based on the I_2 or HRV4 strains of vaccine is very large. Africa has some of the poorest countries in the world and the scope for most villagers paying for vaccines is small. This means that the potential for adoption of the technology based on the I_2 strain, which can be made in villages under local conditions, is probably much greater than adoption of the commercialised HRV4 vaccine.

FAO, World Bank and other international funding agencies have now taken up the challenge and are funding many projects in Africa in an effort to have the HRV4 vaccine tested officially, adopted and widely used in recipient countries. In 1997 FAO published a document recommending the HRV4 vaccine for the control of NCD in village chickens in developing countries in tropical regions as a means of improving the food security of rural communities. In several African countries HRV4 vaccine is being imported with the help of aid agencies.

Trials are being conducted in several countries using the I_2 strain. In some cases there have been difficulties or delays in getting official approval to import the vaccines or seed stock. Developments in several African countries are highlighted below.

- In Tanzania, the work has only reached the laboratory and small village trial stage using the HRV4 vaccines. The I_2 vaccine work has not yet reached the village trial stage but this is planned. The funding is a small part of a large US$28 million World Bank loan to upgrade agricultural research and training programs. There are about 21 million chickens in Tanzania, of which 97 per cent are village chickens. In regional NCD epidemics, mortality rates vary between 50–90 per cent in the absence of vaccination (A. Foster, pers. comm.).

- In Ghana, laboratory and field trials have been carried out with HRV4 using World Bank funding. The I_2 master seed from Queensland has been supplied and trials have begun with a view to local production of the vaccine. Ghana currently has a village chicken population of around 6.8 million, but annual deaths due to NCD are frequently around 50 per cent.

Zimbabwe recently imported 15 million doses of HRV4 vaccine from New Fort Dodge in Sydney, with FAO funding.

Field trials using HRV4 have been completed in Malawi, Mozambique, Ethiopia, Gambia, Uganda and Botswana.

Several other countries have imported I_2 seed and are commencing trials with the vaccine. These include Mozambique, South Africa, Zimbabwe and Ethiopia. Many more have indicated expressions of interest to import the I_2 seed.

6. A benefit–cost Assessment

6.1 Evaluation Methodology

Our economic evaluation of the ACIAR-funded research involves a two stage process.

►►►► First, we evaluate the net benefits which have accrued to date from the adoption of this technology. This involves a comparison of what has actually happened with a 'base scenario' of what could reasonably be expected to have occurred in the absence of the new technology. The focus here is on assessing whether the costs of the research have been recouped.

►►►► Second, we take a thirty year time span commencing in 1983 and compare two scenarios. One is the base scenario which assumes the technology is not adopted and NCD is not controlled in the countries of interest. The other scenario is based on assumptions about the extent to which the technology is adopted in each country and assumptions about increases in productivity which can reasonably be expected.

In each case, standard economic evaluation techniques are used. Annual benefits from the research are evaluated using conventional economic surplus concepts similar to the procedure used by Johnston and Cumming (1991). The benefits for each year are then discounted to present value (1996) using a discount rate of 5 per cent and summed. From this we subtract the present value of total research costs and any other relevant costs to give a net present value (NPV) estimate of the worth of the research. A NPV greater than zero implies that the benefits arising from the research are greater than the costs.

Estimating the benefits

Controlling NCD through adoption of the technology means that more chickens can be harvested from a given flock. As noted by Cumming (1992, as cited in Spradbrow 1994) village chicken populations in developing countries have a very low level of productivity and, in the absence of control of NCD, flocks are periodically devastated. Subsequently, eggs and chickens must be kept for flock replacement which severely limits the harvest of eggs and chickens from a flock. In fact, it is seldom that any eggs are consumed and on average, a little less than one chicken is harvested annually for each chicken in the flock (Johnston and Cumming 1991). Control of NCD enables a substantial increase in chickens turned off from a given flock size—chickens which would have died can be harvested and eggs and chickens previously used for replacement can also be diverted to consumption. Johnston and Cumming (1991) undertook an extensive assessment of the increase in productivity that could be expected from vaccination of chickens against NCD. This was based on field trials in the Philippines where village flocks, which had never been vaccinated, were readily available. The effects of vaccination with HRV4 could then be assessed against control

groups of chickens that had never been vaccinated. They suggested that, as a generalisation, the HRV4 vaccination technology could be expected to increase the turn-off of chickens from a given flock by between 47 and 38 per cent without any increase in flock size.

No similar productivity evaluations have been done since then (Spradbrow, pers. comm.). We have assumed an increase in productivity of 40 per cent when the HRV4 or I_2 technology is fully adopted.

There would be a market response to wide spread adoption. Villagers are both producers and consumers but their actions are influenced by the market price of village chickens which is usually well above the price of commercial chickens (Spradbrow 1994). Benefits can therefore be evaluated in terms of local market prices.

Benefits from adoption of the technology are estimated with reference to the change in consumer and producer surplus. The two key assumptions are as follows:

- the elasticity of demand for village chickens is taken as 1.5. That is, a 1 per cent decrease in the price of chickens would result in a 1.5 per cent increase in consumer demand (Johnston and Cumming 1991); and

- a perfectly inelastic supply function is assumed (production of chickens unresponsive to price). Village chickens are run with minimal inputs and mostly survive on food scraps, which limits flock numbers. However, with control of NCD some supplementary feeding of the extra surviving chickens may be necessary and some allowance for this is made in the analysis.

Total annual research benefits are estimated by summing the estimated change in annual consumer and producer surpluses to give a gross annual research benefit (GARB). This is then adjusted to take account of other factors such as vaccination costs and some extra feed requirements.

A significant problem in analyses of this kind is to properly attribute the appropriate benefits and costs to the new technology derived from the research.

►►►► In some countries such as Malaysia, a proportion of the national village chicken flock was vaccinated with conventional vaccines before this new technology was developed. Johnston and Cumming (1991) suggest that up to 40 per cent of village chickens in Malaysia received

vaccination prior to the development of HRV4 vaccine. They assumed that none of these would benefit from the new technology. But the new vaccine may replace the use of older vaccines.

►►►► In Malaysia a further development has been the production of a freeze-dried form of the HRV4 vaccine which can be applied to drinking water or, less effectively, mixed with local feeds. The technology developed during project 8717 whereby the vaccine HRV4 is coated onto feed carriers is no longer used. It is difficult to assign all the benefits to the original ACIAR research in this case.

►►►► In African countries in particular, several international aid agencies are funding the purchase of HRV4 vaccine trials, and extension programs. Some recipient governments are also providing assistance, mainly of an 'in kind' nature. Some, but not all, of this expenditure can be accounted for in estimates of the cost of vaccine from commercial sources, but the total funding from all sources is largely unknown.

6.2 Cost of the Research

ACIAR has provided details of the costs of the research on the three projects involved (8334, 8757 and 93/222). These are presented in Table 2 and have a NPV (1996 dollar values) of A$ 3.1 million.

Table 2. Research costs of ACIAR projects 8334, 8717 and 93/222 on control of Newcastle disease in village chickens

Year	Research costs in nominal terms (A$ '000)	Factor	Research costs in constant 1996 dollar terms (A$ '000)
1983	14	1.8684	26 157
1984	159	1.7498	278.218
1985	118	1.6518	194.912
1986	198	1.5377	304.465
1987	581	1.4322	832.108
1988	534	1.3366	713.74
1989	285	1.2297	350.465
1990	192	1.1561	221.971
1995	167	1.0556	176.286
			3 098.325

Source: ACIAR, pers. comm., June 1998

7. Estimated Benefits to Date

Have the costs of the research already been recouped? From our earlier discussion Malaysia has widely adopted the technology in a modified form (freeze-dried) and Vietnam is starting to adopt the technology based on I_2. Most other Asian countries have not progressed since the end of the trials mainly because of a lack of supply of the vaccine or higher priorities for responsible bureaucracies. In Africa, the FAO purchased 15 million doses of the HRV4 vaccine for use in Zimbabwe. In most other African countries progress has been confined to the laboratory or field trialling stages for HRV4 or I_2 vaccines, as noted earlier. The analysis below is therefore limited to Malaysia, Vietnam, the Philippines and Tanzania.

7.1 Malaysia

There is little information on the temporal pattern of adoption since 1992. Some assumptions are necessary. These are given in Box 1, together with the basis of our calculations. In general we believe we have made conservative assumptions on the parameters but the extent of supplementing feeding is largely unknown. Some reports indicate that NCD is now largely controlled at the village level, but an issue is the extent to which this can be attributed to the ACIAR projects. In Box 1 conservative judgments have been made to account for vaccination programs in place prior to the research adoption phase, the fact that vaccines in food pellet form—the basis of project 8717—are no longer used, and the recent trend towards semi-intensive rearing of village chickens.

Box 1. Estimation of annual research benefits for Malaysia: 1993–1998.

Key assumptions and parameters	Consumer and producer surplus assuming full adoption
■ 6.5 million village chickens with total turnoff of 6 million annually ■ average initial price of village chicken = Ringgits (Rn)12 ■ elasticity of demand for village chickens = 1.5 ■ increase in productivity due to technology adoption = 40% ■ assumed effective coverage of village chickens with conventional vaccination programs 45%[a] ■ exchange rate Rn per A$1 = 1.9468 Rn ■ full adoption of technology—this would increase annual turn-off of village chickens to 8.4 million and lower price by 24.6 per cent to 8.9 Rn ■ cost of vaccine per 100 doses = A$3.20 f.o.b. (New Fort Dodge Sydney)	■ change in consumer surplus = Rn 23 million ■ change in gross revenue = Rn 2.2 million ■ number of birds vaccinated = 12 million ■ estimated cost of vaccination = Rn 1.6 million ■ gross annual research benefits (GARB) = Rn 23.6m = A$12.1m ■ GARB per village chicken (stock) = 3.6 Rn = A$1.86 ■ allowance for additional feed costs per bird = $0.36 ■ net annual research benefits per bird = A$1.50

Year	Assumed rate of adoption (%)	Proportion of benefits attributed to ACIAR research (%)	Proportion of village chickens kept under traditional conditions (%)	Estimated annual research benefits (A$m)
1993	0	–	100	
1994	2	100	100	0.107
1995	5	70	100	0.188
1996	10	60	80	0.257
1997	40	60	70	0.901
1998	60	60	60	1.158

Undiscounted research benefits A$2.611 million

Discounted research benefits A$2.481 million

[a]Johnston and Cumming 1991

7.2 Vietnam

In 1997 an estimated three million doses of the I_2 vaccine were sold in Vietnam by Navetco, with the aim of distributing it widely throughout Vietnam. Previous vaccination programs have used other virus strains such as 'F Asplin', Lasota strain and H_e1 strain. But the distribution of these to villages has been very limited and concentrated mainly in the north. Box 2 provides the underlying assumptions and analysis of research benefits which can be expected assuming full adoption. Several adjustments are then made to estimate the benefits from the progress already made. The assumption is made that each chicken must be vaccinated at least twice in a year. The approach is to initially estimate the benefits assuming there is full adoption of the technology for all village chickens with none being previously vaccinated. This provides an estimate

of benefits per bird kept. From this, actual benefits derived from the I_2 vaccination program can be estimated. In this case, the costs of vaccine are trivial being no more than one cent per bird.

Allowing for some additional supplementary feeding for the extra birds turned off, the research benefits attributable to the I_2 research would be of the order of A$1.5 million. This assumes that the 1.5 million birds vaccinated with I_2 had not previously been vaccinated.

7.3 Other Countries

Assuming full adoption, Boxes 3 and 4 present the underlying assumptions and analysis of research benefits which can reasonably be expected for the Philippines and Tanzania, respectively.

Although neither of these countries has progressed beyond the trial stage to date, we have included them nonetheless, making assumptions on what can reasonably be expected in the future.

Box 2. Estimation of research benefits for Vietnam: 1997

Key assumptions and parameters	Research benefits assuming I_2 vaccination of all village chickens
■ estimated number of village chickens = 90 million ■ estimated annual turn-off of chickens without vaccinations = 85 million ■ elasticity of demand for village chickens = 1.5 ■ demand elasticity = 1.5 ■ price of village chickens (from Navetco) =35 000 Dong (A$4.04) ■ exchange rate (1996)=8649.6 Dong per A$1 ■ price per dose of I_2 vaccine (Navetco) =50 Dong ■ actual number of chickens vaccinated (1997) =1.5 million	■ change in consumer surplus =A$ 109 million ■ change in producer surplus =A$ 10 million ■ gross annual research benefits =A$119 million ■ gross annual research benefits per bird =A$1.32 ■ allowance for additional feed costs per bird =A$0.35 ■ net annual research benefits per bird =A$0.97
Estimated annual research benefits from 1997 vaccination program=A$1.5 million	

Box 3. Estimation of annual research benefits for the Philippines

Key assumptions and parameters	Research benefits assuming vaccination of all village chickens
■ estimated number of village chickens =76.6 million ■ estimated chicken turn-off per annum =70 million ■ elasticity of demand =1.5 ■ price of village chickens =69.4 pesos (A$3.50) ■ exchange rate =19.856 pesos per A$1	■ change in consumer surplu s=A$78 million ■ change in producer surplus =A$5 million ■ gross annual research benefits =A$83 million ■ gross annual research benefits per bird =A$1 ■ allowance for additional feed costs per bird =A$0.35c ■ net annual research benefits per bird =A$0.65c

Box 4. Estimation of annual research benefits for Tanzania

Key assumptions and parameters	Research benefits assuming vaccination of all village chickens
■ estimated number of village chickens=20.1 million ■ estimated annual chicken turn-off=19 million ■ elasticity of demand=1.5 ■ price of village chickens=1500 Tanz. shillings ■ exchange rate=646.8 Tanz. per A$1	■ change in consumer surplus=A$14.1 million ■ change in producer surplus=A$1.2 million ■ gross annual research benefits=A$15.3 million ■ gross annual research benefits per bird=A$0.76 ■ allowance for additional feed costs per bird=A$0.35 ■ net annual research benefits per bird=A$0.41

7.4 Overall benefits to Date

Considering just Vietnam and Malaysia, we conclude that the cost of the ACIAR projects has already been recouped. If one further considers that 15 million doses of the HRV4 vaccine were sold to Zimbabwe, a conservative estimate is that the benefits from the research would be at least A$10 million. Other sales of the HRV4 vaccine have been made in recent years to several countries including three million doses to Kirkmanistan (John Reeves, New Fort Dodge, pers. comm.).

7.5 Long Term Benefits

Detailed below is an evaluation of the likely flow of benefits resulting from the programs, with various assumptions about technology adoption and productivity increases in the participating countries.

The analysis is done over a thirty-year period, commencing in 1983, when the first research costs were incurred (see Table 2). Our focus in on

Malaysia, Vietnam, the Philippines and Africa. Indonesia and Thailand appear to have progressed using local avirulent NCD strains.

Table 3 profiles the participating countries, outlining our assumptions regarding rates of adoption, the proportion of benefits attributable to ACIAR, and the proportion of village chickens considered to be kept under traditional conditions.

Table 3. Participant country profiles (M = Malaysia, V = Vietnam, P = the Philippines and A = Africa).

Year	Rate of adoption				Benefits attributable to ACIAR				Proportion of village chickens kept under traditional conditions			
	% M	% V	% P	% A	% M	% V	% P	% A	% M	% V	% P	% A
1993	0	0	0	0	1	0	0	0	100	100	100	100
1994	2	0	0	0	100	0	0	0	100	100	100	100
1995	5	0	0	0	70	0	0	0	100	100	100	100
1996	10	0	0	0	70	0	0	0	80	100	100	100
1997	20	2	0	0	65	65	0	0	70	100	100	100
1998	30	3	0	0	65	65	0	0	60	100	100	100
1999	40	5	0	0	60	60	0	0	50	90	90	100
2000	50	7	0	0	60	60	0	0	40	90	90	100
2001	60	10	2	0	55	55	65	0	30	90	90	100
2002	70	15	3	0	55	55	60	0	20	80	80	100
2003	70	20	5	0.5	50	50	55	100	20	80	80	100
2004	70	25	7	1	50	50	50	100	20	70	70	100
2005	70	30	10	2	45	45	45	100	20	70	70	100
2006	70	35	15	3	45	45	45	90	20	70	70	100
2007	70	35	20	4	40	40	40	85	20	60	60	100
2008	70	40	25	6	40	40	40	80	20	60	60	100
2009	70	40	30	8	35	35	35	75	20	60	50	100
2010	70	45	30	10	35	35	35	70	20	50	50	100
2011	70	45	30	10	30	30	30	65	20	50	40	100
2012	70	50	30	10	30	30	30	60	20	50	40	100

Source: Centre for International Economics estimates.

For all participating countries we have assumed that rates of adoption begin slowly given the need for users to familiarise themselves with the technology, as well as the infrastructure requirements to be developed. Malaysia is recognised as a clear leader in adoption following the decision

to carry out large-scale vaccinations while the Philippines and Africa are not expected to begin implementation until after the year 2000.

The proportion of benefits attributable to ACIAR vary owing to the availability of alternative vaccination programs. Farmers in Malaysia are now able to choose from more than 40 types of imported Newcastle disease vaccines beside V4 (Dr Aini Ideris, pers. comm.). This increased competition is reflected in the gradual decline in benefits attributable to ACIAR down to the year 2012.

For Malaysia, Vietnam and the Philippines, we recognise that there is an increasing trend towards semi-intensive rearing of village chickens. This suggests that the number of traditional village chickens contributing to overall production is declining and will continue to decline, as shown by the proportion of village chickens kept under traditional conditions.

Table 4 presents the estimated annual research benefits from the ACIAR programs. The benefits stream begins in 1994 with Malaysia's decision to commence oral vaccination.

The annual benefits are a function of total village chickens, net annual research benefits (Boxes 1–4), the assumed rate of adoption, the benefits attributable to ACIAR, and the proportion of village chickens kept under traditional conditions. We have used the Tanzanian return per bird as a proxy for all of Africa and a figure of 1.5 billion birds for the estimated number of village chickens.

All research benefits, discounted at 5 per cent to 2012, have a value in 1996 terms of approximately A$211 million. With total project research costs amounting to A$3.1 million, the benefits are therefore greater than the costs by a factor of 68. Even considering Malaysia on its own, the benefits are still A$5.2 million.

7.6 Sensitivity Analysis

Sensitivity analysis is an important tool which involves adjusting the parameters of a project to see how they effect the outcome. We reduce the annual increase in productivity from 40 per cent to 20 per cent to ascertain the effect on total net benefits.

Table 4. Estimated annual research benefits: assuming 40 per cent productivity increase

Year	Malaysia A$million	Vietnam A$million	Philippines A$million	Africa A$million	Total A$million
1993	0.000	0.000	0.000	0.000	0.000
1994	0.107	0.000	0.000	0.000	0.195
1995	0.188	0.000	0.000	0.000	0.341
1996	0.300	0.000	0.000	0.000	0.546
1997	0.488	1.135	0.000	0.000	2.022
1998	0.627	1.702	0.000	0.000	2.843
1999	0.644	2.357	0.000	0.000	3.527
2000	0.644	3.300	0.000	0.000	4.470
2001	0.531	4.321	0.583	0.000	5.869
2002	0.413	5.762	0.717	0.000	7.230
2003	0.375	6.984	1.095	3.075	11.837
2004	0.375	7.639	1.220	6.150	15.691
2005	0.338	8.250	1.568	12.300	22.732
2006	0.338	9.625	2.353	16.605	29.197
2007	0.300	7.333	2.390	20.910	31.179
2008	0.300	8.381	2.987	29.520	41.434
2009	0.263	7.333	2.614	36.900	47.235
2010	0.263	6.875	2.614	43.050	53.017
2011	0.225	5.893	1.792	39.975	48.070
2012	0.225	6.548	1.792	36.900	45.649
Total undiscounted	6.944	93.437	21.726	245.385	367.492
Discounted	5.231	58.571	12.501	130.579	211.162
Internal rate of return = 31 per cent					

Source: Centre for International Economics calculations

Table 5. Revised net annual research benefits per bird

Country	A$
Malaysia	0.46
Vietnam	0.36
Philippines	0.25
Tanzania	0.06

Source: Centre for International Economics calculations

Table 5 presents the revised net annual research benefits per bird with the adjusted productivity figure.

Thus when the revised figures from Table 6 are used to calculate the annual research benefits, we obtain a value in 1996 terms of approximately A$47 million. With total project research costs amounting to $3.1 million, the benefits exceed the costs by a factor of 15.

Table 6. Annual research benefits—sensitivity analysis: assuming 20 per cent productivity increase

Year	Malaysia A$million	Vietnam A$million	Philippines A$million	Africa A$million	Total A$million
1993	0.000	0.000	0.000	0.000	0.000
1994	0.033	0.000	0.000	0.000	0.060
1995	0.058	0.000	0.000	0.000	0.105
1996	0.092	0.000	0.000	0.000	0.167
1997	0.150	0.421	0.000	0.000	0.693
1998	0.192	0.632	0.000	0.000	0.982
1999	0.197	0.875	0.000	0.000	1.234
2000	0.197	1.225	0.000	0.000	1.584
2001	0.163	1.604	0.224	0.000	2.124
2002	0.127	2.138	0.276	0.000	2.644
2003	0.115	2.592	0.421	0.450	3.673
2004	0.115	2.835	0.469	0.900	4.413
2005	0.104	3.062	0.603	1.800	5.653
2006	0.104	3.572	0.905	2.430	7.095
2007	0.092	2.722	0.919	3.060	6.868
2008	0.092	3.110	1.149	4.320	8.747
2009	0.081	2.722	1.005	5.400	9.273
2010	0.081	2.552	1.005	6.300	10.003
2011	0.069	2.187	0.689	5.850	8.852
2012	0.069	2.430	0.689	5.400	8.645
Total undiscounted	2.130	34.678	8.356	35.910	81.074
Discounted	1.604	21.738	4.808	19.109	47.259
Internal rate of return = 21 per cent					

Source: Centre for International Economics calculations

8. Conclusions

Newcastle disease in village chickens is a serious problem that affects the welfare of millions of people in developing countries. The ACIAR projects reviewed in this report have made a major contribution towards

combating this disease, providing the potential for significant improvement in the welfare of poor people in African and Asian countries.

The projects successfully developed two heat resistant vaccines based on the avirulent Australian V4 virus. Also, the technology was developed to apply the vaccines under field conditions by coating it onto chicken feed, applying it in drinking water or through eye drops. On the basis of what we regard as conservative assumptions, total investments in these projects have already been recouped.

We can only give indicative estimates of the value of this research. Taking a long term future time horizon and on the basis of conservative assumptions we can say that the potential benefits from this research are at least $220 million in present value (1996) terms. This gives a benefit–cost ratio of 70.

Many benefits are not quantifiable. Australia's reputation in the international scientific community has been enhanced and there has been considerable international cooperation as a result of this work. Supply of the I_2 virus seed stock to developing countries free of charge is undoubtedly appreciated by recipient countries. Through this work there are also opportunities to strengthen the role of women in poor village communities.

From observations on developments since the completion of the main projects 8334 and 8717 in 1992, there are lessons that can be learned.

►►►► Any scientific discovery, no matter how great, has little value unless it is adopted. In this case, the adoption process has been a lot slower than initially anticipated. In some countries, there was little progress beyond the field trial stage. The lesson is that careful thought needs to be given to the adoption phase to ensure that the potential benefits of the technology are not dissipated.

►►►► The commercialisation process can present some difficulties. In this case the technology is targeted mostly at poor people who have little capacity to pay. This has presented severe limitations to the rate of adoption of the HRV4 vaccine in several countries. Development of the I_2 vaccine appears to have overcome this problem.

►►►► Adoption of technologies on a large scale can present difficulties that are unforseen in the research and trial stages. The concept of coating vaccine upon feed was highly appealing and proved to be successful during trials. However the vaccine, once coated onto feed has a limited

potency period. This presents particular difficulties in terms of large scale production, storage and transport of the vaccine-coated feeds, that perhaps were not fully appreciated during the research phase. This led to the development of the freeze-dried form of the vaccine in Malaysia as a more practical solution. The I_2 vaccine which can be produced locally will also overcome this problem.

►►►► There is a need for follow-up work and monitoring of projects long after their completion. In the Philippines and Thailand for example, it is not clear why work on the vaccine technology essentially stopped soon after completion of the projects. The reason given was the HRV4 vaccine had been commercialised and was no longer available. Either the problem was no longer considered to have priority or the authorities were unaware of the development and free availability of the I_2 vaccine.

►►►► Australia faces some dilemmas if one of the aims of ACIAR research is to provide commercial spinoffs to Australia. In this case the technology is likely to be of benefit primarily to the very poorest countries which have little capacity to pay. Commercialisation of the HRV4 vaccine has had limited success and has been of limited commercial benefit for Australia.

Finally the ingenuity of the science of developing the HRV4 and I_2 vaccines and approaches which have been taken are to be commended. To quote Professor Spradbrow (ACIAR 1992, pp. 6)

'I believe we have done something useful'.

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