Preventive Veterinary Medicine, 9 (1990) 207–219
Elsevier Science Publishers B.V., Amsterdam

Cost analysis of immunization for East Coast fever by the infection and treatment method

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(Accepted for publication 22 February 1990)

ABSTRACT

Mukhebi, A.W., Morzaria, S.P., Perry, B.D., Dolan, T.T. and Norval, R.A.I., 1990. Cost analysis of immunization for East Coast fever by the infection and treatment method. *Prev. Vet. Med.*, 9: 207–219.

East Coast fever is a major disease of cattle in eastern, central and southern Africa. Its control has relied on the effective control of the vector tick, *Rhipicephalus appendiculatus*. Recently, however, immunization using the infection and treatment method has provided a possible practical alternative, and field trials are underway in several countries of the region.

This study provides an assessment of the cost of the infection and treatment method based on a hypothetical national laboratory designed to produce sufficient vaccine to immunize 100 000 cattle per annum. The major cost components for the construction of the laboratory, and for the production and delivery of the vaccine were identified. They were quantified and costed for an assumed site in Kenya over a planning period of 30 years. The costs involved were separated into capital and operating, in both local and foreign currency components. The total cost was expressed as the cost of immunization per animal. The cost of vaccine production was expressed as the cost per dose produced. A sensitivity analysis was performed to provide probable ranges for the cost per animal and per dose. The total cost of the method to the government would amount to Kenya Shillings (Kshs) 118.7 million (US$ 7.0 million), of which capital costs were Kshs 12.7 million (US$ 0.7 million) and operating costs were Kshs 95.2 million (US$ 5.6 million). (This included a 10% contingency of Kshs 10.8 million (US$ 0.6 million) which was added to the capital and operating costs to account for unforeseen costs.) The local currency portion of the total cost was Kshs 29.2 million (US$ 1.7 million) or 25% of the total, while the foreign currency portion amounted to Kshs 89.5 million (US$ 5.3 million) or 75%. For the 30-year planning period, 2.9 million cattle were assumed to be immunized. The cost of life-long immunization per animal was Kshs 40.36 (US$2.37), with a range of Kshs 36.31–50.45 (US$2.14–2.97). The cost of vaccine production per dose was Kshs 15.20 (US$ 0.89), with a range of Kshs 7.62–20.07 (US$ 0.45–1.18).

INTRODUCTION

Theileriosis (East Coast fever, ECF) is a major disease of cattle in eastern, central and southern Africa. It is caused by the protozoan parasite *Theileria parva* which is transmitted by the brown ear tick, *Rhipicephalus appendiculatus*. It is controlled conventionally by the control of ticks with acaricides.

0167-5877/90/$03.50

However, this method of control has become less reliable because of the high cost of acaricides in foreign currency, poor management and maintenance of dips, the development of acaricide resistance, shortages of water and uncontrolled cattle movements. Alternative strategies are being considered based upon immunization and controlled exposure to ticks through strategic acaricide use. Tick control would be performed strategically to limit overwhelming tick infestation and other tick-borne disease challenges in animals that have been immunized against ECF.

At present, the only practical method of immunization against ECF is the infection and treatment method. The development of this method has been reviewed by several authors (Purnell, 1977; Irvin, 1984). It involves inoculation of cattle with previously characterized and potentially lethal doses of live sporozoites of *T. parva* and concurrent treatment with a long-acting oxytetracycline antibiotic.

Although the infection and treatment method has been tested in field trials in several countries in the region, no comprehensive assessment of its cost has been made. Radley (1981) estimated that it could cost US$ 2.51 to immunize one animal, of which US$ 0.01 would be the cost of producing one immunizing dose of the vaccine and US$ 2.50 would be the cost of long-acting tetracycline used for treatment. Kiltz (1984) estimated the cost of immunization per animal to be about US$ 20.00 in Burundi. It was estimated (in Irvin, 1984, p. 147) that in Malawi, it cost between US$ 4.00 and 5.00 to immunize one animal, US$ 0.10 being the cost of producing one dose of the vaccine and the balance being the cost of the long-acting tetracycline used. However, all these costings were merely rough estimates.

The purpose of this study was to identify, quantify and cost the major cost components involved in ECF immunization, using Kenya circumstances in 1988 as an example. Cost of ECF immunization for a particular site in Kenya or in other countries could be established, based on the same model, incorporating selected components according to local conditions and requirements and adjusting prices accordingly. Information generated by this exercise would be useful to governments and donor agencies interested in funding ECF immunization programmes in the region.

MATERIALS AND METHODS

Modules for vaccine development and delivery

The components of the infection and treatment method were divided into five procedural steps or modules: the isolation of immunizing stocks, in vivo characterization of laboratory stocks, in vitro characterization of laboratory stocks, preparation of bulk stabilate and vaccine delivery and monitoring (Fig. 1). However, a laboratory may be established which encompasses only some

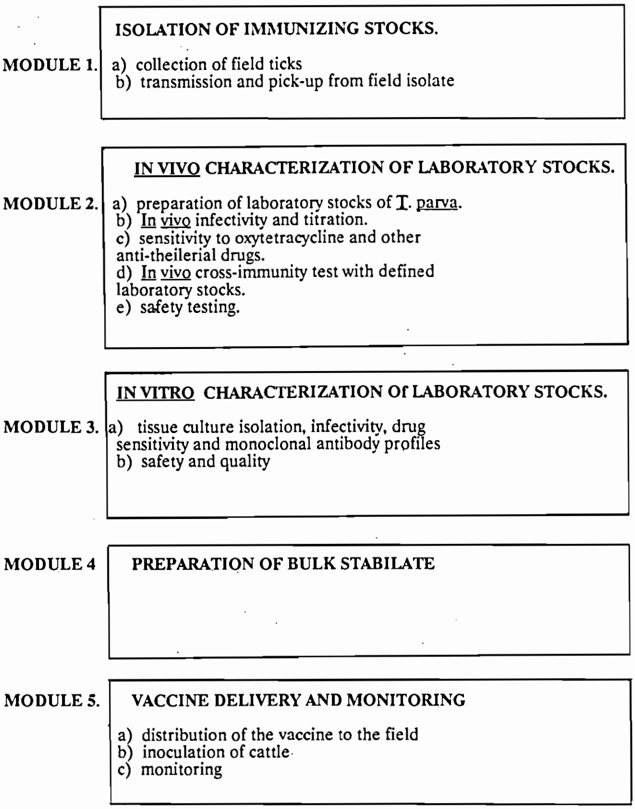

Fig. 1. Modules for the production and delivery of the infection and treatment method vaccine for East Coast fever control.

of the modules, depending upon the local requirements and available resources. For instance, whereas a regional ECF laboratory such as the one in Malawi, or a national laboratory such as the one at Muguga in Kenya have all five modules, a central laboratory such as the International Laboratory for Research on Animal Diseases with no responsibility for the isolation of immunizing stocks and for vaccine delivery has only the second, third and fourth modules.

Major assumptions

It was assumed that the laboratory would be constructed by the government to produce sufficient vaccine to immunize 100 000 cattle of 100 kg average bodyweight year^{-1} for 30 years. In Year 1, 25 000 cattle would be immunized, 75 000 head in Year 2, and 100 000 head year^{-1} from Year 3–Year 30. However, it is recognized that once the adult cattle population in the target area is immunized (which may take several years), only calves (around 3 months old) and any adult animals introduced to the area would need to be immunized. There would exist, therefore, a capacity to immunize cattle in a wider area than the initial target focus. A 30-year planning period was considered appropriate for making long-term budgetary provisions and for spreading out fixed costs of capital items with long useful life spans.

Cost components

For each module, items of capital and operating expenditures were identified, quantified and costed. Capital costs consisted of the costs of land/site improvements (clearing, drainage, roads, utility installations), buildings, laboratory equipment, furniture, vehicles and consultancy services. Operating costs were composed of the costs of personnel (salaries, allowances and benefits), laboratory consumables, animals, animal feeds and maintenance, transport, field immunization costs (drugs, syringes, needles), supplies and materials, and general repairs and maintenance. A 10% contingency for unforeseen costs was added to the total capital and operating costs.

Both capital and operating costs were separated into local and foreign currency components. Local costs represent costs of locally purchased items paid for in local currency. Foreign costs represent costs of imported items paid for in foreign currency. Some donors might be willing to meet the foreign component portion of the total cost, while a host government might be able to absorb the local component in kind and/or cash.

The total cost was expressed as the cost of immunization per animal and the cost of stabilate production per dose. The cost per animal was calculated by subtracting the remaining value of capital items (all operating cost items were assumed to be used up) from the total cost and dividing the resultant net total cost by the total number of cattle assumed to be immunized. The cost per dose was calculated by subtracting field delivery costs from the net total cost, and dividing the resultant net vaccine production cost by the total number of doses produced.

This analysis was limited to a cost analysis of the infection and treatment method. Data on the benefits side (acaricide cost savings and production gains) have yet to be generated from field studies. Accordingly, the discounting of the costs was not considered crucial in the analysis. However, field studies are underway and a benefit–cost analysis will be forthcoming.

Sensitivity analysis

A sensitivity analysis was performed to test the stability of the cost per animal and per dose under probable variations in costs and/or quantities used in the calculations. Sensitivity analysis provided a range of these costs, which would be a more reliable estimate than the single cost estimates.

RESULTS AND DISCUSSION

Capital costs

Land and site improvement

It was assumed that the laboratory would be constructed on existing government land, such as at a veterinary investigation laboratory. Therefore, there was no cost provided for land acquisition. However, such cost would be included in the costings if land was purchased or taken out of production, or where complete government contribution was to be quantified for the purpose of identifying the amount for donor contribution. Costs for site clearing, drainage and road works, fencing and installation of water, power, telephone and other utilities (Table 1) were assumed to be 10% of the cost of buildings.

Buildings

It was assumed that new buildings would be constructed to house offices, a laboratory, tick and cattle facilities, and usual attendant facilities. Provision for construction of senior staff houses was made. It was assumed that four staff houses would be built: three Kenya Government Category E houses for technicians and one Kenya Government Category D house for the scientist-cum-administrator. It was assumed that junior staff would rent houses in the surrounding area. Cost estimates were based on rates in Kenya (January 1988) for buildings of solid but simple design.

Laboratory equipment

For each item, the source-country for importation, the Free On Board (FOB) unit price in the source-country currency (where possible) as of January 1988, and an estimated number of years for which the item would remain in normal use before it would be replaced were specified. The unit cost of an item at laboratory site (which included clearing and forwarding charges, but excluded import taxes because items were assumed to be for government use) was estimated to be 20% above the FOB price.

Items of laboratory equipment would be replaced at their original cost at the end of their useful life over the planning period of 30 years. The straight-line method of depreciation was used with zero salvage value. The total cost of equipment during the first year of operation was estimated as Kshs 2.0 million (US$ 0.1 million). Replacement costs of equipment amounted to Kshs 3.4 million (US$ 0.2 million).

TABLE 1

Cost of a National Laboratory for East Coast fever vaccine production and delivery

Item	Total cost Years 1–30[1]		Local component[2]		Foreign component[2]	
	Kshs	Percent of total cost	Kshs	Percent item cost	US$[3]	Percent item cost
Capital costs						
Staff houses	1 630 000	1.4	1 613 700	99.0	959	1.0
Immunization laboratory	1 100 000	0.9	1 078 000	98.0	1 294	2.0
Cattle facility	330 000	0.3	326 700	99.0	194	1.0
Tick pick-up pens	205 000	0.2	202 950	99.0	121	1.0
Furniture	163 250	0.1	163 250	100	0	0
Utilities and site improvement	326 500	0.3	261 200	80.0	3 841	20.0
Laboratory equipment	5 432 766	4.6	271 638	5.0	303 596	95.0
Vehicles	3 494 863	2.9	31 500	1.0	203 727	99.0
Site plan	17 000	0.0	17 000	100	0	0
Sub-total	12 699 379	10.7	3 965 938	31.2	513 732	68.8
Operating costs						
Personnel	17 083 128	14.4	13 003 128	76.1	240 000	23.9
Laboratory consumables	1 262 109	1.1	315 527	25.0	55 681	75.0
Animals and feeds	4 043 064	3.4	4 043 064	100	0	0
Transport	2 378 000	2.0	2 378 000	100	0	0
Field immunization	68 802 500	58.0	1 376 050	2.0	3 966 262	98.0
Supplies and materials	935 701	0.8	842 131	90.0	5 504	10.0
Repairs and maintenance	725 000	0.6	652 500	90.0	4 265	10.0
Sub-total	95 229 502	80.2	22 610 400	23.7	4 271 712	76.3
Total capital and operating costs	107 928 881	90.9	26 576 338	24.6	4 785 444	75.4
Contingencies, 10%	10 792 888	9.1	2 657 634	24.6	478 544	75.4
Total cost	118 721 769	100	29 233 972	24.6	5 263 988	75.4

[1]Total cost derived by this study.
[2]Proportions of local and foreign currency components were assumed.
[3]Mean exchange rate, January 1988: Kshs 17.00=US$ 1.00.

Vehicles

It was assumed that the following vehicles would be purchased: two four-wheel drive standard vehicles, one motorcycle and two bicycles. The total cost of vehicles was derived in the same way as described for the cost of laboratory equipment above, except that for computation of the straight-line depreciation, a salvage value at 15% of the acquisition cost of vehicles was used.

Miscellaneous capital costs

The cost of office and laboratory furniture including tables, desks, chairs, filing cabinets, typewriter, etc. was assumed to be 5% of the cost of the buildings. A fee of Kshs 17 000 (US$ 1000) was submitted for an architectural site plan.

Operating costs

Laboratory consumables

The type, quantity, unit and total cost of laboratory materials needed for the maintenance and production of well-characterized vaccine stocks of five *T. parva* stabilates were estimated and converted to one stabilate containing 105 000 doses of the vaccine per annum (5% more doses than the number of cattle to be vaccinated for spoilage allowance). The total cost was Kshs 43 521 (US$ 2560) per stabilate per year (Table 1).

Animals and feeds

Twelve cattle of about 200 kg liveweight each would be required each year (six for the tick unit and the other six for stabilate production). A liveweight price of Kshs 12.00 kg^{-1} was used. Major feed components were assumed to be hay, supplements and minerals, costing Kshs 4258 per animal $year^{-1}$. Cattle for stabilate production were assumed to be kept for only 4 weeks in a year after which they would be destroyed with no salvage value.

A total of 330 rabbits would be required per year (300 for the tick unit and 30 for stabilate production). Each rabbit would cost Kshs 70.00 and consume feed worth Kshs 200 $year^{-1}$. Rabbits for stabilate production were assumed to be kept for only 1 week in a year after which they would be destroyed.

Transport operating costs

Transport operating costs for field studies and vaccine delivery were assumed to be similar to those of delivering the artificial insemination (AI) service in Kenya, and were Kshs 2.06 km^{-1} on average (Oscarsson et al., 1987). (In reality, these costs are likely to vary substantially from place to place depending upon many factors, including the number and type of vehicles used, distances and type of terrain.)

Immunization would be carried out at stationary central points to minimize transport costs. An average distance of 60 km would be travelled per immunization visit, which would include vaccine delivery, field studies, monitoring and station transport. The number of cattle immunized per visit was assumed to be 150. Thus, to immunize 100 000 cattle $year^{-1}$ would require 666.7 visits or 40 002 km travelled. This would result in a cost of Kshs 0.82 per immunized animal (Table 1).

Personnel

The number of staff necessary to operate the laboratory, their ranks and annual costs are provided in Table 2. It was assumed that a donor-funded

TABLE 2

Personnel costs for a National Laboratory for East Coast fever vaccine production and delivery[1]

Position	Description	Job group	Mid-point base salary (Kshs per year)	Housing allowance[2] (Kshs)	Other benefits[3] (Kshs)	Total cost per head[4] (Kshs per year)	No. personnel	Total cost (Kshs per year)
Scientist–administrator Years 1–3	Donor funded	FAO P4	–	–	–	1 360 000	1	1 360 000[4]
Scientist–administrator Years 3–30	Vet Officer I	L	82 320	–	16 464	98 784	1	98 784
Technician, senior	Senior lab technician	K	65 520	–	13 104	78 624	1	78 624
Technician	Lab technician	J	54 240	–	10 848	65 088	2	130 176
Secretary	Secretary	E	22 560	8580	4512	35 652	1	35 652
Driver	Driver	C	14 280	6420	2856	23 556	1	23 556
Messenger	Subordinate	B	12 360	2880	1236	16 476	1	16 476
Stockman	Subordinate	B	12 360	2880	1236	16 476	3	49 428
Casual (6 months)	Subordinate	A	5310	–	–	5310	2	10 620
Total personnel costs per year, Years 1–3								1 704 532
Total personnel costs per year, Years 4–30								443 316

[1]Source: based on Kenya Government positions, description and job groups, March 1988.
[2]Housing allowance for non-housed staff.
[3]Based at 20% base salary for local staff other than messenger, and 10% for the latter. Includes field duty allowance, leave allowance, medical claims etc.
[4]Inclusive of all allowances and benefits.

consultant with knowledge of tick-borne diseases and vaccine production would be required for the first 3 years to help set up the operation. A senior veterinary officer would be recruited on local terms to manage the laboratory, with an overlap of 1 year with the consultant. Auxiliary staff would be composed of one senior laboratory technician, two laboratory technicians, one secretary, a driver, a messenger, and three stockmen. Two casual labourers would be employed in a year, each working for a period of 6 months at a time.

The total annual cost of the consultant was taken to be US$ 80 000 inclusive of all costs, allowances and benefits. For the rest of the staff, annual cost per head consists of the basic salary and other benefits and costs such as housing allowance (for non-housed staff), training, field costs, medical expenses and uniforms. These amounted to 20% of the base salary for staff other than the messenger and stockmen, and 10% for the latter groups (Table 1).

Miscellaneous operating costs

These included costs of immunizing materials (syringes and needles) and long-acting oxytetracycline antibiotic; costs of general laboratory supplies and services such as paper, writing materials, filing materials, postage, water, power, telephone and publications which were assumed to be 1% of the total operating costs; and costs of general repairs and maintenance which were assumed to be Kshs 25 000 per annum starting in Year 2 (Table 1).

Total cost, cost per vaccine dose and per immunized animal

Capital and operating costs (Table 1) amounted to Kshs 118.7 million (US$ 7.0 million). Capital costs constituted 10.7% of the total cost. The local currency component of the total cost was 25%. The cost per immunized animal and per dose of stabilate produced are derived in Table 3, and amounted to Kshs 40.36 (US$ 2.37) and Kshs 15.20 (US$ 0.89), respectively.

Sensitivity analysis

Twelve assumptions (Table 4) for sensitivity analysis were made about probable cost increases and decreases, ceteris paribus. These ranged from a 10% decrease to a 25% increase in the total cost. The cost of immunization per animal and the cost of vaccine production per dose for each assumption were derived in the same way as in Table 3.

First, it was assumed that 2 ha of land would be purchased for laboratory construction. More land would be needed where an already existing government station had no more room for expansion. Second, the production of the vaccine would not require construction of any new buildings – laboratory and staff-houses. This would indeed be the case in many countries where these buildings already exist and could easily accommodate the production of an ECF vaccine with minor modifications. Nevertheless, where the separation

TABLE 3

Cost of the infection and treatment method per animal immunized and per dose of vaccine produced

Item	Total cost over a 30-year period (Kshs)
Capital costs	12 699 379
Operating costs	95 229 502
Total capacity and operating costs	107 928 881
10% Contingency	10 792 888
Total cost[1]	118 721 769
Less remaining value of capital items[2]	1 675 355
Net total cost	117 046 414
No. of cattle immunized[3]	2 900 000
Cost per animal (Kshs)	40.36
Cost per animal (US$)[4]	2.37
Net total cost	117 046 414
Less field immunizations cost[5]	68 802 500
Less 75% operating transport cost[6]	1 783 500
Less 10% of the 75% operating transport cost	178 350
Net vaccine production cost	46 282 064
No. of vaccine doses produced[7]	3 045 000
Cost per dose (Kshs)	15.20
Cost per dose (US$)	0.89

[1]Total cost from Table 1.
[2]Remaining capital value at end of Year 30.
[3]Assumed as: 25 000 animals in year 1, 75 000 head in Year 2, and 100 000 animals year^{-1} in Years 3–30.
[4]Exchange rate, January 1988: Kshs 17.00=US$ 1.00.
[5]Field immunization cost from Table 1.
[6]Operating transport cost from Table 1; 75% for vaccine delivery.
[7]Assumed 5% more than the number of cattle immunized.

of foreign and local currency cost components is made for purposes of identifying government and donor contributions, all existing resources, land, buildings, facilities, must be valued to reflect the full government contribution.

Field immunization costs, personnel costs and laboratory equipment costs were assumed to increase by 20% each. From Table 1, it is seen that these are the first, second and third highest cost components, respectively, and changes in them could significantly affect the final costs.

A 10% increase in capital and operating costs, and a 10% and 25% increase in total costs were assumed. These assumptions would account for any general underestimates in the various cost components in terms of quantities and/or acquisition prices.

TABLE 4

Sensitivity analysis of per animal and per dose cost of the infection and treatment method of immunization

Assumption[1]	Total cost (million Kshs)	Net total cost (million Kshs)	Net vacc. prod. cost (million Kshs)	No. doses produced (million)	No. cattle vaccinated (million)	Cost			
						Per animal		Per dose	
						(Kshs)	(US$)	(Kshs)	(US$)
Analysed case[2]	118.7	117.0	46.3	3.0	2.9	40.36	2.37	15.20	0.89
Land purchase, 2 ha at Kshs 150 000	119.1	117.4	46.7	3.0	2.9	40.48	2.38	15.36	0.90
No. buildings built	114.6	114.3	43.1	3.0	2.9	39.41	2.32	14.18	0.83
20% increase in field immunization costs	133.9	132.2	61.0	3.0	2.9	45.59	2.68	20.07	1.18
20% increase in personnel costs	122.6	120.9	49.7	3.0	2.9	41.69	2.45	16.35	0.96
20% increase in laboratory equipment costs	120.0	119.8	48.6	3.0	2.9	41.31	2.43	15.99	0.94
10% increase in capital costs	120.1	118.3	47.1	3.0	2.9	40.79	2.40	15.49	0.91
10% increase in operating costs	129.2	127.5	56.3	3.0	2.9	43.97	2.59	18.52	1.09
10% increase in total costs	130.6	128.8	50.5	3.0	2.9	44.41	2.61	16.61	0.98
25% increase in total costs	148.4	146.3	57.3	3.0	2.9	50.45	2.97	18.85	1.11
100% increase in doses produced	119.3	117.7	46.5	6.1	2.9	40.59	2.39	7.62	0.45
10% decrease in total costs	106.8	105.3	41.3	3.0	2.9	36.31	2.14	13.59	0.80
25% decrease in animals vaccinated	99.1	97.5	44.1	3.0	2.175	44.83	2.64	14.51	0.85
Range						36.31–50.45	2.14–2.97	7.62–20.07	0.45–1.18
Mean						42.32	2.49	15.56	0.91
Standard deviation						3.52	0.21	3.05	0.18

[1]Each assumption was made ceteris paribus. All figures were derived in the same way as for those in Table 2.
[2]See Table 2.

A doubling of the number of vaccine doses produced was assumed. Increasing dosage production would be easy once capital facilities are in place, and would in fact not lead to a proportionate increase in operating costs. Increase in dosage production could be achieved merely by changes in the dilution of the stabilate. However, the number of doses produced should be a function of the potential number of cattle available for immunization, otherwise there would be no sense in producing more doses.

A 10% decrease in total costs was assumed to account for any cost overestimation in the analysed case. Nevertheless, it is usually cost increases (underestimates) rather than cost decreases (overestimates) that are of greater concern for planning purposes. Underestimating costs means that there would be insufficient funds to meet certain expenses when they fall during plan implementation, whereas overestimating costs means that there would be more than sufficient funds to meet expenses.

Finally, it was assumed that only 75% of the 100 000 cattle presumed eligible for immunization would in fact be presented for immunization.

Table 4 shows that the derived costs per animal and per dose of stabilate produced are fairly stable when subjected to various changes in costs. These results imply that minor changes in the quantities and/or costs of identified cost components would yield results that would fall within the above cost ranges. For instance, constructing one or two more staff houses, increasing the number of liquid nitrogen tanks or freezers by a few more units, or hiring one or two more technicians or subordinate staff, or even doubling transport operating expenses would not generate per animal and per dose costs that would be outside these ranges. The cost of immunization per animal would be considerably reduced in places where complementary livestock services such as AI, animal health and animal husbandry would be provided by the government on a cost-sharing basis among the services.

The cost of immunization to the livestock producer (assuming that she/he buys the vaccine from the government delivered at cost) would include the cost of labour for taking the animal to and from the point of immunization. Such cost (which may be an opportunity cost of family labour or a cash cost of hired labour) was not included in the cost calculations. The cost of immunization derived above, plus the producer's labour cost, plus the cost of strategic acaricidal application against ticks and other tick-borne diseases (TBD), would need to be compared with the cost of tick and TBD control by the current acaricidal application and chemotherapeutic methods, to assess the cost effectiveness of the infection and treatment method.

CONCLUSION

The cost of the infection and treatment method of immunizing cattle against ECF will vary with place, country and time, depending upon the types, quantities and costs of components involved. For a given country or site, such cost components should be systematically identified, quantified and costed to derive a comprehensive estimate of the cost of the method. This was attempted in this study for a hypothetical site in Kenya using 1988 financial circumstances as an example. It was found that it would cost the government Kshs 15.20 (US$ 0.89) to produce one dose of the vaccine, with a range of Kshs 7.62–20.07 (US$ 0.45–1.18). Furthermore, it would cost the government a total of Kshs 40.36 (US$ 2.37) to immunize one animal (including the cost of one vaccine dose), with a range of Kshs 36.31–50.45 (US$ 2.37–2.97). In herds where livestock services such as AI and animal health are provided regularly, immunization could be run concurrently, thus sharing and reducing the field delivery costs of the method.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following persons for their instructive comments on the initial draft: Dr. D.P. Kariuki, National Veterinary Research Centre, Muguga, Kenya; Dr. T.S. Kavishe, Ministry of Agriculture and Livestock Development, Tanzania; Dr. S.R. Magembe, Southern African Development Coordination Conference (SADCC), Botswana; Dr. A.D. Irvin, Overseas Development Administration, U.K.; and Dr. F. Musisi, FAO-ECF Control Project, Malawi.

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