Preliminary Analytical Study of Deer Faeces

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Executive Summary

About 96 pellets of deer faeces samples collected from locations in the Vernon Forest District and Okanagan Shuswap Forest District were provided by Ms. Astrid van Woudenberg of Cascadia Natural Resource Consultants Inc for analysis. All the 96 samples were analyzed for protein content using Near-Infrared Spectroscopy. The results were used qualitatively to evaluate the differences among the samples based on the protein level. A preliminary study was also conducted on selected few samples to investigate the potential of using Instrumental Neutron Activation Analysis to obtain the elemental content of the deer faeces. An initial investigation to develop a method for determining diaminopimelic acid, a bacterial biomarker for protein, using Capillary Electrophoresis proved promising.
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1.0 Overview

Deer faeces samples were analyzed using Near-Infrared Spectroscopy (NIR), Capillary Electrophoresis (CE), and Instrumental Neutron Activation Analysis (INAA). The samples were coded for analysis as follows:

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Total number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>33</td>
</tr>
<tr>
<td>OK</td>
<td>8</td>
</tr>
<tr>
<td>TC</td>
<td>10</td>
</tr>
<tr>
<td>CH</td>
<td>45</td>
</tr>
</tbody>
</table>

Sample History

**PA**: The Paxton study site is located in the Vernon Forest District. This site has not been subjected to cutting. The samples were collected in 2003 before the forest fires struck the study site.

**OK**: The Okanagan Park site is located in the Okanagan Shuswap Forest District. The samples were collected in 2003-2004 after the devastation by forest fires. This site has not been cut and is useful as a study control.

**TC**: The Trout Creek study samples were collected in 2003 prior to forest fire damage. Therefore the study site has not been subjected to burn nor has the site been cut.

**CH**: The Cedar Hills study site is located in the Okanagan Shuswap Forest District. This study site was subjected to forest fires and was salvaged. The samples were collected after the fire devastation and the salvage.
2.0 Methods

Three analytical methods were investigated for the analysis of the deer faeces:

2.1 Near-Infrared Spectroscopy (NIR)
- Work was done at Department of Chemistry, University of British Columbia at Okanagan, Kelowna.

2.2 Capillary Electrophoresis (CE)
- Work was done at Department of Chemistry, Thompson Rivers University, Kamloops.

2.3 Instrumental Neutron Activation Analysis (INAA)
- Work was done at the SLOWPOKE Nuclear Reactor Facility, University of Alberta, Edmonton.

2.1 Near-Infrared (NIR) Analysis

NIR information is obtained from the interactions of near-infrared radiation with chemical bonds between non-mineral elements and so does not always accurately predict food mineral contents [1]. NIR methods predict \textit{in vitro} digestibility accurately and precisely, and can predict \textit{in vivo} digestibility at least as well as conventional “wet chemistry” methods such as \textit{in vitro} digestion or the pepsin-cellulase method, and much more rapidly.

Faecal indices, i.e. the concentrations of certain constituents in faeces, can be used to monitor the nutritional status of grazing animals, including wild deer. Faecal indices can be determined by wet chemistry and found to have given mixed success. On the other hand NIR spectroscopy has given substantially better results. NIR spectroscopy is capable of measuring characteristics of faeces which integrate several different aspects of faecal chemistry, while wet chemical analyses focus on single entities.

NIR technology has been used to routinely monitor (through analysis of faecal samples) the nutritional status of cattle, and appears to have potential for identifying tick infestation, pregnancy, gender and animal species.

The technology uses simple sample preparation methods (drying and grinding), is very rapid (once the sample has been prepared, measurements are made in seconds), and inexpensive. In addition, NIR avoids the problems of organic and other chemical waste disposal, and there are few if any hazards associated with the technique because it uses no toxic or corrosive reagents [2].
The near infrared spectrum is between 730 and 2600 nm. Reflectance spectroscopy uses wavelengths between 1000 and 2600 nm [3], although the extremes of this range are not often used. This region of the infrared spectrum gives results which have a signal:noise ratio of about 10,000:1 and are attenuated enough so that samples do not have to be diluted and possible non-linearity caused by strong absorbances is less likely [4].

NIR is based on the Beer-Lambert law. This law describes the relationship between the concentration of a solute (say, protein) and the amount of light absorbed by the protein in the sample:

\[ C_x = \frac{A_x}{\varepsilon l} \]

where:  
- \( C_x \) = concentration of the test solute (protein)  
- \( A_x \) = absorbance of the test solute (protein)  
- \( \varepsilon \) = molar absorptivity of the test solute (protein)  
- \( l \) = path length travelled by the light through the sample

The important feature of this relationship is that it allows the measurement of \( C_x \) directly from \( A_x \).

When infrared radiation is incident on a solid sample, some of it is reflected (specular reflectance) from the surface of the sample. Another proportion of the radiation enters the sample (by about 2 mm) [3] and may be absorbed within it. Radiation which is not absorbed may be transmitted through the sample or reflected from it (diffuse reflectance). While the Beer-Lambert law generally describes the relationship between radiation diffusely reflected from a solid sample and characteristics of that sample, the path length of diffusely reflected radiation cannot be predicted because it is scattered by random reflections, refractions and diffractions within the sample. The variations within NIR diffuse reflectance spectra are mainly a result of (i) non-specific scatter of radiation, (ii) variable path length, and (iii) the chemical composition of the sample [5]. As a result, the relationship between reflectance and analyte content cannot be described by any mathematical relationship [4]. Thus while the characteristics of near infrared radiation reflected from a sample can be used to predict certain sample characteristics, each application of this type must be obtained by calibration. This introduces a number of complications such as the choice of wavelength, mathematical treatment of the reflectance data, methods of sample preparation and the effects of instrumentation differences.

The amount of radiation reflected from the sample is quantified as the reflectance (R) of the sample. The value is usually expressed as \( \log(1/R) \) and this quantity has been found to be proportional to the absorbance. Thus \( \log(1/R) \) gives higher values at higher levels of absorbance (i.e. lower reflectance). There is an almost
linear relationship between log(1/R) and the concentration of an absorbing component [3]. The log(1/R) curve is comparable to an absorption curve with peak values occurring at wavelengths which correspond to absorption bands in the sample [6].

The NIR wavelengths that have been associated with chemical structures are shown in the table below [7-9]:

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Chemical Entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1143</td>
<td>aromatic compounds, lignin</td>
</tr>
<tr>
<td>1496, 1668, 1976</td>
<td>amide bonds</td>
</tr>
<tr>
<td>1660 - 1730</td>
<td>condensed tannins</td>
</tr>
<tr>
<td>1772</td>
<td>ester bonds</td>
</tr>
<tr>
<td>1930</td>
<td>water</td>
</tr>
<tr>
<td><strong>1960, 2180</strong></td>
<td><strong>protein</strong></td>
</tr>
<tr>
<td>2140, 2180</td>
<td>peptide bonds</td>
</tr>
<tr>
<td>2088, 2410 - 2460</td>
<td>cellulose</td>
</tr>
<tr>
<td>2380</td>
<td>hemicellulose</td>
</tr>
<tr>
<td>2461</td>
<td>starch</td>
</tr>
</tbody>
</table>

The relationships between faecal NIR spectra and the chemical constituents in the faeces of deer fed forages have also been studied. The primary wavelengths attributed to protein in the diet are 2324, 1884, 1972, 1356 nm. These represent aromatics, aliphatics (antiquality factors) and nitrites, amino groups, carbonyl groups (protein) [8-10].

Relationships between faecal chemistry and diet composition have been investigated, and used, since the 1940s. For example, the digestibility of pasture was predicted using faecal nitrogen (N) determined by conventional wet chemistry [11]. Various aspects of the use of faecal indices for predicting diet digestibility, and protein and mineral (especially P) contents, have been reviewed [12, 13]. The use of faecal indices with particular emphasis on their use in deer has also been studied [14]. In this work they caution against the uncritical use of faecal/diet relationships. Several authors have also warned about the problems caused by tannins, pasture species composition, fertilisation practice, inappropriate application of regression relationships, etc. [13, 15, 16].
The difficulties inherent in accurately predicting diet characteristics from faecal composition suggested that difficulties in measuring condensed tannins and the relatively uniform amount of monocotyledonous plants in the diets may have impaired the predictive ability of the equations developed [17]. The role of plant tannins in confounding relationships between faecal N and diet protein contents was emphasized. Notwithstanding the difficulties of quantitatively predicting diet nutritive value, faecal indices (especially total N) give good qualitative descriptions of the quality of a grazing animal’s diet.

Many North American deer researchers have used faecal indices (determined by conventional chemistry) of dietary protein, P and energy content, perhaps because of the greater difficulty in obtaining blood, bone or oesophageal extrusa samples from wild deer than from domestic grazing animals. Faecal total N has been used in several instances to monitor the N content of deer diets [18-20]. However, there have been limited controlled studies to attempt to validate this approach.

Deer saliva contains a protein which precipitates tannins and this might be expected to protect the dietary/faecal N relationship of deer from the influence of tannins more than for other ruminants [21]. The confounding effects of food tannins have also been studied [15]. Data obtained showed clearly elevated faecal N contents when tannin-containing diets were fed [22]. Diets with different tannin contents fed were observed to have no effect on faecal N at low diet protein contents, but significantly increased faecal N when high-protein diets were fed [23].

Faecal indices of energy status include 2,6-diaminopimelic acid (DAPA). DAPA is found in some species of bacteria. It is not commonly present in plant food constituents, and does not occur in mammalian tissue. Increased faecal DAPA indicates increased growth of hindgut bacteria. This population is limited by the availability of energy and elevated faecal DAPA suggests an increased supply of bypass energy, originating from the diet [24]. Relationships between faecal DAPA concentration and diet quality have been investigated in several situations. DAPA and total N were shown to increase through spring, summer and autumn as the nutritive value of feed in the white tailed deer and moose range they examined presumably improved [19]. Faecal DAPA have been found to consistently change with the digestible energy and protein contents described above [25]. The effects were large (up to 50 % change) but in different directions – highest faecal DAPA was associated with highest DE but lowest diet protein. It has also been demonstrated that faecal DAPA was not influenced by diet tannin content [23]. Plant fibre is negatively correlated with food digestibility and its concentration in faeces should be consistent with diet quality [12].
2.2 Capillary Electrophoresis (CE)

Capillary Electrophoresis (CE) is a separation technique based on a solute’s ability to move through a solution, usually an aqueous buffer, under the influence of an electric field [26-28]. CE has several advantages over other techniques such as the use of minute amounts of sample, shorter analysis times, higher separation efficiency, very small consumption of expensive reagents, and its easy automation [28-31].

In CE, all separations take place within a tubular capillary that resembles a long strand of hair and has an internal diameter ranging from 25 – 100 µm. The capillary is filled with a buffer solution which serves to carry the analyte (substance of interest being analyzed i.e. DAPA) to the detector for it to be detected. The flow of the bulk buffer towards the detector is called the electroosmotic flow (EOF) [26-28]. Once the capillary is electrically charged, the sample containing the analyte can be injected. Following sample injection, more buffer solution is introduced into the capillary. As the electric current is applied, the buffer moves towards the detector and the sample containing the analytes will move within the buffer and be separated based on their differing electrophoretic mobilities, which are related to their size-to-charge ratios. Once the analyte reaches the detector, it is detected and processed by a computer in the form of an electropherogram. The electropherogram shows peaks, representing different analytes, at different migration times. The area under the peak is proportional to the amount of analyte and the migration time is unique to each compound.

The experimental conditions used for the CE run are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capillary length</td>
<td>70 cm</td>
</tr>
<tr>
<td>Effective Capillary length (to detector)</td>
<td>60 cm</td>
</tr>
<tr>
<td>Capillary internal diameter</td>
<td>75 µm</td>
</tr>
<tr>
<td>Temperature</td>
<td>25 ºC</td>
</tr>
<tr>
<td>Voltage</td>
<td>15 kV</td>
</tr>
<tr>
<td>Buffer</td>
<td>140 mM sodium tetraborate, pH 9.5</td>
</tr>
<tr>
<td>Detector</td>
<td>UV at 214 nm</td>
</tr>
</tbody>
</table>
**Figure 1:** TRU Capillary Electrophoresis System (Beckman Coulter PA 800)

![TRU Capillary Electrophoresis System](image)

**Figure 2:** Schematic Diagram of a Capillary Electrophoresis System

![Schematic Diagram of a Capillary Electrophoresis System](image)
2.3 Instrumental Neutron Activation Analysis (INAA)

Instrumental Neutron Activation Analysis (INAA) is a multi-element analysis technique capable of determining many elements at the same time at very low levels, i.e. ppm to ppb level. Neutron Activation Analysis is a method of qualitative and quantitative element analysis, in which the sample material is irradiated with neutrons in a nuclear reactor. In this process, stable isotopes are converted into radioactive isotopes. While these isotopes decay, having half-lives varying from seconds to years, they are emitting different kinds of electromagnetic radiation, among which gamma radiation. This gamma radiation is measured with semi-conductor gamma-ray spectrometers. Each radionuclide emits gamma radiation of a certain wavelength or energy. So a peak in a gamma-spectrum at a certain energy determines which element it corresponds. The peak area gives information about the amount of this element present in the sample.

One of the most important advantages of INAA is that most sample matrices appear to be transparent, because the atoms of which most of them are composed - H, C, O, N, P, and Si - hardly form any radioactive isotopes. This makes the method highly sensitive for measuring trace elements, because the main compositions are apparently absent and do not cause any interferences. Because of this, it is also not necessary to do any sample preparation other than size reduction and (in some cases) drying, making the technique non-destructive. Another advantage is that the technique requires only small amounts of sample material - 100 to 200 milligrams will do.

The most important disadvantage is that it takes a lot of time to complete a full analysis. Because all radioactive isotopes have different half life times, they can be divided into three categories: short-lived nuclides (half life time from less than one second up to several hours), middle-living nuclides (half life time ±10 hours up to several days), and long-living nuclides (half life time of several days up to weeks, months or even years). To measure elements which form long half life radionuclides, one needs to wait for a few weeks in order for the nuclides with short- and middle half life times to decay so that they will not cause any interference, and the detection limits will become better [32-34].

The significance of the elemental analysis is that it provides an insight into the grazing area that was accessible to the deer. It also sheds some light on possible contamination of the sites that the deer fed. Furthermore, an elemental analysis could provide evidence of possible toxicity that is hazardous to the wildlife. For instance, Arsenic and cyanide are particularly toxic to wildlife [35]. The greatest source of cyanide exposure to ruminants is plants, but exposure to anthropogenic sources of free cyanide in tailings ponds is also a significant concern. Gold and
silver mines are considered the most widespread sources on anthropogenic cyanides in critical wildlife habitat [36].

Trace element nutrition and inorganic composition of the body plays a very important role in physiopathologic state and reproductive efficiency of animals. Long-time metabolic changes of various elements and present as well as past nutritional events in an individual are best reflected in the hair, which is considered as the recording filament [37, 38].

Certain known toxic effects of selenium, such as brittleness of hair [35] appearance of blisters and eruptions in the skin [35] loss of long hair [35], loss of appetite [Seiler] and tendency to wander in a circle [35] were observed in several individuals of all the four animal species studied. Besides these, liver cirrhosis, impaired vision, mutagenic and carcinogenic effects of selenium compounds have been observed in experimental animals [36, 37].

Deficiency of chromium leads to impaired glucose tolerance and weight loss [35], which is likely to have a significant impact on the wild life population. It is known that the uptake of chromium is inhibited by vanadium[38]. Vanadium content of the environment is linked with petroleum combustion [39], burning of coal [40], and dumping of solid industrial wastes [41].

Trace elements such as zinc, copper, and cobalt are needed by all mammals. A small amount of these elements is needed for good health of mammals. However a large amount is hazardous to the well-being of wildlife [35]. A study of the effects on livestock animals by trace element dietary has been conducted [42, 43]. It was found that there is mounting biochemical evidence for the essential nature of correct trace-element balance to neuronal activity and resistance to neurodegenerative disease [43]. It is clear from the biochemical studies that have been carried out that metals do play a role in the pathogenesis of Transmissible spongiform encephalopathies (TSEs). TSEs are invariably fatal diseases of the central nervous system that occur in domestic and wild animals and humans. TSEs in domestic animals include scrapie of sheep and goats, transmissible mink encephalopathy (TME), and bovine spongiform encephalopathy (BSE, also known as mad cow disease). Chronic wasting disease (CWD) is the only TSE currently found in free-ranging wildlife (whitetailed deer, mule deer, and elk), and it also has been found in captive animals of like species [44].
The specific functions of some trace elements have been documented [45] are listed below:

(i) Iron (Fe)-Most of the iron consumed is used to form hemoglobin. The rest is stored in bone marrow, antlers, liver, spleen, and other organs. It is part of the critical enzymes which help in the digestion of feed.
(ii) Copper (Cu) plays a role in the deer's formation of flexible connective tissue and in the functioning of muscles, nerves and in the immune system. A deficiency can cause a weakened heart and blood vessel debilitation.
(iii) Zinc (Zn)-A mineral that produces cells to keep the deer healthy, zinc aids in enzyme activation and is essential in first stage of antler growth. There is an increased need for zinc to create new cells during periods of healing, development, pregnancy, and lactation.
(iv) Manganese (Mn)- plays an important role in biochemical reactions that affect the deer's bone, cartilage, brain function and energy supply. It makes up a part of molecules known as mucopolysaccharides, which are used to form collagen, the strong, fibrous connective material that builds tissue throughout the body including bone and cartilage. It also helps break down carbohydrates and fat for energy.
(v) Cobalt (Co)-Found in B-12, is needed for the deer's growth, digestion, and rumen function.
(vi) Iodine (I) is used by the thyroid gland to produce, thyroxine, an important hormone that helps to regulate energy production and muscle tone. It also aids during breeding and the manufacture and breakdown of tissue.
(vii) Selenium (Se) is a powerful antioxidant that presumably plays a role in eyesight, liver function, heart health, hair and skin health [45].

In addition to the trace elements, elements such as calcium, magnesium, sulphur, phosphorus, potassium, and sodium are required in major quantities in the nutrition of deer. These elements help to regulate metabolism. Calcium, along with phosphorus, is also necessary for bone, teeth, and antler development [45].
3. Results

3.1 Near Infrared (NIR) Spectroscopy

Protein is needed for normal maintenance, such as blood, body cell replacement, growth, reproduction, and lactation of wildlife. Even antler growth requires protein, as the velvet antler prior to mineralization is made almost entirely of a protein called collagen.

The measurements from the NIR data were presented as absorbance charts at four wavelengths (1356, 1960, 2180, 2324 nm) which are characteristic for proteins. Of the four, the most significant wavelength is the 1960 nm as is seen in a reconstructed NIR spectrum for a deer faeces sample in Figure 1. The absorbance at these four characteristic wavelengths are proportional to the protein content in the samples i.e. a higher absorbance represents a higher protein content.

![Reconstructed NIR spectrum for deer faeces sample](image)

Figure 1. Typical reconstructed NIR spectrum for deer faeces sample
3.1.1 OK Samples (1-8)

The absorbance charts of OK is shown in Figure 2. It can be seen that samples OK6, OK7, and OK8, tend to have highest protein content, followed by group of OK1 and OK2. The samples with the least protein content are OK3 and OK4.

![Absorbance values - OK samples](image)

**Figure 2. Absorbance chart for OK samples**
3.1.2 TC Samples (1-10)

For the TC samples, as shown in Figure 3, the largest protein content is found in the group of TC4, TC5, TC6. The next group with the next largest protein content is that of TC8, TC9, TC10, and TC2. The group of TC1 and TC3 has the lowest protein content.

![Absorbance chart for TC samples 1-10](image)

**Figure 3.** Absorbance chart for TC samples
3.1.3 CH Samples (1-25)

For the CH (1-25) samples, the largest protein content is found in the group of CH1, CH2, CH4, CH8, CH18, CH19, and CH22. The group with the next largest protein content is that of CH6 through CH14 and CH22, CH24. The group of CH5, CH15, CH16, CH17, CH21, and CH25, has the lowest protein content.

![Absorbance values for CH samples 1-25](image)

**Figure 4. Absorbance chart for CH (1-25) samples**
3.1.4 CH Samples (26-45)

For these CH (26-45) samples, the largest protein content is found for CH31 and CH32. The rest seem to have lower protein content.

![Absorbance chart for CH samples 26-45](image)

**Figure 5. Absorbance chart for CH(26-45) samples**
3.1.5 PA Samples (1-33)

For the PA samples, the largest protein content is found for PA10 and PA28, followed by PA1 and PA17. The rest seem to have relatively lower protein content, having about the same level of protein content.

Figure 6. Absorbance chart for PA samples
3.2 Capillary Electrophoresis (CE)

An initial study carried out using CE was promising and that CE has the potential to be used for determining diaminopimelic acid (DAPA) in the deer faeces. A typical electropherogram for a standard solution of DAPA is shown below in Figure 7. The first peak is the DAPA peak (~ 5.5 min). The second peak (~7.2 min) is most likely originating from the buffer solution. However the electropherogram shows that there is potential to use CE for DAPA analysis and the technique is fast as the analysis time is less than 8 minutes. This is a preliminary study and more work will need to be done to optimize and fine-tune the analysis. Future work will involve developing a method to extract the bacteria-rich sample which contains the DAPA. This will offer a preconcentration for the DAPA analyte. A calibration (standard) curve will also have to be developed and used to quantify the actual concentrations of DAPA in the deer faeces samples.

![Electropherogram of a 500-ppm DAPA standard showing the DAPA peak at ~ 5.5 min.](image)

Figure 7. Electropherogram of a 500-ppm DAPA standard showing the DAPA peak at ~ 5.5 min.
3.3 Instrumental Neutron Activation Analysis (INAA)

The Instrumental Neutron Activation Analysis (INAA) work was carried out by Dr. John Duke at the University of Alberta SLOWPOKE Nuclear Reactor Facility in Edmonton. A preliminary analysis was undertaken to investigate the possibility of using INAA to obtain the elemental data in the deer faeces samples. Four faeces samples (PAC 200, CH 300, CH 700, CH 701) were arbitrarily selected for this preliminary study. The results are shown in the table below:

<table>
<thead>
<tr>
<th>Element</th>
<th>PAC 200</th>
<th>CH 300</th>
<th>CH 700</th>
<th>CH 701</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>1840</td>
<td>30</td>
<td>1200</td>
<td>1590</td>
</tr>
<tr>
<td>Ba</td>
<td>279</td>
<td>12</td>
<td>228</td>
<td>412</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>1.39</td>
<td>0.09</td>
<td>1.65</td>
<td>1.31</td>
</tr>
<tr>
<td>Ce</td>
<td>1.80</td>
<td>0.14</td>
<td>0.67</td>
<td>1.09</td>
</tr>
<tr>
<td>Co</td>
<td>0.91</td>
<td>0.04</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>Cr</td>
<td>2.96</td>
<td>0.19</td>
<td>1.65</td>
<td>0.92</td>
</tr>
<tr>
<td>Fe</td>
<td>1260</td>
<td>30</td>
<td>499</td>
<td>547</td>
</tr>
<tr>
<td>Hf</td>
<td>0.14</td>
<td>0.02</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Mn</td>
<td>666</td>
<td>16</td>
<td>780</td>
<td>366</td>
</tr>
<tr>
<td>Ni</td>
<td>&lt;12</td>
<td>&lt;11</td>
<td>&lt;12</td>
<td>&lt;12</td>
</tr>
<tr>
<td>Rb</td>
<td>2.6</td>
<td>0.4</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Sb</td>
<td>0.11</td>
<td>0.03</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Sc</td>
<td>0.403</td>
<td>0.005</td>
<td>0.178</td>
<td>0.173</td>
</tr>
<tr>
<td>Se</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Sr</td>
<td>189</td>
<td>9</td>
<td>111</td>
<td>112</td>
</tr>
<tr>
<td>Ta</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Zn</td>
<td>110</td>
<td>2</td>
<td>38</td>
<td>52</td>
</tr>
</tbody>
</table>

- all concentrations in ug/g unless otherwise stated; uncertainties at the 68% confidence level

It can be seen that most of the elements, except Al, Ba, Ca, Mn, Fe, and Sr, are in trace quantities i.e. less than 10 ppm = 10 µg/g. These levels are quite low and thus may not pose a hazard to the wildlife. Ca is the most abundant element detected in the faeces samples of concentrations around 1.3 %. It is also interesting to note that selenium (Se) known to have toxic effects was not found to be of measurable quantities in the samples. In fact, they were detected to be less than 1 ppm (i.e. 1 µg/g). Chromium and zinc which are beneficial trace elements for wildlife were found to be in measurable amounts in the samples analyzed. Iron (Fe) levels were also quite high, ranging from 499 to 1260 ppm. Due to time constraints, some other essential trace elements such as vanadium, copper, magnesium were not detected as some of these may require long irradiation times and longer decay times. These elements could be looked at in the future.
4.0 Conclusion

Analytical techniques such as Near Infrared Spectroscopy (NIR), Capillary Electrophoresis (CE), and Instrumental Neutron Activation Analysis (INAA) were successfully utilized to obtain information from deer faeces. Based on the NIR results the protein levels in the Cedar Hills site were found to be slightly higher than the other three sites. In general, the samples within a site show quite a variation in their protein levels. The elemental data from the INAA study shows reasonable levels for the essential trace elements in the deer faeces. A CE method for determining diaminopimelic acid will yield further information on the protein content of the deer faeces that could be correlated to the nutritional value of the diet of the deer.

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