Selenium metabolism in the dairy cow: the influence of the liver and the effect of the form of Se salt

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1. Six adult Friesian cows were given ^{75}Se as either $^{75}SeO_3^{2-}$ or $^{75}SeO_4^{2-}$ intravenously. Five of the cows had cannulas in an hepatic vein, the portal vein and one carotid artery to enable the uptake of ^{75}Se by the liver to be measured. Radioactive balance studies were carried out on two of the cows given $^{75}SeO_3^{2-}$ and two given $^{75}SeO_4^{2-}$. A seventh cow was given an oral dose of ^{75}Se-labelled barley and the excretion of ^{75}Se in faeces, urine and milk was measured for 14 d.

2. After the injection of $^{75}SeO_3^{2-}$ plasma ^{75}Se concentration decreased during the first 30 min with a mean half-life ($t_{\frac{1}{2}}$) of 15·6 min. From 30 to 60 min after dosing the concentration of radioactivity increased to reach approximately 50% of the level present 2 min after dosing. Following the injection of $^{75}SeO_4^{2-}$ the ^{75}Se was cleared with a mean $t_{\frac{1}{2}}$ of 28·5 min during the first 30 min and plasma radioactivity increased only slightly during the next 30 min.

3. During the phase of rapid clearance of ^{75}Se after the injection of $^{75}SeO_3^{2-}$ the hepatic venous ^{75}Se concentration was approximately 5% lower than portal venous ^{75}Se concentration. During the period when plasma ^{75}Se activity was increasing the activity in hepatic venous plasma was 3% greater than portal activity. Of the ^{75}Se cleared from plasma after injecting $^{75}SeO_3^{2-}$ 40% was calculated to be removed by the liver.

4. After intravenous dosing with $^{75}SeO_3^{2-}$ or $^{75}SeO_4^{2-}$ approximately 9·5 and 17·0% respectively of the dose injected was excreted in faeces and 10% in urine within 14 d. Almost three times as much ^{75}Se was excreted in urine and 3·5 times as much in faeces during the first 24 h after dosing with $^{75}SeO_4^{2-}$ as after $^{75}SeO_3^{2-}$.

In recent years the liver has been shown to have an important role in the regulation and excretion of many trace elements (Klaassen, 1976; Sansom *et al.* 1978). However, there is limited information on the importance of the liver in selenium homoeostasis in the ruminant. Toxic doses of Se for cattle are approximately 1 mg/kg body-weight. Given intravenously this dose is fatal to steers weighing 150–300 kg within 8 h, while 0·75 mg/kg causes malaise and dyspnoea (Herigstad & Whitehair, 1974). Maag & Glenn (1967) reported that 1·2 mg/kg body-weight given in the food was toxic and increased the Se content of the liver, brain, kidneys, muscle and spleen by 3–7-fold. No clinical signs were observed if the Se content of the blood was 3 μg/ml or less. At these dosage rates the highest tissue concentration of Se is found in the liver. When a large dose of selenite is given to rats the liver is important in its transmethylation to the volatile dimethyl selenide which may then be exhaled from the lungs (Imbach & Sternberg, 1967). In low doses Se has a protective function. It prevents liver necrosis and damage due to carbon-tetrachloride (Schwartz & Foltz, 1957) and is prophylactic and therapeutic in nutritional muscular dystrophy caused by Se deficiency in cattle and sheep.

To investigate the function of the liver in Se homoeostasis, cattle with silicone rubber cannulas placed in the hepatic, portal and carotid vessels have been used in conjunction with radionuclide balance studies. The results show that the bovine liver rapidly removes approximately 40% of injected $Na_2{}^{75}SeO_3$ from the systemic plasma, binds it to a plasma component and within 1 h of injection releases it back into the circulation.

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Table 1. *Amount of ^{75}Se radioactivity (μCi) and amount of stable Se (μg) given intrajugularly to each cow*

Form of Se	Cow no.	Amount of ^{75}Se (μCi)	Stable Se carrier (μg)
Sodium selenite	1a	30	8·3
	2	55	20·0
	3a	70	15·0
	3b	67	5·0
	4	67	5·0
	5	92	13·0
Sodium selenate	1b	180	30·0
	6	115	30·0

MATERIALS AND METHODS

Measurement of the rate of clearance of ^{75}Se from systemic blood and its excretion in urine and faeces

Six adult Friesian cows weighing between 450 and 500 kg were used. They were fed on a conventional hay and concentrate ration, the Se content of which was determined only in the later studies (cows nos. 3 and 4) in which the intake of Se was approximately 500 μg/d. Five of the cows had had silicone rubber cannulas (Silastic; Dow Corning Inc.) placed in one hepatic vein, the portal vein and one carotid artery some weeks before the experiments, using a method combining those described by Symonds & Baird (1973) and Baird *et al.* (1975).

Each cow was given between 30 and 180 μCi ^{75}Se (see Table 1 for specific activities) as a single intrajugular injection of $Na_2{}^{75}SeO_3$ or $Na_2{}^{75}SeO_4$. Five cows (nos. 1–5) were given $Na_2{}^{75}SeO_3$, two cows (nos. 1 and 6) were given $Na_2{}^{75}SeO_4$ (cow no. 1 several months after the injection of $^{75}SeO_3{}^{2-}$). Cow no. 3 received two injections of $^{75}SeO_3{}^{2-}$ given 9 months apart.

After dosing blood samples were collected simultaneously from all cannulas, where possible, at 2 min intervals for the first 20 min, 10 min intervals for the next 30 min, 20 min intervals for a further 2 h and then daily or weekly from the carotid or jugular vessel until the end of the study. The excretion of ^{75}Se in faeces and urine after injecting $Na_2{}^{75}SeO_4$ (cows nos. 1 and 6) or $Na_2{}^{75}SeO_3$ (cows nos. 3 and 4) was measured for 14 d (10 d for cow no. 6).

Excretion of ^{75}Se in urine, faeces and milk after an oral dose of ^{75}Se-labelled barley

One lactating cow (cow no. 7) was fed ^{75}Se-labelled barley as a single dose of 130 g of dried tops containing 0·3 μCi ^{75}Se/g and the excretion of ^{75}Se in faeces, urine and milk measured for 14 d. No blood samples were collected. The barley was labelled by growing it in a water culture medium containing $^{75}SeO_3{}^{2-}$. The dose of radioactivity was measured in the Compton whole-body counter (Sansom *et al.* 1971) by comparison with the radioactivity of a small volume of $Na_2{}^{75}SeO_3$ solution. A portion of this solution was also counted in an NE8311 γ-spectrometer (Nuclear Enterprises).

Analytical procedures

Measurement of radionuclide content. The ^{75}Se was obtained as either $Na_2{}^{75}SeO_3$ or $Na_2{}^{75}SeO_4$ from the Radiochemical Centre, Amersham. The amount of ^{75}Se in portions of all the biological samples taken was determined by direct counting of γ-emissions in the NE8311 γ-spectrometer. The efficiency of counting was approximately 75%.

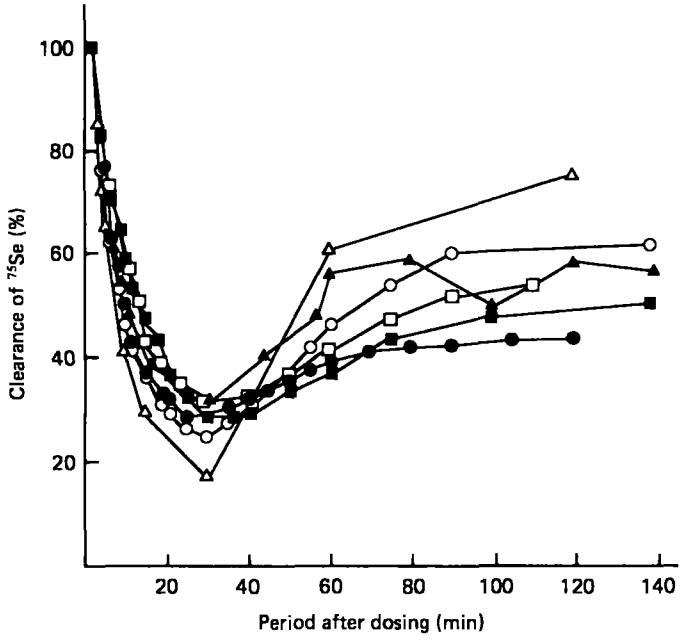

Fig. 1. Clearance of ^{75}Se from the carotid plasma of six cows given $Na_2{}^{75}SeO_3$ intravenously. Values are expressed as a percentage of the radioactivity present in the plasma sample collected 2 min after dosing. (●—●), cow no. 3a; (○—○), cow no. 4; (▲—▲), cow no. 2; (△—△), cow no. 1a; (■—■), cow no. 3b; (□—□), cow no. 5.

Preparation of blood samples. Samples of plasma were obtained by centrifugation after collecting whole blood into universal bottles containing 0·1 ml saline (9 g sodium chloride/l) and 100 IU sodium heparin. Weighed amounts of plasma were transferred into weighed counting vials. In three cows (nos. 1a, 3 and 4) unbound ^{75}Se in plasma was measured and in cow 5 unbound ^{75}Se in whole blood was measured by counting a trichloroacetic acid (TCA) filtrate of each arterial plasma or whole blood sample. Plasma or whole blood (5 g) were added to 10 g TCA (200 g/l). The supernatant fraction was filtered into weighed counting vials which were then reweighed to obtain the weight of filtrate counted. ^{75}Se-labelled TCA standards were prepared from plasma containing a known fraction of the dose solution.

Preparation of faeces, urine and milk samples. Samples of faeces and urine were collected throughout 6 h intervals. For the first 24 h, each 6 h collection was processed separately. Thereafter the total excreted during each 24 h was combined. All collections were mixed thoroughly before taking duplicate 10 g samples into counting vials. Duplicate 10 g samples were taken from the thoroughly mixed, pooled 24 h milk yields into counting vials.

Assay of stable selenium. Stable Se in the food of cows nos. 3 and 4 was estimated by the method described by Little *et al.* (1979).

RESULTS

Changes in plasma ^{75}Se radioactivity

After an intrajugular injection of $Na_2{}^{75}SeO_3$. Fig. 1 shows the clearance curves of ^{75}Se from carotid plasma for the six cows given $Na_2{}^{75}SeO_3$. The values for each animal are normalized by expressing the radioactivity in each plasma sample as a percentage of the radioactivity present in the plasma sample collected 2 min after dosing. The mean (±SE) at 2 min after dosing for all animals was 2·29±0·23% dose/kg plasma.

There was a rapid decline in total plasma radioactivity during the first 30 min after dosing

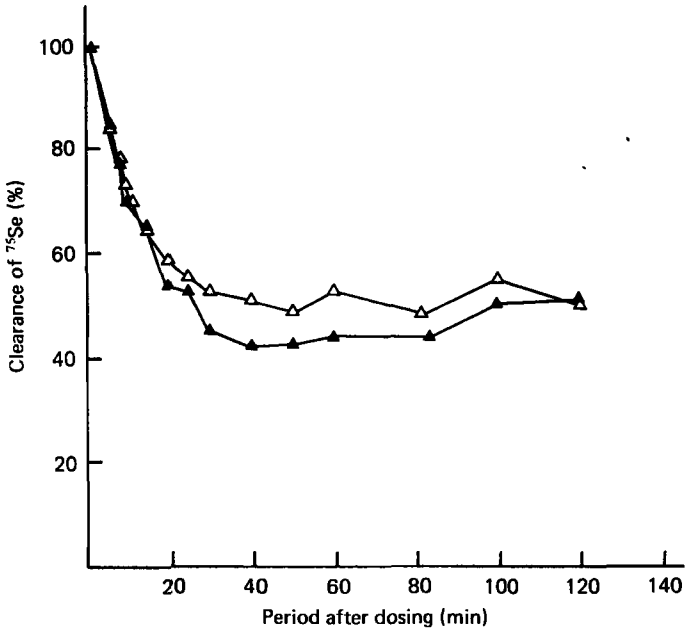

Fig. 2. Clearance of ^{75}Se from the carotid plasma of two cows given $Na_2{}^{75}SeO_4$ intravenously. Values are expressed as a percentage of the radioactivity present in the plasma sample collected 2 min after dosing. (▲—▲), cow no. 6; (△—△), cow no. 1b.

followed during the next 30 min by an increase such that plasma ^{75}Se radioactivity returned to between 40 and 60% of that present 2 min after dosing. Plasma ^{75}Se content then remained constant until it started to decline slowly approximately 4 h after dosing.

The extent to which extraction by the liver is responsible for the changes in plasma ^{75}Se activity is shown in Table 2. The concentration of radioactivity in carotid and portal plasma was similar; the differences between hepatic and portal venous ^{75}Se content therefore indicate qualitatively whether the liver contributed to the clearance and reappearance of ^{75}Se. During the first 30 min after injection the concentration of radioactive ^{75}Se in the portal vein of all four cannulated cows was greater than that in the hepatic vein, but during the second 30 min the hepatic: portal plasma concentration ratios in cows nos. 2, 3 and 4 were reversed. For these cows the hepatic:portal ^{75}Se concentration ratios during the second 30 min were 7·8, 6·0 and 7·6% respectively greater than during the first period. During the first 30 min the mean hepatic:portal ^{75}Se concentration ratio for cow 1 was lower (0·876) and did not exceed unity during the 30–60 min period. However, the increase in the ratio during the second 30 min was 9%, similar to the increase in the other three cows. Qualitatively, the liver removed ^{75}Se during the phase of rapid clearance and released it back into hepatic venous blood during the period of increase in plasma radioactivity. The mean ($\pm$SE) $t_{\frac{1}{2}}$ during the phase of rapid clearance was 15·6$\pm$0·7 min for all six cows.

^{75}Se radioactivity in TCA filtrates of plasma (cows nos. 1a, 3 and 4) and whole blood (cow no. 5). During the first 30 min after the injection of $^{75}SeO_3{}^{2-}$ the concentration of ^{75}Se in TCA filtrates of plasma declined in parallel with the decline in plasma total radioactivity. The radioactivity in the filtrate was a small but constant percentage of the total plasma or blood radioactivity; the mean ($\pm$SE) values for cows nos. 1a, 3, 4 and 5 were 14·1$\pm$0·9, 9·4$\pm$0·2, 11·4$\pm$0·2 and 12·4$\pm$0·9 respectively. As the total plasma ^{75}Se activity increased after 30 min the concentration in TCA filtrates continued to decrease until by 240 min the radioactivity present was only 0·02% dose/l of filtrate.

Table 2. *The half-life ($t_{\frac{1}{2}}$; min) of ^{75}Se in plasma during the period 3–30 min and hepatic:portal venous plasma ^{75}Se concentration ratios during the periods 3–25, 30–50 and 60–240 min after an intravenous injection of ^{75}Se as either $Na_2{}^{75}SeO_3$ or $Na_2{}^{75}SeO_4$*

(Mean values with their standard errors)

Form of Se	Cow no.	$t_{\frac{1}{2}}$ during 3–30 min	Hepatic:portal venous plasma ^{75}Se activity during the periods (min) 3–25		30–60		60–240	
			Mean	SE	Mean	SE	Mean	SE
Sodium selenite	1a	13·9	0·876***	0·010	0·955	0·045	0·955	0·005
	2	17·0	0·954***	0·005	1·029*	0·007	1·018	0·029
	3a	18·2	0·963***	0·005	1·021**	0·004	1·006	0·007
	4	14·4	0·958***	0·007	1·031**	0·007	1·010**	0·003
	3b	16·1	ND	ND	ND	ND	ND	ND
	5	14·2	ND	ND	ND	ND	ND	ND
Sodium selenate	1b	31·4	0·982***	0·002	0·986	0·009	1·010	0·023
	6	25·6	0·978	0·051	1·000	0·006	1·035	0·050

ND, not determined.

Significance of difference of mean ratio from unity; $^{*}P < 0{\cdot}05$, $^{**}P < 0{\cdot}02$, $^{***}P < 0{\cdot}001$.

Table 3. *^{75}Se (% dose) excreted in urine and faeces during the first 24 h and during the first 14 d after dosing intravenously with either $Na_2{}^{75}SeO_3$ or $Na_2{}^{75}SeO_4$ or orally with ^{75}Se-labelled barley*

Form of Se	Cow no.	Urine: First 24 h	Urine: Total during 14 d	Faeces: First 24 h	Faeces: Total during 14 d	$^{75}SeO_4{}^{2-}$ excreted faeces: urine
$^{75}SeO_3{}^{2-}$	3b	3·51	10·23	0·49	9·45	0·92
	4	2·41	6·71	0·60	8·23	1·23
$^{75}SeO_4{}^{2-}$	6*	8·81	10·24	3·11	17·16	1·68
	1	8·96	11·00	2·11	13·96	1·27
^{75}Se-labelled barley	7	0·67	2·67	12·80	68·42	32·2

* 10 d collection only.

After an intrajugular injection of $Na_2{}^{75}SeO_4$. The pattern of clearance and reappearance of radioactivity after injection of $Na_2{}^{75}SeO_4$ was different from that for $Na_2{}^{75}SeO_3$ (Fig. 2). The rate of clearance from the systemic circulation was slower with a mean (±SE) $t_{\frac{1}{2}}$ of 28·5±2·9 min during the first 30 min. The hepatic:portal radioactivities (Table 2) showed that the liver removed ^{75}Se but that the tracer was not returned into the circulation as rapidly as when administered in the form of selenite.

The excretion of ^{75}Se in milk, urine and faeces during the 14 d after an oral dose of ^{75}Se-labelled barley. During the 14 d after dosing 68·4% of the dose of ^{75}Se was excreted in faeces, 2·7% in urine and 2·1% in milk. The ^{75}Se activity in urine was greatest during the second and third days after dosing. By day 14 the daily outputs of ^{75}Se in urine and milk were only 0·05 and 0·09% of the dose respectively. The percentage of the oral dose excreted in faeces during the first 24 h was 18·7% of the total 68·4% excreted; a value similar to the 18·1 and 15·1% appearing during the first 24 h after intravenous dosing with $^{75}SeO_4{}^{2-}$ in cows nos. 1 and 6 and therefore much greater than the percentage excreted after intravenous $^{75}SeO_3{}^{2-}$.

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Body retention of ^{75}Se. The rates of clearance of ^{75}Se from the whole body were calculated for those cows subjected to radioactive balance studies and are shown in Table 4. In all animals the clearance of ^{75}Se was biexponential. However, the first component of $^{75}SeO_3{}^{2-}$ clearance was too rapid for its exponent to be measured accurately and it is not given. The second component of clearance was similar for all animals with a mean (±SE) $t_{\frac{1}{2}}$ of 60·7±3·9 d. At 8 d after oral dosing with ^{75}Se-labelled barley any contribution from the first component of clearance was not detectable and the subsequent clearance of ^{75}Se from the body was therefore by endogenous loss.

Table 4. *Whole body clearance of ^{75}Se from cows after dosing intravenously with either $^{75}SeO_3^{2-}$ or $^{75}SeO_4^{2-}$ or dosing orally with ^{75}Se-labelled barley*

Cow no.	Form of Se	First exponent			Second exponent		
		r	Slope	$t_{\frac{1}{2}}$(d)	*r*	Slope	$t_{\frac{1}{2}}$(d)
1	SeO_4^{2-}	0·986	−0·359	1·9	0·993	−0·010	69·3
6	SeO_4^{2-}	0·976	−0·597	1·2	0·997	−0·014	49·5
4	SeO_3^{2-}				0·999	−0·010	69·3
3	SeO_3^{2-}				0·996	−0·012	57·8
7	^{75}Se-labelled barley	0·995	−0·702	1·0	0·991	−0·012	57·8
						Mean	60·7

$t_{\frac{1}{2}}$, half-life.

DISCUSSION

When ^{75}Se was injected into the peripheral circulation of cows it was rapidly removed from the plasma and then re-entered the circulation. From evidence derived from rats it was probably bound to an α- or γ-globulin (Imbach & Sternberg, 1967). The rate of removal of ^{75}Se and its subsequent re-entry into plasma depended on the form in which the Se was administered. $^{75}SeO_3^{2-}$ was cleared more rapidly than SeO_4^{2-} and re-entered the circulation 30–60 min after dosing. The pattern of clearance of $^{75}SeO_3^{2-}$ was also influenced by the amount of carrier Se injected. The amplitude of the decline and subsequent increase in radioactivity was greatest after injections containing the smallest amounts of carrier Se (5–8 μg Se).

The increase in ^{75}Se activity in plasma between 30 and 60 min after dosing could be attributed to the action of the liver. During this period it was clear that the liver was releasing ^{75}Se into the hepatic vein, because the hepatic venous plasma contained approximately 3% more ^{75}Se than the portal plasma. The amount of carrier Se injected with the ^{75}Se influenced the amplitude of the increase. When very small amounts of carrier were used the initial specific activity of each 1 μg Se bound to globulins would have been high and when the protein was released into the hepatic vein it presumably contained sufficient ^{75}Se to cause a marked increase in total plasma ^{75}Se content. Large amounts of carrier Se would have resulted in less ^{75}Se being bound to protein and insufficient radioactivity being released into the hepatic vein to cause as marked an increase. This observation has been confirmed by comparing the results obtained with doses of $^{75}SeO_3^{2-}$ and $^{75}SeO_4^{2-}$ containing either 5 μg or 5000 μg carrier Se (Symonds, Mather & Vagg, unpublished observations). Using 5000 μg carrier no subsequent increase in plasma radioactivity was observed.

In the rat ^{75}Se became attached to plasma albumin very rapidly after injection as $^{75}SeO_3^{2-}$, the albumin acting as a carrier protein (Imbach & Sternberg, 1967). At 3 min after dosing 58% was attached sufficiently firmly to be precipitated by TCA and sodium tungstate. Subsequently the ^{75}Se was incorporated into α- and γ-globulins. The present work shows that in the cow up to 90% of ^{75}Se became attached to a TCA-precipitable component within 2 min of injection. This binding also occurred in vitro in the absence of the cellular components of blood. The increases in plasma ^{75}Se between 30 and 60 min after dosing due to liver activity may therefore represent the transfer of the ^{75}Se to the globulin fraction of plasma. However, Se given as SeO_3^{2-} may also be bound to plasma protein by erythrocytes. McMurray & Davidson (1979) have demonstrated that sheep erythrocytes can

Table 5. *Plasma ^{75}Se concentrations at times t_1 (2 min) and t_2 min after injection of $^{75}SeO_3^{2-}$, the intervals between the t_1 and t_2 (min) and the values of* K, k, v *and* V *used to calculate the proportion* (P) *of the total plasma clearance of ^{75}Se which was due to clearance by the livers of cows nos.* 2, 3 *and* 4

Cow no.	Observed plasma ^{75}Se concentration (% dose/kg) at: t_1	t_2	Interval between t_1 and t_2 (min)	K (min^{-1})	k	v (l/min)	V (l)	P
2	1·73	0·65	14	0·0699	0·046			0·43
3a	3·28	1·20	16	0·0628	0·037	17·5	27	0·38
4	2·02	0·63	16	0·0728	0·042			0·37

K, the fractional clearance constant of ^{75}Se in systemic plasma.
k, the fractional clearance constant of ^{75}Se across the liver.
V, the plasma volume.
v, the volume of plasma flowing through the liver/min.

bind Se rapidly to protein in vitro and release it back into plasma. This aspect of Se metabolism was not measured in the present studies but uptake by erythrocytes did occur during the first few hours after dosing with subsequent long-term incorporation. The average ^{75}Se activity in the cells was approximately 0·05% dose/l cells during the first 24 h. Subsequently the radioactivity increased, presumably owing to the release of new cells containing ^{75}Se-labelled glutathione peroxidase (*EC* 1.11.1.9) into the circulation (Symonds & Mather, unpublished results).

From our results it is possible to calculate the percentage of the total plasma clearance of ^{75}Se which was due to the liver. During the first 30 min after injection the livers of cows nos. 2, 3 and 4 removed approximately 4·6, 3·7 and 4·2% respectively of the ^{75}Se present in the plasma passing through them (Table 2), i.e. their clearance constants 'k' were 0·046, 0·037 and 0·042 respectively. If the volume of plasma flowing through the livers per min was 'v' 1, the ^{75}Se clearance would have been $k.v$ 1/min. During the same period the clearance constant for total plasma ^{75}Se clearance 'K' may be calculated from the relationship: $C_2 = C_1 e^{-K(t_2-t_1)}$ where C_2 and C_1 are the observed plasma ^{75}Se concentrations at times t_2 and t_1 min after the injection of ^{75}Se. The total clearance of ^{75}Se will therefore be $K.V$ 1/min where V (l) is the plasma volume. The proportion (P) of this total clearance which was due to the liver will therefore be given by: $P = \frac{k.v}{K.V}$. Values for k, v, K and V are given in Table 5 with the derived values for P. The value for v is derived from hepatic venous blood flow measured in cows of similar size (unpublished observations) and the value for V is based on the assumption that plasma volume is 5·4% of the body-weight, which was approximately 500 kg. Thus during the first 30 min after injection the liver of these cows removed approximately 40% of the ^{75}Se cleared from plasma. A similar calculation could not be made for cow no. 1 because the fractional clearance was too great. At post-mortem examination the tip of the hepatic venous cannula was in a position which could have allowed some vena caval blood as well as hepatic venous blood to be sampled. Vena caval blood would have a lower ^{75}Se content because of clearance by the kidney. However, the 9% increase in hepatic:portal venous ^{75}Se concentration ratio in this animal during the 30–60 min period (Table 2) indicates that its liver was removing ^{75}Se and returning it to the circulation at a rate similar to the rate in cows nos. 2, 3 and 4.

The rate of excretion of ^{75}Se by cow no. 7 after feeding with ^{75}Se incorporated into barley

was similar to the rate of excretion observed by Cousins & Cairney (1961) after feeding sheep with ^{75}Se incorporated into red clover. In 14 d 68% ^{75}Se was excreted in faeces, 2·7% in urine and 2·1% in milk. After intravenous dosing with either $^{75}SeO_3^{2-}$ or $^{75}SeO_4^{2-}$ approximately equal quantities of ^{75}Se were excreted in urine and faeces. At 10 d after intravenous dosing the percentage dose of ^{75}Se excreted daily in faeces was more than twice the daily excretion at the same time after oral dosing. Significant amounts of Se are excreted, therefore, into the alimentary tract. The possible routes of this endogenous loss are saliva, bile and other gastrointestinal secretions. In the rat 5·8% of an injected dose of $^{75}SeO_3^{2-}$/h was excreted in bile during the 9 h after dosing and 11·1% was excreted by the digestive tract (Imbach & Sternberg, 1967). In cattle biliary excretion is less important. Cows injected intravenously with $^{75}SeO_3^{2-}$ or $^{75}SeO_4^{2-}$ and 5 μg carrier Se, excreted only 0·2% of the radioactivity in bile during 6 h (Symonds, Mather & Vagg, unpublished observations). Se has been reported to be excreted in saliva in the ruminant (Dejneka *et al.* 1979). The strongly reducing conditions in the reticulo-rumen would probably convert this Se to insoluble selenides which would be unavailable to the animal and excreted in the faeces (Peterson & Spedding, 1963).

More of the ^{75}Se injected as $^{75}SeO_4^{2-}$ was lost in faeces and urine during the first 24 h after dosing than of the ^{75}Se injected as $^{75}SeO_3^{2-}$. This would be expected because of the slower clearance of ^{75}Se from plasma and the absence of the marked secondary rise in plasma radioactivity after $^{75}SeO_4^{2-}$ injection which suggest that the SeO_3^{2-} is more readily metabolisable than SeO_4^{2-}.

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REFERENCES

Baird, G. D., Symonds, H. W. & Ash, R. (1975). *J. agric. Sci., Camb.* **85**, 281.
Cousins, F. B. & Cairney, I. M. (1961). *Aust. J. agric. Res.* **12**, 927.
Dejneka, J., Nowosach, R. & Simoni, J. (1979). *Polskie Arch. Weterynarynje.* **21**, 2.
Herigstad, R. R. & Whitehair, K. C. (1974). *Vet. Med. anim. Clin.* **69**, 1035.
Imbach, A. & Sternberg, J. (1967). *J. Appl. Radiat. Isotop.* **18**, 545.
Klaassen, C. D. (1976). *Drug. Metab. Rev.* **5**, 165.
Little, W., Vagg, M. J., Collis, K. A., Shaw, S. R. & Gleed, P. T. (1979). *Res. vet. Sci.* **26**, 193.
Maag, D. D. & Glenn, M. W. (1967). In *Symposium – Selenium in Biomedicine*, p. 127 [O. H. Muth, editor]. Westport, USA: AVI Publishing Co. Inc.
McMurray, C. H. & Davidson, W. B. (1979). *Biochim. biophys. Acta.* **583**, 332.
Peterson, P. J. & Spedding, D. J. (1963). *N.Z. J. agric. Res.* **6**, 13.
Sansom, B. F., Symonds, H. W. & Vagg, M. J. (1978). *Res. vet. Sci.* **24**, 366.
Sansom, B. F., Taylor, P. J., Wheelock, D. & Vagg, M. J. (1971). *Mineral Studies with Isotopes in Domestic Animals*, p. 125. Vienna: International Atomic Energy Authority.
Schwartz, K. & Foltz, D. M. (1957). *J. Am. chem. Soc.* **79**, 3292.
Symonds, H. W. & Baird, G. D. (1973). *Res. Vet. Sci.* **14**, 267.

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