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CHAPTER 4 - MEAT INSPECTION, MEAT TREATMENT AND DEVELOPMENT OF SAFE ANIMAL SLAUGHTERING FACILITIES

4.1 Introduction

This Chapter should be read in conjunction with the Guidelines on small slaughterhouses and meat hygiene for developing countries (Ed. Dr I. Mann) VPH/83.56 (33).

The limitations of meat inspection in the diagnosis of T. saginata and T. solium cysticercosis have been discussed in Chapter 2. In this Chapter its role and limitations in preventing taeniasis infection of the public is described. At large national and exporting slaughter establishments meat inspection reaches a high standard. Nevertheless, with both T. saginata and T. solium cysticercosis, there are serious limits to the identification of infected carcasses, particularly those with light infections. The Codex Alimentarius Commission, which operates under the aegis of the Joint FAO/WHO Food Standards Programme has prepared codes of practice which include those for inspecting and treating infected meat. For example, the EEC directive No 72/462 of 1972, stipulates that meat originating from animals carrying one or more live or dead cysticerci cannot be imported into EEC countries. Even where very high standards are maintained, infected meat may still reach the consumer to maintain endemic bovine cysticercosis in developed countries (8).

Unfortunately, in many developing countries, only a fraction of the animals slaughtered pass through certified meat inspection facilities. Furthermore, in the case of T. solium, ante-mortem diagnosis through tongue lesions may encourage clandestine slaughter (1). Similarly, cattle owners in many endemic areas avoid the slaughter of animals in places where meat inspection exists, fearing condemnation. Thus, they revert to bush killing and increase the risk of infection, especially to the poorer consumers (33).

Until meat inspection as well as rural and village slaughterhouse facilities reach a high standard and clandestine slaughtering is eliminated, both T. saginata and T. solium are likely to remain focal and hyperendemic in epidemiological pattern in much of the developing world.

4.2 Distribution of cysticerci in carcasses

Many workers have attempted to determine whether or not there are specific sites of predilection in T. saginata cysticercosis (4, 5, 7, 9, 17, 18, 21, 24, 28, 30, 33, 36, 37, 40, 42, 43, 44, 46, 48, 50, 54, 57, 59, 61, 62). The evidence is against there being any favoured site or sites, which if found uninfected, would guarantee freedom of the carcass from cysticerci. For example, the frequency in which cysticerci may be found in different muscle groups in East African cattle are summarized in Table 16. Here, the masseters were rarely parasitized. In this group of cattle, up to 50% would have remained undetected by normal meat inspection procedures.

TABLE 16 - Relative distribution of cysticerci of T. saginata in African cattle (After 33).

Right thigh and leg	12.85%	Abdominal muscles	2.27%
Left thigh and leg	12.06%	Right forearm	2.12%
Back and loins	10.29%	Left forearm	1.57%
Neck and hump	10.17%	Liver	1.43%
Sublumbar muscles	8.84%	Lungs	1.43%
Left shoulder	5.72%	Hyoid	1.11%
Heart	5.35%	Diaphragm	1.06%
Right shoulder	4.39%	Face and ext. masticatory muscles	0.787%
Left shoulder girdle	3.00%	Internal masticatory muscles	0.72%
Tongue	3.00%	Tail	0.34%
Left arm	2.93%	Oesophagus	0.32%
Thorax	2.82%	Trachea	0.25%
Right arm	2.74%	Kidneys	0.09%
Right shoulder girdle	2.51%		

In a study in Tanzania, the detailed dissection of several groups of animals of different ages, showed that routine meat inspection procedures detected only a very small number of cysticerci (33).

A further study involving African cattle showed that the rate of detection of cysticerci in the different parts of the carcass differed markedly (Table 17). Thus, cysticerci were found most frequently in the triceps, heart, tongue and the masseters. In more than 50% of the infected animals, cysticerci were found in the triceps muscle and in 20% of the animals cysticerci were detected at meat inspection in that muscle only.

TABLE 17 - Frequency of detection of cysticerci of T. saginata in different parts examined during routine meat inspection (After 62).

	Number of animals found infected*	Percentage of animals found infected**
Triceps	12	52.2
Heart	9	39.1
Tongue	7	30.4
Muscles of mastication	5	21.7
Oesophagus	2	8.7
Diaphragm	2	8.7
Others	2	8.7

* In some animals cysticerci were detected in more than one part

** Percentage based on 23 animals detected by routine meat inspection

In further studies of 60 infected animals, cysticerci were found in all parts of the carcass examined except the spleen and kidneys (Table 18). The majority of animals had cysticerci in the hind (77%) and fore legs (70%). However, the percentage of animals with cysticerci in the heart, tongue, masseters and oesophagus was 25%, 22%, 13% and 5% respectively. The number of cysticerci per kg muscle did not differ significantly between the different parts of the carcass.

TABLE 18 - Distribution of cysticerci of Taenia saginata in different parts of the carcass found by slicing (After 62).

Part	Number of animals with cysts	Percentage of animals with cysts*	Cysts per kg of muscle
Hind legs	46	76.7	1.03
Fore legs	42	70.0	1.25
Back and ribs	28	46.7	0.64
Neck	24	40.0	1.26
Lumbar region	15	25.0	0.96
Heart	15	25.0	2.14
Liver	15	25.0	0.61
Abdominal muscles	14	23.3	0.47
Tongue	13	21.7	1.33
Head muscles	8	13.3	-
Lung	6	10.0	0.25
Diaphragm	5	8.3	-
Oesophagus	3	5.0	-
Kidneys	0	0	0
Spleen	0	0	0

* Percentage based on 60 infected animals
- Not available

In a study undertaken in Australia (48), using total carcass dissection of 50 cattle 69% of the 16 infected animals were not detected by normal meat inspection of the heart, diaphragm, tongue and masseters.

With such low rate of detection of lightly infected carcasses using normal meat inspection procedures, there can be no guarantee even when the inspection procedure is thorough, of preventing the passage of infective material for human consumption through normal marketing channels.

Diagnosis of porcine cysticercosis is also based on the identification of the parasite in carcasses, although in heavy infections, positive identification can often be made ante-mortem by an examination of the tongue. Heavy infections are readily detected after slaughter (19).

Similar problems in the detection of light infections occur in pigs as in cattle (19, 41, 60). In countries where it is usual to make a limited incision in the musculature (to avoid decreasing the commercial value of the carcass) infection may be missed. For example, in 1000 pigs in which cysticercosis was not detected by a routine incision of the anconeus muscle, further examination showed 1.1% to be infected with cysticerci in the masseters or tongue.

The distribution of cysticerci in swine musculature has been studied in 500 pigs condemned for having four or more cysticerci at the sites examined at meat inspection (see Figure 30). This indicates that a generalized infection throughout the carcass, including the brain, is common in some endemic areas.

FREQUENCY OF CYSTICERCI IN DIFFERENT MUSCLES OF THE PIG

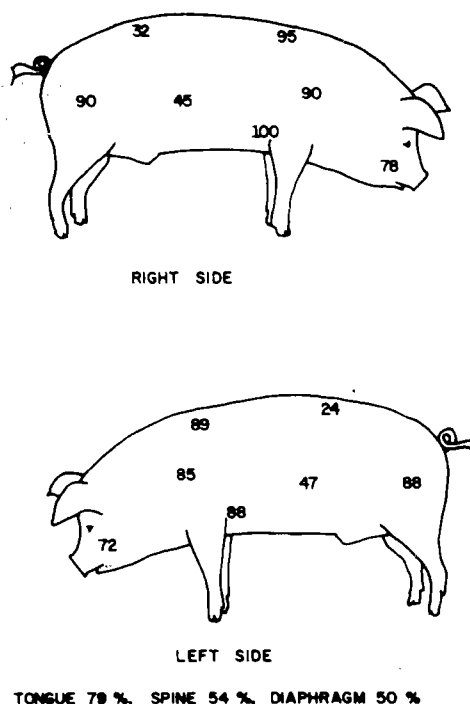


FIGURE 30 - Distribution of Taenia solium in heavily infected carcasses (After 60).

4.3 Improvements in meat inspection

Various studies have been made on such factors as training, rewards, motivation, psychological disposition, adequate lighting and improving methods of processing carcasses (6, 14, 22, 25, 26, 54, 59). These are important, but they do not overcome the problem that there is no specific site for examination that can be relied upon to detect all infected carcasses.

Failures in the detection of cysticercosis during post-mortem inspection may be reduced if meat inspection is practiced by experienced and conscientious inspectors under optimal conditions (25, 38), which should include adequate rest periods. These conditions also include good lighting, a low noise level and a system of inspection integrated with slaughtering procedures. Meat inspection manuals should be explicit in their directions for the examination of carcasses and organs for cysticerci. Meat inspection should be well planned, organized and managed at every slaughterhouse. It has been observed that the efficiency of meat inspection diminished after two hours of routine work in a given position.

Several studies have been made to determine the value of fluorescence from ultra violet light in the detection of cysticerci (10, 13, 23, 29, 34, 35, 42, 45, 49). Generally, this is not regarded as an effective diagnostic technique for detecting cysticerci. For example, in T. ovis cysticercosis both cysticerci and fat fluoresced and no differentiation could be made between them (51).

4.4 Processing of infected carcasses and meat

Regulations vary in different countries depending on the number of cysticerci found at inspection. Where few (e.g. up to 5 per carcass) cysticerci of T. saginata are identified, the carcass is retained for freezing or heat sterilization. Where more (e.g. 6-20) cysticerci are found, the meat may be used only for processing into meat products employing procedures that safely destroy the cysticerci. Where heavy infections (e.g. more than 20)

are detected, the carcass is condemned, buried, rendered or incinerated (17, 18, 33, 42). Similar rules usually apply to T. solium cysticercosis (42).

Lightly infected carcasses can be sterilized by freezing, boiling or pickling in common salt. Freezing of beef carcasses at -20°C for 10 days is effective (16). Several recommendations have been made on the freezing times and temperatures required to kill T. saginata and T. solium (2, 3, 11, 12, 15, 27, 31, 39, 42, 47, 52, 53, 55, 56, 58, 63, 64). In a carefully controlled study, it has been shown that 12 and 16 week-old cysticerci are much more susceptible to the lethal effects of freezing than 24 week old cysticerci (Table 19) (20). The times and temperature combinations required to ensure death of all cysticerci irrespective of age were 360 h at -5°C , 216 h at -10°C and 144 h at -15°C or lower.

TABLE 19 - Time and temperature required to kill 24 week-old cysticerci of Taenia saginata in beef. Results expressed in percentage of dead cysticerci. (After 20).

Time (h) \ Temp. ($^{\circ}\text{C}$)	72	84	96	120	132	144	168	192	216	240	264	288	360
- 5	-	-	-	75	0	50	63	-	100	-	86	-	100
-10	-	-	20	82	88	100	84	-	100	-	100	-	100
-15	20	63	90	80	-	100	-	100	-	100	-	100	-
-20	25	100	89	100	-	100	-	100	-	100	-	100	-
-25	60	100	0	100	-	100	-	100	-	100	-	100	-
-30	50	63	72	68	-	100	-	100	-	100	-	100	-

Similar detailed studies for T. solium cysticerci are not available.

With respect to boiling of meat for sterilization, beef can be rendered safe by boiling 2 kg pieces in an open boiler for 3 h at a steam pressure of 0.5 atmospheres. Pork infected with cysticerci can also be rendered safe provided the internal temperature reaches 80°C (42). For effective salting, beef or pork is cut into 2.5 kg pieces and covered with ordinary salt and pickled for 20 days (42). With respect to all treatments, the size of the meat joint determines the time required for adequate sterilization.

4.5 Prevention of illegal slaughtering and illicit sale of meat

If control is to be established in rural endemic areas over the slaughtering and sale of cysticercotic meat, butchers at licensed village abattoirs must notify the health authorities of the days and times when slaughter will take place. Meat or health inspectors must oversee meat hygiene procedures and ensure that all infected carcasses are treated appropriately. Inspected carcasses should be stamped to overcome problems of illegal slaughter and sale.

Periodic inspections of butchershops and restaurants may be necessary to enforce the regulations.

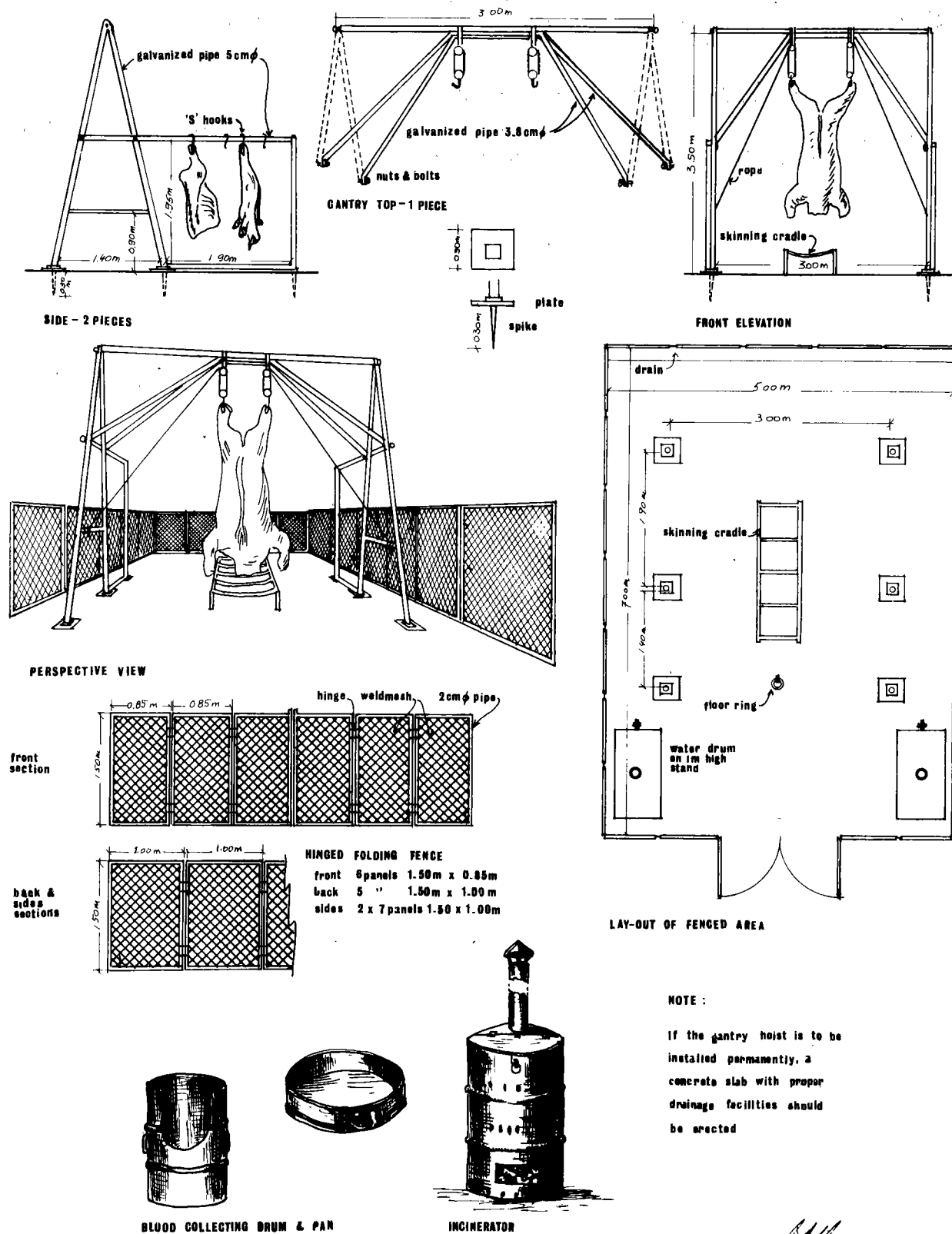
4.6 Development of safe slaughtering facilities in village communities and undeveloped rural areas

This section should be read in conjunction with the Guidelines on small slaughterhouses and meat hygiene for developing countries. They deal with construction of slaughter facilities, slaughter processes, handling of meat and by-products, meat hygiene, environmental sanitation, local energy sources suitable for small slaughterhouses and prevention of meat-borne diseases (32, 33).

4.6.1 The site and requirements for village-animal slaughter facilities

The design of an ideal rural slaughterhouse meeting the standards required for sanitary slaughter, including proper layout, effluent disposal and clean water supply are illustrated in Figures 31 to 35.

For permanent installation or as travelling demonstration unit



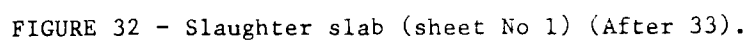
NOTE :

If the gantry hoist is to be installed permanently, a concrete slab with proper drainage facilities should be erected

FIGURE 31 - Portable prefabricated fenced gantry hoist (After 33).

PREPARED BY:

Erica Mann



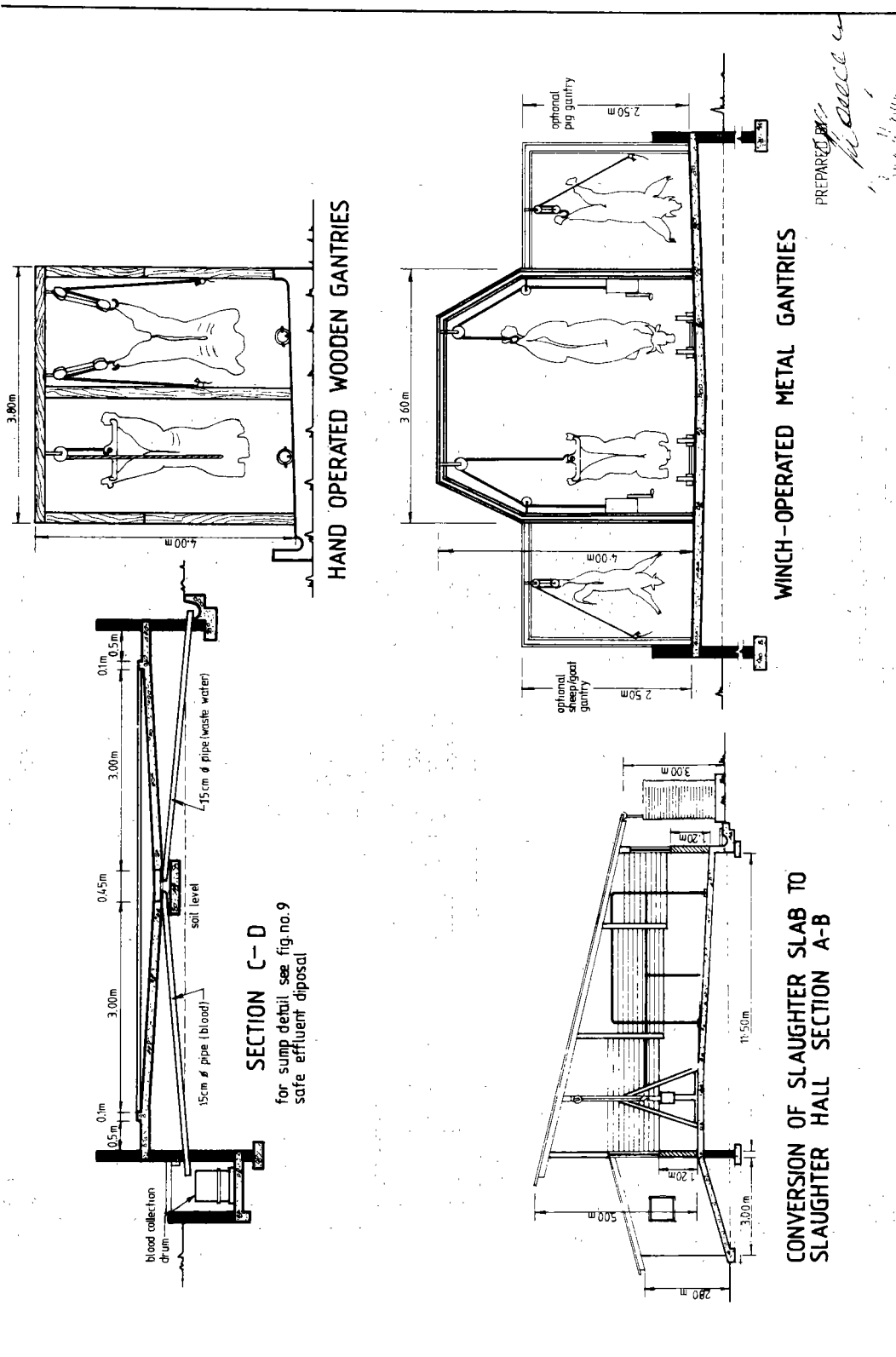


FIGURE 33 - Slaughter slab (sheet No 2) (After 33).

ANCILLARY STRUCTURES FOR SLAUGHTER SLAB
(WHOLE AREA INCLUDING LAIRAGE SHOULD BE FENCED)



FIGURE 35 - Safe effluent disposal (After 33).

4.6.2 The development of safe slaughtering under austere conditions

In many hyperendemic areas where there are no public slaughterhouse facilities, butchers slaughter animals wherever they choose, such as in an empty room in a dwelling-house, a backyard in a densely-populated area, the branch of a tree or a thicket in a banana grove (Figure 36)(32). This uninspected meat is then used for feasts or perhaps sold on the spot or marketed in towns. These unhygienic practices can be resolved by the creation and licensing of slaughter slabs and slaughter houses. However, to be effective they must be equipped with facilities for trained meat inspectors to work under good conditions.

In remote and sparsely populated areas, where the consumption of meat is small and only occasional slaughtering is undertaken, the local administrators should erect a slaughter slab. The basic difference between a slaughter slab and the smallest slaughterhouse is that the latter consists of several slaughter slabs under a roof, while the slab has neither roof nor walls. Both require basic facilities for humane slaughter and for the maintenance of a good standard of hygiene and meat inspection.



FIGURE 36 - Slaughtering in the field (After 33).

4.6.2.1 The main requirements

The slaughter place should:

- (1) not be part of a dwelling-house;
- (2) not be on a road leading to a dwelling-house;
- (3) be at a reasonable distance from human habitation so that it does not become a nuisance to the neighbourhood;
- (4) not be near public latrines;

- (5) be screened from view;
- (6) have a hard, smooth, impervious flooring, sloping towards a drain and grooved to give better footing to beasts and staff;
- (7) be provided with a wooden or iron frame, not less than 3.60 m above floor level, with hoisting facilities;
- (8) be provided with one or more floor rings to secure the animals;
- (9) be provided with a water point on the slaughter slab, or a hose-pipe of sufficient length to connect to the nearest water point if this is not more than 7.50 m away;
- (10) have adequate facilities for the disposal of effluents and of condemned meat and blood (pits);
- (11) be provided with meat and offal hanging rails;
- (12) have a scalding vat for pigs;
- (13) have electric or pressure lamps to give adequate light to both butcher and inspector if slaughtering takes place at night;
- (14) be properly fenced to prevent the access of other animals, or unauthorised persons.

4.6.2.2 Design and equipment

A basic factor in hygienic slaughtering and producing meat of good keeping quality, is the lifting of the carcass. The most primitive form of hoist is required to lift the carcass by means of ropes thrown over a horizontal beam 3.60 m high. Owing to the effort involved, this method is justifiable only when the occasional beast is slaughtered.

No matter how small a slaughter slab or house may be, it must be equipped with proper lifting facilities which can be operated by one or two men. (Figures 31, 33, 37). There are three methods which may be applied:

- (a) Two sets of blocks and tackle arranged so as to lift and pull the sides apart to facilitate splitting;
- (b) Chain block and gambrel. The chain block lifts the carcass and it can be fitted so that it may be used to convey the carcass as well. The gambrel or beef tree parts the sides;
- (c) Winch or wall hoist. The winch lifts the carcass, and, as before, the gambrel parts the sides. If used in a slaughterhouse provided with an overhead rail the carcass can be moved on to roller hooks;

A tubular gantry hoist is particularly suitable for countries where good quality timber is not available. It is suitable for use in those places where a fair number of large and small animals are slaughtered and the meat is removed at once.

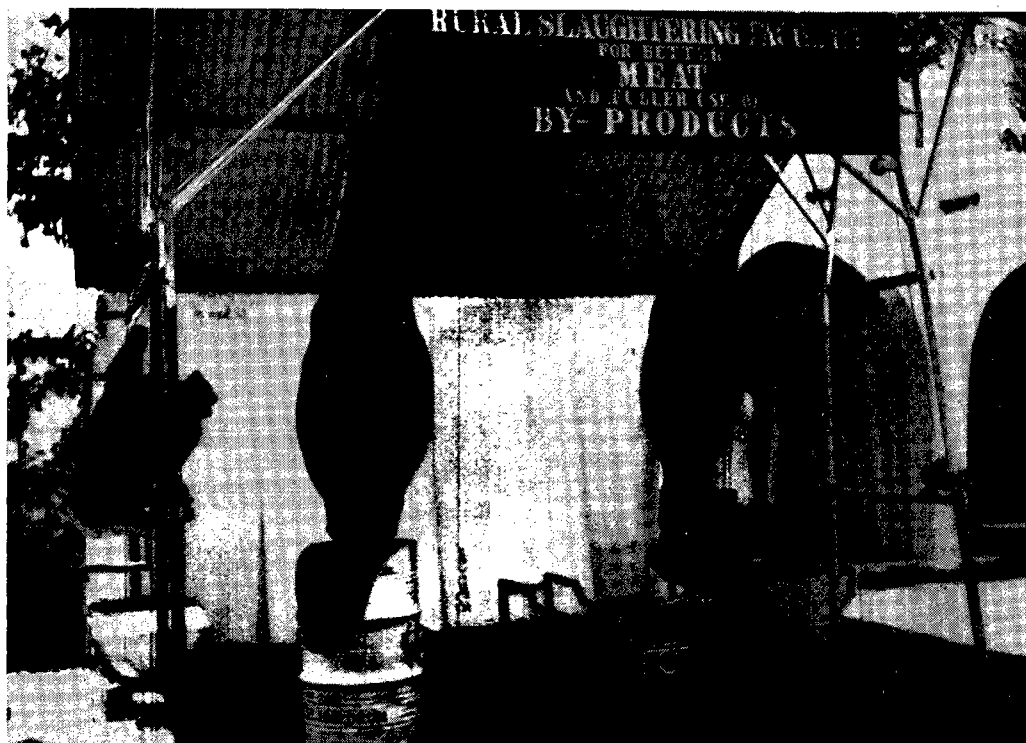


FIGURE 37 - A mobile roofed, double hoist at an agricultural exhibition (After 33).

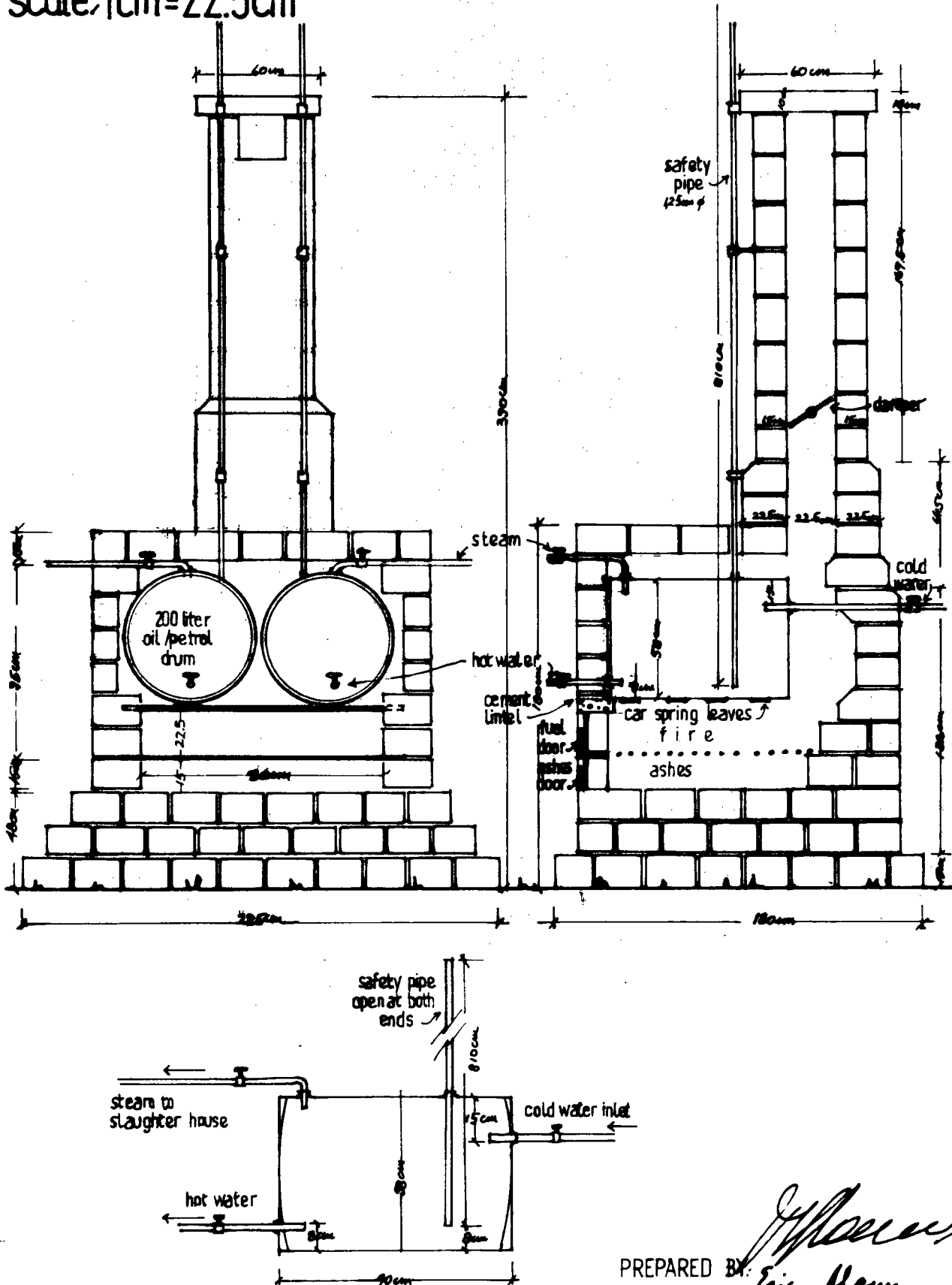
Ideally, the gantry hoist should be protected by a roof as shown in Figure 37. The details of the concrete slab required for the gantry hoist when erected on a permanent site are shown.

The slaughter slabs which already exist without hoist facilities could be improved by installing such a gantry. This would ensure that the carcass is lifted from the contaminated floor. Uniform equipment would allow for the interchanging of spare parts and the training of butchers on a country-wide scale.

Certain operations, such as the maintenance of sanitary conditions of the premises, tripe washing, etc., require warm water (45-50°C). Pig scalding uses water at 60°C. However, slaughterhouse tool sterilization and the boiling of conditionally passed meat (e.g. infected with *C. bovis*) require steam and boiling water. For this purpose a simple steam and hot water boiler can be constructed (Figure 38).

DOUBLE STEAM & HOT WATER BOILER

scale: 1cm = 22.5cm



PREPARED BY: *Erica Mann*

FIGURE 38 - Double steam and hot water boiler (After 33).

4.6.2.3 Licensing

All slaughterhouses must be licensed before activities commence. Legislation should be enacted making it an offence to use premises for slaughtering purposes unless the butcher holds a valid licence to operate on these premises. Licenses should be granted for a period of not more than one year. A veterinarian's or health officer's written report to the effect that both premises and equipment were inspected and found to be in good working order and that sanitary conditions have not deteriorated since the previous inspection, should be conditional to the renewal of a licence.

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CHAPTER 5 - CHEMOTHERAPY

5.1 Introduction

Cestocides can be used to treat individual patients infected with adult worms of either T. saginata or T. solium or for mass chemotherapy in campaigns aimed at controlling these infections. Metacestocides can be used to treat patients with T. solium cysticercosis or they may be employed in the control of T. solium and T. saginata cysticercosis in pigs or cattle.

In individual cases it is desirable to make a specific diagnosis before treatment as this can determine the drug of choice and also affect the subsequent advice given to the patient. Knowledge of the relative abundance of the different species has obvious implications in relation to the public health assessment of the problem of taeniasis in any particular area, especially where it is proposed to use mass chemotherapy or selective chemotherapy for control.

Where taeniasis is entirely due to T. saginata and human cysticercosis is non-existent a variety of cestocidal drugs can be used. Where T. solium exists, it is advisable to use cestocides that have no effect on the cystic stages. This is because silent cystic infections, such as those in the eye and brain, may be exacerbated by treatment if larvicides are used. Also, drugs that are likely to produce vomiting should not be used because of the theoretical danger of auto-infection from reverse peristalsis.

None of the presently available cestocides are ovicidal. Therefore, special precautions should be taken in the case of T. solium infection when handling tapeworms or faecal material. In the case of both T. saginata and T. solium it is important to be aware of the increased risk of focal contamination of the environment following mass chemotherapy (98).

The efficacy and tolerance of taeniocides may differ in various parts of the world depending on ethnic factors, nutritional status, diet and concomitant infections. The selection of drugs for mass treatment and the optimal dose rate must be based on local experience.

5.2 Cestocides

During the 1950s, a derivative of acridine, mepacrine hydrochloride (Quinacrin, Atebrin), extract of male fern and tin compounds were the main drugs for treating tapeworm infections. A marked progress in chemotherapy of human taeniasis has been noted since dichlorophen was introduced in 1956 and niclosamide in 1960.

During the past 30 years, several reviews have been made on the efficacy of tapeworm drugs (43, 44, 71, 96, 125, 156). Data collected in trials to establish the efficacy of a drug are likely to be highly variable. There are great advantages in using biometry in designing and interpreting clinical trials.

Where possible, the criterion upon which a drug should be assessed for efficacy is an estimate of the single dose required to free 90% (together with a 95% confidence interval) of the hosts from infection. Alternatively, the number of treatments required to achieve the ED₉₀ and falling within the non-toxic dose range should be found (71). In this Chapter, a description of the drugs most commonly used in outpatient treatment of T. saginata and T. solium taeniasis, is given.

5.2.1 Drugs previously used in T. saginata and T. solium taeniasis, but no longer recommended: Dichlorophen, Trichlorophen and Bithionol

Dichlorophen (Antiphen, Dicestol, Didroxane, Diphenthane - 70, Hyosan, Parabis, Plath-Lyse, Preventol G-D, Teniathane, Teniatol), has the chemical formula 2,2' - dihydroxy - 5,5' dichlorophenylmethane. The analogue Trichlorophen (G-610), is 2, 6 - bis (2' oxy-5-chlorobenzyl-4-chlorophenyl).

More than 20 clinical trials were reported on the use of Dichlorophen or Trichlorophen in the treatment of T. saginata and T. solium infections (8, 10, 25, 51, 85, 90, 101, 104, 114, 116, 124, 140, 142, 143, 147). With none of them was it possible to define the ED₉₀ and 95% confidence interval. Indeed, the results were variable, with cure rates varying from 30 to 90%. Dichlorophen was extensively used in the mass drug treatment programmes in the USSR.

Bithionol (Actamer, Bithin, Bitin, Lorotheidol), has the formula 2,2' - thiobis (4,6-dichlorophenol) and bithionol sulphoxide (Bitin-S, Disto-5), is 2,2'-sulphinyl-bis (4,6-dichlorophenol). Bithionol has been used successfully in the treatment of T. saginata infections (7, 14, 36, 37, 50, 51, 61, 120, 169). Toxic side effects included nausea, anorexia, abdominal discomfort and diarrhoea. This drug caused death at high dose rates in animals (71) and its safety in man has been questioned (125).

5.2.2 Drugs at present used in the treatment of human tapeworm infections

Niclosamide

Niclosamide (Bayer 2353, Cestocid, Devermin, Lintex, Mansonil, Nasemo, Phenasal, Radeverm, Sagimid, Sulqui, Tredermine, Vermitin, Yomesan, Zemun) is 2',5-dichloro-4'-nitrosalicylanilide. Phenasal used in USSR is N-12'chlor-4'-nitrophenyl)-amino-5-chlorosalicylic acid.

Niclosamide was introduced into human medicine for the treatment of tapeworm infections in 1960 and it is claimed to be the drug of choice with a high level of safety. As an indication of its popularity among physicians more than 100 case history studies have been reported on its efficacy against T. saginata and T. solium taeniasis (2, 3, 4, 5, 6, 8, 9, 21, 22, 26, 41, 47, 49, 54, 55, 56, 57, 64, 74, 91, 92, 93, 97, 98, 100, 101, 107, 110, 113, 118, 124, 125, 129, 141, 144, 145, 148, 149, 150, 151, 152, 166). Almost all reports confirm that there are very few side effects in the treatment of human taeniasis, the main ones being nausea, vomiting and abdominal pain.

With regard to efficacy, only one report defined a dose rate and this was 60 mg/kg in a divided dose treatment schedule over 1 h. Eleven of 13 treated patients were cured (97). Generally, the drug was regarded as providing a 90% cure rate, but this varied between 50 and 100%. However, in one study only a 7% cure rate was achieved (93). It seems that some batches of Vermitin, Radeverm and Phenasal (USSR) were of low efficacy (23, 94, 124), possibly because of inadequate micronization of the drug particles (101). The generally recommended dose was of the order of 2 000 mg for adults and about half this amount for juveniles. This is usually given in a single dose.

Several drugs have been mixed with niclosamide. This was done with a primary objective of improving the efficacy of drug treatment in Hymenoplepis nana infections and extensive studies were undertaken with some of them against T. saginata taeniasis.

Dichlosal (dichlorophen mixed with niclosamide) and Trichlosal (trichlorophen mixed with niclosamide), were regarded as useful in the treatment of T. saginata taeniasis in the USSR. Several studies were reported on the value of Dichlosal (3, 45, 48, 58, 59, 60, 77, 79, 93, 94, 100, 101, 102, 109, 115, 130, 161) and similar studies were undertaken with Trichlosal (1, 102, 112, 119) but there is no statistical evidence that these mixtures were more effective than niclosamide alone.

Other combinations examined for efficacy in the treatment of Taenia saginata taeniasis included niclosamide with bithionol (7) and niclosamide with acrichin or with aminoacrichin (3, 60, 78, 79, 93, 94, 161); with male fern extract (78, 79) and with paromomycin (131). Again no evidence could be found to show that these mixtures were superior to niclosamide alone.

Praziquantel

Praziquantel (EMD 29810. Embay 8440, Cysticide, Cisticid, Droncit, has the formula 2-(cyclohexylcarbonyl)-4-oxo-1,2,3,6,7,11b-hexahydro-4H-pyrazino(2,1-a)-isoquinoline. The strong efficacy of this compound for cestode infections was first reported in 1975 and since

that time its pharmacokinetic properties have been extensively investigated in vitro and in vivo (11, 46, 105, 146, 157, 158). This drug (Biltricide) is also used extensively for the treatment of shistosomiasis and other trematode infections of man. The drug has been thoroughly investigated for acute, subacute and subchronic toxicity including teratogenicity, embryotoxicity, peri- and post-natal toxicity as well as mutagenicity (20, 110, 117, 121). No ill effects have been reported. Clinical pharmacology trials with volunteers suggest that the drug may have no contraindications in healthy persons (106). Some side effects of a gastrointestinal nature may occur over a period of 24 hours following treatment of cestodiasis (80); but patient tolerance is regarded as good (180).

With regard to its dose rate, the ED₉₀ with 95% confidence intervals has been determined for a wide range of cestodes (Figure 39). The ED₉₀ has not yet been reported for T. saginata and T. solium taeniasis. However, the evidence from extensive clinical trials (18, 38, 53, 81, 127, 132) suggests that the 95% confidence interval of the ED₉₀ for these infections may lie between 5 and 15 mg/kg.

While further carefully designed trials to define the ED₉₀ are required, praziquantel can be regarded as a highly effective drug for the treatment of T. saginata. However, caution is required if concurrent T. solium neuro- or ocular cysticercosis is suspected because it is possible that even a low single dose of praziquantel used for treatment of taeniasis may implicate concomitant cysticercosis. In this case, the alternative is treatment of the adult tapeworm with niclosamide.

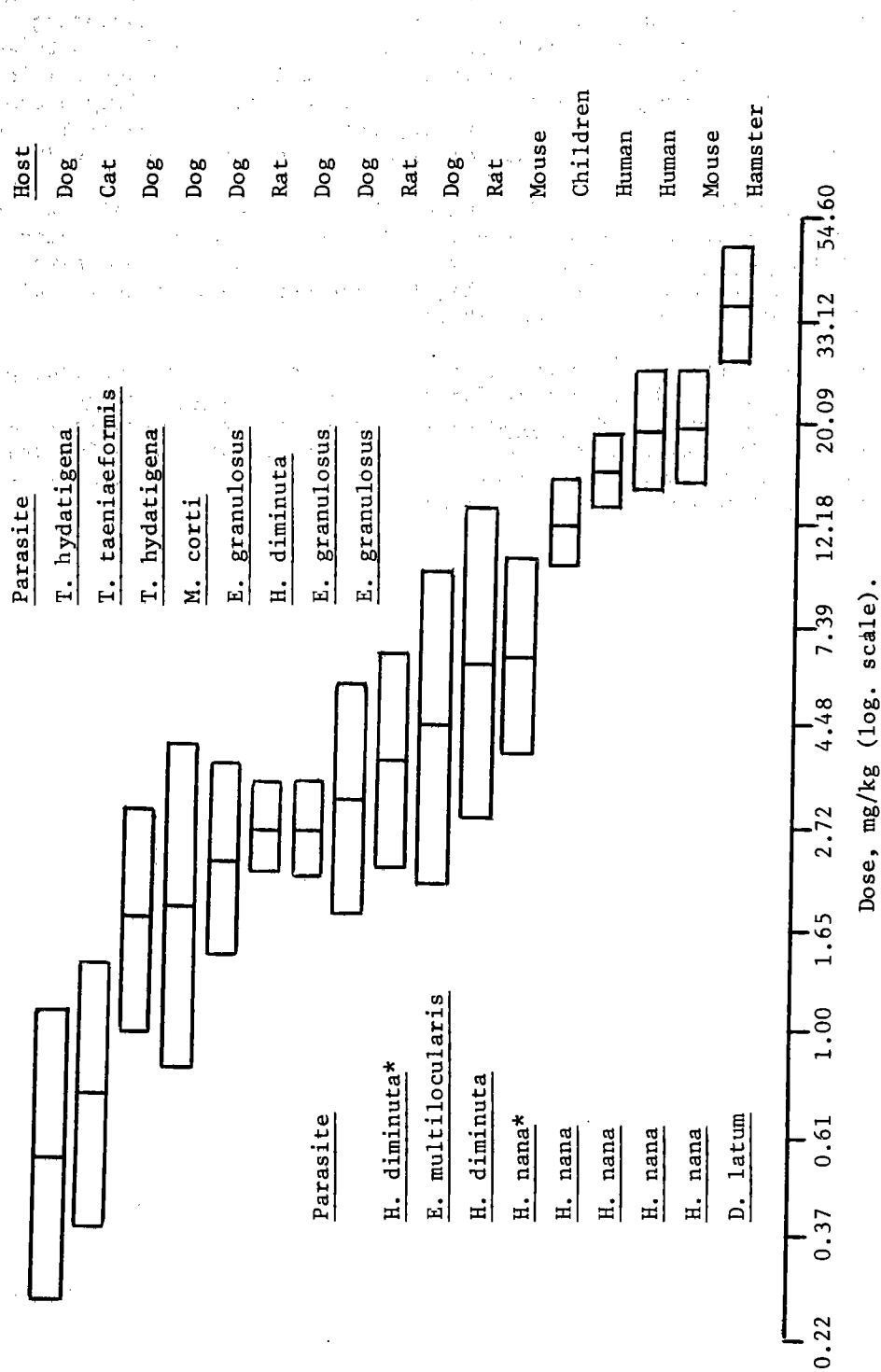


FIGURE 39 - The ED₉₀ with 95% of confidence intervals for praziquantel in the treatment of adult tapeworms of man and animals. It has been suggested that the dose rate against Taenia saginata and Taenia solium may be about 10 (5-15) mg/kg (After 71).

5.2.3 Other drugs that have shown some cestocidal effects

Antibiotics

Several antibiotics have shown quite strong cestocidal activity. One of the most important for the treatment of T. saginata taeniasis is paromomycin (Humatin, Monomycin A, Pargonyl) from Streptomyces rimosus var paromomycinus. This was discovered as a cestocide when tapeworms were eliminated following treatment of patients with amoebiasis (65, 66, 138).

Almost invariably high cure rates (90%) have been recorded in the treatment of T. saginata and T. solium taeniasis, although the ED₉₀ could not be estimated from the data presented (27, 39, 65, 66, 123, 138, 139, 153, 171, 172, 181). With regard to dose rate a 100% cure was achieved when the drug was administered in the treatment of T. saginata taeniasis with 50 mg/kg given on 5 but not 3 consecutive days (139). High efficacy was reported with a single dose at 75 mg/kg (27, 181) in a small number of cases. The drug appears to be well tolerated even by young children when administered for a period of 3-5 days at 15-45 mg/kg (171).

Toxicological reports do not suggest that the side effects such as diarrhoea and less frequently nausea and vomiting prevented patients from completing the treatment schedule (139) and it has been suggested that paromomycin can be regarded as the alternative to niclosamide for the treatment of taeniasis (125).

Mebendazole

Mebendazole (Telmin, Vermox) is methyl-5-benzoyl-2-benzimidazole carbamate. It has been shown to have a wide safety margin in animals and man and is extensively used in nematode infections. Several reports indicate a successful treatment of T. saginata and T. solium taeniasis at 200 mg twice daily for 4 days and at 300 mg twice daily for 3 days (13, 95, 128). However, poor results were achieved in one trial with a treatment schedule of 300 mg daily for 4 days (173). There is some evidence in animal models that efficacy is a function of particle size and this may be modified if agglomeration of particles occurs during the manufacture of the tablets (71). No evidence of any side effects has been reported with this short-term treatment schedule.

5.3 Drugs for the treatment of human cysticercosis

In the treatment of cysticercosis, there are three approaches: surgery, symptomatic treatment including the use of steroids and specific chemotherapy. Surgical and symptomatic treatment have been recently reviewed (35). This section deals mainly with chemotherapy in man, but also discusses the possible use of chemotherapy for the control of cysticercosis in animals.

A large number of studies have been reported on the efficiency of praziquantel against human cysticercosis (19, 28, 29, 30, 31, 32, 34, 75, 76, 81, 82, 83, 84, 132, 133, 134, 135, 136, 137, 154, 155). It was first demonstrated to be effective against subcutaneous cysticercosis and it has now been used in many cases of neurocysticercosis. However, in ocular cysticercosis the use of praziquantel may be contraindicated. In the case of subcutaneous cysticercosis, changes first appear at about 2 weeks after treatment with praziquantel (133, 134). The microtriches disappeared and vesiculation and degeneration of the cysticercal tegument occurred. It has been reported that the parasites die within 14 days of treatment (19). Many of the cysticerci disappear completely within 3 months.

To date, about 700 cases of human neurocysticercosis have been treated with praziquantel in 17 clinical centres in 8 countries in the American continent and in South Korea. Praziquantel was given in a daily dose varying between 10 and 75 mg/kg for 6 to 21 days; the majority of cases were treated with 30 or 50 mg/kg for 12 to 15 days. In about 80% of the treated cases the tolerance was good; in other cases some symptoms were observed. These were attributed to the host reaction to the killed parasite; in a few cases an acute intracranial hypertension (due to cerebral oedema or changes in CSF flow) appeared requiring specific emergency treatment. Clinical trial reports suggest that treatment with praziquantel produced good or satisfactory results in about 60% of the treated cases of human neurocysticercosis.

Although the use of praziquantel is considered as an important advance in the treatment of neurocysticercosis, many aspects related to the disease and its treatment need to be solved; such as the precise indications and contraindications for chemotherapy, the optimal dosage and duration of the treatment, concomitant use of steroids and the evaluation of efficacy of the treatment with praziquantel.

At present it is considered that praziquantel should be administered orally in a daily dose of 50 mg/kg BWT divided into 3 doses for 14 days to hospitalized patients (total dose = 700 mg/kg). The patient should be treated in a neurological ward under strict medical supervision during treatment and for a few days thereafter.

The final decision concerning treatment with praziquantel should depend on the individual, bearing in mind that calcified cysts do not benefit from praziquantel treatment and that asymptomatic cases may become symptomatic either because of the natural course of the disease or due to the changes in cysticerci or host reactions induced by treatment.

The clinician will also have to decide whether concomitant treatment with corticosteroids will be used to prevent immunological reactions, bearing in mind that high doses of steroids might activate other infections. If epileptiform manifestations occur, appropriate treatment with anti-epileptic drugs is essential.

Studies have been reported on the use of metrifonate (Trichlorphon) in the treatment of neurocysticercosis (167, 168, 170) but there is insufficient information on the efficacy of this drug in man and animals to make any recommendations.

5.4 Drugs for the treatment of animal cysticercosis (metacestocides)

In any consideration on the introduction of a larvicide as part of the package of control measures, cost-effectiveness and cost-benefits must be established. Where the concentration of larvae are likely to be high, as in bovine, ovine and porcine/epizootic-type outbreaks (for example cattle feedlots), there are likely to be considerable advantages in applying the drugs at the appropriate time (68,71). However, no field trials have as yet been reported on the practical application of larvicides.

Benzimidazole

A considerable volume of research has been undertaken to elucidate the value of benzimidazole compounds in the treatment of bovine cysticercosis. These include albendazole (42, 67, 108, 160) cambendazole (15, 111), fenbendazole (15, 52, 178), mebendazole (15, 24, 62, 89, 126) and oxfendazole (178). Other studies have been made with fenbendazole (12) and flubendazole (162) and mebendazole against T. solium in pigs (179) and with mebendazole against ovine and porcine cysticercosis caused by T. hydatigena (73, 86, 88, 103, 122).

It seems that with all these compounds, several treatments may be required before a reliable lethal effect can be achieved and the number of treatments at specified dose rates required to reach the ED₉₀ with a 95% confidence interval has not yet been determined. To be logistically practical in any mass treatment programme, a drug should kill almost all cysticerci when given on one or two occasions. Of the benzimidazoles so far tested, none qualify for general application in the control of bovine or porcine cysticercosis.

Praziquantel

Larvicidal activity was first reported in small animal models in 1975 (164, 165). Considerable information is now available on the efficiency of praziquantel in the treatment of bovine cysticercosis (15, 24, 33, 63, 84, 87, 89, 126, 159, 176, 177) as well as in the treatment of T. hydatigena, T. ovis and T. multiceps in sheep or pigs appropriately (16, 17, 69, 70, 72, 90, 122, 174, 175) but few studies have yet been reported on its efficiency against T. solium in pigs (40).

While strong lethal effects were shown with a single treatment in some cases, not all trials were successful.

Evidence has been reported that there is an age effect which modifies the efficacy of the drug. In the case of *T. saginata*, stronger lethal effects were obtained at 50 mg/kg against 3 month old larvae than against 4 week old organisms (63). This was also the case with *T. taeniaeformis*, where stronger lethal effects were achieved by treating the larvae at 7 or more weeks than at 4 weeks of age (163). In the case of *T. hydatigena* the single dose ED₉₀ with 95 per cent confidence intervals for 6 month old and aged organisms was estimated to be 13.1 (5.5-31.4) mg/kg and 6.1 (2.4-15.5) mg/kg respectively. Susceptible larvae not killed within the 95% confidence intervals of the ED₉₀ lost their ability to infect dogs. Below 6 months of age many organisms were killed, but the effects were not dose rate dependent within the dose rates 12.5 mg/kg to 250 mg/kg Figure 40 (69, 70, 72).

In most of the studies on cysticercosis, the drug has been tested when the larvae were 3 months old. The dose rates (with 95 % confidence intervals) that may be reliably used if the drug is applied at specific times post infection now requires to be defined for the treatment of bovine and porcine cysticercosis.

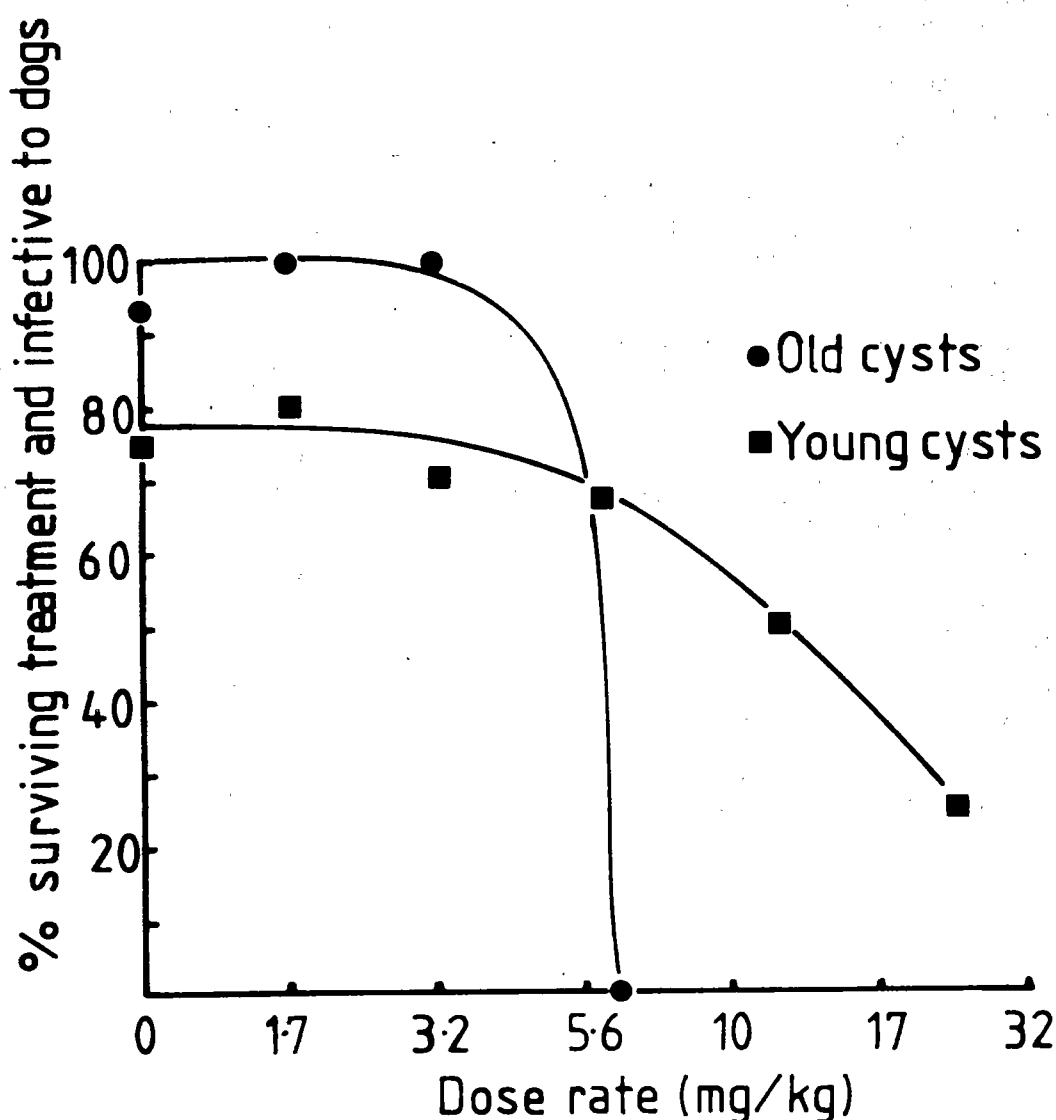


FIGURE 40 - Proportion of old and young surviving larvae of *Taenia hydatigena* still infective to dogs following treatment of sheep with praziquantel at specified dose rates (Courtesy, Hydatid Research Unit, New Zealand).

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CHAPTER 6 - HEALTH EDUCATION

6.1 Introduction

Health education can be regarded as the key factor in obtaining the commitment for, development of, and continuing involvement in a control programme. Proper health education should be principally oriented to: a) diminish the number of tapeworm carriers, thus lowering egg output; b) change attitudes, traditions, socio-cultural and behavioural factors that favour a high infection pressure from carriers; and c) educate people on the risks of human and animal cysticercosis on their prevention. This chapter summarizes the specific combinations of the different elements involved in health education against the cysticercoses: (i) target groups, (ii) information packages and methodologies, (iii) evaluation of the effects of health education upon taeniasis/cysticercosis control programmes.

6.2 Target groups

The general public, especially communities in endemic areas, have to be made aware of the danger to health as well as the economic importance of taeniasis/cysticercosis. Full use should be made of the mass media. All available means of informing each community should be used, but the most effective methods include discussions within small groups. In such discussions, the health worker (educator) suggests some kind of concrete action, for example, persuading tapeworm carriers to have treatment. Meetings of this kind have proved extremely useful in the initial phases of several echinococcosis control programmes. (Readers should consult the Guidelines on Echinococcosis/Hydatidosis Surveillance, Prevention and Control, VPH/81.28, as many of the problems of health education are similar for both infections) (4).

In securing community support and participation, it is useful to enlist the aid of: (i) opinion leaders who are identifiable in all communities; (ii) parents, especially mothers of children at risk; (iii) persons who have undergone treatment for taeniasis/cysticercosis or still suffer from this disease; (iv) persons who suffer direct economic loss because of condemned beef and pork.

An important group to be consulted in the early stages are national policy makers. Community support and involvement in the programme can often help to achieve a political commitment with appropriate funding. Cost-benefit studies are helpful in this regard.

In the operational phases of the programme, health education should continue, but special attention should be paid to the groups described below:

6.2.1 Persons likely to infect food animals

These include:

- (1) Farmers: butchering their own meat and producing meat for the market;
- (2) Agricultural workers;
- (3) Hunters, campers and tourists from the same country and from foreign countries.

6.2.2 Persons processing meats for human consumption

These include:

- (1) Protection of the public; (i) butchers; (ii) food handlers; (iii) small farmers; (iv) hunters;
- (2) Self protection; (i) food handlers and (ii) cooks and housewives.

6.3 Information packages to be disseminated

Information packages should be disseminated to:

6.3.1 Farmers

Farmers should be informed of the risks associated with the use of human sewage for fertilization and/or irrigation of pasture; they should be instructed on the benefits of providing effective toilet facilities for their own and worker's families. Farm workers share the same responsibilities as farmers, but because they move from farm to farm, they may contaminate several environments. They should be committed to a policy of: (i) having all cases of taeniasis reported and properly treated; (ii) using effective toilets when available; or, if not available, avoiding defecation in places accessible to susceptible animals or burying their faeces.

6.3.2 Campers and tourists

These groups are often exposed to taeniasis because they may eat raw or improperly cooked meat. They defecate in the fields or by the roadside and thus should be informed about the life cycle of taeniasis and advised to: (i) refrain from eating unsafe, raw beef or pork in countries where cysticercosis is endemic, (ii) inspect their faeces for tapeworm proglottids and report for treatment; (iii) use toilets when available, but if these are not available, avoid defecating in places accessible to cattle and pigs, or bury their faeces.

6.3.3 Hunters

They have responsibilities similar to campers and tourists in general, particularly in the use of uninspected meat from the killed animals as food for their families or for local consumers. Hunters should be advised to: (i) have wild pig meat properly inspected, and if it is found to be infected, to have this meat properly treated by cooking or freezing; (ii) if inspection is not feasible, to learn how to detect cysticerci, and (iii) cook the meat thoroughly and avoid tasting before it is cooked.

6.3.4 Butchers

Butchers should be advised to: (i) cooperate in the veterinary inspection to detect cysticerci, (ii) if veterinary inspection is not available, to detect cysticerci, and properly treat the infected meat; (iii) avoid tasting, eating or selling suspect, untreated raw meat.

6.3.5 Food handlers

Food handlers should be advised to: (i) look for cysticerci and use infected meat only if it has been previously treated by freezing or cooking; (ii) use suspect (uninspected) meat only if it has been previously treated by freezing or cooking; (iii) thoroughly clean hands, and all kitchen tools (e.g. knives, chopping-boards, etc.) which have been used in the preparation of the meat; (iv) avoid tasting raw or insufficiently cooked, infected or suspect meat.

6.3.6 Persons involved in home slaughtering

Some people raise cattle or pigs for home slaughter and distribute meat to their families or to local consumers. This may create urban foci as well as act to disseminate infection to rural areas. This is one of the activities where education is most needed in the village situation, as it is improbable that the carcasses are properly inspected.

Cattle and pig owners should be informed of the life cycle and the health risks to their families and to the consumers of the meat they produce. They should also be informed of the economic implications (possible closure of their small business by the health authorities and the loss of customers). Sometimes the best way to involve these animal owners is through their children, who can be taught the life cycle of these parasites at school.

These animal owners should be advised to: (i) prevent their animals from having contact with human faeces or materials directly or indirectly contaminated by them; (ii) have their animals inspected at slaughter but if this is not possible, to learn how to detect cysticerci in the meat; (iii) use the infected meat only if properly treated by cooking or freezing; (iv) clean all tools used to cut the meat, in order to prevent the transfer of cysticerci; (v) report and have treated all cases of taeniasis occurring to themselves or to their families.

6.3.7 Consumers, cooks and housewives

These people should be advised to: (i) purchase only inspected meat; (ii) if this is not possible, to consider uninspected meat as suspect and use it only after thorough cooking or freezing.

6.3.8 Persons at special risk of infecting livestock

People dealing with herds of animals should be encouraged to: (i) report and have their infections treated; (ii) use toilets and avoid contaminating the environment; (iii) consider their families and people living in the same environment and having the same food habits as being at risk, and to take the necessary precautions.

6.4 Education of community members in taeniasis/cysticercosis prevention

These people should be informed of the life cycles and of the public health and economic implications of these parasites. They should be encouraged to: (i) report and have treated all cases of taeniasis; (ii) insist that proper public and private toilets with effective sewage disposal are made available and are used; (iii) keep pigs in styes or behind fences; (iv) insist on the adequate meat inspection services.

6.5 The role of pharmacists

Pharmacists play an important role, as they sell taeniocides, often without medical prescription and/or are asked to diagnose taeniasis. They can be actively involved in health education particularly in the supply of educational materials. The educational curricula of pharmacists should include a course of lectures on diagnosis, treatment, prevention and control of taeniasis/cysticercosis.

6.6 The role of schools

Taeniasis/cysticercosis is an appropriate subject to be introduced into schools along with discussions on food hygiene, food habits, environmental sanitation, man/animal relationships, life cycles of the organisms and their zoonotic importance. In many endemic areas this is an important opportunity for education to reach isolated farms. The preparation of teachers to become active health educators should be encouraged.

6.7 Training of health workers and school teachers

As far as possible, health educators should be drawn from the community in which they will be working. Everyone involved directly or indirectly in preventing taeniasis/cysticercosis must carry out public health education. It is, therefore, essential that this subject should have an important place in staff training. Such training should be planned and preferably imparted by a specialist, who should also advise on the selection of appropriate educational methods and preparation of educational material suited to local conditions and to the various phases of the programme. The general training that health workers may have received in schools of public health also needs to be supplemented with briefing on the various aspects of the local situation.

It is useful to prepare and distribute a poster, booklet or manual dealing with the technical, administrative and educational aspects of the programme. This can then be used by all persons involved in the project, including lay members of committees or other groups set up to obtain public cooperation and support. A manual helps to avoid confusion caused by different answers to the same questions given by different people.

6.8 Further considerations

It is important that health education should be included in the control project from the very beginning and it should be closely linked to and coordinated with all its phases. A continuing evaluation of the impact and limitations of health education should be undertaken and modifications should be made as and when indicated.

The educational material and programme used should take into full consideration the beliefs, perceptions, behaviour, expectations and needs of the people (felt and unfelt). This highlights the need to carry out sociocultural and socioeconomic surveys to ensure that the information imparted will be accepted by each target group. There is a need to measure the impact of each educational programme to ensure that it does meet the needs and cooperation capabilities of the target group.

In developing countries there are special educational problems to be solved (1, 8). By and large, experience suggests that any initial health education should be closely integrated with the development of primary health care and be directed not specifically or only towards taeniasis and cysticercosis, but rather towards the development of (a) effective fresh water supplies; (b) safe toilets; (c) composting of human excreta and (d) training in elementary hygiene to ensure that once these necessities have been supplied, they are used. It follows that the elementary principles of sanitation must be developed and that the changes are accepted or, better still, requested by the community.

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CHAPTER 7 - IMMUNITY AND IMMUNIZATION

7.1 Introduction

Immunity to larval tapeworm infections plays an important role in the dynamics of transmission (Chapter 3).

Extensive studies have been undertaken to characterize the immune response to cysticercosis in man, cattle and pigs (10, 11, 12; 15, 21, 26, 27, 30, 35, 36). In part this has assisted in the development and evaluation of immunodiagnostic tests, but an additional long-term aim has been to develop vaccination procedures by which neonatal and adult infections might be controlled. While good progress is being made in research on immunization in animals, none of the procedures has yet reached the stage of being generally applicable in the field in either animals or man. The several problems which must be solved include the identification of an alternative to the human parasites as a source of immunogen, the large scale production of such material and the design of an immunization procedure, which will ensure freedom from infection to satisfy meat inspection regulations, and also modify the dynamics of transmission in the hyperendemic or endemic field situations.

7.2 Immunity in cysticercosis

7.2.1 Human cysticercosis

There is little doubt that immunological mechanisms participate in the events of human cysticercosis: most patients produce an antibody response (4), high prevalence may occur in immunologically deficient children (5) and low reactivity to PDP has been reported in terminal neurocysticercosis (6). However, there is no evidence that the immune reactions in neurocysticercosis are protective. Therefore, vaccination of humans with T. solium antigens is not recommended at present and, in fact, may invalidate the use of serodiagnostic tests and seroepidemiological data.

7.2.2 Bovine cysticercosis

Early studies in Australia (19, 20) indicated that complete immunity to reinfection developed following infection of cattle. Cysticerci derived from the initial infections were destroyed within 9 months and then resorbed, so that later, animals were clear of the infection. However, this situation does not pertain in Africa, for example, where cysticerci acquired by neonatal infection, possibly due to induction of immunological unresponsiveness (24, 25, 28, 29) may remain viable for several years, despite the fact that immunity to reinfection with eggs may be established by later contact with the parasite (8).

Experimental infections have confirmed these early data and have, in addition, provided valuable information on the antibody and cell mediated immunity responses to infection. For example, infections in fully immunologically competent cattle lead to an antibody response demonstrable by various serological tests within 2 weeks (1, 17, 23, 25) and this may persist for several months, reaching a maximum response about 2 to 3 months after infection (9). Antibody responses in neonatal animals are different: they are low or absent (8, 25) and remain so for several months.

Cell mediated immunity (CMI) responses have been followed in experimentally infected cattle and the various in vitro correlates of CMI, such as antigen induced blastogenesis of lymphocytes (14) and macrophage migration inhibition (2) have been demonstrated.

7.2.3 Swine cysticercosis

There have been very limited studies on the immunology of swine cysticercosis. Antibody responses have been demonstrated in experimentally infected swine (12) but there is a paucity of information on the susceptibility of previously infected pigs to reinfection.

7.3 Immunization in bovine cysticercosis

7.3.1 Passive immunization

The passive transfer of immunity by serum or colostrum and the immunoglobulin class of antibody responsible for protection has been demonstrated in metacestode infections of rodents (27, 36). Early studies with T. saginata in calves gave variable results, and specific studies to this effect in East Africa failed to show passive transfer of immunity from cows to calves (7), although the passive transfer of resistance to T. hydatigena and T. ovis in sheep with serum has been demonstrated (3, 10). The importance of neonatal infection has emphasized the need to control this type of infection, possibly by passive immunization.

Indeed, recent studies have shown that neonatal calves can be protected passively against T. saginata infection by feeding immune serum immunoglobulins or immune colostrum. Immunoglobulins obtained by the parenteral or intramammary injection of activated oncospheres of T. saginata into cattle (13). Further, cows vaccinated with antigens obtained from cultures of activated embryos of T. saginata produce colostrum which will induce high level of resistance to a challenge infection with T. saginata eggs in calves (13, 21, 22). Passive transfer of immunity to calves does not interfere with the development of active immunity when immunizing antigens are injected into calves at 8 - 10 weeks of age and which had received immune colostrum previously (22). Encouraging results were also obtained with heterologous antigens prepared from other taeniids, including T. hydatigena (22) and T. taeniaeformis (13, 16, 34).

7.3.2 Active immunization

Experimental immunization has been attempted using oral infection with X-irradiated attenuated eggs of T. saginata (30), parenteral injection of eggs (24) and artificially hatched oncospheres (32, 33). In some cases a high degree of artificial immunity was induced, in others a lesser degree of immunity occurred. In the case of injected eggs or oncospheres, immunity was most effective when a vaccinal colony of metacestodes became established at the site of injection, however, occasionally systemic distribution occurred.

These approaches have been superseded by the use of soluble and particulate preparations derived from in vitro cultures of activated oncospheres of T. saginata or related Taenia species. Thus encouraging data showing significant protection for cattle to experimental challenge have been obtained with such material from T. saginata (21) and T. taeniaeformis (13). The ability to induce immunity against bovine cysticercosis with non-human tapeworm material has obvious advantages. However, other workers have not been able to induce protection in cattle by in vitro derived antigens of T. saginata oncospheres (18, 31) and further work on this approach is necessary.

7.4 Immunization in swine cysticercosis

There have been no thorough studies of active or passive immunization in swine cysticercosis. It is possible that the approaches used in bovine cysticercosis would be of value.

7.5 Future prospects

Experimental data suggest that the development of an effective, practical vaccine against T. saginata is feasible though the provision of adequate amounts of antigen is a major difficulty at present. The demonstration that heterologous antigens may be used is encouraging, since these are more readily available than human-derived material. However, large-scale antigen production is likely to depend on in vitro culture of tissues on cell-lines (Appendix 5) and a critical development in vaccination will be the identification and isolation of the relevant immunogens. Techniques utilizing murine hybridomas and recombinant DNA may prove useful for this.

The prospects of a vaccine for T. solium in pigs is not good at present, mainly because of the shortage of antigen and lack of experimental data on the immune response of the pig to the parasite. Much more basic information on the immune response to T. solium is required before vaccination can be contemplated.

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CHAPTER 8 - SURVEYS, SURVEILLANCE AND CONTROL

8.1 Introduction

This Chapter takes account of the subjects described in the previous chapters and spells out a programme of integrated control.

Surveys are of fundamental importance to:

- establish the prevalence and geographical distribution of taeniasis/cysticercosis;
- obtain basic epidemiological data and an insight into the processes of transmission;
- provide base-line data for the subsequent establishment of control measures; and
- monitor control measures, continuing surveys (surveillance), provide the information on any changes in the prevalence brought about by the introduction of specific control measures or by such factors as changes in the standards of living or education or changes in animal husbandry and meat processing.

Surveys and surveillance may serve distinct purposes and require different approaches. Of fundamental importance to the success of taeniasis/cysticercosis control is the establishment of a long-term surveillance programme to act as an indicator of change. A surveillance programme has two main functions. The first is to identify problems requiring special attention; the second is to provide data monitoring progress, or the lack of it, in control. These measures include changes in prevalence of:

- adult tapeworm infections in man;
- larval tapeworm infections in livestock;
- larval tapeworm infections in man; and
- the extent of environmental contamination.

8.2 Planning and collection of data

For the establishment of a control programme against taeniasis/cysticercosis, the type of minimal base-line information that should be obtained is summarized in Table 20. This includes:

- the collection of data from two sources; (a) information from existing medical and veterinary services, and (b) specific surveys on the prevalence of infection in man and animals;
- documentation and evaluation of the methods used for the collection and processing of data on infections in man and animals;
- assessment of the age-specific prevalence and geographical distribution of human and livestock taeniasis/cysticercosis respectively;
- correlation of data on both human taeniasis and cysticercosis with occupation and other important epidemiological and sociological factors; and
- assessment of the economic losses caused by (a) human taeniasis and cysticercosis in terms of hospital costs, man-hours lost, total and partial handicap for work, and (b) condemnation or extra processing requirements for beef and pig meats in slaughterhouses and meat packing plants.

Methods used for the diagnosis of human taeniasis include: questioning of possible carriers for the presence of proglottids; the examination of perianal swabs and coprological

examinations. These are reviewed in Chapter 2 together with the methods used for the diagnosis of human cysticercosis and those used for the examination of carcasses at abattoirs.

Assessment of the prevalence and distribution of taeniasis and cysticercosis should be correlated with such factors as age, sex, profession, population density, feeding habits and human migration patterns as well as age, sex and movement patterns of cattle and pigs.

One of the important activities in surveillance is an active search for human carriers of Taenia in epicentres of animal cysticercosis (e.g. feedlot situations). Because the diagnostic techniques for detecting taeniasis may not be adequate, the treatment of suspected individuals both for diagnostic and curative purposes may be justified in an epicentre situation.

Studies on the contamination of the environment (soil, sewage) may be helpful for a better understanding of the various transmission patterns. This can be undertaken by grazing sentinel animals. Environmental studies should also be related to the examination of sanitary standards, human defaecation habits and the methods of animal husbandry (indoors/outdoors, natural/prepared foods).

Quantitative studies on the number of eggs in the faeces are of no value in determining the worm load in man, but they may provide useful information on the environmental contamination and the possible risks of cysticercosis to man and animals. Heavily infected pigs or cattle are likely to have become infected directly from a carrier by eating a proglottid or food highly contaminated with Taenia eggs, whereas light infections may occur from eggs spread more widely in the environment (see Chapter 3).

In general, pigs are good indicators of T. solium transmission in an area because they live less than one year and do not move as much as cattle. Also for the same reason, reductions in prevalence of pig cysticercosis can be used as an indicator of successful control of T. solium in man.

To implement effective surveillance, it is necessary to have an efficient identification system of animals that are slaughtered so that infected animals can be traced rapidly to the herd of origin. Without identification, the focus may remain undiscovered for long periods. However, there are obvious limits to this type of surveillance because of the wide dispersal of food animals during their lifetime.

If possible, a coded number tag should be fixed to each animal by the owner, purchaser or dealer before the animal is transported to slaughter. Animals sold through the auction systems can also be identified in this way. When large consignments are involved from a single herd or feedlot, individual identification is not necessary because records are kept by the transporter and management.

8.3 Ongoing control programmes

The life cycles of both T. saginata and T. solium were fully worked out in Germany between 1860 and 1880 and this led to the introduction of meat inspection as a method of control. Individual patients were usually treated with extracts of male fern and although there were no national control programmes, the improvement in meat hygiene and meat processing had a major impact on the prevalence of the parasites in many countries. Taeniasis in man was reduced to a minor public health problem in most of Western Europe and the USA, and in many countries T. solium has disappeared except for imported cases. The effect of these early control measures on T. saginata were less effective and localised epidemics of bovine cysticercosis have continued to occur even in areas where there are advanced methods of animal husbandry and a high standard of meat inspection.

The introduction of less toxic and more effective drugs made it possible to develop integrated programmes for the control of taeniasis/cysticercosis in countries where the infections were considered to be of both public health and economic importance. For example, in the USSR, where integrated control was used against both bovine and porcine taeniasis/cysticercosis (2). Elsewhere, the main emphasis in control has continued to depend

on meat hygiene, although special measures have been needed to control outbreaks of bovine cysticercosis in feedlot situations. In some countries legislation has been introduced to ensure that all personnel associated with the cattle industry are routinely tested to exclude infection with T. saginata.

Although it is of no public health significance, the nation-wide ovine cysticercosis (T. ovis and T. hydatigena) programme in New Zealand has provided a useful model to assess changes in the epidemiology of Taenia infections and also the limitations of mass drug treatment. The results of these trials are, therefore, described in this section as they are of relevance to an understanding of the epidemiological processes that may take place in human taeniasis control programmes.

8.3.1 Control programmes against T. saginata

In the USSR constructive efforts have been made to limit the prevalence of T. saginata (1, 3, 4, 10, 11). The first pilot experimental programme in T. saginata taeniasis/cysticercosis control was implemented in 1937-1938 in the Kirov area (4). It involved both medical and veterinary services. The primary aim was to provide environmental protection against egg dispersal. The methods applied were: (i) mass population treatment; (ii) sanitary supervision of human faecal disposal; and (iii) health education. The veterinary component involved meat inspection at meat packing plants, slaughterhouses and markets. Within 18 months there was a 2.5 fold reduction in the prevalence of taeniasis and cysticercosis (4).

During the decade 1950 to 1959, these methods were extended to cover all endemic regions of the USSR. Relatively simple measures of patient identification and treatment were applied. Certain problems were identified that were sometimes difficult to overcome. For example, in Burjat ASSR only 50% of infected persons were detected. Many concealed their infection because they were afraid of the treatment and the parasite caused few health problems. Thus, active cooperation of the entire population was not achieved. The drugs available then included the comparatively toxic extract of male fern and acrichin. In addition, these drugs were not ideal because it was necessary to hospitalize all treated persons. This involved a further limiting factor, particularly in hyperendemic zones, because the use of these drugs was contraindicated in quite a large proportion (up to 30%) of the affected individuals. Further, in-patient treatment involved a heavy load on hospital facilities. For example, it was calculated that in Uzbekistan, an in-patient establishment for 300 beds was required to accommodate all patients identified annually. Rural hospitals and urban establishments were unable to supply sufficient facilities and day-care centres had to be established. These difficulties seriously handicapped progress in taeniasis/cysticercosis control and it was difficult to transform from hyperendemic to endemic situations.

8.3.1.1 Treatment programmes involving safer drugs

During the 1960s, dichlorophen, niclosamide and their mixtures (Dichlosal or Trichlosal) were introduced for the treatment of T. saginata taeniasis. This permitted out-patient and home treatment and eliminated some of the costs and logistic problems of hospitalization. Once these drugs were firmly established, the importance of population participation and patient identification became evident. The inquiry method on its own was not regarded as effective and it had to be supplemented with faecal examination (see Chapter 2). The mixture of measures applied by the medical component included identification, treatment, health education and the development of a registration system to provide total surveillance.

The veterinary component included: (a) the expansion of sanitary measures in human settlements and on farms to protect pastures, stock routes and watering places; (b) the upgrading of killing facilities; and (c) expansion of meat inspection services to identify taeniasis foci through trace back procedures. This procedure permitted a more thorough search for untreated carriers.

It was determined by surveillance that farm workers were particularly important in transmission. It was found necessary for this group to be mandatorily subjected to special

investigation 2-4 times each year not only by inquiry but also by parasitological examination. Mass population check-ups were performed by household visits and inquiries were made by medical personnel. Cooperation of the population with the medical workers, was found to be essential for the successful implementation of the plan. Cooperation improved following the use of niclosamide and dichlorophen (5).

No regular mass inquiries were organized in towns which were not regarded as important foci, and also in towns where the tapeworm population prevalence was low. There, surveillance was restricted to individuals with gastro-intestinal symptoms.

Continuing educational campaigns were regarded as most important. During household visits discussions on taeniasis prevention were obligatory. Information on prevention was included in seminars, in technician-training courses and among persons working in cattle-feeding complexes.

In remote areas, where there were few laboratory facilities and transhuman farming practices were applied, cattle herders received treatment prior to, and after their return. For example, in Buryat ASSR and in Uzbekistan, obligatory niclosamide treatment was introduced from 1966 for all shepherds and members of their families who accompanied them during summer grazing. From 1970, regular niclosamide preventive treatments were applied as an obligatory measure for livestock workers on beef fattening farms throughout the USSR.

A similar programme was introduced in Bulgaria. Where these measures have been applied there has been a 4-fold reduction in bovine cysticercosis and the number of foci in which bovine cysticercosis had been identified declined by about half.

In summary, in the USSR medical measures directed against T. saginata taeniasis have received a high priority (4). It was reported in some areas that drug treatment together with the package of educational measures resulted in a 4-fold reduction in prevalence of the tapeworm in the adult population. For example, in the Buryat ASSR, the prevalence declined from 0.9% in 1965 to 0.02% in 1978. Similar results were obtained in Uzbekistan, Azerbaijan and in Dagestan ASSR. However, it was observed that progress in control was not uniform. Where this occurred, instead of surveillance with a discriminatory treatment programme, a non-discriminatory mass drug treatment programme was applied. In, for example, the Khiva region of Uzbekistan, this latter measure was found to be justified. A one-time mass treatment resulted in a 2-4 fold decline in taeniasis prevalence (4). Thus it was considered that mass treatment in hyperendemic areas with safe drugs was acceptable in reducing the tapeworm prevalence. However, the impact of these mass treatment programmes on T. saginata cysticercosis has not been published in detail.

8.3.2 Proposals for the development of control programmes against T. saginata in Poland and Czechoslovakia

8.3.2.1 Poland

Extensive studies on the epidemiology of T. saginata in Poland were undertaken between 1972 and 1977 (9). These resulted in the recommendations which follow for the control of taeniasis/cysticercosis and that have recently been implemented, but it is too early to determine their effectiveness.

These control activities against T. saginata include: (a) an active search for T. saginata taeniasis carriers on farms and in areas where heavy carcass infections requiring condemnation have been detected and also among persons associated with the cattle industry; (b) improvements in the systems of notification of taeniasis and cysticercosis including upgrading of data from laboratories and institutions undertaking post-mortem examinations; (c) the ready availability of cestocides; (d) expansion of training and supervision of meat inspectors; (e) improvements in working conditions for meat inspectors with upgrading of lighting in slaughterhouses and increasing the number of cuts through masseters, heart, tongue, diaphragm and shoulder muscles; and (f) freezing or boiling or destruction of cysticercotic carcasses according to the intensity of infection.

8.3.2.2 Czechoslovakia

The favourable conditions for massive infection of cattle with T. saginata from a single source have been created by the unsanitary habits of some farm workers and tourists in areas where the large scale concentration of cattle has been applied in modern feedlots. The following recommendations on cysticercosis control in cattle have been made:

(a) Detection of persons infected with T. saginata and periodic coprological examination of farm employees and the installation of lavatories at appropriate sites in all cattle plants; b) treatment of infected persons; c) accurate registration of patients; d) thorough meat inspection; e) close collaboration in reporting between medical and veterinary officials; f) heat treatment of meat in public food service departments; g) devitalization of eggs in sewage before application to pastures for long-term composting; h) separation of cesspools for human excreta from those of cattle; i) improvement of the environment by increasing the number of lavatories in an attempt to prevent contamination with eggs of pasture and fodder crops near motorways, camping sites, etc; j) supply of clean drinking water for cattle.

The programme of control of human taeniasis and bovine cysticercosis has now been implemented and is being regularly monitored by the medical and veterinary services (12, 14).

8.4 T. solium control programmes

In Europe, T. solium is rapidly disappearing due almost certainly to increased standards of living, hygiene and meat inspection, as well as changes in pig husbandry in the direction of large plants. It seems that large pig-fattening plants are much safer than cattle feedlots in avoiding epidemic outbreaks of cysticercosis.

A similar programme to that described in the USSR for T. saginata control has also been applied to T. solium infections in the USSR. The prevalence of infection in pigs has been reduced from 0.16 to 0.005% between 1960 and 1975 (1, 2).

8.5 Lessons based on control programmes using animal models

While drug treatment programmes are intuitively appealing, they may have some limitations especially if they form the major control measure. Animal model systems have been used to study the stability of the cysticercoses when subjected to drug treatment programmes directed against the adult tapeworms.

Two control trials have been reported on the limitations of drug treatment programmes directed over several years against T. hydatigena and/or T. ovis in dogs. These were the Many peaks trial in Western Australia (15) and the Styx Field-Trial in the South Island of New Zealand (5, 6). Neither achieved eradication, but in each trial the epizootiological pattern was transformed from an hyperendemic to a focal epidemic pattern.

Taenia hydatigena has been used to define the epidemiology, because the lesions can be clearly seen. Surveillance of T. ovis, like T. saginata, is only a herd or flock test and its epidemiology is more difficult to define as only a fraction of the infected carcasses can be identified during routine meat inspection. This section examines the reasons for the limited success achieved by drug treatment programmes. The explanations for the results obtained may be found to be useful for those planning programmes involving drugs for the control of bovine and porcine cysticercosis.

8.5.1 A 9-year study on a 3-monthly dosing programme

The trial area of the Styx Field-trial consisted of 11 farms covering an area of 30,000 hectares with a population of 100 to 150 dogs and 30,000 sheep (see Figure 10 in Chapter 3). During the first 9 years (1943-1951), all available dogs (except those for which the drug was contraindicated) were treated with arecoline hydrobromide every 3 months. There was no educational programme advising of the need to withhold sheep meat or offal to dogs. During the whole period T. hydatigena remained hyperendemic in the sheep population and almost all lambs became infected shortly after birth. The reasons for this include: (a) the

drug was used at an interval outside the prepatent period; (b) it was inefficient in the expulsion of tapeworms; (c) no educational programme was applied; and (d) arecoline was contraindicated for some animals, particularly pregnant bitches.

8.5.2 A 7-year study on a 3-monthly surveillance dosing programme plus an educational component

A similar treatment schedule was applied as in the first 9 years (1958-1964), but in this case there was an educational component and the owners were shown the tapeworms following the arecoline treatment and advised on appropriate preventive measures. During the whole period, the pattern remained hyperendemic in type and most of the susceptible lambs were parasitized within a few months after birth. Despite the educational component, most of the same reasons applied for the failure of the 3 monthly dosing programme, as in the first 9 years.

8.5.3 A 9-year study on a 4-weekly dosing programme with a relatively toxic drug

During this 9 year period (1965-1973), a strong drug dosing programme was enforced on all dogs every 4 weeks with bunamidine hydrochloride at 25 mg/kg. There were 47 epidemic outbreaks of T. hydatigena in lambs on individual farms and the pattern remained hyperendemic in type with almost all lambs becoming parasitized within the first year after birth. This failure was due to: (a) the occasional introduction of already infected dogs; and (b) the fact that the drug had to be used, for safety reasons, below the lower limit of the 95% confidence interval of the single dose ED₉₀.

8.5.4 A 7-year study on a 4-weekly dosing programme with safe drugs

Few breakdowns occurred because nitroscanate and praziquantel were administered within the 95% confidence limits of the ED₉₀. The pattern became focal epidemic in type on those few farms where breakdowns occurred with a spread of some eggs throughout the whole trial area. Most breakdowns were due to introduced dogs or the occasional drug failure. Where a breakdown occasionally occurred, superinfection and reinfection occurred in those sheep that had lost their immunity. Similar observations have been made with T. ovis when the trial was expanded to include the whole province.

It was concluded from this long-term trial with T. hydatigena that if drugs are used at an effective dose rate to control taeniasis where the parasite is hyperendemic, the pattern is likely to change first to endemic and then to epidemic foci. Heavy infections will occur at the epicentre and at the periphery some animals may become lightly infected. When breakdowns occur at intervals of about one year, reinfection and superinfection of the intermediate host may take place. Once the stage of an epidemic-type process has been achieved, non-discriminatory drug treatment programmes may no longer be considered cost-effective. When this occurs, surveillance with targetting of the control measures to the affected premises with discriminatory dosing then becomes possible. These trials imply that drug treatment programmes directed against the adult tapeworm are only likely to be successful if, at the same time, sanitary and educational measures are taken to ensure that eggs from untreated carriers cannot be dispersed into the environment (7).

8.6 Actions applied to epidemic foci of T. saginata infection

Generally epizootic-type foci occur where there is a low or no immunity in the intermediate host population. With T. saginata taeniasis/cysticercosis, many foci of bovine cysticercosis have been recorded from feedlots (see Chapter 3). Usually they involve an individual farm worker with taeniasis. However, epizootic foci may also occur in a pastoral or urban situation and involve one or several farms. These may result from promiscuous defaecation by an individual worker or visitor or result from the spraying of a pasture with sludge from a sewage farm (Chapter 3). These are the easiest epidemiological situations to prevent a recurrence, but are difficult to anticipate.

8.7 Recommended control

The first step in determining the management strategies is to determine whether or not the objective is to achieve eradication or sustained control.

An accepted definition of eradication is the purposeful reduction of specific disease to the point of continued absence of transmission within a specified area by means of a time-limited campaign (16).

Geographical eradication programmes are well known with such veterinary diseases as piroplasmiasis and in the medical field with smallpox (13). In an evaluation of the world-wide attempts to eradicate smallpox, six preconditions were found to be essential. These were:

1. there should be a main tool (control measure) completely effective in breaking transmission, simple in application and relatively inexpensive;
2. the infection should have epidemiological features facilitating case detection and surveillance in the advanced stages of the programme;
3. the infection must be of recognized socio-economic importance both nationally and internationally;
4. there should be a specific reason for eradication rather than control of the infection;
5. adequate resources must include finance, administration and operational facilities;
6. socio-ecological conditions must favour the performance of the attack measures (absence, or only a small extent of adverse factors of human behavioural characteristics unfavourable to the effective application of the attack).

Compliance with all six preconditions is required in order to make a positive decision to eradicate an infection in a specific situation. However, it may be possible to tolerate a certain weakness in one component if this is compensated by a particularly favourable set of criteria in another precondition.

For T. saginata and T. solium taeniasis/cysticercosis, the preconditions for eradication sensu stricto are rarely met with in any country so that a realistic objective in most situations will be control rather than eradication. In this Chapter, emphasis is given to the various control measures which may be applied under the very different socio-economic and epidemiological situations described in these Guidelines.

8.7.1 Justification and motivation to introduce a control programme

Human taeniasis and cysticercosis caused by T. solium obviously must have a high national priority because it is a life threatening disease with obvious effects on the health and social care budgets of countries where it is prevalent. Unfortunately, T. solium infections are endemic in both rural and urban situations in some countries that have limited resources to introduce and sustain control programmes. Human T. saginata taeniasis and bovine cysticercosis cannot be regarded as life threatening. It is prevalent in hyperendemic form in developing countries where health resources are also limited for control, but where there is a great local demand for animal protein and for developing an export meat industry. However, it is present in endemic and epizootic forms in countries with well developed agricultural systems and in the latter form it may produce socio-economic losses, particularly in large livestock feedlots.

The potential spread of both T. saginata and T. solium through meat export and human migration also provides reasons for the development of preventive control strategies.

8.7.2 The objectives of a control programme

A primary objective may include eradication in a selected area and this may be possible with limited foci of T. solium in areas where there are efficient sanitary services. Theoretically, this goal might be achieved either by a massive nation-wide effort and long-term action and/or by indirect changes in the environment, social life and economic advancement, especially through changing animal husbandry methods. So far, there are no examples of the effective eradication of T. saginata through national control programmes and this final objective seems to be unrealistic. However, T. solium has almost completely disappeared in most of western Europe due mainly to changes in meat hygiene standard and in local sanitary and economic conditions.

A second objective would be the reduction of the existing high level of transmission both in human and animal populations. Consideration should be given to achieving this objective by intensifying and improving the control measures within the already existing medical and veterinary health service systems. These include: (a) effective meat inspection; (b) free, safe and easy treatment of human carriers; (c) special health and sanitary education; and (d) introduction of effective latrine systems in the many situations where environmental contamination with eggs is known to take place.

A third objective would be to stop or prevent epidemics. Specific control steps in feed-lots situations and ranches have been demonstrated to be effective. However, control measures have been less effective in Irian Jaya in Indonesia where there has been an epidemic of human taeniasis and neurocysticercosis.

8.7.3 The strategies required for the introduction and continuation of control programmes

In Chapter 3 it was recorded that the host-parasite relationships of taeniid tapeworms are complex. In addition, social customs, economic developments and changes in animal production practices modify these relationships. During the past few decades these factors have led to an increase in T. saginata and a reduction in T. solium in some parts of the world. Both T. saginata and T. solium are relatively stable parasites having a high egg production, massive egg dispersal and long egg survival time. In addition, there is a strong immunological regulation of the number of cysticerci in cattle. This wanes in the absence of stimulation by continuing egg ingestion.

Different control strategies are required for T. saginata taeniasis/cysticercosis, for: (a) hyperendemics of pastoral type; (b) endemics of pastoral or urbanized type; and (c) epidemics of feedlot and pastoral types.

In T. solium taeniasis/cysticercosis, the epidemiological patterns have not been clearly distinguished. However, it would appear that the hyperendemic type, involving circumscribed foci with sporadic-type infection at the periphery of each focus, predominate in many of the endemic areas.

The strategies selected for T. saginata and T. solium taeniasis control will vary according to the national health and economic priorities and the realistic possibilities to carry out a successful programme. Most of the control and preventive measures are well known and belong to the categories covered by generally accepted hygiene measures described in these Guidelines and in the FAO/UNEP/WHO Guidelines on Echinococcosis/Hydatidosis Surveillance, Prevention and Control, WHO Document VPH 81/28, Geneva 1981.

Flow charts, based on the known biological parameters, have been constructed to identify methods that are already available for application as well as those that may be developed in the future for the control of T. saginata and T. solium taeniasis/cysticercosis (Figure 1). The usefulness of each control measure or group of measures will depend on the epidemiological and ecological factors operating in each endemic area or epizootic focus.

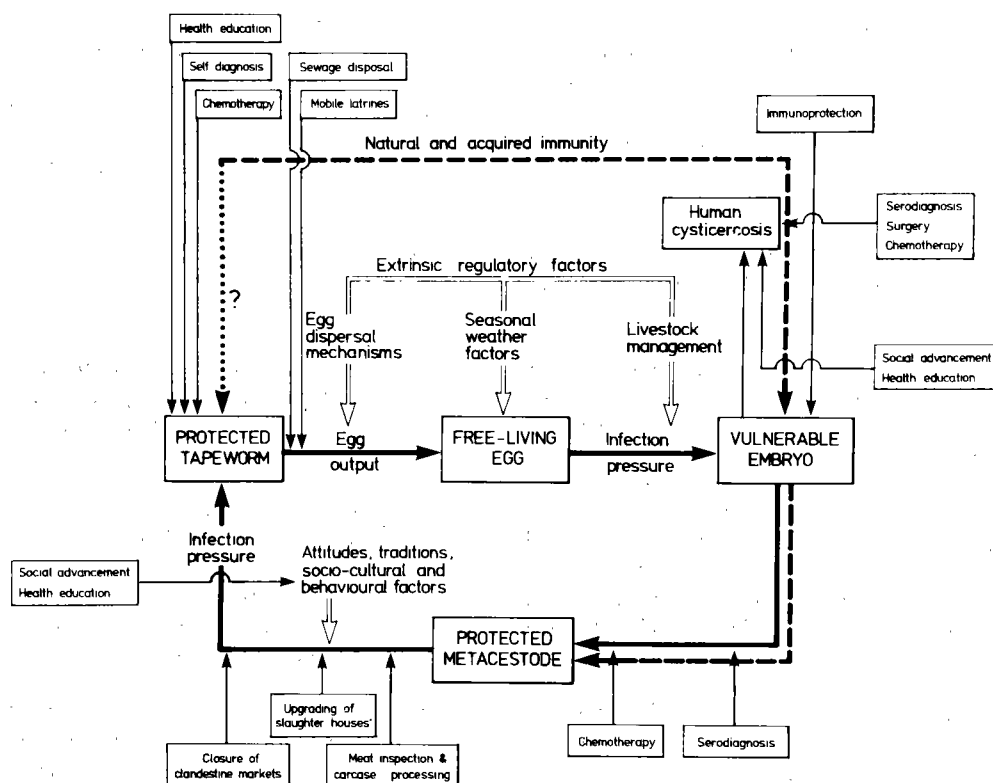
8.7.4 Control measures applicable to different epidemiological situations

The importance of health education and the role of sanitation have been pointed out in Chapters 3 and 6. Both of them may have a very positive impact on the programmes irrespective of the local epidemiological situation. Other control methods will differ depending on the epidemiological problems described in Chapter 3. In the following account of the different types of epidemiological situations, it is necessary to recognize that they are not fixed categories and that during the control programme the situation may change from one category to another.

8.7.4.1 Hyperendemic pastoral *T. saginata* infections

In hyperendemic pastoral *T. saginata* infections (Table 2), there is frequently a high prevalence of infected humans and cattle and the environment is heavily contaminated with eggs. Almost all cattle are infected as calves and are immune to superinfection. An example of this type of epidemiology is seen in the Masai cattle husbandry systems in East Africa (see Chapter 3).

Here, emphasis should be placed on the diagnosis and treatment of human infections through primary health care systems as a routine everyday but long-term activity of the medical services. It is also essential as part of the veterinary services to build up the meat inspection services and provide adequate government controlled killing facilities and reduce the possibility of clandestine slaughter and marketing. Encouragement should be given to research institutes to carry out surveys to define the important epidemiological and socio-ecological factors involved in transmission. Under these conditions, a mass dosing campaign is unlikely to have much effect on transmission.



8.7.4.2 Endemic urban T. saginata infections

In this situation there are usually only a few infected individuals, but they are responsible for contaminating the environment with small numbers of eggs over a wide area e.g. through sewerage systems and other dispersion agents between the urban and rural environment. Cattle may become infected at any age and may be superinfected. This type of transmission has been reported from Poznań province in Poland. Here, the detection and treatment of human carriers should form an active part of the normal health services. Upgrading of sewerage systems and the effective treatment of sewage should be undertaken and farms in the endemic area should be provided with effective lavatory systems as part of the health services. The use of sewage, sludge and effluent for agricultural purposes should be prohibited, unless it is heated at 55°C for 2 hours or stored for more than one year. Upgrading of meat inspection services and surveillance with traceback of infections to their source should form a priority for the veterinary services.

A mass dosing programme of the rural community in this situation is not justified on cost-benefit grounds, but every effort should be made to encourage the reporting of cases and the provision of free treatment.

8.7.4.3 Epidemic (feedlot) - T. saginata infections

These may occur in two ways. First, by direct contamination of the environment with eggs by unhygienic toilet habits, and second by the feeding of cattle on food from egg-contaminated pastures.

In the first situation this can be prevented by routine tests of all staff for tapeworms at regular intervals as part of a health care programme for agricultural workers. Here also, regular non-discriminatory treatment of all staff is justifiable as an additional precautionary measure. Visitors should be strictly supervised. Another precautionary measure is the installation of sufficient toilets with effective drainage for the disposal of eggs, even though many of the eggs will be dispersed due to the free escape of the proglottids. Human and cattle effluent systems must be separated and fresh water supplies provided.

In the second situation, cattle fodder should not be obtained from pastures which have been fertilized in the previous 12 months with human sewage. Alternatively, high temperature processing of grass meal or pelleting may be applied. As part of a nationwide health measure, lavatories should be made available at scenic and picnic areas to take account of the needs of tourists and others.

The public health value of non-discriminatory treatment of cattle with a larvicide to reduce the chances of light infections escaping detection at meat inspection once an outbreak has been detected, requires investigation.

8.7.4.4 Hyperendemic T. solium infections

These are essentially focal and result from inadequate or no toilet facilities at the village level, together with the eating of undercooked and uninspected pig meat. The introduction of effective lavatory systems and clean water supplies must be regarded as part of the long-term aims of primary health care services. Once a focus has been identified by survey, a mass treatment programme of taeniasis of the affected community is justified. Unless appropriate action is taken public health education may have the undesirable effect of encouraging the population to sell pigs to uninfected villages and thereby spread the parasite over a very wide area.

On the veterinary side, every effort should be made to provide meat inspection services which cover the home slaughtering and preparation of pig meats for feasts or other purposes. In confined foci the veterinary authorities might consider replacing the whole pig population. Once a focus has been eradicated, sentinel pigs can be introduced to identify any breakdown.

8.7.4.5 Endemic rural and urban T. solium infections

These patterns are found in countries with inadequate slaughtering, and where meat inspection services are inadequate, and where clandestine slaughter and sale is the rule rather than the exception. A fundamentally important step to lower the prevalence in these situations is health education and the detection and treatment of carriers.

On the veterinary side, there is a need to bring slaughtering facilities and meat inspection to high standards and prevent the clandestine sale of uninspected pig meat. The development of surveillance techniques to a high level of efficiency to detect foci of infection is important. Here encouragement should be given to research institutes and universities to carry out surveillance projects defining geographical distribution and the factors involved in the variations in prevalence.

TABLE 20 - Surveillance activities in prevention and control programmes.

AIM OF THE SURVEY	HUMAN TAENIASIS	HUMAN CYSTICERCOSIS	ANIMAL CYSTICERCOSIS	ENVIRONMENT
A. To establish the prevalence & geographical distribution of infection A1. From existing medical & veterinary services data (may be incomplete)	morbidity reporting (cases diagnosed and/or treated); amount of taeniacides used; cases detected by mass coprological examinations for intestinal parasites	morbidity registration; morbidity reporting (cases diagnosed and/or treated in hospitals; serological or CTS laboratories); cases detected by postmortem examination	routine meat inspection data number of carcasses condemned, frozen or boiled	
A2. From specific surveys in some samples of population	Mass diagnosis by questioning anal swabs & coprological examinations	mass diagnosis by serological techniques	specific diagnostic techniques in slaughtered animals (extended cuts, serological tests)	
B. To obtain basic epidemiological data & an insight into the process of transmission	A2 plus diagnostic treatment; differentiation of species; study of migration; study of eating habits; an active search for Taenia carrier in an area	A2 plus study of sanitation level & other fecalborne infections	A2 plus identification of animal by marking; study of feeding animals; distribution of infected animals by trace-back technique; distribution of infected animals in an area	Taenia eggs in sewage, soil & dust; study of sanitation level distribution of infection in different ecological zones
C. To provide base-line data for subsequent establishment of control measures	mass or selective treatment of taeniasis in a pilot study		effect on prevalence of pig cysticercosis within a year	
D. To monitor introduced control measures			As C	

TABLE 21 - Summary of the epidemiology of taeniasis/cysticercosis.

Pattern of infections	in man	in cattle	in pigs
<u>T. saginata</u>			
1. Hyperendemic, pastoral type	+++	+++	
2. Endemic, urban type	+	+	
3. Epidemic, feedlot type (focal)	+	+++	
<u>T. solium</u>			
4. Hyperendemic type	+++*		+++
5. Endemic type	++*		++(+)
6. Sporadic (introduced)	(+)		(?)
<u>T. saginata and T. solium</u>			
7. Mixed endemic type	++	++	+

+++ high; ++ moderate; + low; (+) sporadic; (?) possible.

* refers to both taeniasis and human cysticercosis

8.7.4.6 Sporadic or introduced T. solium infections

The finding of a sporadic case of T. solium infection, either in man or pig meat, in areas supposed to be free from this infection, as in Europe or the United States, calls for an immediate investigation. Actions, such as quarantine or slaughter should be taken to prevent the spread of infection.

8.7.4.7 Endemic mixed T. solium and T. saginata infections

In areas where T. solium and T. saginata co-exist (Table 21) the programmes should deal with both infections together, as the differential diagnosis between them may be difficult at the primary health care level.

8.7.4.8 Conclusions

The emphasis on the particular methods employed may change during the programme. For example, the experiments in animal model systems have shown that when an extensive mass chemotherapy lowers the prevalence from an hyperendemic level to a low endemic one, the risks of epidemic outbreaks increase. At this stage the preventative components of the control programme become especially important.

8.7.4.9 Summary of procedures that may be used in control programmes

1. Legislation

Legislation may be necessary to allow the following: (a) compulsory examination of all personnel associated with the cattle industry as a regular routine; (b) to prevent the marketing of uninspected meat; (c) to prevent the concealment of taeniasis; (d) to notify cases of taeniasis/cysticercosis; (e) to enable mass treatment of taeniasis; (f) to provide "trace-back" and "trace-forward" systems for cysticercosis in slaughterhouses; (g) to instruct veterinary and medical services to proceed to specific actions to control and prevent taeniasis/cysticercosis; (h) to register safe drugs and make them available; (i) to install specific hygiene measures at slaughterhouses, farms, spas, markets, restaurants and tourist areas; and (j) to reduce indiscriminate defaecation.

2. Surveys and surveillance

Medical activities will include: (a) discriminatory and non-discriminatory medical and laboratory examinations for taeniasis; (b) laboratory serological, radiological and autopsy data collection and analysis; and (c) inspection of levels of sanitation.

Veterinary activities will include: (a) meat inspection in slaughterhouses; (b) "on-farm" hygiene investigations; (c) development of "trace-back systems; (d) use of sentinel animals; and (e) improvement of facilities at abattoirs.

3. Education

Education of medical importance will include: (a) teaching self diagnosis of taeniasis; (b) encouragement of early treatment; (c) promotion of individual preventive measures by proper feeding habits; (d) encouragement of general hygiene education; (e) dissemination of relative information to schools and universities; (f) formation of local interest groups; and (g) use of mass media in education.

Veterinary educational activities will include: (a) advising on farm hygiene; (b) on the importance of meat inspection; (c) the formation of local interest groups; (d) the use of mass media in education; and (e) the development of special educational programmes for farmers and workers in the meat industry.

4. Ecological and environmental measures.

These include: (a) improving sanitation throughout the country, particularly to avoid open-air defaecation by tourists and farm workers; (b) improving sewage systems; (c) improving animal husbandry methods; and (d) protecting pastures, stock routes and watering places.

5. Preventive activities

These include: (a) discriminatory and non-discriminatory treatment programmes; (b) inspection of meat sale outlets; (c) confiscation of uninspected meat and condemnation or appropriate treatment of infected material; and (d) inspection of meat sale outlets.

8.7.4.10 Summary of actions in a short-term control intervention in highly endemic areas of *T. solium* infections*

1. Justification for an intervention by a survey:

(a) high prevalence of human cysticercosis based on hospital records, on serological investigations in samples of out-patients and on high prevalence of epilepsy (or burns);

* The control intervention of taeniasis/cysticercosis is suggested to be practised in a small pilot project first before being organized on a large scale because there is so far little experience in the world in the community-oriented control of human taeniasis.

(b) high prevalence of porcine cysticercosis based on meat inspection data and on in vivo examination for cysticerci;

(c) high prevalence of human taeniasis based on questioning and coprological examination of population subsamples and on local medical services information including amount of taenicides used locally, etc.

2. Preparatory stage of intervention:

(a) promotion of community cooperation in order to understand the aims of intervention, collaboration on better sanitation and help on specific national actions (meat inspection, treatment of people);

(b) cooperation of local medical services on individual contra-indications for mass-treatment, on distribution of taenicides, on monitoring of possible side effects, on evaluation of mass-treatment;

(c) cooperation with local veterinary services on establishing local meat inspection points, on registering all pigs in the area, on restriction of pig movements, on proper handling of infected carcasses;

(d) cooperation with local administration on human and pig population surveys, on improvement of local sanitation;

(e) development of a team of specialists for designing control intervention (parasitologist, epidemiologist, veterinarian and public health administrator, etc.);

(f) purchase of an adequate amount of a taenicide.

3. Community oriented treatment of taeniasis in all infected people together with all people eating raw meat, or all above 10 years of age, etc. Repetition of community-oriented treatment programme at appropriate intervals.

4. Evaluation of the effect of mass-treatment for taeniasis by surveillance of all local pigs slaughtered.

5. Care-oriented control of taeniasis/cysticercosis (if hyperendemic situation changes to epidemic foci) by active search for human tapeworm carriers in a focus of pig cysticercosis.

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APPENDIX 1

WORLDWIDE DISTRIBUTION OF TAENIA SOLIUM AND
TAENIA SAGINATA CYSTICERCOSIS IN
ANIMALS IN 1982

(extracted from FAO/WHO/OIE Animal Health Yearbook, 1982)

CODE

ANIMAL GROUP

02 bov: bovine (including buffalo)
08 fau: wild fauna
10 sui: swine

DISEASE INCIDENCE

- Not recorded; obviously not present
(-) Not recorded; probably not present
Year last occurrence: below symbol.
0000: never
? Suspected but not confirmed
(+) Exceptional occurrence
+ Low sporadic incidence
++ Moderate incidence
+++ High incidence
... No information available
+/- Disease much reduced, but still exists
+o Confined to certain regions
+ = Mostly in imported animals
+' Disease only recently recognised in country
+ Seasonal occurrence
+.. Disease exists; distribution and incidence entirely unknown

DISEASE CONTROL

test Systematic testing under official control scheme
Cn Control of non-vertebrate vectors
Cr Control of wildlife reservoirs
P Prohibition of imports from infected countries
Q Quarantine, movement control and other precautions at frontier and inside the country
Qf Quarantine and other precautions at frontier
Qi Quarantine measures and movement control inside the country
S Slaughter policy
T Treatment (therapeutic and preventive)
Tp Preventive treatment
Tt Therapeutic treatment
V Vaccination
* Notifiable disease

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Afghanistan	-	+
Albania	(+)	-
Algeria	-	+o
Angola	+++	++
Antigua	-	-
Argentina	(+)	++
Australia	(+)	+
Austria	(+)	+
Bahamas	(-)	(-)
Bahrain	-	+ + =
Bangladesh		++
Barbados	-	-
Belgium	-	(+)
Belize	+o	(-) 0000
Benin		++
Bermuda	-	-
Bhutan	+	(-)
Bolivia	+	+
Botswana	(-)	+++
Brazil	++	+
Brunei		
Bulgaria	-	(+)
Burma	++	+

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Burundi	++	++
Cameroon, United Republic of	++	++
Canada	(+)	(+) Qi*
Cape Verde	+ n 1	?
Central African Republic	+	++
Chad	+	+
Chile	+	+
China		
Colombia	+..	+
Comores	-	...
Congo	++	+
Costa Rica	+	(+)
Cuba	+o	+
Cyprus	-	-
Czechoslovakia	+ *	+ *
Denmark	-	-
Djibouti	-	+
Dominica	-	-
Dominican Republic	-	++
Ecuador	+++ *	(+) *
Egypt	+	+
El Savador	++ *	++ *

n 1 - Confirmed only in abattoirs; mostly in animals from herds of traditional farming.

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Ecuatorial Guinea		
Ethiopia	-	+++
Falkland Islands (Malvinas)	-	-
Fiji	-	-
Finland	-	+
France	-	++
French Polynesia	-	-
Gabon
Gambia	+	+
Germany, Democratic Republic of	(+)	+
Germany, Federal Republic of	(+)	+
Ghana	++	++
Greece	(+)	(+)
Grenada	(-)	(-)
Guinea	(-)	++
Guinea-Bissau	+++	+++
Guatemala	+++ S*	++ S*
Guyana	-	-
Haiti	+	+
Honduras	+++	+++
Hong Kong	++	+
Hungary	(+)	(+)
Iceland	-	-
India	+	++
Indonesia	+o +	(+)

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Iran	(-) n 2	+
Iraq	...	(+)
Ireland	- n 3	+ n 3
Israel	-	(+) n 3
Italy	(+)	(+)
Ivory Coast	+++ +o	+++
Jamaica	-	-
Japan	- n 4	- n 4
Jordan		++
Kampuchea, Democratic	++	++
Kenya	- 1954	++ n 5
Korea, Republic of	+/	+..
Kuwait
Lao People's Democratic Republic	+++	++
Lebanon	++ T	++ T
Lesotho	(+)	+
Liberia	+..	+
Libyan Arab Jamahiriya	-	(+)
Loro Sae (formely Portuguese East Timor)	++	(+)
Luxembourg	(-)	+

n 2 - 08 fau: (+)

n 3 - Controlled at meat inspection

n 4 - Controlled by the Food Sanitation Law and the Slaughter House Law which are covered by the Ministry of Health and Welfare.

n 5 - Controlled at meat inspection.

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Macau	+ = n 6	+ = n 6
Madagascar	+	(-) Qf
Malawi	+	+
Malaysia (Peninsular)	-	(-) 1977 n 7
Malaysia (Sabah)	-	-
Malaysia (Sarawak)	(+)	-
Mali	++ T	++ T
Malta	-	-
Mauritania	-	+
Mauritius	-	-
Mexico	++ *	+ *
Mongolia		
Morocco	(-)	++
Mozambique	++	++
Namibia	+	++
Nepal	++	++
Netherlands	-	(+)
New Caledonia	(-)	(-)
New Zealand	-	(+)
Nicaragua	+++	++ T

n 6 - 02 bov, 10 sui: Found mostly in slaughter stock.

n 7 - One case in 1976 in an animal imported for slaughter; detected at meat inspection; carcass condemned. Not recorded in national livestock.

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Niger	+	+
Nigeria	+++ PST n 8	++ PST n 8
Norway	- *	+ *
Oman		
Pakistan	-	-
Panama	++	(+)
Papua New Guinea	- 0000 Q*	- 0000 Q*
Paraguay	+	++
Peru	++	(-)
Philippines		
Poland	(+)	(+)
Portugal	(-)	(-)
Qatar	-	(+) T
Réunion	-	-
Romania	(+) S	(+) S
Rwanda	+++	++
Saint Lucia	(-)	(-)
Saint Vincent	-	-
Samoa	(-)	(+) n 9
Saudi Arabia	-	-
Senegal	...	++

n 8 - Abattoir returns.

n 9 - In imported cattle only.

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Seychelles	-	-
Sierra Leone	...	+
Singapore	-	-
Solomon Islands	-	-
Somalia	-	(+) n 10
South Africa	++	++
Spain	(+) +0	-
Sri Lanka	(+)	(+)
Sudan	-	+
Suriname	-	-
Swaziland	++ Tp	+++ Tp
Sweden	- *	+ *
Switzerland	-	+
Syrian Arab Republic		++
Tanzania, United Republic of	(-)	++ n 11
Thailand	+ S	+ S
Togo	+++	+

n 10 - Controlled at meat inspection.

n 11 - Controlled at meat inspection, and treatment of infected humans.

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Trinidad and Tobago	-	-
Tunisia	- 1958	++
Turkey	-	+++ Cn
Uganda	+++	+++
Union of Soviet Socialist Republics	(+) Cr	(+) test STp
United Arab Emirates	-	-
United Kingdom (Great Britain)	-	+
United Kingdom (Isle of Man)	-	(+)
United Kingdom (Channel Islands)	-	-
United Kingdom (Northern Ireland)	- 0000 n 12	+ n 12
United States of America	+	+o Tt
Upper Volta	...	+
Uruguay	+	+
Vanuatu, Republic of (formerly New Hebrides)	-	-
Venezuela	+ n 13	+ n 13
Viet Nam	++ S	++ S
Yemen, Arab Republic		+ =

n 12 - Control at meat inspection.
n 13 - Confiscation at abattoir

Country	<u>Cysticercus</u> <u>cellulosae</u> 10 sui	<u>Cysticercus</u> <u>bovis</u> 02 bov
Yemen, Democratic	-	+ =
Yugoslavia	-	(+) Tp*
Zaire	++	++
Zambia	+ n 14	+ n 14
Zimbabwe	+	+

n 14 - Affected carcasses condemned at abattoirs. Situation in animals slaughtered outside abattoirs not known.

APPENDIX 2

OTHER TAENIIDS OF OCCASIONAL ZONOTIC IMPORTANCE

Taenia ovis Cobbold, 1869

This is a common tapeworm of dogs and carnivores in most parts of the world. The intermediate hosts are primarily sheep and goats. The cysticercus (Cysticercus ovis) has been found in the human spinal cord in a sheep breeding area of the Soviet Union.

Taenia hydatigena Pallas, 1766

The life cycle is similar to T. ovis. This parasite has been reported in hepatic tissue.

Taenia crassiceps Zeder, 1800

This occurs in foxes, coyotes, etc. and the cysticercus (Cysticercus crassiceps) occurs in various rodents in North America and Europe. The infection has been reported in a human in Canada.

Taenia multiceps Leske, 1780

This occurs in the small intestine of the dog and other carnivores throughout the world. The intermediate stage is a coenurus (Coenurus cerebralis) and develops in the brain of sheep and other ungulates and has been recorded in man.

Taenia serialis Gervais, 1847

This is the tapeworm of the dog and fox with a cosmopolitan distribution. Intermediate hosts are lagomorphs, in which a coenurus (Coenurus serialis) develops in the subcutaneous tissues. Human infection has been reported.

Taenia krabbei Moniez, 1789

This is a tapeworm of wild carnivores and the dog in northern countries. The intermediate stage (Cysticercus tarandi) occurs in the muscles of reindeer and other wild ruminants and may be confused with the cysticercus of Taenia saginata.

Taenia taeniaeformis Batsch, 1786

This is a tapeworm of cats with rodents as intermediate hosts. It has been reported in the liver of man.

Other taeniids of carnivores

A large number of other taeniid cestodes occur in the small intestines of carnivores. In many cases, their life cycles are unknown but they may occur in various wild ruminants. A list of these various taeniids is as follows, and further details of their morphology and geographical distribution may be found in reference 78, Chapter 1.

These include: Taenia brauni Setti, 1897 of dogs and jackals in tropical and southern Africa, the larval stage is a coenurus in Muridae and Hystricidae and has also been reported from man where it occurs in the subcutaneous tissue, lungs, brain and eyes; T. bubesi Ortlepp, 1938 of the lion (Panthera leo); T. crocutae Mettrick and Beverley-Burton 1961 of the spotted hyena (Crocuta crocuta); T. erythraea Setti, 1897 of the black-backed jackal (Canis mesomelas); T. gongamai Ortlepp, 1938 and T. hlosei Ortlepp, 1938 of the lion and cheetah (Acinonyx jubatus) in the Republic of South Africa; T. hyaenae Baer, 1924 of various species of hyena in Central and Southern Africa, with cysticerci in various antelopes; T. laticollis Rudolphi, 1819, in various carnivores in North America and Central and Southern Africa with larval stages occurring in lagomorphs and rodents; T. lycaontis

Baer and Fain, 1955 of the hunting dog (Lycaontis pictus) in Central and East Africa; T. macrocystis Diesing, 1850, Lühe, 1910 of the lynx and coyote in North America with larval stages in Lepus californicus; T. martis Zeder, 1803, Freeman 1956 in Martes spp. in Europe and North America and cysticerci occur in Clethrionomys (vole); T. mustela Gmelin, 1790, in Martes and Mustela species in Europe and North America with larval stages in moles (Talpa spp.) and various rodents; T. omissa Lühe, 1910 of the cougar (Felis concolor) and larvae occur in various deer; T. parva Baer, 1926 in Genetta spp. and larval stages in various rodents in Europe and Africa; T. polyacantha Leuckart, 1856 occurs in foxes in Alaska and larval stages occur in microtine rodents; T. regis Baer, 1923, in Panthera leo; T. rileyi Loewen, 1929, of the lynx in North America, larval stages occurring in the mesentery of a variety of rodents; and T. twitchelli Schwartz, 1924 in wolverines and larval stages in the lungs and pleural cavity of porcupines in North America (various rodents may be infected experimentally).

APPENDIX 3

EXAMINATION AND STAINING OF TAPEWORMS

1. Fresh examination

- a. If contaminated with mucus or intestinal debris, rinse in warm mammalian saline (Hanks, Ringer or Earles) to remove the surface debris.
- b. If the scolex is present, the hooks are readily seen and the identity of the specimen as T. solium can be confirmed with certainty. If specimens are retained in unsuitable conditions (i.e. in faecal material) for a long time the hooks may drop out and an incorrect diagnosis of T. saginata could be made.

2. Stained preparations

- a. Flatten* clean specimens (i) mature, (ii) gravid proglottids, between microscope slides held at the ends with rubber bands or, for smaller specimens by a dab of petroleum jelly (vaseline) or (in warm countries) vacuum grease, at each end of the slide.
- b. Slides with the flattened specimens in between are placed in fixatives such as (i) 80% ethanol (ii) 10% formol saline (10% formaldehyde) (A few drops of acetic acid improves the staining after these fixatives) (iii) AFH (40% Formaldehyde - 10 ml; 95% ethanol - 50 ml; glacial acetic acid - 5 ml; H₂O - 45 ml) - for 24 hours.
- c. Remove flattened specimen from between slides and place in stain. Carmine stains are generally better than haematoxylin stains, but when diluted (1:1) the latter can often give excellent results. Gowers carmine or aceto alum carmine are recommended. Stain overnight.
- d. After staining, rinse thoroughly in several changes of distilled water (to remove the alum crystals) and differentiate in acid alcohol (70% ethanol - 100 ml; 2 ml concentrated HCl) for 1-24 hours or longer, until the internal organs can be seen. Upgrade through the alcohols, clear in xylene (or methyl benzoate) and mount in balsam. Small weights placed on the coverslip during drying and hardening help to keep specimens flat.

* CAUTION: Flattening may grossly distort the shape of the internal organs so that some unflattened specimens should also be fixed and stained.

APPENDIX 4

PREPARATION OF ANTIGENS FROM TAENIA SOLIUM

The crude antigen extract from *T. solium* is obtained as described below. Cysticerci are excised from newly slaughtered pig skeletal muscle, the vesicular fluid is discarded, and the walls and scolices are washed overnight in 0.01 M sodium phosphate in 0.15 M NaCl, pH 7.4 (PBS), containing antibiotics (40 mg/l of kanamycin sulphate, nalidixic acid, and ampicillin) and the protease inhibitors phenylmethylsulfonylfluoride (0.006%) and p-hydroxymercuribenzoate (0.04%) at 4°C. The cysticerci are then homogenized in 3 M KCl PBS containing the same protease inhibitors as above. The mixture is left overnight at 4°C with gentle stirring. The homogenate is dialyzed exhaustively with PBS at 4°C and centrifuged at 25,000 x g. The supernatant is adjusted to 15 mg/ml protein and stored at -20°C in aliquots.

Antigen B is prepared by homogenizing the solid parts of the cysticerci in 0.2 M 2-mercaptoethanol in 0.45 M NaCl containing the same protease inhibitors described above. The homogenate is centrifuged at 25,000 x g for 60 min at 4°C, and the supernatant is dialyzed overnight against 0.5 M acetic acid, pH 2.3, and recentrifuged. The protein concentration of the supernatant is dialyzed overnight against 0.5 M acetic acid, pH 2.3, and recentrifuged. The protein concentration of the supernatant is adjusted to 0.5 mg/ml. Antigen B is precipitated with NaCl to a final concentration of 0.86 M and resuspended in 0.5 M acetic acid. At this step of purification the preparation gives a single precipitation band with hyperimmune sera raised against the whole extract of the cysticercus, and SDS-PAGE reveal two bands, typical of antigen B preparations (3) with very few contaminants. Figures 1 and 2 illustrate the IEP and PAGE patterns of the whole extract and of antigen B.

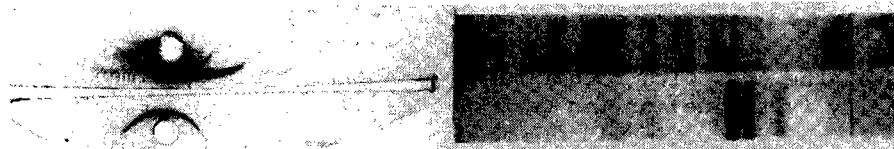


FIGURE 1 - Analysis of a whole extract (top) and antigen B (bottom) obtained from the cysticerci of *Taenia solium* using immunoelectrophoresis against hyperimmune rabbit serum (left) and polyacrylamide gel electrophoresis with sodium dodecyl sulfate and 2-mercaptoethanol (right). The crude extract obtained with 3 M KCl has at least 11 precipitating antigens and 20 protein bands. Antigen B obtained by solubilization in 0.5 M acetic acid and precipitation with 0.86 M NaCl corresponds to the isoelectric precipitation arc and yields two major protein bands and 4-5 minor contaminants (After 1).

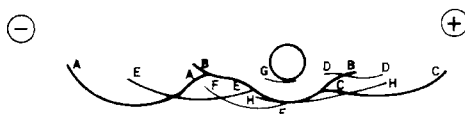


FIGURE 2 - Composite diagram showing all the precipitation bands formed during immunoelectrophoresis of sera from 116 neurocysticercotic patients with antigen extract from Taenia solium cysticerci (After 2).

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APPENDIX 5

TECHNIQUES FOR EXTRACTING CESTODE EGGS FROM SEWAGE, HERBAGE AND SOIL

1. Wash no more than 500 g of material through a sieve (1 mm pore size) into a large bucket. Leave overnight to sediment.
2. (i) Siphon off the supernatant and discard. Wash the slurry through a series of sieves, sedimenting overnight, and siphoning off the supernatant between each process.

(ii) A quick method: catch the material that passes through each time by using a large 25 μ m sieve. Use a thin high pressure jet of water. Mesh aperture of sieves could be 211 μ m, 106 μ m, 90 μ m, 45 μ m and 38 μ m. The 45 μ m sieve will retain all Ascaris spp. eggs. After each sieve discard the retained material, concentrate the material that passed through the 25 μ m sieve by pouring and washing, transfer the retained material to a beaker and then wash it through the next sieve in the size range. Cestode eggs are retained by the 25 μ m sieve.

3. Place the final material from the 25 μ m sieve into centrifuge tubes and spin at 1000 rpm for 5 minutes. Suck off supernatant. Resuspend slurry in each tube in a small volume of saturated NaNO_3 until there are 5 volumes of salt solution to one of the slurry. Let it stand for 15 minutes.

4. Suck off half the fluid with a wide mouthed pipette. Wash down sides with water in wash bottle and suck off remaining fluid.

5. Wash all fluid through a 25 μ m sieve and inspect the retained material.

In case the sieves are not available the alternative technique is as follows:

1. The sludge or soil is first sieved into water and allowed to sediment overnight.

2. Next morning the water is decanted and replaced with a saturated solution of sodium chloride. More salt is added and the vessel is vigorously shaken and then left for two hours to ensure that there is a true saturation and the specific gravity obtained is 1.12. At such density *Taenia* eggs do not float, and this step may thus be used to clean some of the unwanted, light detritus from the material.

3. After the two top layers of the salt float are decanted, the base sediment is washed in water and allowed to settle.

4. The sediment is then subjected to saturated sodium nitrate concentration either in bulk, or, if preferred, in a series of 15 ml tubes to which glass coverslips are added on top. The latter method permits direct transfer of eggs (adhering to the coverslip) to the microscope.

5. The formol-ether concentration may also be used in place of sodium nitrate. However, this method is not advised if the medium contains much grit or soil, because the eggs will be centrifuged at the bottom of the tube along with any grit, and the subsequent microscopy will be made more difficult (Figure 1) (1).

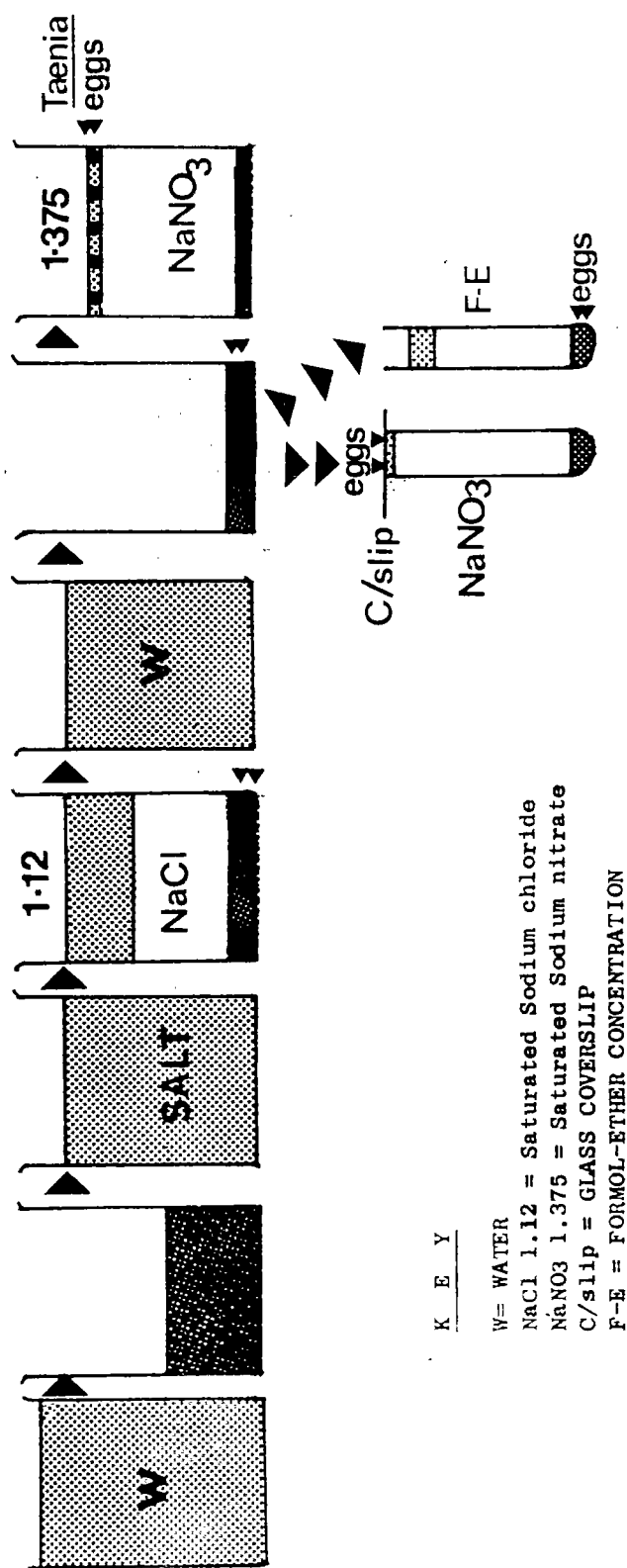


FIGURE 1 - A method for the recovery of Taenia eggs from sewage sludge (After 1).

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APPENDIX 6

IN VITRO CULTURE

1. Introduction

In vitro cultivation of taeniid cestodes - especially T. saginata and T. solium - has long been regarded as a desirable goal in taeniasis/cysticercosis research. In particular, the successful in vitro cultivation of the adult and larval stages of these species could be of value in the following areas: (i) maintenance of supply of adult and larval stages independent of host animals; (ii) production of "metabolic (E/S) antigens" for (a) vaccination and (b) immunodiagnostic studies; (iii) improvement of differentiation procedures between eggs and proglottids of T. solium and T. saginata; (iv) evaluation of anthelmintics; (v) study of general biochemistry, physiology and possible pointers to the development of new chemotherapeutic approaches; and (vi) establishment of cell-cultures to use in the preparation of myeloma hybrid (or similar) cells to produce an in vitro Taenia antigen producing system.

Minimal study has been done on the in vitro cultivation of T. solium and T. saginata. The current position is reviewed below.

2. In vitro culture of oncosphere to cysticercus

2.1 Taeniid cestodes in general

The in vitro cultivation of a number of species of taeniid cestodes from oncosphere to fully developed cysticerci or early cystic stages has been achieved. The basic technique used being that developed for T. hydatigena, T. ovis, T. pisiformis and E. granulosus (5).

Taeniid eggs, concentrated by centrifugation, may be surface sterilized before culture by washing twice in distilled water and treating with 5% Hibatane (Imperial Chemical Industries, UK) for 1 h. (a technique used successfully for E. granulosus (4)).

2.2 Taenia saginata

Cultivation of oncospheres of T. saginata to early cystic larvae (with cavitation), but no further differentiation, has been achieved (3). This approximates the average rate of development reported in calves in vivo (7, 14). Although this result represents very limited development in vitro, it is sufficient for the production and collection of E/S antigens which have been used with some success in preliminary vaccination attempts in cattle against T. saginata (6, 12).

Since other taeniid oncospheres have been grown to (nearly) fully-developed cysticerci e.g. T. pisiformis (5), growth to fully developed C. bovis should also be possible. Failure to grow in vitro could be attributable to one or more of the following factors described below.

2.2.1 Serum quality

It is well recognized in the tissue culture field that different batches of sera may vary greatly in their growth-producing properties. This problem appears to be particularly acute with T. saginata (3) and extensive trial and error may be necessary in each series of experiments to find an appropriate serum that promotes growth.

Recent work has indicated that three of the growth factors provided by serum are insulin, transferrin and selenium. These substances are now available commercially and their use in cestode culture may overcome the problem of variability in serum quality. This is a field that may be worth exploring in further research.

2.2.2 Oncosphere activity

Another problem in attempting to grow T. saginata oncospheres in vitro has included the low percentage of "activated" oncospheres i.e. those which, after release from their embryophore, actually become "activated" by breaking out of the oncospherical membrane and becoming mobile. Most workers (3, 8, 13) report very low activation rates; seldom more than 10%.

The techniques used for hatching and activation involve treatment with two solutions, the first containing pepsin which breaks up the embryonic blocks, and the second containing pancreatin and/or trypsin bile salts and sodium biocarbonate.

Recently, it has been shown that at an appropriate concentration, sodium hypochlorite, which is well known for its ability to dissolve keratin, can be used to disintegrate the keratin blocks of taeniid oncospheres without killing the released oncosphere (10). This is also the case with sodium sulphide. Moreover, solubilization of the blocks takes place so that clean oncospheres are obtained. This technique may be of special value in the preparation of oncospheres for in vitro cultivation, especially in relation to the preparation of E/S antigens.

Details of the technique are described below.

1. Wash eggs.
2. Incubate at room temperature in a solution of sodium hypochlorite (NaOCl) at pH 12, with an active chlorine concentration of 2% (blocks disintegrate and dissolve completely in 10 min).
3. Centrifuge at 1500 g for 3 mins; remove NaOCl.
4. Wash twice in 0.02 M phosphate buffer in 0.85% NaCl at pH 7.2.
5. Activate in solution B.

2.2.3 Development of T. saginata oncospheres to cystic larvae

The morphology of the early cystic stages are given in (3). The early stages of development of T. saginata are remarkably similar to those described for other taeniid larvae (5). The rate of development of T. saginata in vivo is not well documented for the early stages, but the appearance of cavitation (i.e. the development of a central cavity) in vitro at 10 days approximates that described in vivo (7, 14).

3. In vitro cultivation of cysticerci to adult worms

To date, no worker has succeeded in growing any species of the genus Taenia from a cysticercus, or comparable larval stage, to an adult worm. Such an achievement would greatly expand the scope of research into the immunology, physiology and biochemistry of the genus as well as eliminate the difficult problem of obtaining adult specimens as a source of eggs and/or antigenic material.

3.1 Other Taenia species

The in vitro cultivation of the strobilar stages of several non-human Taenia species has been partly successful since both Taenia crassiceps and T. hydatigena have been grown to early sexual differentiation, with development of genital pore and immature male and female genitalia (2)

3.2 T. saginata

Limited attempts to grow T. saginata in vitro from cysticerci employed a diphasic medium, consisting of a disrupted solid phase of coagulated calf serum and a fluid phase of Hepes-buffered RPMI-1640, with foetal calf serum and sodium pyruvate as additives (1). Segmentation and early development of sexual organs took place, but no further differentiation occurred. This result is in keeping with those described above for T. crassiceps and T. hydatigena and suggests that the later stages of sexual differentiation and maturation are much more demanding in their requirements and are likely to prove exceptionally difficult to achieve.

3.3 T. solium

Some preliminary attempts to cultivate the cysticercus stage to the adult worm have been made. The parasites were maintained for 60 days, but with little reported growth (9).

4. Cell cultures

No worker has yet succeeded in preparing cell cultures of a Taenia species. The establishment of stable T. saginata or T. solium cell lines would open up the way to the eventual preparation of hybrids with myeloma (or similar) cells to produce hybrid cells capable of producing the appropriate antigen. The latter would then be available for diagnosis and/or vaccination experiments.

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