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Venom yields from Australian and some other species of snakes

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Abstract The wet and dry venom yields for most Australian native dangerous snakes and a number of non-Australian species are presented. Snakes from the *Pseudonaja* genus yielded higher than previously published amounts and suggest reconsideration be given to increasing the volume of antivenom in each vial. Higher percentage solids were obtained from venoms from the 4 cobra species (*Naja*) and *Pseudechis* genus included in this series.

Keywords Venom · Yield · Snake

Introduction

The amount of venom produced by a snake when it bites is described as the yield. The whole snake venom is comprised of salts, water, enzymes, proteins and various other macromolecular and smaller organic and inorganic compounds. The traditional way venom yield is measured and compared is in its dried powder form where the free water is removed by some method of drying leaving the remaining solids. The remaining solids or dry yield is normally just called the yield as opposed to the wet yield which is the total weight of the venom (water plus all the solids). The percentage solids are the fraction of the solid weight divided by the total weight (solids and liquid) of the venom expressed as a percentage [(solid weight/total weight) × 100 = % solids].

There have been many ways in which snakes have been artificially milked for their venom and indeed many ways of drying venom. Some early milking techniques included forcing the snake to bite on a watch glass whereupon the venom spread out over the glass. Another method was to force the snake to drape its fangs over the side of a beaker and allow the venom to run down the inside of the beaker (a method more suited to longer-fanged vipers). A later improvement saw a rubber latex diaphragm stretched over a glass beaker and the snake was forced to bite through it which stimulated it to express venom but it had the disadvantage of either forcing snakes milked subsequently to bite over the same area of rubber thus increasing the chance of transferring infection.

Methods used to milk low yielding snakes like the *Pseudonaja* genus, have in the past resorted to forcing the snake to bite on to rubber latex stretched over a beaker as with most other snakes resulting in some venom being wasted when it came in contact with the latex. For high yielding snakes, the proportional amount lost by this method is less significant. The method used by us to milk low yielding snakes exposes the venom to smaller surface area thus reducing contact losses and the pressure of the capillary tube against the *vagina dentis* (fleshy sheath surrounding the fang), stimulates the snake to express venom into the tube. The plastic used to make the capillary tubes also has

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less binding affinity for the venom than latex rubber allowing greater recovery of venom into the vial.

Early venom drying was carried out simply by allowing the water in the venom to evaporate in air. Later improvements to drying the venom involved placing the venom into a closed container where desiccants such as silica gel or calcium chloride accelerated the drying by removing moisture from the air in the container. Freeze drying is a more recent refinement where the venom is quickly frozen after milking and then subjected to a vacuum supplied by a vacuum pump which forces any water vapor coming off the frozen venom through a moisture trap condensing it on a cold surface. The process of sublimation of the frozen water in venom to a vapor when the pressure is reduced to almost zero, bypasses the liquid stage and so hastens drying thus preserving the more delicate macromolecules in the venom.

Scientific studies on snake venoms are quite extensive. Using key words ''snake'' and ''venom'' on the National Library of Medicine's internet database PubMed, some 13,236 papers were found. Clearly this does not reflect all scientific works. Scientists spend considerable sums of money carrying out this research and depend faithfully on the venoms they obtain, in many cases from commercial venom suppliers. It could be useful to reflect on the way these venoms are produced as it may influence the outcome of research results.

When working with venoms, whether it is in development of antivenoms, evaluating the lethal capacity of snake species or working with venoms in pure research applications, knowledge of the basic venom yield of the species in question is valuable. Often this basic knowledge is unknown. Moreover, in some cases, it is also useful to know the maximum and minimum yields, the weight of wet and dry venom delivered by the snake and the percentage of solids in the venom. This work aims at providing this basic information for most of the dangerously venomous Australian snakes and for a comparison with some other non-Australian species. The data has been collected over 6 years at the venom production laboratories at Venom Supplies Pty Ltd. The species assessed were:

Notechis ater serventyi	Chappel island tiger snake (Bass Strait, Australia)
Notechis ater niger	Peninsula tiger snake (Kangaroo Island, Australia)
Notechis scutatus	Common tiger snake (South east of South Australia, Australia) (kept in outside pits).
Notechis scutatus	Common tiger snake (South east of South Australia, Australia)
Notechis scutatus	Common tiger snake (Victoria, Melbourne & environs, Australia)
Notechis scutatus	Common tiger snake (South Australia, Lake Alexandrina)
Notechis scutatus	Common tiger snake (South Australia, Lake Alexandrina, Australia) (kept in outside pits)
Pseudechis porphyriacus	Red bellied black snake (South Australia, Australia)
Pseudechis australis	King brown or mulga snake, (NT, Alice Springs, Australia)
Pseudechis australis	King brown or mulga snake, (South Australia, Eyre Peninsula, Australia)
Pseudechis australis	King brown or mulga snake, (Queensland, Australia)
Oxyuranus microlepidotus	Inland taipan (South Australia, Goyders Lagoon)
Oxyuranus scutellatus	Coastal taipan (Queensland, Australia)
Hoplocephalus stephensi	Stephens banded snake (Queensland, Australia)
Acanthophis antarcticus	Common death adder (South Australia, Australia)
Austrelaps superbus	Lowland copperhead (South East of South Australia)
Tropidechis carinatus	Rough scaled snake (Queensland, Australia)
Pseudonaja guttata	Speckled brown snake (Queensland, Australia)
Pseudonaja textiles	Common brown snake (Queensland, Australia)
Pseudonaja textiles	Common brown snake (South Australia, Barossa Valley & environs)
Pseudonaja nuchalis	Western brown snake (South Australia, Eyre Peninsula)
Pseudonaja affinis	Dugite (Western Australia, Perth)
Pseudonaja inframacula	Peninsula brown snake (South Australia)
Bitis gabonica rhinoceros	Gaboon viper (Africa)
Bitis arietans	Puff adder (Africa)
Bitis nasicornis	Rhinoceros viper (Africa)
Vipera latasti	Lataste's viper (Spain)
Crotalus vegrandis	Uracoan rattlesnake (Venezuela)
Agkistrodon bilineatus	Mexican moccasin (Mexico)
Naja kaouthia	Monocled cobra (Thailand)
Naja siamensis	Indo-chinese spitting cobra (Thailand)
Naja mossambica	Mosambique spitting cobra (Africa)
Naja melanoleuca	Forest cobra (Africa)

The relevance of some of these venom yield results to snakes in the wild is discussed.

All of the snakes examined are considered dangerous to humans, i.e., either it is a species which has caused fatalities or has high potential to cause them in bites not treated with an appropriate antivenom.

The inclusion of the non-Australian species here is mainly for comparative purposes however the data will inevitably be useful for researchers.

Materials and methods

Snakes were kept at Venom Supplies Pty Ltd laboratories in Tanunda South Australia in individual modules of either floor pens of 885 × 630 × 600 cm or 720 × 510 × 500 cm and plastic tub modules of dimensions 800 × 400 × 165 cm or 420 × 310 × 235 cm. The snakes were kept at temperatures ranging from a winter low of 18°C and summer maximum of 31°C. They were fed on either rats (*Rattus norvegicus*) or mice (*Mus domesticus*).

The snakes were milked either fortnightly or after longer intervals. Adult snakes were used at all times. For some Australian species, geographical yield data variants are included for comparison.

Venom was extracted using 3 methods: One of the methods (method 2), is a commonly used method in the industry and is shown in Fig. 2 for comparative purposes. The other 2 methods (Figs. 1, 3) have been developed by Venom Supplies Pty Ltd.

Method 1 – for low yielding snakes

A 100 µl plastic pipette tip which had approximately 4 mm of the tip trimmed off, was placed independently over each fang of the snake thus forcing the *vagina dentis* upwards and out of the way of the pipette tip. At the same time pressure was exerted on the venom gland with the hand restraining the snakes head (Fig. 1). Venom was expelled into the pipette tip and was retained in the tip due to surface tension. The venom was expelled into a vial from the pipette tip with air using a rubber puffer bulb.

Fig. 1 *Pseudonaja textilis* being milked using Method 1

Fig. 2 *Oxyuranus scutellatus* being milked using Method 2. This method is also used in the first step in method 3

Method 2 – for Viperid snakes and Australian *Oxyuranus scutellatus*

The snake was forced to bite through a parafilm membrane which was stretched over a 70 ml vial (Fig. 2). The venom was collected in the vial below the membrane.

Method 3 – for other elapids with moderate to short fangs

A method described as the ‘‘Mirtschin technique’’ (Sutherland and Tibballs 2001) is described as forcing the snake to bite through a parafilm membrane which

Fig. 3 *Pseudonaja textilis* using constriction to subdue prey

was stretched over a 70 ml vial (Fig. 2). The venom was collected in the vial. Following this initial procedure, the snakes were again milked in a secondary milking as described in Method 1 (Fig. 1). Venom collected in this latter step was then expelled into the 70 ml vial.

In instances where 70 ml vials were used, to reduce the need to handle dried venom, once all snakes in a batch were milked, the venom was aliquotted from the 70 ml vial to smaller 5 ml vials.

During venom collection, the venom vials were weighed between each snake to allow determination of the wet yield produced by each snake. Once the venom was collected for any batch and aliquotted when 70 ml vials were used, it was then snap frozen inside the vials in powdered dry ice and then stored for Lyophilization at a later date. Lyophilization was carried out using either a cold finger method whereby the temperature differential was provided by a mixture of alcohol and dry ice or a similar method provided by a Heto Drywinner freeze drier machine. Both methods produced similar results for any venom.

When the venom was dry, it was then re-weighed and the % solids calculated. Using the calculated % solids and the wet weight of the venom for each snake, the dry venom yield could be calculated for each snake. The use of the average % solids to calculate the dry venom yield is the only practical way of avoiding the necessity of using a separate vial for each snake milked.

Results

The results are shown in Tables 1–6. In Table 4, results for *Pseudonaja inframacula* published earlier (Masci et al. 1998) have been included for comparison. The different tables are sorted into logical groups. All the *Notechis*, *Pseudechis*, *Pseudonaja* and *Naja* (Tables 1, 2, 4 and 6, respectively) are in their own specific groups because there are multiple species occurring in those groups (genera) of which some are studied here. The remaining miscellaneous Australian species studied are presented in a single table (Table 3). The venom yield data for all the vipers examined are combined in Table 5.

Each table lists the numbers of snakes used in the study, the number of times snakes were milked to obtain the results, the minimum, maximum and average wet and dry venom yields, the standard deviation and variances of the wet and dry yields the average percentage solids of the venom and the milking method used for each species studied.

Discussion

Generally, the average Australian elapid snake venom yields (Tables 1–4) are low compared with cobra or Viperid species (Tables 5, 6) included in this study.

Table 1 Venom yield data for *Notechis* species

	Notechis ater serventyi Chappel Is.	*Notechis ater niger* Kangaroo Is.	*Notechis scutatus (SA) pits*	*Notechis scutatus* (SA)	*Notechis scutatus* (VIC)	*Notechis scutatus* Lk. Alex. pits	*Notechis scutatus* Lk. Alex.
No. snakes	5	9	7	105	31	4	17
No. milkings	54	263	83	4363	983	42	424
Min (wet) gm	0.005	0.006	0.004	0.001	0.004	0.045	0.004
Min (dry) gm	0.002	0.001	0.001	0.000	0.001	0.008	0.001
Max (wet) gm	0.519	2.257	0.540	1.267	0.985	0.426	0.525
Max (dry) gm	0.125	0.636	0.111	0.336	0.224	0.083	0.107
Av. (wet) gm	0.231	0.433	0.200	0.175	0.153	0.177	0.137
Av. (dry)gm	0.056	0.110	0.042	0.034	0.033	0.036	0.028
STD (wet)	0.132	0.391	0.134	0.127	0.109	0.073	0.080
STD (dry)	0.031	0.103	0.029	0.026	0.025	0.015	0.017
Var. (wet) gm	0.017	0.153	0.018	0.016	0.012	0.005	0.006
Var. (dry) gm	0.001	0.011	0.001	0.001	0.001	0.000	0.000
Av. % solids	25.35%	24.96%	20.40%	19.30%	21.35%	20.29%	20.06%
Milking method	3	3	3	3	3	3	3

Notes: For each species summarized in this table, the numbers of snakes is noted, the number of times snakes were milked to obtain the results, the minimum, maximum and average wet and dry venom yields, the standard deviation and variances of the wet and dry yields the average percentage solids of the venom and the milking method used for each species studied is recorded

In Tables 1–7, STD is the standard deviation and is calculated as follows: STD = $\sqrt{\Sigma(a–\bar{a})^2/(n–1)}$ where STD = standard deviation, a = a single milking value, $\bar{a}$ = average of milking values, n = number of values in the data set and Σ = sum of values and $\sqrt{}$ the square root of the calculated value of the formula to the right of the symbol. Standard deviation indicates how tightly the data is spread

Variance (=Var.) is a measure of the average distance between each of a set of data points and their mean value; equal to the sum of the squares of the deviation from the mean value and is calculated thus $\sigma^2 = \Sigma(a - \bar{a})^2/(n - 1)$ (where STD = σ)

Table 2 Venom yield data for *Pseudechis* species[a]

	Pseudechis porphyriacus (SA)	*Pseudechis australis* Alice Spr.	*Pseudechis australis* (QLD)	*Pseudechis australis* Eyre Pen.	*Pseudechis guttatus* (QLD)	*Pseudechis colletti*	*Pseudechis butleri*
No. snakes	14	4	10	5	4	6	2
No. milkings	367	23	80	25	74	94	60
Min (wet) gm	0.012	0.046	0.182	0.106	0.008	0.010	0.026
Min (dry) gm	0.004	0.015	0.054	0.038	0.003	0.003	0.008
Max (wet) gm	0.895	0.673	2.442	2.438	0.540	0.705	0.220
Max (dry) gm	0.298	0.238	0.787	0.802	0.213	0.226	0.064
Av. (wet) gm	0.198	0.213	0.785	0.813	0.177	0.134	0.131
Av. (dry)gm	0.055	0.074	0.251	0.271	0.058	0.042	0.036
STD (wet)	0.149	0.135	0.412	0.590	0.118	0.138	0.050
STD (dry)	0.041	0.048	0.133	0.191	0.042	0.045	0.013
Var. (wet) gm	0.022	0.018	0.170	0.348	0.014	0.019	0.002
Var. (dry) gm	0.002	0.002	0.018	0.036	0.002	0.002	0.000
Av. % solids	27.89%	34.53%	31.29%	33.89%	31.91%	31.49%	27.58%
Milking method	3	1	1	1	3	3	3

[a] See Table 1 for notes

Table 3 Venom yield data for assorted Australian dangerous snakes[a]

	Oxyuranus microlepidotus	*Oxyuranus scutellatus* (QLD)	*Hoplocephalus stephensi*	*Acanthophis antarcticus* (SA)	*Austrelaps superbus*	*Tropidechis carinatus* (QLD)
No. snakes	21	78	5	29	33	9
No. milkings	214	2543	83	153	314	190
Min (wet) gm	0.023	0.006	0.017	0.010	0.006	0.002
Min (dry) gm	0.005	0.002	0.005	0.002	0.002	0.001
Max (wet) gm	0.883	2.977	0.514	0.507	0.528	0.287
Max (dry) gm	0.217	0.882	0.154	0.113	0.155	0.084
Av. (wet) gm	0.260	0.616	0.156	0.197	0.084	0.071
Av. (dry) gm	0.062	0.146	0.044	0.045	0.022	0.020
STD (wet)	0.188	0.418	0.108	0.092	0.087	0.044
STD (dry)	0.046	0.102	0.030	0.021	0.025	0.013
Var. (wet) gm	0.035	0.175	0.012	0.008	0.008	0.002
Var. (dry) gm	0.002	0.010	0.001	0.000	0.001	0.000
Av. % solids	24.01%	23.82%	28.02%	22.98%	24.75%	27.86%
Milking method	3	2	3	2	3	3

[a] See Table 1 for notes

The relationship between venom yields obtained from milking and those delivered by wild snakes when either hunting or using a defensive bite have been studied (Morrison et al. 1982, 1983, 1983–1984). It is clear that generally, yields from snakes milked are usually higher than yields from wild snakes hunting or those obtained from snakes using a defensive bite. Milking yields could represent a venom yield potential high and these amounts of venom may possibly be approached from snakes in some instances of frenzied attack or multiple bites. Snake venom yield is highly variable and injected amount varies with prey size and type (Allon and Kochva 1974) and with snake age (Fiero et al. 1972).

The average yields for the *Pseudonaja* species are considerably higher than previously reported (Sutherland and Tiballs 2001; Masci et al. 1998; Morrison et al. 1983–4). The average yields for *Pseudonaja textilis* Queensland were much higher than *Pseudonaja textilis* South Australia. This could be due to the fact that in the wild a greater number of rats prey items are available to Queensland snakes than smaller mammalian prey items in the South Australia *P. textilis* used in this study. Greater amounts of venom are required to quickly immobilize larger prey animals and rats retaliate fiercely when bitten or trapped by snakes. *P. textilis* also uses prey restraint to hold its prey whilst delivering the venom (Fig. 3) and offers a brief opportunity for the rat to bite and injure the snake. More rapid immobilization by the venom through increased yield, would minimize injury to the snake.

Table 4 Venom yield data for *Pseudonaja* species[a]

	Pseudonaja guttata	*Pseudonaja textilis* (QLD)	*Pseudonaja textilis* (SA)	*Pseudonaja nuchalis* (SA)	*Pseudonaja affinis* (WA)	*Pseudonaja inframacula* (SA[b])
No. snakes	5	21	103	8	5	4
No. milkings	24	1013	4436	290	140	137
Min (wet) gm	0.001	0.005	0.002	0.003	0.020	0.009
Min (dry) gm	0.000	0.001	0.000	0.001	0.005	0.002
Max (wet) gm	0.019	0.536	0.189	0.291	0.588	0.298
Max (dry) gm	0.006	0.155	0.051	0.074	0.143	0.076
Av. (wet) gm	0.006	0.122	0.037	0.087	0.165	0.105
Av. (dry) gm	0.002	0.026	0.008	0.021	0.040	0.024
STD (wet)	0.005	0.090	0.024	0.055	0.101	0.061
STD (dry)	0.001	0.020	0.005	0.014	0.026	0.015
Var. (wet) gm	0.000	0.008	0.001	0.003	0.010	0.030
Var. (dry) gm	0.000	0.000	0.000	0.000	0.001	0.232
Av. % solids	27.28%	21.04%	22.14%	23.95%	24.08%	23.24%
Milking method	1	1	1	1	1	1

[a] See Table 1 for notes

[b] Figures from Masci et al. (1998), included here for comparison

Table 5 Venom yield data for some viperid snakes[a]

	Bitis gabonica rhinoceros (Africa)	*Bitis arietans* (Africa)	*Bitis nasicornis* (Africa)	*Vipera latasti* (Spain)	*Crotalus vegrandis* (Venezuela)	*Agkistrodon bilineatus* (Mexico)
No. snakes	2	2	7	2	14	12
No. milkings	11	33	96	11	65	60
Min (wet) gm	0.847	0.034	0.108	0.023	0.008	0.260
Min (dry) gm	0.206	0.007	0.021	0.004	0.002	0.071
Max (wet) gm	3.611	1.140	1.475	0.103	0.496	2.862
Max (dry) gm	0.848	0.290	0.353	0.026	0.129	0.688
Av. (wet) gm	2.173	0.667	0.628	0.056	0.161	1.076
Av. (dry)gm	0.507	0.166	0.138	0.014	0.042	0.269
STD (wet)	0.875	0.300	0.317	0.021	0.109	0.734
STD (dry)	0.210	0.076	0.076	0.006	0.030	0.188
Var. (wet) gm	0.766	0.090	0.100	0.000	0.012	0.539
Var. (dry) gm	0.044	0.006	0.006	0.000	0.001	0.035
Av. % solids	23.32%	24.66%	21.95%	23.99%	26.05%	24.80%
Milking method	2	2	2	2	2	2

[a] See Table 1 for notes

Given the reported problems of CSL Ltd Brown snake antivenom in neutralizing the procoagulant toxin fraction of *Pseudonaja* venoms which induces blood coagulation (Tibballs and Sutherland 1991; Sprivulis et al. 1996; Masci et al. 1998; Judge et al. 2006) and small molecular weight toxins, the implications of these results suggest that if there is no change to the efficacy of the antivenom serum, further consideration be given to both the quantity of antivenom in the vial and the initial dose. The amount of antivenom present in vials of Australian antivenoms (CSL Ltd) is related to the average amount of venom produced when the snakes are milked (Sutherland and Tibballs 2001). The antivenom amount is calculated from tests measuring the amount of antivenom necessary to prevent death in small animals. In unpublished work, we have shown that these tests merely evaluate the neurotoxic effect and allow little time to measure other enzymatic effects, such as the procoagulant toxins which may take longer to manifest themselves. The venom neurotoxic effect is very fast in small animals, especially due to the post-synaptic neurotoxins. Two specimens of *Pseudonaja textilis* from Queensland had maximum dry yields of 155 and 112 mg and averaged 64 and 44.5 mg respectively (Table 7). They are abnormally high yields for this species and the *Pseudonaja* genus in general and demonstrate the potential of this species. A single antivenom vial of Brown snake antivenom is capable of neutralizing 10 mg of Brown snake venom (White 1995) based on the efficacy tests performed by CSL Ltd

Table 6 Venom yield data for some cobra species[a]

	Naja kaouthia (Thailand)	*Naja siamensis* (Thailand)	*Naja mossambica* (Africa)	*Naja melanoleuca* (Africa)
No. snakes	14	11	10	2
No. milkings	140	82	80	59
Min (wet) gm	0.176	0.193	0.175	0.623
Min (dry) gm	0.058	0.072	0.057	0.181
Max (wet) gm	1.897	1.690	1.806	2.766
Max (dry) gm	0.742	0.738	0.656	1.102
Av. (wet) gm	0.741	0.817	0.966	1.616
Av. (dry)gm	0.266	0.341	0.335	0.571
STD (wet)	0.316	0.352	0.410	0.514
STD (dry)	0.123	0.157	0.149	0.216
Var. (wet) gm	0.100	0.124	0.168	0.264
Var. (dry) gm	0.015	0.025	0.022	0.047
Av. % solids	35.63%	41.34%	34.60%	34.66%
Milking method	3	3	3	3

[a] See Table 1 for notes

Table 7 Venom yield data for two individual *Pseudonaja textilis* (QLD)

	Pseudonaja textilis CB 27 (QLD)	*Pseudonaja textilis* CB 34 (QLD)
No. snakes	1	1
No. milkings	101	33
Min (wet) gm	0.060	0.015
Min (dry) gm	0.011	0.003
Max (wet) gm	0.536	0.401
Max (dry) gm	0.155	0.112
Av. (wet) gm	0.309	0.206
Av. (dry)gm	0.064	0.045
STD (wet)	0.099	0.083
STD (dry)	0.026	0.022
Var. (wet) gm	0.010	0.007
Var. (dry) gm	0.001	0.000
Av. % solids	20.58%	21.20%
Milking method	1	1

Snakes, collection numbers CB 27 and CB 34

For the 2 snakes summarized in this table, the number of times snakes were milked to obtain the results, the minimum, maximum and average wet and dry venom yields, the standard deviation and variances of the wet and dry yields the average percentage solids of the venom and the milking method used for these 2 snakes is recorded

which are solely reliant on animal ED_{50} tests (Smith, Pers. Communication, 2006). The average venom yields resulting from milking, for most of the *Pseudonaja* species, are well over this amount. Using anaesthetized dogs, it was shown that to neutralize the effects of severe coagulopathy and cardiac depression, 25 times the recommended dose was required for *Pseudonaja textilis* and 10 times the recommended dose was required for *Pseudonaja affinis* (Tibballs and Sutherland 1991). This discrepancy between the recommended dose, and the dose required, suggests that the antivenom-antibodies (immunoglobins) present in the antivenom are inefficient in neutralizing the venom procoagulant toxin. The reason for this could be quantitative (insufficient immunoglobins) or qualitative (the antivenom antibodies are of low affinity). Recent research work on this indicates that the problem is probably qualitative in nature (Madaras et al. 2005), but clearly higher than expected venom yields will simply exacerbate this problem.

The average and maximum yields from the *Notechis* genus are also worth noting. Kangaroo Island tiger snakes, *Notechis ater niger*, averaged 110 mg and one specimen achieved a maximum yield of 636 mg. In earlier work we recorded a maximum yield in of 695 mg in a male *Notechis scutatus* (Sutherland and Tibballs 2001) and in this work 336 mg. These maximum yields are much higher than previously recorded average yield for *Notechis scutatus* of 35 mg (Sutherland and Tibballs 2001) and indeed our average yield of 28–42 mg depending on the geography of the snake's origin. The greater yields for *Notechis ater niger* over *Notechis scutatus* could reflect a variations in the toxic components of the venom. In work unpublished, we have found that the quantity of procoagulant

toxin in the *N. ater niger* venom is only 60% of *N. scutatus*. This may have a bearing in immobilizing prey. Tibballs and Sutherland 1991 showed that cardiovascular depression was caused by the procoagulant toxin in this *Notechis scutatus* venom and therefore this toxin could be important in immobilizing prey. Having less of this toxin in the venom could require a greater venom yield to subdue some prey items.

It is interesting to note the generally higher percentage solids in the 4 *Naja* (cobra) and *Pseudechis* genus venoms produced. The reasons for this are unknown.

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