TETANY IN HAND-REARED COMMON BRUSHTAIL POSSUMS

(Trichosurus vulpecular)

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Introduction

During the last 3 years I have identified what has been a previously unreported condition in hand-reared juvenile Common Brushtail Possum. Their presentation has been exactly the same in all instances with the young juvenile 250 to 550 grams being presented in a state of tetany. All had been in care for some considerable time.

Case 1

6/2/03 a small female juvenile about 360 grams was presented at 7pm in the evening in a state of tetany. The body was rigid, the hands and feet were clenched, the nose and mm were bright and the possum felt hot and fevered. The tail was still prehensile and the possum was still aware of surroundings. The ears were not bunched and the nictitavic membrane was not affected as in tetanus. The possum was unable to walk due to the general tetany of muscles See Video 1.

My initial differential diagnosis for tetany were

- Tetanus - No! Ears not bunched, and does not worsen with stimulus.
- Toxoplasmosis - needs a blood test-- subsequently ruled out.
- Hypocalcaemia - rejected as animal was young and still on milk.

My initial treatment was to give some Valium to relax the possum, some Dexamethazone and some pennicillin i/m. The next morning the possum was normal and I really had no idea what I had treated. It re-presented with identical symptoms twice over the next two weeks. It was given Valium only and was normal by morning. Blood samples were taken for Toxoplasmosis and a full blood picture. This showed low calcium 1.3 mmol/L. The possum was placed on calcium sandoz syrup as a supplement and made an un eventful recovery. Toxoplasmosis test was negative.

In hindsight the possum exhibited all the signs that we see with milk fever in our domestic animals eg tetany, rigidity, hyperthermia caused by increased muscle activity, increased respiration and bright mm. My initial query was why should a small juvenile possum still on a milk diet supplemented with some fruit develop Hypocalcaemia?

Case 2

September 03 was not seen by me personally as it occurred 100km away but the symptoms were the same, similar age and weight and was treated with calcium supplements by the local vet and recovered.

Case 3

February 04 was an older female juvenile possum about 550 grams in weight, completely humanised, lived free in the house and fed entirely fruit with little or no native tucker. Was weaned but totally humanised and spent a lot of time with carer. Was presented in the mid morning in Tetany, with exactly the same symptoms. Was treated with diluted 10% Calcium Gluconate sub cutaneously and sent home and rechecked in the afternoon and found to be normal again. A calcium supplement was added to the diet and the possum made an uneventful recovery and was eventually released. There was no reaction at the injection sites.

Show Video 2 “Emma”

Case 4.

12th January 05 "Emma". This 210 gram possum had been reared from a 52 gram pinkie by a very experienced carer and was presented in Tetany at 7.30pm. It was treated with Calcium gluconate sub/cut and responded rapidly to be normal in 25 minutes, see video.

Looking back on the carer's history sheet it appears it was found 6 days earlier suffering from "Heat stress" (symptoms similar to that on presentation). A veterinary consult failed to diagnose the problem. Next few days it was fine as long as it was kept cool (in a/c) and quiet or it started to get the shakes and clenched its paws. Had "Fits " the two nights before being presented in a state of tetany. It is obvious looking at the history that the possum was barely keeping its calcium at a level to prevent clinical signs for a whole week before presentation.

Symptoms were classic for this condition. Unfortunately with this treatment I made two errors of judgement in my haste to treat it.

1. I did not dilute the Calcium Gluconate and this subsequently caused a slough on each side of the ribs, at the injection sites, over the next week. These wounds healed slowly over a two to three week period

2. I overdosed it with Calcium Gluconate causing its demise four weeks later due to kidney damage by calcium crystals. Whenever we think we are on top of a situation we are often humbled by our own stupidity. I'm afraid I was thinking of a cat or small dog in milk fever and not paying attention to the fact that this was a small juvenile possum weighing only 300 grams and I had probably overdosed by a factor of 8.

Discussion

In all species calcium metabolism is very similar.

Of the total circulating serum calcium, 50% is protein bound, 40% is ionised, and 10% is complexed with other substances. Protein bound calcium can not diffuse through membranes and thus is unusable by the tissues.

Only the ionised form is available to tissues, so only changes in this faction of total serum calcium are responsible for clinical problems. Measurement of ionised calcium is difficult so biochemical profiles only show total serum calcium.

Calcium-

The body's requirements for calcium are generally met by eating or drinking dairy products, especially milk. Most calcium (90 percent) is stored in bone, with a constant exchange occurring among blood, tissue, and bone. The intake is balanced by losses in urine and faeces. The blood levels of calcium and its intestinal absorption, deposition, or mobilization from bone are all controlled by a complex interplay of vitamin D, parathyroid hormone, and calcitonin a hormone produced by the Thyroid gland.

Besides promoting rigidity in bones, calcium regulates nervous excitability and muscle contraction; it is also important in maintaining the integrity of intracellular cement and cellular membranes. During periods of growth, pregnancy, and lactation, calcium intake needs to be supplemented. Diseases of calcium metabolism include vitamin D deficiency (rickets), hypervitaminosis D, hypoparathyroidism and hyperparathyroidism, and some forms of renal disease.

Phosphorus-

Phosphorus plays an important role in the hemostasis of calcium and in reactions involving carbohydrates, lipids, and proteins. The chemical energy of the body is stored in "high energy phosphate" compounds.

Elemental phosphorus is extremely poisonous, but phosphorus ingested as phosphates in the diet is not toxic.

Vitamin D –

The active forms of vitamin D are ergocalciferol vitamin D-2 and cholecalciferol vitamin D-3, both of which arise in the body from ingested precursors by exposure of the skin to ultraviolet light. Vitamin D primarily regulates calcium metabolism by determining the movement of calcium from intestines to blood and from blood to bone. It interacts with parathyroid hormone and calcitonin (a hormone produced in the thyroid gland) in controlling calcium levels. In tropical countries, where exposure to sunlight is high, vitamin D deficiency is rare. It is much more common in northern regions. Ultraviolet irradiation of food products, a practice common in some countries, increases their vitamin D content.
A deficiency of vitamin D results in failure to absorb calcium and phosphorus, causing faulty formation of bone. In children and dogs the syndrome is known as RICKETS and is manifested by deformities of the rib cage and skull and by bowlegs as a consequence of long bone deformity. Adult rickets, or osteomalacia, is characterized by generalized bone calcification and, eventually, gross bone deformities. Symptoms of hypervitaminosis D consist of weakness, fatigue, lassitude, headache, nausea, vomiting, and diarrhoea. Urinary symptoms occur when calcium deposits build up in the kidneys.

Mechanisms involved in Hypocalcaemia involve: -

- Low concentrations of binding proteins- Hypoalbuminaemia
- Reduced intestinal absorption- Deficient Vitamin D (renal disease or severe intestinal disease
- Reduced renal and bone reabsorption - Hypoparathyroidism
- Inadequate dietary intake
- Excessive loss- Lactation
- Sequestration – saponification (acute pancreatitis)
- Binding/complexing with administered ingested chemicals—phosphate containing enemas, ethylene glycol toxicity and low calcium / high phosphate diet (nutritional secondary hyperparathyroidism)

Systems affected: -

- Nervous / Neuromuscular – seizures, tetany, ataxia and weakness.
- Cardiovascular – ECG changes and bradycardia
- Gastrointestinal – anorexia and vomiting
- Ophthalmic – Posterior lenticular cataracts
- Respiratory – panting

Signs: -

Signs of underlying disease may be seen without clinical signs of hypocalcaemia because the latter do not occur until the total serum calcium falls below 1.7mmol/l

- Seizures
- Muscle trembling, twitching, or fasciculations
- Ataxia or stiff gait
- Weakness
- Panting
- Facial Rubbing
- Vomiting
- Anorexia
- Fever
- Cataracts

Pathological Hypocalcaemia: -

- Primary hypoparathyroidism
- Secondary hypoparathyroidism
- Renal failure – acute or chronic
- Ethylene glycol poisoning
- Acute pancreatitis
- Puerperal tetany – eclampsia
- Phosphate containing enemas
- Nutritional secondary hyperparathyroidism
- Hypomagnesemia
- Intestinal malabsorption

Medications: -

Calcium gluconate 10% solution 5-15mg/kg (0.5 –1.5ml/kg) i/v slowly to effect over a 10 minute period. Monitor heart rate and stop administration if heart rate indicates bradycardia.
Can be given subcutaneously if diluted 50% with normal saline.

Calcium chloride 10% solution, three times more potent but very irritant if outside vein. Use one-third the volume. Can't be given subcutaneously. Unsuitable for those reasons.

Serum calcium should be at least >2.0 – 2.5 mmol/L

Calcium carbonate Pdr. orally 0.25 – 0.5gram /day adult possum

Calcium Sandoz liquid orally 1-2mls /day (22mg/ml)

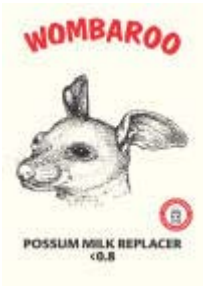
Vitamin D3 0.25ug capsule "Rocatrol"

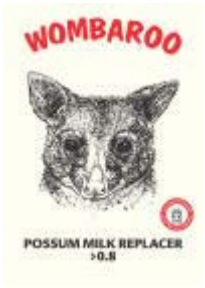
Daily dose 0.03 – 0.06 ug/day
Maximum effect in 1-4 days
Short life <1day
Given in divided doses
N.B. Make sure there is adequate Calcium in the diet for it to work

What's in Wombaroo Possum Milk Replacer?

POSSUM MILK REPLACER

Two stages of possum milk are available. The stage required is dependent on the developmental stage of the joey. The illustrations on the front of each packet provide a visual guide in determining the milk type to be used. The possum milk replacers are suitable for all species of possums and gliders.





STAGE	STAGE
<0.8	**>0.8**
160g/Litre	250g/Litre
PACK SIZES	**PACK SIZES**
160g, 800g	250g, 1.25kg
ANALYSIS	**ANALYSIS**
Min Crude Protein 33%	Min Crude Protein 30%
Min Crude Fat 15%	Min Crude Fat 35%
Max Fibre 0%	Max Fibre 0%
Max Salt 1%	Max Salt 1.1%

We will deal with >0.8 because all the possums that showed clinical signs were on >0.8.

You will notice in the Table below that there 3.3 grams Ca /L = 3.3.mg/ml

220 gram possum drinking 6ml four times a day 792mg Ca
= 3.6Grams /kg This should be sufficient. Please note Ca:P ratio is 1.44 : 1 it should be adequate. Note that the Calcium content of <8 is half that of >8 (1.8gm vs 3.3 gm)

There is also added Vitamin D3 (Cholecalciferol) 20 ug/litre 22
220 gram possum on 4x 6ml feeds receives 0.48ug (recommended dose above = 0.03 -0.06 ug / day)
Again there is more Calciferol (Vit D) in >0.8 compared to <0.8 (13 vs 25 ug)

By way of Comparison
Biolac has 2.00 mg/ml Ca and 1.50 mg/ml Phos. ratio 1.33
Di-Vetelact 1 scoop per 60ml 1.00 mg/ml Ca and 0.70mg/ml Phos. ratio 1.43
1 scoop per 40 ml 1.50 mg/ml Ca and 1.05mg/ml Phos. Ratio 1.43

All have added vitamins including vitamin D3 and other trace minerals

POSSUM MILK REPLACERS

email: *wombaroo@adelaide.on.net* ***Phone: 08 8379 1339***

TYPICAL COMPOSITION PER LITRE OF PREPARED MILK

Lactation Stage Milk Stage	Units	Early to Mid <0.8	Mid to Late >0.8
Milk Powder Solids	g	160	250
Protein	g	55	7
Fat	g	25	90
Carbohydrate	g	60	50
ME	MJ	3.1	5.7
α-Tocopherol (Vit E)	mg	15	25
Retinol (Vit A)	mg	0.4	0.5
Cholecalciferol (Vit D_3)	µg	13	25
Phytomenadione (Vit K_1)	mg	1	2
Choline	mg	50	80
Inositol	mg	30	60
Ascorbic Acid (Vit C)	mg	30	50
Nicotinic acid (Vit B_3)	mg	30	60
Pantothenic Acid (Vit B_5)	mg	10	20
Thiamine (Vit B_1)	mg	7	15
Pyridoxine (Vit B_6)	mg	3	5
Riboflavin (Vit B_2)	mg	2	4
Folic Acid	mg	0.8	1.6
Biotin (Vit H)	µg	85	180
Cyanocobalamin (Vit B_{12})	µg	25	40
Calcium	g	1.8	3.3
Phosphorus	g	1.4	2.5
Potassium	g	0.8	1.4
Sodium	g	0.3	0.6
Magnesium	mg	90	170
Iron	mg	6	10
Zinc	mg	4	7
Manganese	mg	2	4
Copper	mg	0.7	1.6
Iodine	µg	110	220
Selenium	µg	30	50

AGE ESTIMATION

Age estimation may be based on tail, foot, arm or leg length or combinations of these measurements. Body weight should not be used to estimate age. Only use these tables as a guide. They do not take into account regional differences in size or variations in size due to sex.

BRUSHTAIL POSSUM - DAILY FEED ESTIMATES

Milk	Age	Tail	Foot	Weight	Feed
	days	mm	mm	g	ml
	20	13	10	6	3
	30	20	13	8	3
	40	27	16	11	5
	50	35	20	16	6
<0.8	60	44	24	22	9
	80	65	33	42	12
	90	77	38	58	16
Emerging from pouch	100	91	44	79	19
Transition	101 to 105		12ml <0.8 + 3ml >0.8		15
from	106 to 110		9ml <0.8 + 6ml >0.8		15
<0.8 to >0.8	111 to 115		6ml <0.8 + 9ml >0.8		15
	116 to 119		3ml <0.8 + 12ml >0.8		15
	120	121	56	151	17
>0.8	130	137	62	209	20
	140	155	69	282	26
Fully out of Pouch	150	174	77	390[A]	35[B]

A. Average growth rate from now is about 15g per day
B. Milk volume now depends on other food consumed.
Provide fresh drinking water between feeds on hot days and once joey has emerged from the pouch.
It is important to weigh joeys regularly to confirm growth. Overfeeding can cause diarrhoea so feed the suggested milk volumes in our tables.

WOMBAROO HIGH PROTEIN SUPPLEMENT

This product used extensively by animal carers and keepers as a protein booster in the diet of many fruit and nectar eating animals. The sources of protein in this supplement are soy protein isolate and whey protein isolates with high lactalbumin content. Together these ingredients produce a protein mix with an excellent amino acid composition. The supplement is fortified with vitamins, minerals and the essential fatty acids α-linolenic acid, EPA and DHA. Product palatability and protein quality make it a useful food additive to boost the protein level in the diet of debilitated animals.

TYPICAL COMPOSITION PER KG

	Units			Units	
Protein	g	520	Riboflavin (Vit B2)	mg	10
Fat	g	120	Folic Acid	mg	5
Fibre	g	30	Biotin (Vit H)	µg	600
ME	MJ	18	Cyanocobalamin (Vit B_{12})	µg	150
α-Tocopherol (Vit E)	mg	90	Calcium	g	13
Retinol (Vit A)	mg	1	Phosphorus	g	9
Cholecalciferol (Vit D_3)	µg	80	Potassium	g	4
Phytomenadione (Vit K_1	mg	9	Sodium	g	2
Choline	mg	600	Magnesium	mg	800
Inositol	mg	400	Iron	mg	9
Ascorbic Acid (Vit C	mg	200	Zinc	mg	25
Nicotinamide (Vit B_3)	mg	200	Manganese	mg	25
Pantothenic Acid (Vit B_5)	mg	75	Copper	mg	5
Thiamine (Vit B_1)	mg	30	Iodine	µg	600
Pyridoxine (Vit B_6)	mg	12	Selenium	µg	150

Ingredients
Whey protein, soy protein, ground cereals, maltodextrin, dextrose, lysine, methionine, vegetable oils, omega-3 and omega-6 fatty acids, vitamins A, B_1,B_2, B_6, B_{12}, C, D_3, E, K, nicotinamide, pantothenic acid, biotin, folic acid, choline, inositol, calcium, phosphorus, potassium, sodium, magnesium, zinc, iron, manganese, copper, iodine, selenium. If unopened, or opened and correctly resealed, the powder remains stable for up to 18 months if stored below 30° C and protected from moisture.

Available in 250g, 1kg & 5kg packs

PROTEIN REQUIREMENTS Providing protein intake supplies adequate levels of all essential amino acids then maintenance protein requirement for mammals ranges from about 1.5g to 6g per $kg^{-0.75}$ per day. Protein requirement is related to the amount of energy expended. If there is no gain in body weight then energy intake can be substituted for energy expended. An average value of 6mg of protein per kJ of energy intake can be used to estimate maintenance protein requirement. For Wombaroo as the protein source this translates into 90mg per kJ of energy or 4g per $kg^{-0.75}$ per day. The amount of supplement needed will depend on the protein quantity and quality in the existing diet and the species of animal.
FRUGIVOROUS ANIMALS: Fruit can represent a large proportion of the diet for some animals and birds. To ensure that there is sufficient quality protein in their diet disperse 2 heaped teaspoons of Wombaroo High Protein Supplement over each 100g of fruit.
FLYING FOXES: Disperse 2 heaped teaspoons of Wombaroo High Protein Supplement over 300g of fresh cut apple and feed this quantity to each adult animal. Increase the amount of supplement to 4 heaped teaspoons when feeding pregnant or nursing females and juveniles.
OTHER USES: Wombaroo High Protein Supplement can be substituted for the High Protein Cereal used in the many food recipes for animals and birds. You only need to use half the quantity of Wombaroo High Protein Supplement because of its superior protein quality and higher concentration.

www.wombaroo.com.au Phone: 08 8391 1713

APPROXIMATE ANALYSIS

	M-100	M-150	M-200
Protein	5%	7.5%	10%
Carbohydrate	5%	3.5%	2%
Lipid	5%	7.5%	10%
Total Solids	16%	19.5%	23%

FEEDING REGIME

M-100 160 grams of milk powder per litre of water
16 grams or 2 well heaped teaspoons per 100ml
Feed 10-15% of bodyweight per day over 5 or 6 feeds

M-150 180 grams per litre or 3 well heaped teaspoons per 100 ml
Feed 10-15% of bodyweight per over 5 feeds

ACCESS TO SOLID FOOD

M-200 240 grams per litre or 3 well heaped teaspoons per 100 ml
Feed 10-15% of bodyweight per day over 5 feeds

Don't be confused by the use of 3 heaped teaspoons for both the **M-150** and **M-200** The bulk density of each is different

VITAMIN AND MINERAL PROFILE

Vitamin mg or ug per litre

Ascorbic Acid	50 mg	Thiamine	1 mg	Riboflavin	2 mg
Vitamin B6	1.5 mg	Nicotine Acid	50 mg	Pantothenic Acid	10 mg
Folic Acid	400 ug	Vitamin B12	40 ug	Biotin	60 ug
Retinol	800 ug	a -Tocopherol	4 mg	Vitamin D	10 ug
Vitamin K1	50 ug	Inositol	300 ug		

Minerals g or mg per litre

Calcium	2.0 g	Phosphorus	1.5 g	Sodium	1 g
Potassium	0.8 g	Citrate	0.5 g	Magnesium	100 g
Iron	20 mg	Copper	5 mg	Zinc	5 mg
Manganese	1 mg	Iodine	0.15 mg		

Reliable and comprehensive values for milk compositions in marsupials are so far available for only few species. The **BIOLAC** formulas for marsupials are based on published information on milk composition in the Tammar Wallaby, Red Neck Wallaby, Brushtail Possum and Koala.

As more scientific information becomes available, we may modify our products accordingly **BIOLAC** can supply specific milk products for most domestic animals as well as marsupials. We also supply feeding teats for all marsupials, kittens, puppies, calves and lambs as well as feeding bottles.

BIOLAC

FOR MARSUPIALS

BIOLAC provides the most advanced milk formulas ever produced for Australian native animals. **BIOLAC** formulas contain fully digestible carbohydrates, proteins, lipids and elevated levels of many vitamins and minerals. The lipids have a more favourable balance of saturated, mono and poly unsaturated fatty acids.

BIOLAC contains NO maltodextrins, sucrose or soy proteins.

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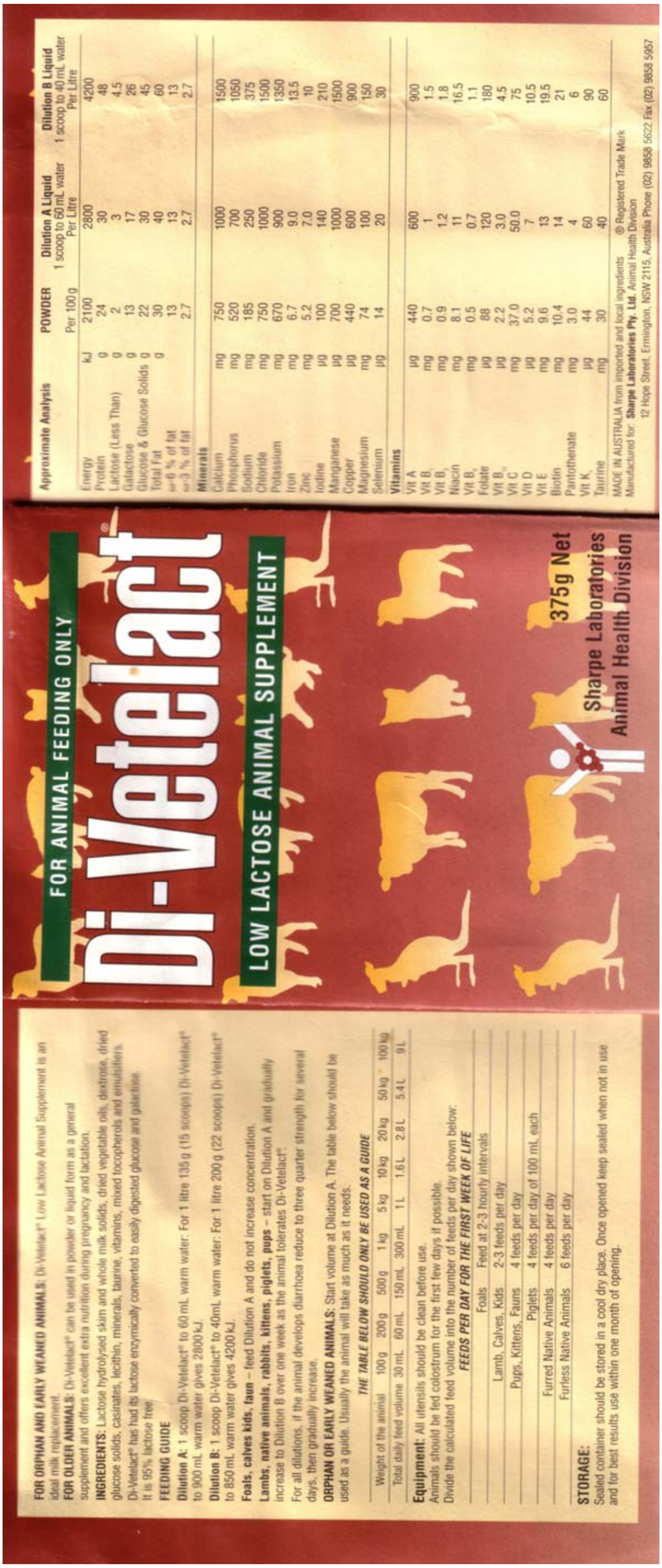
FOR ORPHAN AND EARLY WEANED ANIMALS: Di-Vetelact® Low Lactose Animal Supplement is an ideal milk replacement.
FOR OLDER ANIMALS: Di-Vetelact® can be used in powder or liquid form as a general supplement and offers excellent extra nutrition during pregnancy and lactation.
INGREDIENTS: Lactose hydrolysed skim and whole milk solids, dried vegetable oils, dextrose, dried glucose solids, casinates, lecithin, minerals, taurine, vitamins, mixed tocopherols and emulsifiers.
Di-Vetelact® has had its lactose enzymically converted to easily digested glucose and galactose.
It is 95% lactose free.
FEEDING GUIDE
Dilution A: 1 scoop Di-Vetelact® to 60 mL warm water: For 1 litre 135 g (15 scoops) Di-Vetelact® to 900 mL warm water gives 2800 kJ.
Dilution B: 1 scoop Di-Vetelact® to 40mL warm water: For 1 litre 200 g (22 scoops) Di-Vetelact® to 850 mL warm water gives 4200 kJ.
Foals, calves kids, faun – feed Dilution A and do not increase concentration.
Lambs, native animals, rabbits, kittens, piglets, pups – start on Dilution A and gradually increase to Dilution B over one week as the animal tolerates Di-Vetelact®.
For all dilutions, if the animal develops diarrhoea reduce to three quarter strength for several days, then gradually increase.
ORPHAN OR EARLY WEANED ANIMALS: Start volume at Dilution A. The table below should be used as a guide. Usually the animal will take as much as it needs.
THE TABLE BELOW SHOULD ONLY BE USED AS A GUIDE
Weight of the animal 100 g 200 g 500 g 1 kg 5 kg 10 kg 20 kg 50 kg 100 kg
Total daily feed volume 30 mL 60 mL 150 mL 300 mL 1 L 1.6 L 2.8 L 5.4 L 9 L
Equipment: All utensils should be clean before use.
Animals should be fed colostrum for the first few days if possible.
Divide the calculated feed volume into the number of feeds per day shown below:
FEEDS PER DAY FOR THE FIRST WEEK OF LIFE
Foals Feed at 2-3 hourly intervals
Lamb, Calves, Kids 2-3 feeds per day
Pups, Kittens, Fauns 4 feeds per day
Piglets 4 feeds per day of 100 mL each
Furred Native Animals 4 feeds per day
Furless Native Animals 6 feeds per day
STORAGE:
Sealed container should be stored in a cool dry place. Once opened keep sealed when not in use and for best results use within one month of opening.
FOR ANIMAL FEEDING ONLY
Di-Vetelact®
LOW LACTOSE ANIMAL SUPPLEMENT
375g Net
Sharpe Laboratories
Animal Health Division
Approximate Analysis | POWDER Per 100 g | Dilution A Liquid 1 scoop to 60 mL water Per Litre | Dilution B Liquid 1 scoop to 40 mL water Per Litre
Energy kJ 2100 2800 4200
Protein g 24 30 48
Lactose (Less Than) g 2 3 4.5
Galactose g 13 17 26
Glucose & Glucose Solids g 22 30 45
Total Fat g 30 40 60
ω-6 % of fat 13 13 13
ω-3 % of fat 2.7 2.7 2.7
Minerals
Calcium mg 750 1000 1500
Phosphorus mg 520 700 1050
Sodium mg 185 250 375
Chloride mg 750 1000 1500
Potassium mg 670 900 1350
Iron mg 6.7 9.0 13.5
Zinc mg 5.2 7.0 10
Iodine µg 100 140 210
Manganese µg 700 1000 1500
Copper µg 440 600 900
Magnesium mg 74 100 150
Selenium µg 14 20 30
Vitamins
Vit A µg 440 600 900
Vit B mg 0.7 1 1.5
Vit B mg 0.9 1.2 1.8
Niacin mg 8.1 11 16.5
Vit B mg 0.5 0.7 1.1
Folate µg 88 120 180
Vit B µg 2.2 3.0 4.5
Vit C mg 37.0 50.0 75
Vit D µg 5.2 7 10.5
Vit E mg 9.6 13 19.5
Biotin mg 10.4 14 21
Pantothenate mg 3.0 4 6
Vit K µg 44 60 90
Taurine mg 30 40 60
MADE IN AUSTRALIA from imported and local ingredients ® Registered Trade Mark
Manufactured for: Sharpe Laboratories Pty. Ltd. Animal Health Division
12 Hope Street, Ermington, NSW 2115, Australia Phone (02) 9858 5622 Fax (02) 9858 5957

The generally accepted Dogma is that a juvenile on an adequate milk diet would not be expected to suffer from Hypocalcaemia, as there should be sufficient calcium in the diet to meet their needs.

Vitamin D is essential for absorption of calcium from the gut and its utilisation. Many small possums up to 250 grams are kept inside and in bags so they don't get a real chance at direct sunlight to synthesize Vitamin D themselves. Is this putting them in a negative Calcium balance early in their lives?

Most small possums start out eating common fruit as they are weaned and are sometimes only introduced to native tucker of new leaf tips, bottlebrush and Grevillia flowers and other suitable foods when they get past 450grams.

Many of the common fruits and vegetables that we have in our normal groceries are used to supplement our juvenile possums because they are sweet, palatable and convenient. However they may not have a good Ca: P ratio and this may be a major cause of hypocalcaemia induced by Nutritional Secondary Hyperparathyroidism?

For example Apple, Avocado, Broccoli florets, Cantaloupe, Carrots, Cauliflower, Corn, Cucumber, Grapes, Melons, Kohlrabi (also causes bloat and should not be fed to possums) Peaches, Peas, Plums, Potato, Pumpkin, Radishes, Strawberries, Tomatoes and Mangoes all have a < 1 : 1 ratio

What we should be feeding in order of high calcium yield is Rhubarb (Oxalate toxicity), Turnip Greens, Broccoli leaves, Parsley, Paw Paw, Orange, Kale, Beet Greens, Silver Beet and Broccoli stems.

Please see lists of vegetables and fruit below. Ratio 2 column is from a second source but generally they agree.

Cheese and Yoghurt are good foods with High Calcium Values and a positive calcium ratio.

100 Gram Sample	Cal gms	Phos gms	Ratio
Cheddar Cheese	728	517	1.4
Yoghurt (Non- fat milk)	199	156	1.27

Nutritive Values of Food USDA Human Nutrition Information Service Home and Garden Bullitin No.2 1991
Ratio 2 table is fromFry, Fredrick L A Practical Guide for Feeding Captive Reptiles (1991) Table 9 pp 86 & 87

100 GM SAMPLE	Cal mgm	Phos mgm	Ratio	Ratio 2
Apple	29	29	1 : 1	1 : 1.7
Apricot	14	18	1 : 1.3	1 : 1.8
Asparagus	23	61	1 : 2.6	1 : 1.9
Avocado	10	40	1 : 4	1 : 1
Banana	5	20	1 : 4	1 : 3.5
Beans,Green	46	39	1.1 : 1	1 : 3.1
beet Greens	113	40	2.8 : 1	2.4 : 1
Beets	11	31	1 : 2.8	1 : 1.5
Blackberries	32	21	1.5 : 1	1 : 1
blueberries	6	10	1 : 1.6	1.6 : 1
Broccoli Florets	48	66	1 : 1.3	1 : 1.6
Broccoli Leaves				3.9 : 1
Broccoli Stems				2.4 : 1
Brussel Sprouts	36	56	1 : 1.6	1 : 4.5
Cabbage	47.23	23	2 : 1	
Cantalope	10	27	1 : 2.7	1.1 : 1
Carrots	26	42	1 : 1.6	1.1 : 1
Cauliflower	29	46	1 : 1.6	2 : 1
Celery	35	25	1.4 : 1	1.7 : 1
Celeary Greens				2.1 : 1
Chard				3 : 1
Cherries	14	19	1 : 1.4	1 : 1
Collards				2.8 : 1

Seeds

Pumpkin Seeds	428	1189	1 : 2.8	
Sunflower seeds	117	714	1 : 6.1	

100 GM SAMPLE	Cal mgn	Phos mgm	Ratio	Ratio 2
Corn	2	47	1 :23	1 : 12.9
Cucumber	14	17	1 : 1.2	1 : 2.1
Dandelion Grns	140	41	1 : 3.4	2.4 : 1
Eggplant	7	21	1 : 3	1 : 2.8
Endive	52	28	1.9 : 1	2.7 : 1
Grapefruit	12	8	1.5 : 1	1 : 1.1
Grapes	12	14	1 : 1.1	1 : 1.8
Guava				1 : 1.1
Honeydue	11	11	1 : 1	0 : 0
Huckleberry				1.3 : 1
Kale	72	27	2.7 : 1	2.9 : 1
Kohlrabi	24	45	1 : 1.9	3.3 : 1
Leeks				1 : 1
Lettuce Green Lf	32	23	1.4 : 1	1.8 : 1
Mushrooms	6	104	1: 17	1 : 7
Mustard Greens	74	41	1.8 : 1	3.5 : 1
Okra	63	56	1.1: 1	1.2 : 1
Onions	60	33	1.8 : 1	1 : 1
Orange	40	13	3.0 : 1	2.4 : 1
parsley	130	40	3.3 : 1	1.5 : 1
Parsnips	37	69	1 : 1.9	1 : 1.3
Peaches	5	11	1 : 2.2	1 : 1.9
pear	11	11	1 : 1	1 : 1.2

Vitamin D Sources

EggYolk	135	476	1 : 3.5	
Liver	10	461	1 : 46	

100 GM SAMPLE	Cal mgm	Phos mgm	Ratio	Ratio 2
Peas Fresh	41	55	1 : 1.3	1. : 4.5
Persimmon				1 : 1.0
Pineapple	7	7	1 : 1	1 : 3.3
Plums	5	11	1 : 2.2	1 : 1.4
potato	5	44	1 : 8.8	1 : 4.1
Potato sweet				1 : 2.4
Pumpkin	15	30	1 : 2	1 :2.2
Radishes	22	14	1 : 1.6	1 : 1.4
Rasberries	21	12	1.8 : 1	1.1 : 1
Rubarb	145	8	18 : 1	
Spinach	98	49	2 : 1	1.7 : 1
Squash Summer	27	38	1 : 1.4	1.2 : 1
Squash Winter				1.3 : 1
Strawberries	14	19	1 : 1.4	1.2 : 1
Tangarine	11	14	1 : 1.3	2.5 : 1
Tomatoes	7	22	1 : 3.1	1 : 2.6
Turnips	21	19	1.1 : 1	1.2 : 1
Turnip Greens	136	29	4.7 : 1	7.1 :1
Watercress				3.6 : 1
Watermellon	7	10	1 : 1.4	3.7 : 1
Yam				1.1 :1
Mango	10	11	1 : 1.1	
Paw Paw	25	8	3.1 : 1	

Please Note those foods > 2 : 1 ratio in yellow and those in red with > 3 : 1 ratio

Foods That Are Unsuitable For Feeding Animals with Low Calcium Blood Levels

Include all foods where the calcium is in a negative ratio

Nutritive Values of Food USDA Human Nutrition Information Service Home and Garden Bullitin No.2 1991
Ratio 2 table is fromFry, Fredrick L A Practical Guide for Feeding Captive Reptiles (1991) Table 9 pp 86 & 87

100 GM SAMPLE	Cal mgm	Phos mgm	Ratio	Ratio 2
Apple	29	29	1 : 1	1 : 1.7
Apricot	14	18	1 : 1.3	1 : 1.8
Asparagus	23	61	1 : 2.6	1 : 1.9
Avocado	10	40	1 : 4	1 : 1
Banana	5	20	1 : 4	1 : 3.5
Beans,Green	46	39	1.1 : 1	1 : 3.1
beet Greens	113	40	2.8 : 1	2.4 : 1
Beets	11	31	1 : 2.8	1 : 1.5
Blackberries	32	21	1.5 : 1	1 : 1
blueberries	6	10	1 : 1.6	1.6 : 1
Broccoli Florets	48	66	1 : 1.3	1 : 1.6
Broccoli Leaves				3.9 : 1
Broccoli Stems				2.4 : 1
Brussel Sprouts	36	56	1 : 1.6	1 : 4.5
Cabbage	47.23	23	2 : 1	
Cantalope	10	27	1 : 2.7	1.1 : 1
Carrots	26	42	1 : 1.6	1.1 : 1
Cauliflower	29	46	1 : 1.6	2 : 1
Celery	35	25	1.4 : 1	1.7 : 1
Celeary Greens				2.1 : 1
Chard				3 : 1
Cherries	14	19	1 : 1.4	1 : 1
Collards				2.8 : 1
Seeds				
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Grapes	12	14	1 : 1.1	1 : 1.8
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parsley	130	40	3.3 : 1	1.5 : 1
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Rasberries	21	12	1.8 : 1	1.1 : 1
Rubarb	145	8	18 : 1	
Spinach	98	49	2 : 1	1.7 : 1
Squash Summer	27	38	1 : 1.4	1.2 : 1
Squash Winter				1.3 : 1
Strawberries	14	19	1 : 1.4	1.2 : 1
Tangarine	11	14	1 : 1.3	2.5 : 1
Tomatoes	7	22	1 : 3.1	1 : 2.6
Turnips	21	19	1.1 : 1	1.2 : 1
Turnip Greens	136	29	4.7 : 1	7.1 :1
Watercress				3.6 : 1
Watermellon	7	10	1 : 1.4	3.7 : 1
Yam				1.1 :1
Mango	10	11	1 : 1.1	
Paw Paw	25	8	3.1 : 1	

Please Note those foods < 1 : 1 ratio in Green and those in red with <1 : 2 ratio

Normal Blood Values for Adult Common Brushtail Possums from Paul J.A. Presidente, Post Graduate Committee in Veterinary Science Proceedings No. 36 Fauna Part B 1978. (From 164 samples)

		Reference	Range	Case 1
Hb	**g/l**	**139**	**± 4**	**92↓**
PCV	**%**	**42**	**± 1**	**22↓**
RBC	**10^6/mm^3**	**6.38**	**± 0.16**	**2.8↓↓**
MCV	**ug**	**66**	**± 1**	**79↑**
MCH	**pg**	**21.7**	**± 0.2**	**33↑**
MCHC	**%**	**32.8**	**± 0.2**	
WBC	**10^3/mm^3**	**8.2**	**± 0.5**	**13.2↑**
	Neutrophils	**2.6**	**± 0.3**	**2.6**
	Lymphocytes	**4.9**	**± 0.5**	**10.2↑**
	Monocytes`	**0.4**	**± 0.1**	**0.1↓**
	Eosinophils	**0.2**	**± 0.1**	**0.1**
	Basophils	**0.2**	**± 0.1**	

Plasma Electrolytes and serum Proteins **Random Sample**

		Reference		Case 1	Emma	Grace	Male	Female
				360g	210g	309g	350g	280g
					18D post Tx			
Na^+	**mmol/l**	**152**	**± 2.6**		**132**			
	156							
K^+	**mmol/l**	**4.0**	**± 0.2**		**17**	**6.1↑**		
Ca^{++}	**mmol/l**	**2.9**	**± 0.1**	**1.3 ↓↓↓**	**2.9**	**1.5↓ ↓**	**2.5↓**	**2.6L↓**
Mg^+	**mmol/l**	**1.2**	**± 0.1**					
Cl^+	**mmol/l**	**102**	**± 3.2**			**75↓↓**		
PO4	**mmol/l**	**2.2**	**± 0.3**	**3.3↑**	**>7.8↑↑↑**	**>7.7↑↑↑**	**3.1↑**	**2.1 N**
Ca:P Ratio		**1.31**		**0.4↓↓↓**	**0.37↓↓↓**	**0.25↓↓↓**	**0.8↓**	**1.2 N**
BUN	**mmol/l**	**4.99**	**± 0.49**					
Glucose	**gm/l**	**8.63**	**± 1.54**					
Total Protein	**gm/l**	**63**	**± 2**		**81**	**53↓**		
Albumin	**gm/l**	**35**	**± 2**		**48**	**39↑**		
Globulin	**gm/l**	**25**	**±2**		**33**	**14↓**		
Toxoplasmosis				**-ve-**		**-ve**		

Case 5 was not a case of Tetany but had Hypocalcaemia

"Grace" was rescued on 15/12/04 as a 100 gram pouched juvenile. She was difficult to feed from the start with Wombaroo< 8. She was eating peeled grape by 128 gram and was on a I:I transition milk <8:>8.

At 320 gram she was eating moist food from dish and nibbling on sweet potato and still on >8 milk

10/2/05 she was trembling and salivating, 3rd eyelid was up. Grace's vet placed her on Baytril (5mg/kg) and Antirobe (6mg/kg) and some blood tests done. Because "Grace's'" carer was also "Emma's" carer she was well aware of the need for a calcium supplement and started giving some calcium sandoz, chicken wings and cuttlefish in cage

- Toxoplasmosis test negative
- Calcium 1.5 mmol/L Very Low
- Phosphate 7.7 mmol/L Very High
- Ratio 0.2
- Total Protein 53 g/L
- Albumin 39 g/L
- Globulin 14 g/L
- There was also low chloride and High Potassium Anion

Grace showed signs of trembling most evenings, excessive salivation, some ataxia and weak grip

7/3/05 Grace's vet eventually looked at blood results and suspected Hypothyroidism and instituted treatment with Calciferol "Rocatrol"0.25 ug capsule Dissolved in 2 ml water and dosed orally with 0.2 ml (Dose =0.025ug) This was given daily and the calcium and phosphate levels monitored

Dosed on dates 7,8,9,11,15,17,20,23,28th March,

On 6/4/05 dose dropped by half to 0.025ug and repeated approximately once weekly on 13,21,30,16 April.

Unfortunately the veterinarian decided to withdraw the calcium supplement once the Calciferol injections were instituted and the calcium levels improved. Why? I don't know. I believe that this contributed to her decline. Though the calcium levels improved it is obvious in hindsight that the Calciferol injections in association with a high phos / low calcium diet caused the possum to mobilise calcium from the bones to the blood leading to metabolic bone disease.

Trembling and salivation continued and the entire belly was wet a lot of the time
11/3/05 490 grams in weight 3 x 15 ml feeds eating some mashed fruit often being force fed with syringe. Developed tremors in the hind legs that were weak.
29/3/05. It was noted that there was an electrolyte imbalance with lowered Potassium and Chloride.

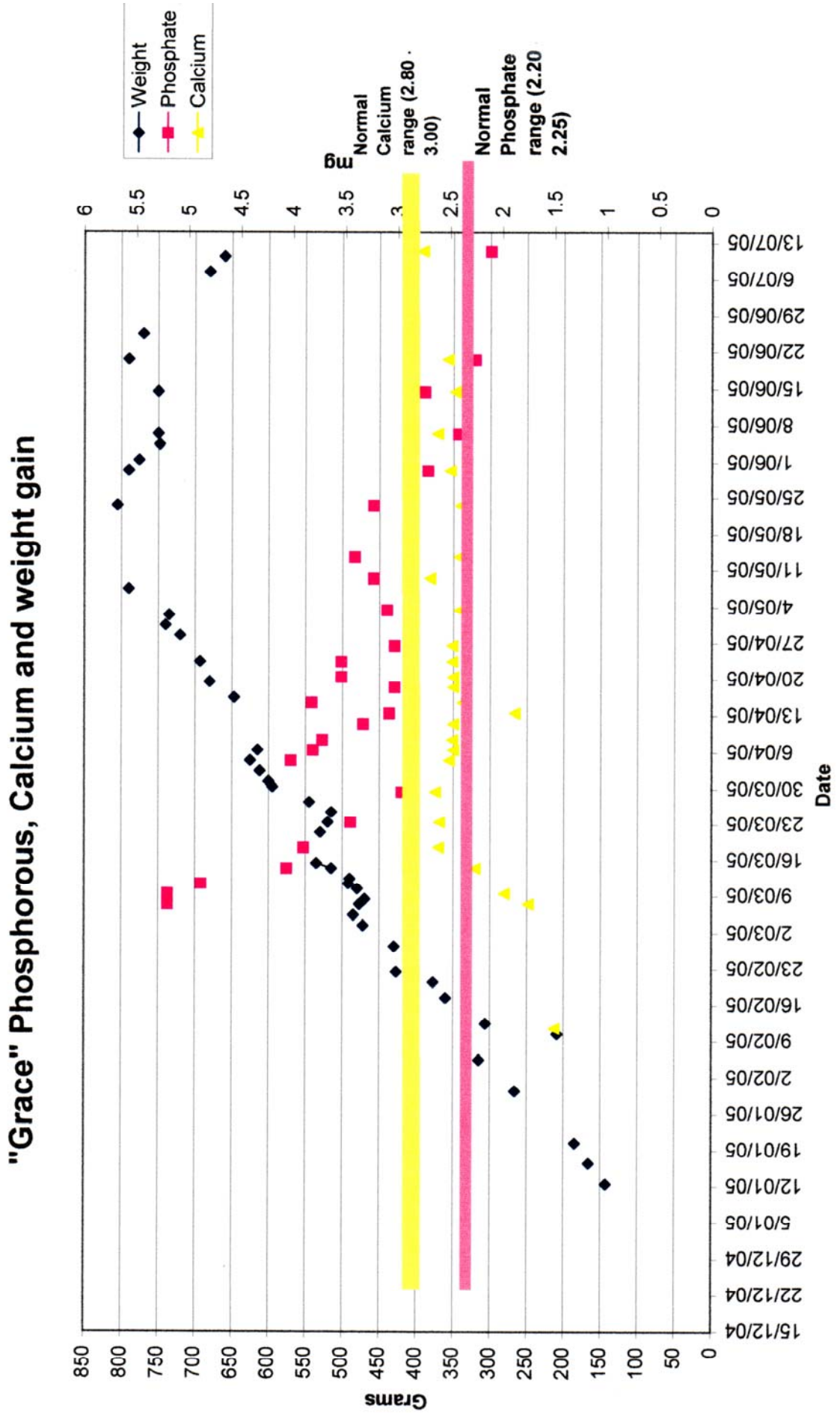
16/5/05 790 grams – on one milk feed / day and taking pureed fruit Last Calcitriol given
Ca: P ratio was 0.74 Ca 2.4mmol/L Phos 3.23 mmol/L, Na and Cl lowered.
6/6/05 Ca 2.62 mmol/L , Phos 2.42 mmol/L First positive Ca/P Ratio 1.08

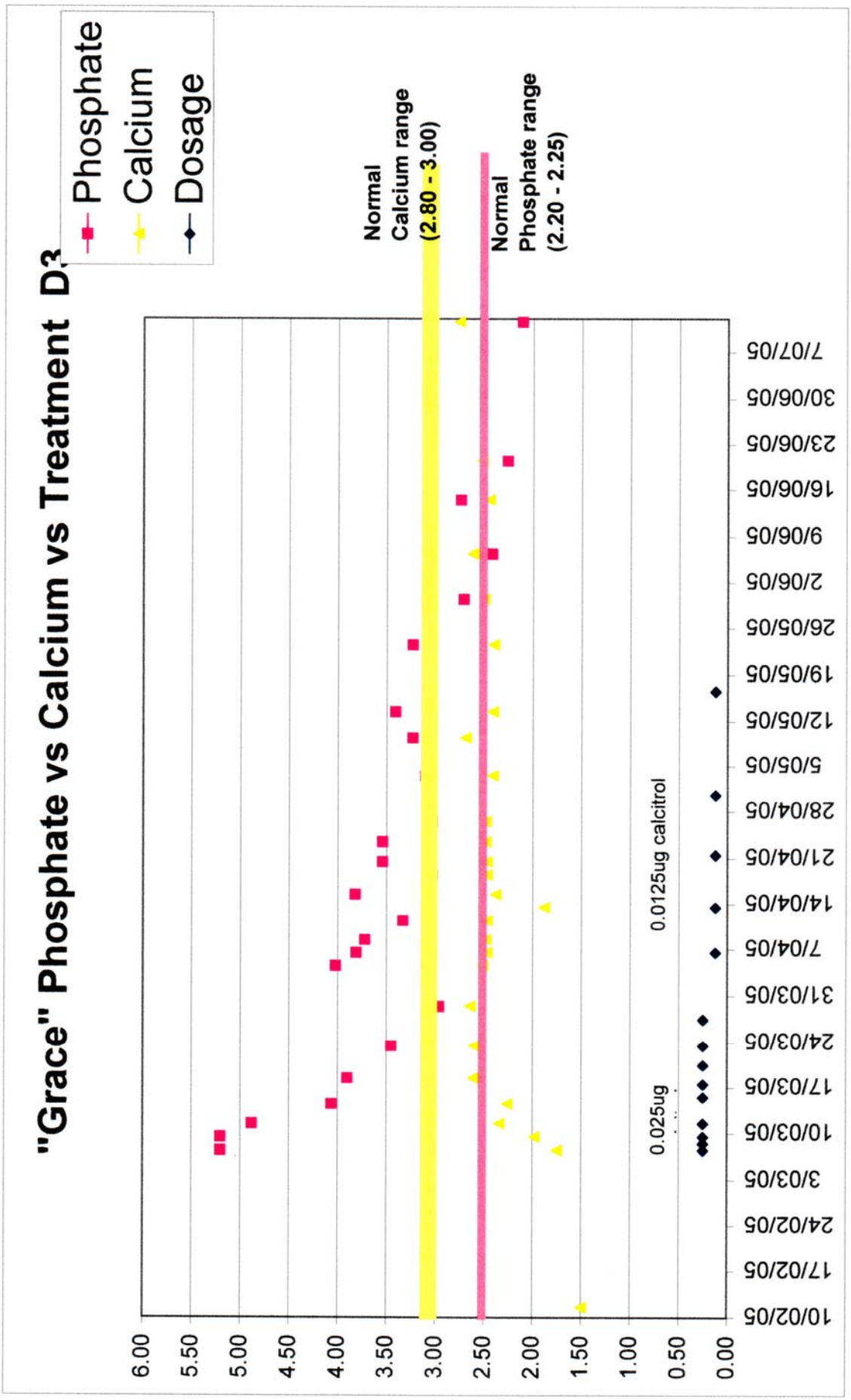
Over the next few weeks her mobility decreased and it was painful to get around. There was no pain relief or improvement with Metacam. In retrospect Metabolic Bone Disease easily explains all this

Some early X-rays had revealed some degenerative changes in the hips.

28/6/05 X rays revealed extensive metabolic bone disease with all the long bones affected and showing Lysis in the bone that indicates that the calcium was taken from the bone. 0/7/05 Grace was in constant pain, reluctant to move and had lost 100 grams to be only 660 grams. Her Ca/P Ratio was 1.3, but the quality of life was deteriorating and Gracie was euthanased blood taken for full analysis and body sent to JCU for full post-mortem and Histopathology of all organs and tissues including bone.

Pelvis and back legs


"Grace" Phosphorous, Calcium and weight gain
Weight
Phosphate
Calcium
Normal Calcium range (2.80 - 3.00)
Normal Phosphate range (2.20 - 2.25)
mg
Grams
Date
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
15/12/04
22/12/04
29/12/04
5/01/05
12/01/05
19/01/05
26/01/05
2/02/05
9/02/05
16/02/05
23/02/05
2/03/05
9/03/05
16/03/05
23/03/05
30/03/05
6/04/05
13/04/05
20/04/05
27/04/05
4/05/05
11/05/05
18/05/05
25/05/05
1/06/05
8/06/05
15/06/05
22/06/05
29/06/05
6/07/05
13/07/05


"Grace" Phosphate vs Calcium vs Treatment D3
Phosphate
Calcium
Dosage
Normal
Calcium range
(2.80 - 3.00)
Normal
Phosphate range
(2.20 - 2.25)
0.025ug
0.0125ug calcitrol
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
10/02/05
17/02/05
24/02/05
3/03/05
10/03/05
17/03/05
24/03/05
31/03/05
7/04/05
14/04/05
21/04/05
28/04/05
5/05/05
12/05/05
19/05/05
26/05/05
2/06/05
9/06/05
16/06/05
23/06/05
30/06/05
7/07/05

Main findings of the Post Mortem Report were: -

- Parathyroid could not be found
- Kidneys: Extensive subcapsular lymphocyte reaction associated with tissue degeneration. Lesions extended into deeper tissues. Some fibrosis.
- Brain: No abnormalities detected.
- Femoral head: Epiphyseal cartilage still present but irregular on the epiphyseal side. Adjacent bone and marrow well developed. Lateral epiphyseal bone showed focal osteoclastic activity and lymphocyte and plasma cell hyperplasia extending into the periosteum ("periostitis"). The diaphysis and bone marrow were well developed.
- Tibia-fibula: Epiphyseal and metaphyseal marrow appeared fibrotic. Marked osteoclastic activity among the metaphyseal bone. Diaphysis appeared normal.

Diagnosis:
1. Subacute nephritis. The lesions are compatible with leptospirosis.
2. Epiphyseal dysplasia of the femur and tibia-fibula associated with periostitis.

The pathologist assures me that it is not unusual to see nephritis caused by leptospirosis in adult possums. I do dot think that this was a primary disease in one so young, but more likely secondary to her deteriorating condition. This possum's weight gains were always suboptimal.

The marked Osteoclastic activity in the bone supports the leaching of calcium from the main long bones and a diagnosis of Metabolic bone Disease.

I believe this was a case of Nutritional Secondary Hyperparathyroidism

Nutritional Secondary Hyperparathyroidism is a metabolic disease and the direct result of nutritional imbalances that causes a compensatory increase in Parathyroid Hormone (PTH) levels. The diet that results in this disease will have a low content of calcium, excessive phosphorus with normal or low calcium, or inadequate amounts of Vitamin D

The end result is hypocalcaemia and parathyroid stimulation with release of PTH

This metabolic bone disease is seen primarily in immature growing animals. The result of the metabolic imbalance is bony resorption resulting in osteoporosis. Cortical bone becomes uniformly thinner and pathological fractures are common.

Why did this possum develop Metabolic Bone Disease and not Tetany? Was it because it was more insidious and was exacerbated by Vitamin D medication without adequate calcium supplements?

What causes the tetany cases to drop their calcium levels more precipitously thus triggering tetany?

I don't know, and as more people become aware of the problem we should be able to prevent this happening with improvements to our husbandry techniques.

When I queried Brian Rich about the possibility of increasing the calcium content of milk replacers, he replied as follows.

Jim,
The National Research Council publishes nutrient requirements for most domestic animals. Our Departments of Primary Industry also publish recommended nutrient requirements for many production animals. I know of no publications relating to nutrient requirements for marsupials.

Your comments regarding the Ca/P in many of the common fruits fed to possums are very relevant. I believe that >0.8 possums should be fed some milk along with native vegetation up to 200 days before weaning is completed. If non native fruits are fed we recommend the addition of either Wombaroo High Protein Supplement or Small Carnivore Food to the fruit diet.

As animals eat primarily to satisfy energy requirements nutrient concentrations expressed as weight per unit of energy reflect a more realistic view of requirements. In a study of the tolerance of pouch young red and grey kangaroos to different amounts of glucose and lactose in milk replacers Walker & Vickery 1988 (Aust. Mammal.,11:125-33) observed fractures when calcium levels were 307mg/kJ. Increasing calcium levels to 486mg/kJ resolved the problem. Now possums not being kangaroos this data may not necessarily be transferable, however they are marsupials and it probably is a sound base. A comparison of the 3 milk replacers discussed in your paper is as follows.

	Ca (mg/L)	*Gross Energy (kJ/L)*	*Ca(mg/kJ)*
Di-Vetelact 1 scoop/60mL	*1000*	*2800*	*357*
Di-Vetelact 1 scoop/40mL	*1500*	*4200*	*357*
Biolac M100	*2000*	*3950*	*506*
Biolac M150	*2000*	*4840*	*413*
Biolac M200	*2000*	*6820*	*293*
Wombaroo <0.8	*1800*	*3570*	*504*
Wombaroo >0.8	*3300*	*6290*	*525*

Given the above I can see no reason to increase the calcium concentration in Wombaroo, although there could be an argument to supplement Di-Vetelact and Biolac M150 and M200 with calcium and phosphorus.

The Biolac milk replacers present an interesting but common problem in dietary formulation. If the energy in a diet is increased by the addition of an energy dense component such as fat then the other nutrients have their concentration/energy diluted. If no adjustments are made to the other nutrient concentrations then essential nutrients may be diluted to the point of deficiency.

Regards
Brian.

Where do we go from here?

- Continue to feed existing milk replacer.
- Be aware that many common fruits have a negative Ca: Phos ratio and try to feed appropriately.
- Advocate some addition of Calcium to diets e.g. Calcium sandoz liquid, Calcium Carbonate powder.
- Place cuttlefish in aviary with possums
- Feed chicken wing tips or similar to boost calcium in diet
- Remember that brushtail possums are omnivorous and will eat insects, raid birds nests, eat fledglings and chew on old carrion bones. Young back riders eat what mother eats.
- Are we allowing access to solid food too early?
- Please advise if you have similar problems, as I want to gather more cases.

Dr Jim Pollock
Telephone - 07 47797708
Email – aachilpa@bigpond.com

Bibliography; Information was derived from

Nutritive Values of Food USDA Human Nutrition Information Service
Home and Garden Bullitin No.2 1991

Fry, Fredrick L A " Practical Guide for Feeding Captive Reptiles" (1991) Table 9 pp 86 & 87

Paul J.A. Presidente, Post Graduate Committee in Veterinary Science Proceedings No. 36 Fauna Part B 1978.

Stephen J. Ettinger, DVM "Textbook of Internal Medicine" Third Edition Volume 2

MA Thrall, DJ Meuten "Clinical Pathology for Practitioners" Post Graduate Committee in Veterinary Science Proceedings No. 322 April 99
Australian Mammals, Biology and Captive Management. Stephen Jackson CSIRO 2003.

Thanks to Brian Rich of Wombaroo and Christine Smith of Biolac for the provision of an analysis of their products.

Additional reading

http://www.pawprintonline.com/central-diet-calcium.html

My special thanks to Trudi Holt, the carer of "Emma" and "Grace" whose extensive history notes provided me with so much valuable information.