End of Project Report

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ELECTRONIC ANIMAL IDENTIFICATION

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Contents

Summary

- The technology for electronic identification (ID) of bovines is currently available with the advent of passive electronic transponders. At issue is the most appropriate method to attach the electronic ID to the animals. The options include an electronic button tag in the ear, an implantable electronic chip in the ear base or an electronic bolus placed in the rumen/reticular via the oesophageal route.
- A series of experiments which compared different implantation sites for electronic chips found that the most suitable site for implantation was under the scutellar cartridge of the ear. This site gave very good retention values and was also a secure site, however, it was not possible to palpate the transponder.
- The recovery of injectable transponders post slaughter was problematic and as a result due to potential risk of implantable transponder entering the food chain it was not possible to recommend the injectable (implantable route).
- Electronic rumen boluses with a specific density less than 2 were rapidly expelled from the rumen, with 100% expulsion by day 56 following placement in the reticulo-rumen.
- Rumen boluses with a specific density of 2.75 and greater had an annual non reading rate of less than 1%, however, the loss rate in adult beef cows was greater than in growing and finishing cattle. The reason for this difference was unclear and may be diet related.
- Recovery of boluses at slaughter was undertaken in the offal hall and generally the bolus was present in the reticulum and was easily detected by palpating the reticulum. One hundred percent recovery was not achieved in practice, various unforseen events including accidental dislodgment and cutting techniques prevented recovery.
- A bolus dispenser with a long connection will facilitate delivery of the bolus directly to the calf's reticulum.

- Electronic failure of transponders in the reticulo-rumen was not a problem and read-failure rate was associated with boluses expelled from the reticulo-rumen.
- There was no differences in read-failure rate (or loss rate) between two commercial boluses which were compared in different catgories of cattle.
- Electronic button tags from two commercial companies were compared and it was found that any difference between the electronic button ear tags was associated with a defective applicator taggers.
- Overall, the animal loss rate for electronic button tags was somewhat higher than that reported for electronic rumen boluses.

INTRODUCTION

Traceability of meat to farm of origin is a consumer requirement which would be greatly facilitated if electronic animal identification was used. Government agencies responsible for detection and control of animal diseases need improved methods of tracing animals back to the farm of origin and of monitoring animal movement. These agencies would operate more effectively if animals could be identified by a highly accurate and tamper-proof electronic tagging system. The level of production supports in the form of direct payments on animals within the European Community, additionally, mandates a high level of security in bovine identification within their region. The use of electronic readers with a memory would facilitate rapid and accurate transfer of data from a farm location to a central computer database and eliminate errors associated with the manual transcription of data. Farmers, livestock markets and meat processing plants would also benefit greatly from automated electronic animal identification. Other practical uses include identification for feeding, weighing, milk yield recording, monitoring of animal health, and meat inspection (Lambooij, 1991).

The technology for electronic identification of bovines is currently available with the advent of passive electronic transponders. The main issue awaiting resolution concerns the vehicle to be used to attach the electronic ID to the animal. The options available are for an electronic button tag in the ear, an implantable electronic chip in the earbase or an electronic rumen bolus which is placed into the rumen/reticulum by the oesophygeal route. This report investigates the development of electronic rumen boluses as a method of animal identification.

IMPLANTABLE ELECTRONIC IDENTIFICATION

Background

The potential of electronic identification include automated recording of the identification of individual animals which is desirable for good husbandry and management on the farm. It also has off-farm potential in the detection and control of animal diseases by government agencies and also the payment of headage and subsidies by the agencies responsible. Practical uses include feeding, weighing, milk yield, monitoring of health status and in meat inspection (Merks and Lambooij, 1989).

An implantable electronic transponder (IET) offers a reliable and relatively tamper-proof, system of identification of individual animals (Lambooij, 1991, Konermann, 1991, Pirkelmann *et al.* 1991). However, the optimum site of implantation is controversial. Dorn (1987) recommended a subcutaneous implantation site in the lateral left side of the neck, approximately 10 cm cranial to the shoulder in cattle, sheep and goats. Merks and Lambooij (1989) studied four different sites for IETs in veal calves. The sites were (a) subcutaneously at the front of the head, 10 cm lateral and caudal to the nostril, (b) at the base of the ear, (c) intramuscularly in the neck, ventral to the *ligamentum nuchae* and 10 cm cranial, and (d) at the lateral side of the neck, cranial to the shoulder.

Sheridan (1991) stated that the recovery of implants in abattoirs is important for two reasons. Firstly, it is necessary to prevent reuse of tags if the characteristic of uniqueness is of value. Secondly, and more importantly, the food chain must be protected from accidental adulteration with foreign bodies. In this regard, the implantation site is a critical factor.

Experiments with cattle were conducted at Grange Research Centre over a period of 3 years to assess implant type, implant site and implant device in relation to readability of the IETs, and their recovery post-slaughter. The effects of handling pre- and post-slaughter on damage to the IETs were also studied.

Table 1 and Figure 1 summarise the details of experiments designed for the different IETs.

Table 1. Summary of implant device, implant type, type of animal and accommodation used in the six experiments.

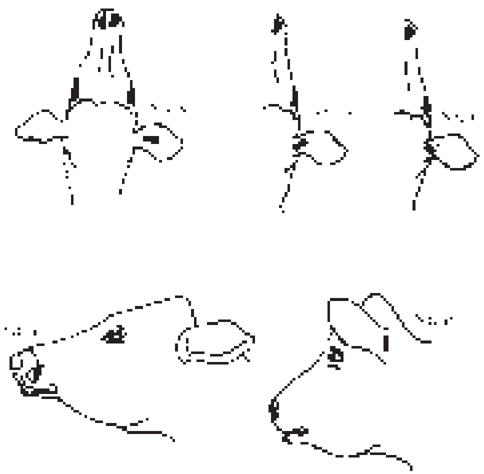
Exp	Duration (days)	Implant Type[1]	Site[2]	Animal details No	Age (mo)	weight (kg)	Management system[3]
1	65	A	D	144	21	500	I
	65	A	S				I
2	90	B	P	60	20	550	I
	90	B	C				I
3	121	C	C	30	18	500	I
	121	C	C				I
	121	D	L				I
4	121	C	C	20	1.5	80	I
	121	C	C				I
	121	D	L				I
4	469	C	C	58	1.5	80	OI
	469	C	C				OI
	469	D	L				OI
5	150	E	C	179	18	480	I
	150	E	C		18		I
	150	E	C		18		I
6	186	E	C	125	18	500	I

[1]A = rigid plastic capsule, 28 mm long and 3.6 mm diameter
B,C = rigid glass capsule, 28 mm long and 3.6 mm diameter
D,E = rigid glass capsule, 19 mm long and 2.8 mm diameter
[2] See Figure 1 for explanation
[3]I = indoors on concrete slats and offered grass silage plus concentrates
OI = outdoors on pasture and then indoors as for I.

Implantation sites

Site S: The entry point was in the middle of the caudal surface of the ear, 4 cm from its base. A 4.5 cm needle was advanced subcutaneously to its full length towards the base of the ear, along its long axis. The IET was deposited in the base of the ear tissue at that point (Figure 1).

Figure 1



Site D: The entry point was as above. A 4.5 cm needle was advanced subcutaneously to its full length towards the base of the ear, but downwards at 45 degrees to its long axis. The IET was deposited in the base of the ear tissue at that point (Figure 1).

Site C: The entry point was in the palpable depression anterior to the apex of the scutiform cartilage. This is a triangular, shield-like cartilage, which projects laterally from the caudosuperior side of the base of the ear (Popesko, 1977). The base of the triangle is towards the skull and the apex points towards the tip of the ear. A 4.5 cm needle was advanced to its full length, at first subcutaneously, and then underneath the cartilage, towards the base of the ear, along its

long axis. The IET was deposited in the base of the ear tissue at that point (Figure 1). Site C was selected because it was considered that implantation under the scutiform triangular cartilage would provide good protection for the IET.

Site L: The IET was placed subcutaneously in the upper lip, 5 cm caudolateral to the nostril (Figure 1).

Site P: The entry point was on the caudal base of the ear, at a right angle to its long axis. A 4.5 cm needle was advanced to its full length towards the ground. The depth at which the implant deposited was controlled by a guide rail 1 cm distant from, and parallel to, the needle (Figure 1). This site was selected for evaluation, because it was found to work well in pigs and was also likely to protect the IET (Lambooij, 1990).

Electronic transponders

Implant A was 28 mm long and 3.6 mm in diameter and was encapsulated in a rigid plastic capsule. A cartridge injector was used to implant the IET and the read distance was approximately 30 cm.

Implant B was 28 mm long and 3.6 mm in diameter and was encapsulated in a rigid glass capsule. The injector and reader were the same as those used for Implant A.

Implant C was 28 mm long and 3.6 mm in diameter and was encapsulated in rigid glass capsule. A cartridge injector was used to implant the IET and the read distance was approximately 20 cm.

Implant D was 19 mm long and 2.8 mm in diameter and was encapsulated in a rigid glass capsule. The injector and read distance were the same as those used for implant C.

Implant E was 19 mm long and 2.8 mm in diameter and was encapsulated in a rigid glass capsule. A single shot injector (prototype and standard) was used to implant the IET and the read distance was less than 20 cm.

Implantation, reading and recovery of transponders

The animal was restrained in a cattle crush and the head was restrained by one operative while a second operative inserted the implant at the designated site. Animals were not restrained at any of the subsequent readings. The operative moved along a full shute of cattle and used a hand held reader to determine the presence of the IET.

Assessment was standardised in all experiments as follows. Using the appropriate hand-held electronic reader, all IETs were read before insertion, immediately post-insertion, on days 4, 7, 14, 21 and 28 post-insertion and at 28-day intervals thereafter. IETs were read again immediately before departure to the abattoir, on arrival at the abattoir and immediately before recovery post-slaughter. IETs were recorded as reading or not reading at each assessment. In experiment 1, the site of implantation was palpated for the presence of the IET on day 28. Also, the site of implantation was examined for the presence of infection on the first five assessment occasions post-insertion.

The removal of the transponders at the abattoir was undertaken on the slaughter line prior to hide removal. The reader was used to check the presence of each transponder in the implant site. The ear and tissue 5 cm outside the circumference of the base of the ear was removed by pulling the ear away from the skull and cutting the tissues as closely as possible to the skull when the carcass was on the slaughter-line. The ear was then checked for the presence of the transponder and if it was present, the ear was placed in a plastic bag for later dissection in the laboratory. If the transponder was not detected by the reader, the head was removed from the carcass and retained for later dissection at the abattoir.

The equipment used for implantation and reading was supplied by the manufacturers of the implants. Three different manufacturers were represented and the associated implants were A+B, C+D and E, respectively.

Results

Experiment 1: A total of 144 cattle (49 Hereford x Friesian females, 66 beef x steers, 29 Friesian steers) within 60 to 90 days of slaughter were used to evaluate implant A at sites S and D. These were selected to ensure that IETs would be removed by standard excision of the ear, its base and surrounding tissue. The IETs (n=288) were inserted using both ears. IET sites were alternated between left and right sides.

Read-failure rates for IETs were unacceptably high at both sites D and S (Table 2). In the period from implantation to immediately before transportation to the abattoir, read-failure rates were 9 and 19% respectively. In the period from transportation to post-slaughter, a further 3 and 13% of IETs failed to read at sites D and S, respectively (Table 2). Weakness of the IET capsule probably caused the high rate of read-failure. Capsule fragility was apparent by a read-failure rate of 32% in the subcutaneous site S at slaughter, when the head often impacts with the floor post-stunning. IET recovery was similar for both sites (D and S) and all were found in the excised ear tissue. There was no evidence of migration from either site. Palpation of the site for presence of the IET indicated that site D provided more protection than site S (Table 2).

TABLE 2. Effect of insertion site on the performance of implantable electronic transponders (Experiment 1).

	Site D[1]	Site S[1]
Number inserted[2]	144	144
Percentage reading		
Day 0	100	100
Day 14	99.3	92.4[a]
Day 28	98.6	92.4[a]
Before transportation	91.0	80.6[a]
At abattoir post-slaughter	88.2	68.1[b]
Not recovered (%)	0.7	4.2
Palpated day 28 (%)	2.1	68.1[b]

[1]See Figure 1 for site specifications
[2]See Table 1 for description of implants
[a]Significant ($P<0.01$) difference between sites
[b]Significant ($P<0.001$) difference between sites

Experiment 2: A total of 60 cattle (30 Hereford cross Friesian females, 30 beef cross bulls) within 90 days of slaughter were used to evaluate implant B at sites C and P. One hundred and twenty IETs were inserted with sites alternating between the right and left ear.

In finishing heifers and finishing bulls, respectively, post-slaughter IET reading-rates at site C were 100 and 90%. In contrast, post-slaughter IET reading-rates at site P were 83 and 80%, respectively (Table 3). Also, site P made recovery of IETs more difficult; 10% of IETs were not recovered post-slaughter as they fell through a grid into the blood drain during the excision of the ear and a further 8% had migrated more than 5 cm from the implant site. Site C, protected by the triangle of cartilage, had the necessary attributes for a successful implant site; it gave good recovery at the abattoir, no migration post-implantation and good protection of the IETs against damage. However, a read-failure rate of 10% at site C in finishing bulls was a cause for concern. It suggested that the aggressive behaviour of bulls, particularly the practice of headbutting, subjected the IETs to undue pressure, which resulted in breakage and indicated the need for a more robust capsule.

TABLE 3. Effects of insertion site and animal type on the performance of implantable electronic transponders (Experiment 2).

	Heifers		Bulls	
	Site C[1]	Site P[1]	Site C[1]	Site P[1]
Number inserted[2]	30	30	30	30
Percentage reading				
On day 0	100	100	100	100
On day 14	100	90	100	90
On day 28	100	90	100	90
At Grange before transportation	100	90	90	86.7
At abattoir post-slaughter[a]	100	83.3	90	80
Not recovered (%)	0	10	0	10

[1]See Figure 1 for site specification
[2]See Table 1 for description of implants
[a]Significant site effect (P>0.05) when one analysis examined effects of sex and site

Experiment 3: A total of 30 beef cross bulls within 121 days of slaughter were used to evaluate implant D (site C in left ear), implant C (site C in right ear) and implant D (site L in left lip). A total of 90 IETs were inserted. Site L was selected, because Dutch experience (Lambooij and Merks, 1989) indicated that the IETs could be removed by excision of the upper lip, cutting downward along the cheek bone towards the nostril.

All IETs were active post-slaughter in the finishing bulls; (Table 4). For Site C, when the ear was removed by cutting close to the skull, 100% of IETs were removed with the ear. A total of 5 implants were not recovered. The implant was dislodged during excision and fell through a grid into the blood drain. Three of IETs not recovered were from the upper-lip, site L, and two from Site C were dislodged during excision of the ear.

TABLE 4. Effect of insertion site and implant type on the performance of injectable electronic transponders (Experiment 3).

	Site C[1] (implant C)[2]	Site C[1] (implant D)[2]	Site L[1] (implant D)[2]
Number inserted	30	30	30
Percentage reading			
On day 0	100	100	100
On day 14	100	100	100
On day 28	100	100	100
Before transportation	100	100	100
At abattoir post-slaughter	100	100	100
Not recovered (%)	3.3	3.3	10

[1]See Figure 1 for site specification
[2]See Table 1 for description of implants

Experiment 4: A total of 78, 6-week old calves within 121 (n=20) or 469 (n=58) days of slaughter were used to evaluate implant D (site C in left ear), implant C (site C in right ear) and implant D (site L in left lip). Site C was selected, as it was known to provide protection and that the IETs could be removed by the excision procedure used in Experiment 2. For animals slaughtered at 121 days, the recovery took place at the post-mortem facility at Grange Research Centre.

In the 20 bulls slaughtered 121 days post-implantation (6 months old), read-failure from site C was 5% for implant C and 0% for implant D (Table 5). It is assumed that the one missing IET was lost soon after insertion, as it failed to read on day 7 post-insertion. Read-failure rate at the site L was 0%. IET recovery was equally effective from both implantation sites. In the 58 finishing bulls slaughtered (469 days post-implantation) (18 months old), read-failure and failure of recovery were both 3.6% for implant C and 3.6% for implant D at site C and 0% for implants at site L (Table 5). Of the 4 non-recovered IETs, two were lost between day 0 and day 14 and 2 were lost after day 28. Post-slaughter IET recovery was a major problem at both implantation sites (Table 5). In the recovery procedure at the abattoir, 45% of the larger IETs (implant C) remained in the head after standard excision of the ear, as compared with 11% of the micro IETs (implant D); 20% of IETs in site L were not recovered. Failure to recover IETs by removal of ear necessitated the removal of the head from the slaughter line and dissection of the implant site to recover the IET. The recovery problems may have been due to implantation into 6-week old calves. In such calves, the needle deposited the implant deeper under the triangle of cartilage than would be the case in an adult animal weighing over 400 kg and within 4 to 6 months of slaughter.

TABLE 5. Effect of insert site and implant type on the performance of injected electronic transponders in bull calves at 1.5 months of age (Experiment 4).

	Site C (implant C)[2]	(implant D)[2]	Site L[1] (implant D)[2]
Bulls slaughtered at 6 months of age			
Number inserted	20	20	20
Percentage reading			
Day 0	100	100	100
Day 14	95	100	100
Day 28	95	100	100
Grange pre-slaughter	95	100	100
Grange post-slaughter	95	100	100
Bulls slaughtered at 18 months of age			
Number inserted	58	58	58
Percentage reading			
Day 0	100	100	100
Day 14	98.2	98.2	100
Day 28	98.2	98.2	100
Pre-slaughter	96.4	96.4	100
Post-slaughter	96.4	96.4	100
Not recovered (%)	3.6	3.6	0
Recovered from excised ear (%)	51.8	87.5	78.6

[1]See Figure 1 for site specification
[2]See Table 1 for description of implants

Experiment 5: A total of 179 finishing bulls and steers within 186 days of slaughter were used to evaluate a prototype single injector and a standard single injector using implant E at site C. Three hundred and fifty eight IETs were inserted using both right and left ears.

The type of injection device significantly influenced IET read-failure when micro IETs (implant E) were placed at site C (Table 6). The use of the prototype injection device was discontinued when it was apparent that failure to read was greater than 10% within 14 days of insertion. Only the standard injected device was used on the remainder of the animals. When a prototype device with a restricted plunger action was used, the IETs were not injected free of the tip of the needle. This lead to a read-failure rate of 14%, as compared with 3% for an effective injection device which had an adequate plunger action to expel the IET totally from the lumen of the needle. On dissection of the ear post-slaughter, all IETs implanted by the standard method were recovered under the triangle of cartilage and there was no evidence of migration. In contrast, IETs inserted by the prototype injector were not found under the triangle of cartilage (where they were expected) but were recovered from ear tissue between the point of needle insertion and the triangle of cartilage.

TABLE 6. Effect of implanting device on the performance of implantable electronic transponders at site C1 (Experiment 5).

	Prototype device	Standard device
Number inserted[2]	108	250
Percentage reading		
Day 0	100	100
Day 14	88.9	98[a]
Day 28	88.0	97.6[a]
Pre-slaughter	86.1	97.2[a]
Post-slaughter	86.1	97.2[a]
Not recovered (%)	11.1	1.6[a]

[1]See Figure 1 for site specification
[2]See Table 1 for description of implants
[a]Significant ($P<0.001$) difference between implanting devices

Experiment 6: A total of 41 beef cross steers, 35 Friesian bulls and 49 beef cross bulls within 150 days of slaughter were used to compare the effect of animal type on reading rate using implant E at site C. Two hundred and fifty IETs were inserted using both left and right ears.

Compared with steers, IET insertion in bulls tended to increase the number of IETs broken when site C was used (Table 7). This result confirms the need for the glass capsule of the IET to have adequate strength to withstand the aggressive headbutting activities of group-housed sexually mature bulls. All IETs were found under the triangle of cartilage and there was no evidence of migration.

TABLE 7. Effect of animal type on the performance of injected electronic transponders at site C1 (Experiment 6).

	Animal type		
	Beef cross steers	Friesian bulls	Beef cross bulls
Number inserted[2]	82	70	98
Percentage reading			
Day 0	100	100	100
Day 14	98.8	97.1	98
Day 28	98.8	97.1	98
Grange pre-slaughter	98.8	97.1	95.9
Abattoir post-slaughter	98.8	97.1	95.9
Not recovered (%)	1.2	1.4	2.0

[1]See Figure 1 for site specification
[2]See Table 1 for description of implants

Choice of implant site

Many potential IET sites were eliminated during the initial phase of the study. Site S was eliminated as it did not protect the IETs from damage associated with external pressure of feed barriers and the impact of head-contact with the floor immediately post-stunning with a captive bolt. Site S also allowed palpatation of the implant under the skin which could facilitate fraudulent removal.

Site P, posterior to the ear [the preferred site in pigs (Lambooij, 1991)] was eliminated as recovery post-slaughter was difficult and 10% of IETs migrated from the site of insertion. The migration may be associated with the fact that the animals thus implanted were finishing animals within 4 months of slaughter with considerable subcutaneous fat in the area immediately posterior to the ear.

Site D was eliminated when it was found that site C, which facilitated the protection of the IET under the scutiform triangle of cartilage was a more effective location. The lateral neck site, suggested by Dorn (1987), the shoulder site, used by Wade *et al.* (1991), were eliminated after a preliminary study undertaken at Grange Research Centre (Fallon and Rogers, 1991).

Site L, described by Lambooij (1991), was eliminated as the IET was implanted into sensitive tissue and it was believed that such a site would prove unacceptable on aesthetic and animal welfare grounds. Recovery from site L, when used in 6-week old calves slaughtered at 17 months of age, was difficult and there was evidence of migration in 10% of animals implanted at that site.

Site C was therefore the preferred site. This site, first described by Fallon and Rogers (1991), has been confirmed as suitable by Hasker *et al.* (1992). The latter group recommended that IETs be implanted in cattle only under the scutiform cartilage of the ear. Recovery from site C post-slaughter was totally reliable when older cattle were implanted within 6 months of slaughter (Fallon and Rogers 1999). The IETs were removed when the ear was excised as close as possible to the skull. Hasker *et al*. (1992) reported similar reliability. However, recovery failures from site C occurred when IETs were implanted in 6-week old calves. The ear size of a 400 to 500 kg animal is approximately twice as large as that of a 6-week old calf. Reducing the depth of injection in smaller animals may improve recovery-rates post-slaughter, but this needs to be confirmed.

The work suggests that parenteral insertion into cattle of an IET at any of the tested sites can cause problems of read-failure and/or recovery from the carcass. Information from Meat Inspectors, who monitored the work in the abattoirs, supports this conclusion (B. Bennett, personal communication).

Implant device

The precision of the implant device to accurately deposit the implant at the appropriate site influences both reading rate and recovery. In Experiment 5, a prototype implant device with a short plunger action failed to deposit the IETs reliably at the site C with a significant increase in the loss rate of IETs in the 14 days post-insertion. Post-mortem results confirmed that the IETs were deposited close to the point of entry of the injection needle. In Experiment 4, the use of the implant device in 6-week old calves resulted in 28% of IETs targeted at the base of the ear (site C) being deposited deeper in the ear socket, such that post-slaughter excision of the ear failed to remove the IET. The problem of IET recovery from calves thus implanted has been found in two other studies, one in England and one in Germany (A. Stains, personal communication). The results indicate that implant devices should be designed such that the needle length and point of insertion are such that the IET is deposited under the triangle of cartilage and not short of the site or not deeper into the ear cavity.

It was concluded that the site under the triangle of scutiform cartilage at the base of ear provided protective security for injectable electronic transponders. However, the risk of not recovering a transponder from the carcass makes injectable electronic transponders an unacceptable method of animal identification.

Rumen boluses

Background

Implantable electronic transponders offer a reliable, tamper proof system of individual animal identification (Lambooij 1991, Konerman 1991, Pirklemann *et al*. 1991). The outcome from a number of studies (Fallon and Rogers 1992, Hasker *et al*. 1992, Conill *et al*. 1996) indicated that injectable transponders placed in the ear beneath the scutellar cartilage (C site) achieved the lowest failure rates. Implantation at the C site in a number of studies gave 100% retention and reading rate (Fallon and Rogers 1999). However, this site had one very serious disadvantage: recovery at slaughter was unpredictable. In calves implanted at 1 to 2 months of age, 35/112 transponders (31%) remained in the head when the ear was removed post slaughter at 22 months of age (Caja et al., 1997). Similar results were obtained in an English and in a German study with calves (A. Sains, personal communication). Due to the possibility of a transponder which could not be recovered at slaughter subsequently entering the food chain, it was considered impractical and unwise to proceed with an animal identification system based on transponders implanted subcutaneously or intramuscularly. Hanton (1981) showed that it was possible to electronically identify cattle using an active (internal power source) rumen electronic transponder which was administered via the oral route. Hanton's bolus was approximately 8cm long and 1.5cm in diameter. It had a specific density of 2.0 and was administered to the animal with a bolus gun similar to that commonly used for cattle. This bolus was successfully administered orally to newborn calves in the first 3 days of life.

Rumen boluses development

Rumen boluses have been used as vehicles to deliver various products directly into the rumen on a slow release basis (Allen *et al.* 1983). The products included trace elements, growth promoters, anthelmintics and antibiotics. This development of the rumen boluses used to electronically identify cattle incorporated the previous knowledge gained from the use of such therapeutic boluses in the rumen.

Rumen bolus – trace elements: Soluble-glass boluses administered selenium (Se) intraruminally, by balling gun, have been used to increase whole blood glutathione peroxidase concentrations in cattle (Hemingway 1999, Henry *et al.* 1995, Hidiroglou *et al.*1987, Maas *et al.* 1994 and Millar *et al.* 1988). Similarly copper (Cu) was administered to ruminants using sustained-release rumen boluses (Allen *et al*. 1986, Givens *et al.* 1988 and Parkins *et al.* 1994). Cylindrical rumen boluses (55mm length x 18 mm diameter with a density of 2.9 g cm^3) suitable for ruminating calves over 75 kg liveweight were used to supply trace elements and vitamin (Hemingway *et al.* 1997). Investigations in Edinburgh used a soluble glass bolus to provide a slow release of Cu or cobalt (Co) into the rumen (Allen *et al.* 1986). Other studies have investigated the acid base reaction of cements in the construction of rumen boluses used to supply Cu, Co and Se (Manston *et al.* 1985).

Rumen bolus – growth promotors: Capsules (boluses) were used to provide slow release of an ionophoer, monensin, used to modify rumen fermentation (Micol *et al.* 1987, Tudor *et al.* 1980 and Watson and Laby 1978). The monensin capsule consisted of a metal cylinder within which was a matrix containing the monensin. A spring driver plunger pushed the matrix through an orifice (Watson and Laby 1978). The total core length was approximately 11 cm. The rate of plunger travel was independent of the concentration of monensin in the matrix over the range examined (12.5 to 50.0%). Thus, by choosing the appropriate combination of orifice size and matrix composition, the capsule can be designed to reliably release monensin at a given rate for a predetermined period so as to obtain maximum advantage from the use of the drug. The monensin delivery device was also described as a core assembled into a metal cylinder and secured by means of an adhesive filling the annular space between the matrix core and the interior wall of the cylinder. Either plastic snap-on end-caps with perforations or a plastic shell with perforated ends were applied to the metal cylinder to provide protection to the exposed flat faces of the cylindrical core matrix (Watson and Laby 1978).

Rumen bolus – dispensors: A slow release rumen capsule or bolus containing pluronics was used to control bloat in grazing cattle (Langlands and Holmes 1975). A sustained-release rumen bolus containing tetrachlovinphos was used against *musca autamnalis* (Riner *et al.* 1981).

A study (Riner *et al.* 1982) was conducted to determine the relationship between density of the bolus and location in the forestomachs and the influence of these factors on bolus erosion. Boluses with densities of 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, and 2.4 g/cm^3 were produced from inert materials and administered to 6 fistulated Hereford heifers. A minimum density of 1.6 g/cm^3 was required to prevent regurgitation from the ruminoreticulum and a minimum of 2.0 g/cm^3 required for retention in the reticulum.

Boluses containing hexacyanoferrates were developed to effectively bind radioactive caesium thereby preventing its uptake by animal tissue in cattle grazing pasture after the Chernobyl accident (Hove 1993, Ratniknov *et al.* 1998).

ELECTRONIC RUMEN BOLUS

Previous studies have shown that an injectable transponder at the ear base site in cattle was a reliable method of animal identification. However with the injectable transponder it was possible that it might not be removed at slaughter and could therefore enter the food chain (Fallon and Rogers 1999). Based on these findings it was decided to seek alternatives to the injectable transponders, and that the rumen was an appropriate location for an electronic identification transponder. The electronic industry in addition to incorporating existing technology into developing a rumen bolus also developed a transponder specific to the rumen.

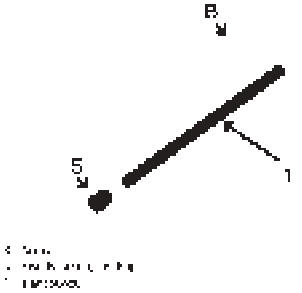
Ceramic Bolus

The various ceramic boluses commercially available adopted a technology whereby an injectable transponder was encased in a ceramic cylinder. The ceramic case produced the necessary size and density to ensure that the bolus was retained in the rumen/reticulum. Caja *et al.* (1999) reported that zero porosity and atoxic ceramic material (alumina, Al_2O_3) of high specific weight (>3.3 g/cm^3) was used to produce a bolus for enclosing different types of glass encapsulated transponders (Caja and Vilaseca 1996, Caja *et al.* 1997). Shape (cylindrical, with truncated edges in the extremes) and features (external diameter, 20 mm; length, 66 mm; weight, 65 g) of the bolus were designed in order to make its oral administration to young and adult animals possible and to ensure its permanent retention in the forestomach of sheep, goats and cattle. A drill hole of 7 x 45 mm in the center of one of the bases made sufficient room for enclosing different types of glass encapsulated transponders. The boluses were sealed with epoxy resin (MP Super, Ceys S.A., Barcelona, Spain). Final weight of sealed boluses was > 67 g. The ceramic cylinder was encapsulated with a plastic coat.

Similarly, Ferri *et al*. (2000) reported on a bolus for bovines (66 mm long, 20 mm in diameter, weight 63 g and density of 3.6 g/cm^3)

where the ceramic material is used to shield the transponder (Figure 2). The ceramic vane for transponder is made by a dry powder (alumina – $A1_2 0_3$ – 96%) cold pressed and then fired at 1580°C for 10 hours, while the transponder is a commercially available product of Texas Instruments Inc. (TIRIS, reading rate of 120 msec).

Figure 2. Exploded schematic drawing of ceramic bolus (courtesy of Innoceramics).



Monolithic Bolus

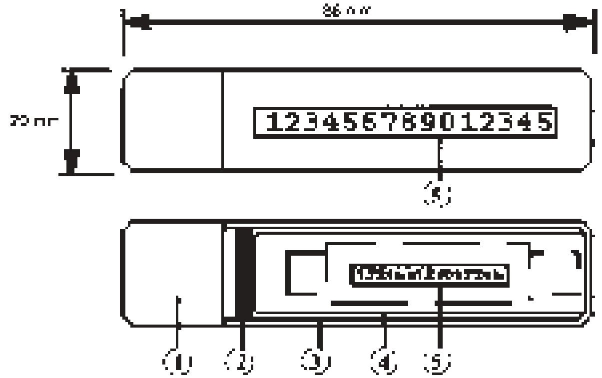
In the United States in co-operation with AVID ID Systems, EZ.ID is co-developed a new monolithic bolus and it was introduced as the EZ.ID rumen bolus in 2001. Under a joint development agreement with the bolus manufacturer Du Pont specialists developed a special heavyweight grade of Hytrel and provided assistance in mold design and processing techniques. The monolithic (overmolded) rumen bolus weights 72 grams and is 68.5 mm long with a diameter of 21.5 mm.

Steel Weighted Bolus

In the Netherlands Nedap Agri developed a weighed electronic bolus specifically for use in the rumen (Figure 3). The main feature is a glass cylinder containing the electronic components. The passive radio frequency identification (RFID) tag is integrated in a glass capsule to protect it against penetration of rumen fluids. To withstand damage the glass capsule is integrated in a plastic protective casing with damping material. (Figure 3) A stainless steel weight attached to the electronic rumen bolus is positioned eccentrically to enable swift submersion through the rumen surface.

The electronic life number is also visibly printed on the bolus. This enables easy identification and recording before application without the necessity of a RFID reader. Also, it provides a back-up in the slaughter process, in the unlikely event of the radio frequency identification part in the bolus being defective.

Figure 3. Schematic drawing of steel weighted bolus (courtesy of Nedap Agri)



Readers

There are basically two types of readers used which are either the static or portable type. The static readers would be located in facilities with a large throughput of livestock such as livestock marts, abattoirs, feedlots or cattle export premises. The static reader would automatically read the animal as it passed through the reading field. The electronic ID would be stored and downloaded into a data base containing an information file relating to that animal. The portable reader would operate on farms and the electronic identity of the animal would be linked to a veterinary inspection or other management procedures.

Bolus administration

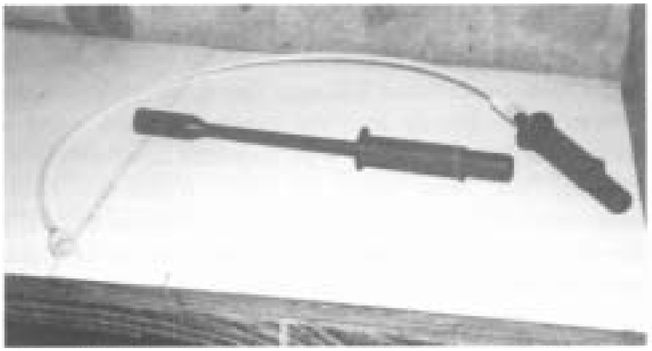
In respect to ruminating cattle more than 100 kg liveweight the administration procedure is similar to that used to insert anthelminthic boluses i.e. administer orally by the use of an oesophygeal balling gun which delivers the bolus directly into the top of the gullet. The bolus should be inserted into the applicator as directed. The applicator should be inserted from the front (not sides) of the mouth and over the back of the tongue, with no more than gentle firm pressure. As the animal begins to swallow the end of the gun, the passage down the throat becomes easier. The applicator is now in position for firing. The trigger is squeezed to eject the bolus. Normal care should be taken not to cause any injury by placing the applicator too far inside the throat of the animal. Ensure that each animal has swallowed the bolus by observing the animal for a short time after dosing.

In the European Community there is a legislative requirement for all bovine animals to be officially identified within 4 weeks of birth. This would necessitate the insertion of the bolus at a time prior to full development of the rumen/reticulum. In respect to young calves > 2 weeks of age a different approach is required. Caja *et al.* (1999) reported that the application of a rumen bolus was possible in milk fed calves (> 30 kg). Stimulation of the involuntary deglutition reflex by placing the bolus in the oropharynx seems to be a key practice for safe application in young animals (Caja *et et al.* 1999). The same authors also reported some difficulties with swallowing with four milk-fed calves (4.1%) in the first week of life. In these cases the bolus descent was helped by a downwards massage on the throat and neck or the bolus was retrieved by upwards massage and the application delayed for 1 week. No injuries or accidents were produced to the animals during the application of the new ceramic boluses used. Analogous results were reported by Hasker and Bassingthwaighte (1996) with ceramic capsules of similar dimensions but lower weight (60 x 20 mm. 40 g) in cattle.

Muller (1998) concluded that the procedure of administering electronic boluses to neonatal calves should aim at introducing the device directly into the ruminoreticular compartment in order to prevent oesophygeal obstruction or passage of the bolus to the abomasum. An applicator was developed for use with the steel weighted bolus that allows administration of electronic boluses directly into the ruminoreticular compartment of neonatal calves (Figure 4). The dimensions of the applicator are based on those of oesophygeal tubes that are well known by farmers for years. The latter devices are used to administer colostrum or electrolyte solutions to neonatal calves. These conclusions are supported by the proposal (Muller 1998) that a technique that is suitable for oral administration of electronic boluses has to aim at introducing the devices into the forestomach compartment (reticulorumen) but not into the abomasum of the newborn calf. Foreign bodies present in the lumen of the abomasum of calves have been shown to cause severe harm by irritating the mucous membranes by occluding the omasal or abomasal or pyloric orifice (Welchman and Baust 1987). In contrast to these findings, hardly any complications have been described concerning boluses or magnets that have been deposited into the reticulum of adult cattle.

In order to introduce the bolus into the reticulorumen compartment, closure of the reticular groove has to be circumvented. Previous studies have shown that capsules with a diameter of 6 mm and a length of 31.6 mm reach the reticulum if no liquids are consumed during administration (Muller 1998). In contrast, the capsules passed through the oesophygeal groove to the omasum when at the same time the animals were allowed to drink milk. Although these findings show that it is more likely that the bolus would reach the reticulum when administered by hand, there still remains a certain risk that contraction of the oesophygeal groove could result in deposition of the bolus in the omasum or even in the abomasum. Bolus guns (length 24 cm) are used to administer therapeutics to ruminating calves (Figure 4). These bolus guns have to be inserted into the mouth as far as the pharyngeal region to stimulate the reflex of swallowing. By this means chewing or rejection of the bolus is prevented. When bolus guns are used to administer the boluses to neonatal calves it is possible that the electronic bolus, due to its dimensions, could be retained in the oesophygeal lumen (Muller 1998). This assumption is supported by observations from previous studies in which it was possible on several occasions to palpate the bolus in the cervical part of the oesophygus after it was administered using a balling gun. The bolus present in the oesophygeal lumen forms a continuing stimulus for oesophygeal contractions. Spasmodic contractions of the oesophygus at the site of the bolus could result in oesophygeal obstruction (Muller 1998). In addition, the bolus lying in the oesophygeal lumen could pass through the oesophygeal groove to the abomasum at the moment when liquid foodstuffs are consumed. Using bolus guns to administer therapeutics in calves can cause severe problems. Anderson and Barrett (1983) describe severe lesions of the pharyngeal region as well as perforations of the oesophygus caused by excessive force used during oral administration of boluses by means of balling guns.

Figure 4. Examples of long and short bolus applicators.



The technique using a long bolus applicator analogous to an oesophygeal tube will deposit the bolus directly into the rumen/reticulum and elimate thus the risk of the bolus causing blockage of the oesophygus. The long bolus applicator (Figure 3) is

90 cm in length. In autumn 2000 and 2001, the long bolus applicators were successfully used to deposit boluses in the rumen/reticulum of 220 Friesian calves with a mean liveweight of 50 kg (range 36 to 67 kg) without any difficulty (Fallon unpublished). The ability to deposit the rumen bolus directly into the rumen/reticulum using a specially designed applicator is an important development as concern has been expressed with regard to boluses administration to 8 day old calves. A number of calf deaths were directly attributed to the bolus being retained within the oesophagus and other deaths due to damage to the oesophygeal wall which caused infection and death. In all instances it appears the bolus gun had a short range and deposited the bolus at the beginning of the oesophygus. In contrast the long bolus applicator delivers the bolus directly into the rumen/reticulum.

Evaluation of rumen boluses

The objective of a series of experiments conducted at Grange Research Centre over a 4-year period was to evaluate electronic rumen boluses with different densities and ultimately to achieve a 99% reading and retention rate.

Experiment 1: Evaluation of boluses of different specific gravity
One hundred and nineteen 18-month old beef-cross steers on a grass silage diet were assigned at random to 3 treatments with boluses differing in density. Forty animals received boluses with a density of 1.75, 38 animals received boluses with a density of 2.15 and 41 animals received boluses with a density of 2.35. An additional 57 6-month old beef cross steers received a bolus with a density of 1.75. Mean liveweight of the 18-month and 6-month old steers were 500 and 150 kg, respectively.

Within 7 days, 78% of the boluses with a density of 1.75 given to the 18-month old cattle, and 67% of those given to the 6-month old calves were lost (Table 8). By 56 days all boluses were lost from both groups. Loss was most likely from regurgitation as no positive reading resulted from scanning dung pads with the hand-held reader and boluses were found on the pasture. Increasing the density to 2.15 substantially improved the reading rate (87% by day 56 after administration). Further increasing the density to 2.35 improved the retention rate (98% on days 56 and 150 after administration).

Table 8. Reading rate (number of boluses) for electronic rumen transponders with different densities.

	Density		
Day	**1.75[b]**	**2.15**	**2.35**
0	97	38	41
2	71	35	40
7	28	35	40
14[a]	21 (22 %)	33 (87%)	40 (98 %)
28[a]	11	33	40
56[a]	0 (0 %)	33 (87 %)	40 (98 %)
150	0	33	40

[a]loss rate significantly higher ($p<0.001$) for the lowest density bolus than for either of the other two types or
[b]Combined data for the 6 and 18 month old groups.

Experiment 2: Evaluation of boluses with a density of 2.45 in different categories of cattle.
A total of 166 boluses were used. Boluses with a 30-g added weight (density 2.45) were inserted into the following animals: 1) 3-month old suckled beef cross calves (n=15) offered grass diet *in situ,* 2) 8-month old beef cross steers (n=54) offered a grass silage diet, 3) 20-month old beef cross steers (n=57) offered a grass silage diet, and 4) adult beef cows (n=40) offered grass diet *in situ*.

All boluses with a density of 2.45 were reading at 56 days after administration (Table 9). The proportion of transponders that were readable after periods ranging from 115 to 1100 days for the bolus with a density of 2.45 were 53/54 from 3-month old, 13/15 for 8-month old, 57/57 for 20-month old and 37/40 for adult cows. There were two failures to read in the growing category of cattle in the period 56 to 112 days and there were three failures to read in the adult cows in the period 112 to 365 days. Retention of boluses in the 56-day period following insertion did not appear to be affected by type of diet, grass grazed *in situ* or a grass silage diet.

Table 9. Reading rate number of boluses for electronic rumen transponders with a density of 2.45 in different categories of bovines (percentage of boluses)

	Animal Category at insertion			
Days after		Growing		Adult cows
insertion	3 - month	8 - month	20 month	
0	54	15		40
28	54	15	57	40
56	54	15	57	40
112	54	13 (86%)	57	40
182	54	13	-	38 (95%)
365	54	13	-	37
730	-	-	- 37	
Final read	53 (100%)	13 (86%)	57 (100%)	37 (93%)
Days to final read	508	634	130	1110

Experiment 3: Evaluation of boluses with a density of 2.75 in different categories of cattle.

A total of 331 boluses were used. Boluses with 50-g added weight (density 2.75) were inserted into the following animals: 1) 2-week old beef cross calves (n=97) offered a milk replacer diet, 2) 3-month old suckled beef cross calves (n=90), 3) 20-month old beef cross heifers (n=80) offered a grass silage diet, and 4) adult beef cows (n=64) offered a grass diet *in situ*.

Up to 56 days there was no reading failure of the bolus with a specific gravity of 2.75 (Table 10). The proportion of transponders that were readable for periods ranging from 115 to 1100 days for the 50 g bolus were 96/97 for 2 week old, 90/90 for 3 month old, 80/80 for 20-month old and 62/64 for adult cows. Thereafter 3 boluses (0.9%) failed to read during the observation period. One failure to read occurred in a calf that was administered a bolus at 2 weeks of age and the other two failures to read were in adult cows. The three failures to read occurred in the period 6 to 12 months after administration.

Table 10. Reading rate number of boluses for electronic rumen transponders with a density of 2.75 in different categories of bovines, and number (percentage of boluses)

	Animal Category at insertion			
Days after		Growing		Adult cows
Insertion	2 weeks	3 months	20 months	
0	97	90	80	64
28	97	90	80	64
56	97	90	80	64
112	97	90	80	64
182	97	90	-	64
365	96 (99%)	90	-	62 (97%)
730	96	-	-	62
Final read	96 (99%)	90 (100%)	80 (100%)	62 (97%)
Days to final read	778	634	115	1110

Growing versus Adult Cattle

In experiment 2 bolus reading rate was not significantly different between growing and adult cattle for the bolus with a density of 2.45 (Table 11). However, in experiment 3 there was a significantly higher reading rate for growing cattle compared to adult beef cows (Table 11). Combined data for Experiments 2 and 3 in respect to growing and adult cattle showed that the reading rate was significantly ($p > 0.01$) better in the growing cattle (Table 11).

Table 11. **Overall reading and failure to read rate for electronic rumen transponders with densities of 2.45 or 2.75 in growing cattle and adult beef cows in Experiment 2 and 3.**

	Animal category at insertion				
	Growing		Adult cows		
	Reading	Not reading	Reading	Not reading	Significance
Èxperiment 2	123	3	40	3	
Experiment 3	266	1	62	2	*
Experiment 2 + 3	389	4	102	5	**

BOLUS LOSSES

Failure to read in boluses with densities of 2.45 and 2.75 is likely to be due to bolus loss from the reticular rumen rather than read failure of the bolus. All boluses recovered in the abattoir were reading correctly. Boluses were also reading correctly at 8 weeks after administration in Experiment 2 and Experiment 3. This indicates that diet at time of administration did not affect reading rate and that the bolus was successfully located at the bottom of the reticulum. The bolus would have entered the forestomach through the cardia lying in the dorosmedial wall of the reticulo-rumen. Heavy foreign bodies fall to the bottom of the reticulum and tend to remain there (Leek 1993). Van Soest (1985) also stated that very dense objects such as metal and stones may be too large or heavy to escape from the reticulorumen. The above would suggest that boluses reading 8 weeks after administration would be located at the bottom of the reticulum and would remain there. However the sporadic losses of boluses in Experiments 2 and 3 indicate that a condition could develop in the rumen-reticulum that would allow the bolus to be regurgitated. Van Soest (1985) stated that the diet markedly influences the structure and composition of rumen contents. Coarse hay diets produce ruminal contents with a large, dense floating layer beneath a gas dome, with relatively liquid contents and suspended fibre beneath. The floating mat is composed of the most recently ingested forage. The floating mat is diminished in animals fed higher-quality diets, and it may be eliminated altogether in animals fed pelleted and concentrate diets. In order for a bolus to be regurgitated it would be necessary for it to be lying on a dense floating layer (raft) beneath the gas dome. Unless cattle were to spend much time lying flat on their sides, or were to accidentally roll over on their backs, the logistics of a bolus moving from the floor of the reticulum to the top of the raft are not evident. The available literature does not explain such an event. However the type of diet may influence this event. In Experiments 2 and 3, when losses for growing cattle (4/393) and adult beef cows (5/104) were compared, there was a four-fold increase in bolus losses in the adult cows compared to the growing cattle. The diet of the adult cows was either grass or grass silage with a medium DMD and no concentrates were fed; in contrast, the diet of the growing cattle was grass or grass silage with a high DMD, plus concentrates.

Due to the higher fibre content of the diet the ruminal raft of adult cows would be thicker and more dense than that of growing animals. The hypothesis for bolus-loss is that a combination of ruminal and reticular contractions coincided with a particular movement of the animal, or its lying-position (on its side or on its back), which causes the bolus to migrate by gravity to the top of the raft. Should it occur quickly after the bolus had been trapped in the raft, subsequent cudding would allow the bolus to be regurgitated with a cud. Once in the mouth, the animal would "tongue out" the bolus.

Conclusions

Retention rates in the reticulo-rumen of 97% or more were achieved with a bolus with a density of 2.45 and 2.75 for periods of 16 weeks and longer. In adult cows there appeared to be an increased failure to read for both boluses compared to growing and fattening cattle.

Bolus specific weight

There is considerable divergence as to what is the critical specific density required in order to achieve good bolus retention in the rumen. Hanton (1981) reported that a specific density of 1.75 was the minimum which would allow the capsule or bolus to remain in the rumen. Riner *et al.* (1981) compared seven different bolus densities in the range 1.2 to 2.4 specific density. They reported that a minimum density of 1.6/cm^3 was required to prevent regurgitation from the rumino-reticulum and a minimum of 2.0 g cm^3 for retention in the reticulum. Hanton (1981) used boluses with a specific density of 2.0 in new born calves and achieved permanent retention. Recent developments of boluses for electronic identification in sheep (Ribo *et al*.1984, Caja *et al*. 1996a, Caja *et al.* 1996b, 39, 40), goats (Caja *et al.* 1996b and Caja *et al.* 1997) and cattle (Allen *et al*. 1983, Haskin and Bassinghwaighte 1996, Ribo *et al.* 1994, Caja *et al.* 1996a) 39) showed varied retention results depending on the physical characteristics of the bolus. Fallon and Rogers (2001) using a bolus with a specific density of 1.75, reported a 100% loss rate within 8 weeks of administration. The loss was through regurgitation. Ribo *et al.* (1994) reported that boluses with a low density were regurgitated in both sheep and goats with only 50% and 7% respectively remaining after 3 months. Boluses with a specific density of 2.15 had a loss rate of 13% within 8 weeks of administration (Fallon and Rogers 2001). The latter authors also reported that when the specific density was increased to 2.35 there was still a loss rate of 2% within 8 weeks of administration. However, when boluses had a specific density of 2.45 or 2.75 there were no losses in the 56 day period after implantation (Fallon and Rogers 2001). It was not initially expected that the bolus needs to have a specific density more than twice that of rumen fluid in order to avoid losses through regurgitation. However, the solid raft of digesta floating on top of the rumen fluid may retain a bolus with a specific density of less than 2.35 on the surface of the ruminal contents such that it could be easily regurgitated. A "bottom heavy" bolus, with specific density of 2.75, was however sufficiently dense to remain in place on the floor of the rumen reticulum (Fallon and Rogers 2001). All boluses (331) with the 50 g added weight were present 6 months after administration; 328 were present after 12 months representing a loss of 3 (<1%) in the period 6 to 12 months and there were no subsequent losses. Caja *et al*. (1999) evaluated the retention rate for ceramic boluses of high specific weight (> 3.3 g/cm^3) in 1,487 cattle and found a 99.7% readability. Losses in cattle (0.3%) were due to three beef calves and two beef cows that expelled the bolus in the first hours after application. These animals were administered new boluses without further losses (Caja *et al*. 1999) over the three experimental years (Table 12).

Table 12. Effect of the application of high density boluses in the electronic identification of cattle at different ages.

Cattle type	Calves 2-10 day	Calves 2-6 week	Mature Ruminants	Dairy Cows	Beef Cows
Ceramic Bolus[a]					
No. of animals	97	971	70	119	230
No. lost	0	3	0	0	2
No. failed	0	0	0	0	0
Steel weighted Bolus[b]					
No. of animals	-	97	170	-	64
No. lost	-	1	0	-	2
No. failed	-	0	0	-	0

[a]Caja et al.1999
[b]Fallon and Rogers,2001

Hasker and Bassinghwaite (1996) reported a 100% retention rate for 1059 feedlot steers which were given an electronic transponder in a ceramic capsule 55 to 107 days before slaughter. The ceramic bolus in the Australian study (34) had a specific density of 3 and was similar to that described by Caja *et al.* (1999). They (Caja *et al.* 1999) described the ceramic boluses used in their studies (66 mm long, 20 mm in diameter and weighing 65 g) enclosing a passive transponder

(32.5 m long and 3.8 mm in diameter). It is evident from the various studies that for a rumen transponder to be retained in the rumen that it requires a specific density in excess of 2.75 and preferably of 3. Studies from Glasgow (Hemingway *et al.* 1997) used a cylindrical rumen bolus (55 mm length x 18 mm diameter with a specific density of 2.9) as a method to supply trace element to ruminants. The steel weighted bolus with a specific density of 3 was developed following various field trials with boluses of lower density. An additional feature of the Nedap bolus is an attached stainless steel weight which is positioned eccentrically to enable swift submersion through the fibrous mat in the rumen/recticulum.

High specific density ruminal boluses

Bolus with a specific density in excess of 2.75 heavy are recognised as having the capacity to have a very good retention rate in the rumen. JRC, Ispra, have tested a large number of boluses for their electronic reliability. The list of suppliers of such boluses which achieve a read distance > 80 cms to a static reader or a read distance > 25 cm to a portable reader has been prepared by the JRC and is presented in Table 13.

Table 13. List of companies which were certified to supply electronic rumen boluses.

Company	Technology	Equipment
Alfa Lavel	HDX1	Alus ceramic bolus
Allflex	HDX	Innoceramic bolus
Cermtec	HDX	Cermtag bolus
Cermtec	FDX-B2	Cermtag bolus
Datamars	FDX-B	Datamars UE ceramic bolus
Destron	FDX-B	Ceramic bolus
Gesimpex	HDX	UE ceramic bolus
Innoceramico	HDX	Innocermaic bolus
Nedap	FDX-B	Nedap electronic rumen Bolus MK 11
Sokymat	FDX-B	Ceramic bolus FDX-B.

[1]Half Duplex [2]Full Duplex

The heavy transponder irrespective of source had > 99.5% retention rate. Electronic failure of transponders in the reticulo rumen was not a problem in any of the studies reported (Caja *et al.* 1999, Fallon and Rogers 2001).

Recovery at slaughter

At slaughter the rumen boluses were generally easily recovered (Caja *et al*. 1999; Fallon and Rogers 2001). They were recovered by palpating the reticulum. Infrequently (1 in 30) the bolus was not present in the reticulum when the rumen arrived in the offal hall but was found in the rumen contents adjacent to the reticulum (Fallon and Rogers 2001). The displacement was most likely associated with the rumen turning over on its way from the abattoir line to the offal hall. A facility to redirect rumens off the offal line may be required in order to achieve 100% recovery in the rumen/reticulum particularly in a fast (100 cattle/hour) moving slaughter line. Caja *et al*. (1999) stated that recovery of the boluses was easy and recovery time varied from 12 to 15 seconds/animal in cattle (mean 12.3 seconds). A comparison between animals with and without ruminal boluses showed that the reticulo-rumen was unaffected by bolus administration (Hasker and Bassingthwaighte 1996).

One hundred percent recovery of boluses present in the reticulo-rumen is not always achieved in practice. In the recent electronic bolus versus tag comparison various unforeseen events (namely, accidental dislodgement, cutting technique employed to remove the abomasum and foot and mouth restrictions) prevented 100% recovery.

The electronic rumen bolus has the advantage over an injectable electronic implant as it avoids potential contamination of meat or by-products. It also had significant advantages as regards to security. However an external electronic ear tag would be much easier to recover at slaughter compared to a rumen bolus.

Electronic Identification of Cattle - a comparison of two rumen boluses and two electronic eartags

A prototype bolus was designed, developed and tested at the Teagasc, Grange Research Centre. This prototype lead to a bolus which is now commercially available. The objective of the study was to (1) to compare the effectiveness of two commercially available rumen boluses designed to electronically identify animals using different categories of cattle under standardised controlled condition and (2) to compare the effectiveness of two commercially available electronic ear tags using different categories of cattle under standardised controlled conditions.

One thousand and twenty one cattle used in the study were selected from animals at Teagasc, Grange Research Centre. The different animal categories include beef cows, calves 1 to 5 weeks of age, weanling animals, replacement heifers and fattening cattle that are not due for slaughter in the next 100 days.

The following transponders electronic identification EID (treatment) are being evaluated
1. Allflex rumen bolus 2. Nedap rumen bolus 3. Allflex ear tag 4. Nedap ear tag

The following procedure was employed in respect to allocation of animals to the project. Within each category or group of animals on the farm and the first animal in that group was allocated at random to an Allflex or Nedap bolus, thereafter each alternate animal received the same bolus type while the other animal received the other bolus. An animal which receives an Allflex bolus also received a Nedap ear tag and *visa versa.*

The animal phase of the study commenced in September 2000 and the results for first 7 months of the study are summarised in Table 14. At 28 days all boluses were reading, however, 6 Allflex (6/511) and 19 Nedap (19/510) ear tags were not reading. An 11 of the Nedap ear tag losses were due to an incorrect connection between the male and female components of the tag as evidenced by finding a number of lost tags where the components were separated. At 7 months after insertion 5 Allflex (5/510) and 5 Nedap (5/511) boluses were not reading. Subsequent losses of ear tags in the period 28 days to 7 months was 2 for Allflex (2/511) and 5 for Nedap (5/510). Details of the animal used to date in the study are presented in Table 15 and the reading at the completion of study (slaughter or September 2002) are presented in Table 16.

Table 14: Reading rate for Nedap and Allflex transponders at different periods following insertion up to 7 months

	Allflex		Nedap	
	Bolus	Eartag	Bolus	Eartag
Day 0	510	511	511	510
Day 7	510	511	511	499
Day 28	510	506	511	489
At 7 months	506	503	506	487
Not reading at 7 months	5	8	5	23

Table 15: Category of animals allocated with transponders and ear tags

Herd	No.	Age (month)	Sex[1]	Breed[2]
1	84	18	M	CH x
2	100	7	B	FR BB x
3	71	7	M	LIM x
4	90	7	M	CH x FR x CH
5	73	8	M + F	LI x FR x CH
6	104	18-36	F	CONT X
7	48	18	M	FR
8	110	1	M	FR
9	33	36	F	LI x FR x CH
10	32	3	M+F	((LxFR)xCH)xBB
11	98	4-5	M+F	CONT x
12	72	16	M	LI x FR
13	108	1	M	FR

[1]M=Male, F=Female
[2]Breeds or breed crosses

Advantages of Rumen Bolus

The heavy electronic rumen bolus provides a safe tamper proof method of electronic animal identification. Its placement in the rumen/reticulum area makes it a very difficult target to tamper with unless surgery is performed to remove the transponder from the rumen. Electronic ear tags can be easily removed and replaced with a similar type tag. The high density electronic rumen boluses has a high retention rate of > 99% per annum. In contrast the retention rate for plastic ear tags is in the order of 95% per annum in extensive farming conditions. The rumen bolus therefore has a much lower replacement rate.

Disadvantages of Rumen Bolus

The heavy electronic rumen bolus is more expensive than either the injectable transponder or the electronic ear tag. In addition the animal with the rumen bolus will require an external method of identification for routine management of the animals. The recovery of the rumen bolus post slaughter is more problematic than the removal of an electronic ear tag.

Preference for Rumen Bolus

Preference for a rumen bolus over electronic ear tags will very much depend on possible financial incentive to fraudulently change the identity of an animal. The motivation to fraudulently change an animal's identity can be for a variety of reasons including to collect additional premia, to conceal a diseased animal or in extreme cases introduce a diseased animal into a herd in order to claim compensation. Traceability is of major importance for consumers and meat retail outlets. The consumer needs to know where the beef came from, how and where the animal was reared and finished. In such instances the rumen bolus provides more consumer protection that does the external ear tag. Because of the cost difference detailed risk analysis may be required before deciding between an ear tag or rumen bolus as the preferred method of electronic animal identification.

Reading distance

A recent German study (Klindtworth *et al.,* 1999) made the following comments regarding read distance:

Reading of a bolus seems to be more difficult and time consuming than reading of injectable transponders and electronic ear tags when hand held readers are used.

Reading devices should be improved in future. Important features include an increased reading range, better battery management and improved protection against shock and water.

The limitation of field strength (122 dBµV/m in Germany) leads to a suboptimal reading range and must be taken into account, when the results are compared to other European countries which may use a field strength at the higher level of the I-ETS 300330 standard.

A reading distance of 25 cms for a portable reader may present difficulties in reading a bolus in the rumen of a large mature cow. Failure to identify an animal due to the inability of the reader to activate the microchip in the bolus should be a valid reason for failure if the read distance is inadequate. The basics of radio frequency identification (RFID) has been described (Eradus and Jansen 1999). Basically, a RFID transponder consists of a RFID microchip with most of the electronic circuitry on it and a radio frequency (RF) coil assembly. In many cases, the resonating capacitor of the coil is also incorporated in the microchip. The coil has two purposes. In the first place, it acts as a receiving antenna for the RF activation field emitted by the reader. This activation field induces an electrical voltage in the coil which is used to power up the microchip. Secondly, the microchip uses the coil to send back its identification code to the reader. In this case the coil serves as a transmitting antenna. The procedure for a so called full duplex (FDX) transponder was outlined (Eradus and Jansen 1999). When the reader is being operated, it emits a strong electromagnetic activation field. When the transponder is in the vicinity of the reader, the induced voltage in the transponder coil is high enough to bring the microchip to "life".

The microchip starts sending back the identification code which is programmed in its memory. In case of a FDX transponder it sends back the identification code by influencing the strength of the activation field according to the bit sequence of the code. The reader detects this influence on the activation field and translates it back into a digital signal (Eradus and Jansen 1999). After error checking, the identification code is displayed on the reader's screen or is available on an output port of the reader. A half duplex (HDX) transponder operates somewhat different (Eradus and Jansen 1999). In this case the transponder's microchip is activated by the same activation field but waits until the field is switched off again. When this is the case it starts sending back its identification code by generating the response signal internally. During this period the transponder is powered from an internal capacitor which was charged up during the activation period. By switching the activation field on and off periodically, the transponder is alternately charged up during the "on" period and transmits its code during the "off" period of the activation field (Eradus and Jansen 1999). Both FDX and HDX systems have their own advantages so both are incorporated in the ISO standards 11784 and 11785. They have in common that no internal battery is needed, so their lifetime is only limited by the endurance of the electronic circuitry and/or its encapsulation. There is also little difference in reading speed and reading range. The identification code is unalterable after it is programmed during the manufacturing phase (Eradus and Jansen 1999).

The importance of adequate reading distance for portable readers is evident from the above. The reading distance limitation does not appear to be a consideration with static readers which have a reading distance greater than 80 cm.

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References

Aarts, H.L.M., Borgstein, M.H., Merks, J.W.M. and Bots, J.M. (1989). De toepassingsmogelijkheden van implanteerbare electronische levensnummers in de varkenshouderij: een verkennend onderzoek. IVO B-rapport 334, Zeist.

Allen, W.M., Drake, C.F., Thrusfield, M.V. (1986). Controlled release glass for drug delivery in beef production systems. Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine, 66-76.

Allen, W.M., Sansom, B.F., Drake, C.F. (1983). Trace element supplementation using controlled release glass. Proceedings of the Fifth International Conference on Production Disease in Farm Animals: Uppsala, Sweden, 10 to 12 August. Swedish University of Agricultural Sciences, Uppsala, Sweden, 334-387.

AMLC (Australian Meat and Livestock Corporation), (1995). Integration of automated cattle identification with industry management practices. Supplementary report to intern report AMLC.010. 28 November, pp 5.

Anderson, B.C., Barett, D.P. (1983). Induced pharyngeal and oesophygeal trauma in cattle – selected cases and their consequences. Comp Cont Educ Pract Vet, 5: 431-432.

Brownlee, K.A. (1960). Statistical Theory and Methodology in Science and Engineering. John Wiley and Sons Inc., New York.

Caja, G., Barillet, F., Nehring, R., Marie, C., Conill, C., Ricard, E., Ribo, O., Lagriffoul, G., Peris, S., Aurel, M.R., Solanes, D., Jacquin, M. (1997). State of the art on electronic identification of sheep and goat using passive transponders. Options Mediterr. 33, 43-58.

Caja, G., Barillet, F., Nehring, R., Marie, C., Ribo, O., Ricard, E., Lagriffoul, G., Conill, C., Aurel, M.R., Jacquin, M. (1996a) Comparison of different devices for electronic identification in dairy sheep. In: Performance recording of animals. State of the Art, 1996. Proceedings of 30th biennial session of the International Committee for Animal Recording (ICAR), 87: 349-353.

Caja, G., Conill, C., Nehring, R., Ribo, O. (1999). Development of a ceramic bolus for the permanent electronic identification of sheep, goat and cattle. Computers and Electronics in Agriculture, 24: 45-63.

Caja, G., Conill, C., Nehring, R., Ribo, O., Korn, C., Vilaseca, J.F., (1998a). Ceramic ruminal bolus as a safe and tamper-proof method for electronic identification of dairy cattle at all ages. American Dairy Science Association (ADSA)-American Society of Animal Science (ASAS) Joint Meeting, Denver, 27-31 July.

Caja, G., Ribo, O., Nehring, R. (1994). Evaluation of migratory distance of transponders implanted in different sites of the body of adult sheep for electronic identification. In: Electronic identification of farm animals using implantable transponders (Contract CCAM 93-342), Research Project, Caja, G. (Coord.). Commission of the European Communities, General Directorate of Agriculture, FEOGA, Final Report, Vol. I. Objective 2. Biological test of transponders in sheep. Experience UAB-01/2.1., 22 p.

Caja, G., Ribo, O., Nehring, R., Conill, C., Prio, P. (1996b). Electronic identification in sheep, goat and cattle using ruminal bolus. In: Performance recording of animals. State of the Art, 1996. Proceedings of 30th biennial session of the International Committee for Animal Recording (ICAR), 87: 355-358.

Caja, G., Vilaseca, J.F., (1996). Capsula para la identificacion de rumiantes. P9601530. Oficina Espanola de Patentes y Marcas, Madrid, 13 pp.

Caja, G., Vilaseca, J.F., Korn, C., (1997). Bolus ruminal pour l'identification electronique d'un ruminant. Demande International publiee en Vertu du Traite de Cooperation en Matiere de Brevets (PCT). WO 98/0125. PCT/FR97/00744.

Conill, C., Caja, G., Nehring, R., Ribo, O. (1996). Effects of implantation site and transponder size in electronic identification in beef cattle. In: Performance Recording of Animals: State of the Arts. Proceedings of the 30th biennial session of Veldhoven, The Netherlands, June 23-28, 341-342.

Dorn, H.J. von (1989). Vorstellung des EURO I.D. System zur Kennzeichnung von Tieren mit Mikrochips in Transpondern. Tierhrztl. Umschau 42 (12), 978-981.

Eradus, W.J. and Jansen, M. B. (1999). Animal identification and monitoring. Computers and Electronics in Agriculture 24: 91-98.

Fallon and Rogers (2001). Evaluation of rumen boluses as a method of electronic animal identification. Irish Journal of Agricultural and Food Research 40:161-168.

Fallon, R.J. and Rogers, P.A.M. (1991). Use and recovery of implantable transponders in beef cattle. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 61-67.

Fallon, R.J. and Rogers, P.A.M. (1992). Use and recovery of different implantable electronic transponders in beef cattle and calves. Irish Journal of Agricultural and Food Research, Volume 31, 100-101.

Fallon, R.J. and Rogers, P.A.M. (1999). Evaluation of implantable electronic identification systems for cattle. Irish Journal of Agricultural and Food Research 38: 189-199.

Fallon, R.J. (2001). The development and use of electronic ruminal boluses as a vehicle for bovine identification. Rev. Sci. Tech. Off. Int. Epiz. 20 : 2: 480-490.

Ferri, N., Di Fancesco, C., Monaco, F., Egizi, F. (2000). Identificazione elettronica negli ovini: sperimentazione di un prototipo di supporto ceramico elettronico a localizzazione endoruminale. In press.

Givens, D.I., Zervas, G., Simpson, V.R., Telfer, S.B. (1988). Use of soluble glass rumen boluses to provide a supplement of copper for suckled calves. Journal of Agricultural Science, U.K. 110: 1, 199-204.

Hanton, J.P. (1981). Rumen-implantable electronic identification of livestock. Proceedings of the United States Animal Health Association, 85: 342-350.

Hasker, P.J.S. and Bassingthwaite, J. (1996). Evaluation of electronic identification transponders implanted in the rumen of cattle. Australian Journal of Experimental Agriculture, 36: 1, 19-22.

Hasker, P.J.S., Bassingthwaight, J., Round, P.J. (1992). A comparison of sites for implanting identification transponders in cattle. Australian Veterinary Journal, 69: 4, 91.

Hasker, P.J.S., Bassingthwaighte, J. (1995). Implanting electronic identification transponders under the scutiform cartilage of beef cattle is inappropriate under Australian conditions. Australian Journal of Experimental Agriculture, 35: 1, 15-18.

Hemingway, R.G. (1999). The influences of dietary selenium and vitamin E intakes on milk somatic cell counts and mastitis in cows. Veterinary-Research-Communications. 23: 8, 481-499.

Hemingway, R.G., Parkins, J.J., Ritchie, N.S. (1997). Sustained-release boluses to supply trace elements and vitamins to calves. Veterinary Journal. 153: 2, 221-224.

Henry, P.R., Ammerman, C.B., Ammerman, C.B., (ed.); Baker, D.H., (ed.); Lewis, A.J. (1995). Selenium bioavailability Bioavailability of nutrients for animals: amino acids, minerals, and vitamins. 121: 303-336.

Hidiroglou, M., Proulx, J. and Jolette, J. (1987). Effect of intraruminally administered, selenium soluble-glass boluses on selenium status in cows and their calves. Journal of Animal Science. Sept 65: 3 815-20.

Hove, K. (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. Science of the Total Environment, 137: 1-3.

Janssen, J. (1991). Opening address. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 3-4.

Klindtworth, M., Wendl, G., Klindtworth, K. and Pirkelmann, H. (1999). Electronic identification of cattle with injectable transponders. Computers and electronics in agriculture 24: 65-80.

Konermann, H. (1991). Identification of horses by implantation of microchips. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor). No. 13198, 37-43.

Lambooij, E. (1991). Automatic electronic identification systems for farm animals. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 21-27.

Langlands, J.P., Holmes, C.R. (1975). Consumption of pluronics administered in drinking water and roller drums to grazing beef cattle. Australian Journal of Experimental Agriculture and Animal Husbandry, 15: 72, 5-11.

Leek, (1993). Digestion in the ruminant stomach. In Duke's physiology of domestic animals edited by Swenson M.J. and Reece W.O., Cornell University Press Ithaca p 387-426.

Maas, J., Peauroi, J.R., Weber, D.W., Adams, F.W. (1994). Safety, efficacy, and effects on copper metabolism of intrareticularly placed selenium boluses in beef heifer calves. American Journal of Veterinary Research. 55: 2, 247-250.

Manston, R., Sansom, B.F., Allen, W.M., Prosser, H.J., Groffman, D.M., Brant, P.J., Wilson, A.D. (1985). Reaction cements as materials for the sustained release of trace elements into the digestive tract of cattle and sheep. 1. Copper release. Journal of Veterinary Pharmacology and Therapeutics, 8: 4, 368-373.

Merks, J.W.M. and Lambooij, E. (1989). The use of implantable electronic identification systems in pig production. Proceedings 40th Annual Meeting European Association of Animal Production, Dublin, 237.

Micol, B.D., Muller, A., Peccatte, J.R. (1987). Effect of a Rumensin bolus on the performance of dairy steers finishing on pasture from twenty-four to thirty months. Bulletin Technique, Centre de Recherches Zootechniques et Veterinaires de Theix, 68: 25-28.

Millar, K.R., Meads, W.J., Albyt, A.T., Scahill, B.G., Sheppard, A.D. (1988). The retention and efficacy of soluble-glass boluses for providing selenium, cobalt and copper to sheep. New Zealand Veterinary Journal. 36: 1, 11-14.

Muller, K.E. (1998). Feasibility of the concept of orally administered electronic boluses for identification of cattle. Department of Farm Animal Health, Faculty of Veterinary Medicine, Utrecht University, The Netherlands.

Parkins, J.J., Hemingway, R.G., Lawson, D.C., Ritchie, N.S. (1994). The effectiveness of copper oxide powder as a component of a sustained-release multi-trace element and vitamin rumen bolus system for cattle. British Veterinary Journal. 150: 6, 547-553.

Pirkelmann, H., Wendl, G., Wendling, F. (1991). Experiences with injected transponders in calves. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 53-60.

Pollitt, R.D.A. (1991). Automatic identification. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 13-18.

Popesko, P. (1977) Atlas of Topographical Anatomy of the Domestic Animals (Vol 1, Ed 2). B. Saunders Company, Philadelphia. p 27.

Ratnikov, A.N., Vasiliev, A.V., Alexakhin, R.M., Krasnova, E.G., Pasternak, A.D., Howard, B.J., Hove, K., Strand, P. (1998). The use of hexacyanoferrates in different forms to reduce radiocaesium contamination of animal products in Russia. Science of the Total Environment, 223: 2-3.

Ribo, O., Caja, G., Nehring, R. (1994). A note on electronic identification using transponders placed in permanent ruminal bolus in sheep and goats. In: Electronic identification of farm animals using implantable transponders (Contract CCAM 93-342), Research Project. Caja, G. (Coord). Commission of the European Communities, General Directorate of Agriculture, FEOGA, Final Report, Vol. I, Objective 2. Biological test of transponders in sheep. Experience UAB-01/2.6, 7 p.

Riner, J.L., Byford, R.L., Hair, J.A. (1981). Sustained-release Rabon bolus for face fly control in cattle faeces. Journal of Economic Entomology, 74: 3, 359-362.

Riner, J.L., Byford, R.L., Stratton, L.G., Hair, J.A. (1982). Influence of density and location on degradation of sustained-release boluses given to cattle. Am. J. Vet. Res., 43: 11 2028-30.

Sheridan, M.K. (1991). Electronic identification systems: governmental considerations. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor), No. 13198, 109-113.

Tudor, G.D., Laby, R.H., Utting, D.W. (1980). The response of cattle on a sorghum-based feedlot diet to monensin supplied either via intraruminal capsules or in the feed. Australian Journal of Experimental Agriculture and Animal Husbandry, 20: 106, 522-528.

Van Soest, P.J. (1985). Function of the ruminant forestomach. In nutritional ecology of the ruminant, Cornell University Press Ithaca, p 230-280.

Wade, J.M., Gallagher, M.G. and Gordon, I. (1991). Electronic identification of cattle. In: Automatic electronic identification systems for farm animals. Proceedings of a seminar held in Brussels, Belgium, 17-19 October, 1990. E. Lambooij (Editor) No. 13198, 49-52.

Watson, M.J., Laby, R.H. (1978). The response of grazing cattle to monensin administered from a controlled release capsule. Proceedings of the Nutrition Society of Australia, 3: 86.