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# Compositional Study of *Apios priceana* Tubers

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*Apios priceana* Robinson (Fabaceae), a reputedly edible tuber native to North America, contains 61.9% water, 5.0% fiber, 2.6% crude protein, 2.7% ash, 27.1% carbohydrate, and 0.7% fat. The amino acid content of the crude protein was of poor nutritional value because of a high proportion of nonessential amino acids. Removal of the nonprotein nitrogen fraction by alcohol extraction significantly improved the nutritional quality. The protein, after removal of nonprotein nitrogen, was limiting in threonine and sulfur-containing amino acids.

## INTRODUCTION

The North American plant *Apios priceana* Robinson (Sadie Price's Potato Bean) has been classified as an underutilized, edible legume (National Academy of Sciences, 1979) with potential as a new crop. Cultivation of *A. priceana* would expand land utilization for food production because in the wild it produces a tuber in highly alkaline (pH >8) and wooded habitats. *A. priceana* produces significantly larger tubers than its widely distributed relative *Apios americana* Medicus, but *A. priceana* has only been collected from eight widely distinct habitats in Alabama, Mississippi, Tennessee, Kentucky, and Illinois (Seabrook, 1973; Medley, 1980). This plant is so rare that it has been proposed as a candidate for the Federal Endangered and Threatened Plants list (Federal Register, 1980).

Although rare and endangered plants have been protected in part because of their potential as new foods or medicines, to our knowledge this the first nutritional analysis to evalute a rare plant's potential for food. Although a rare plant, *A. priceana* can readily be propagated by chipping the seed coat (Seabrook, 1973) or by acid scarification.

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## MATERIALS AND METHODS

***A. priceana* Tubers.** The tubers were harvested in February, near University, MI, packed in damp sphangum moss, and air-shipped to North Carolina State University for analysis. The tubers were received in excellent condition. Three tubers were selected for analysis. The tubers were a deep brown color with numerous wartlike projetions about 1 × 3 mm. They were 12–14 cm across and 7–8 cm high. The weights ranged from 303.6 to 438.7 g. The tubers were sliced into 2-mm-thick sections. Duplicate samples were removed for moisture measurements, and the remainder was freeze-dried and ground to pass through a 60-mesh screen.

**Analyses.** The moisture content was measured by drying tuber slices at 60 °C for 24 h, followed by drying at 100 °C until constant weight was attained. The moisture content was calculated from the differences in weight between fresh and dried samples. All other analyses were carried out on freeze-dried material. The moisture content of the freeze-dried powder was measured as described for tuber slices. The values given in this paper were converted to fresh weight and dry weight basis by appropriate factors. Crude protein, crude fat, and ash were determined by using AOAC (1975) methods. Acid detergent fiber was measured according to Van Soest (1963). The carbohydrate content was obtained by difference.

Alcohol-insoluble solid (AIS) content was obtained by extraction of the powder with boiling 80% ethanol three times (four parts by volume ethanol to one part by weight

**Table I. Chemical Composition of *Apios* Species**

| % compn | *Apios priceana*[a] fresh basis | *Apios priceana*[a] dry basis | *Apios americana*[b] fresh basis | *Apios americana*[b] dry basis | *Apios fortunei*[c] fresh basis | *Apios fortunei*[c] dry basis |
|---|---|---|---|---|---|---|
| water | 61.88 | | 81.00 | | 68.60 | |
| fiber | 4.95 | 12.99 | 5.20 | 27.37 | 1.20 | 3.82 |
| crude protein | 2.62 | 6.87 | 3.12 | 16.42 | 4.19 | 13.34 |
| nonprotein N | 0.15 | 0.39 | 0.19 | 1.00 | 0.42 | 1.34 |
| protein N | 0.27 | 0.69 | 0.31 | 1.63 | 0.25 | 0.80 |
| crude fat | 0.82 | 2.15 | 0.67 | 3.53 | 0.19 | 0.61 |
| ash | 2.67 | 7.00 | 0.99 | 5.21 | 1.30 | 4.14 |
| carbohydr[d,e] | 27.06 | 70.97 | 9.02 | 47.47 | 24.52 | 78.09 |
| starch | 7.84 | 20.58 | | | 18.30 | 58.28 |
| alcohol-insol solids | 15.08 | 39.55 | | | | |

[a] This study. Mean of duplicate analyses from a tuber composite. [b] Sanchez and Duke (1984). [c] Hemmi (1918). [d] By difference [100 − (% water + % fiber + % crude protein + % ash)]. [e] Value for *A. priceana* includes hemicellulose and pectin. Value for *A. americana* includes pectins. Value for *A. fortunei* includes portions of cellulose, lignin, hemicellulose, and pectin.

powder). The starch content was measured by enzymatic hydrolysis of a portion of the AIS with α-amylase–amyloglucosidase (Dekker and Richards, 1971), followed by measurement of the glucose content by gas–liquid chromatography (Walter and Hoover, 1984).

Nonprotein nitrogen (NPN) content was determined by extraction of 3-g samples of the freeze-dried powder with 40 mL of 13% aqueous trichloroacetic acid (TCA). After centrifugation, the nitrogen content of both the supernatant and pellet was measured by the macro Kjeldahl method using copper and selenium catalysts.

Amino acid analyses were conducted on freeze-dried powder and AIS after hydrolysis in 6 N HCl at 123 °C for 24 h. A Waters amino acid analyzer with post-column *o*-phthaldehyde derivitization, followed by measurement of fluorescence intensity (Klapper, 1982), was used to quantitate the individual amino acids.

## RESULTS AND DISCUSSION

Comparison of the reported compositional data (Table I) for *A. americana* (Sanchez and Duke, 1984) and for *Apios fortunei* (Hemmi, 1918), an Asian member of the genus, with our compositional data for *A. priceana* (Table I) demonstrated the high degree of variability between several members of the same genus. *A. fortunei* and *A. priceana* contained more than 30% dry matter, while the dry matter content of *A. americana* was less than 20%. *A. fortunei* and *A. priceana* were less fibrous and contained a much greater amount of nonfibrous carbohydrates than did *A. americana*. On the other hand, the amount of crude protein on a dry weight basis decreased in the following order: *A. americana*, *A. fortunei*, *A. priceana*. Both *A. americana* and *A. priceana* had similar percentages of nonprotein nitrogen 19%, 15%), while *A. fortunei* contained 42% nonprotein nitrogen. Starch accounted for 74.6% of the carbohydrate in *A. fortunei* and for 28.9% of the the carbohydrate in *A. priceana*. A large part of the carbohydrate fraction was extracted by 80% ethanol. Were the carbohydrate mostly insoluble, the AIS value would approach 38% (Table I). The actual AIS content as found to be 15.1% (fresh weight), indicating that most of the dry matter (23.0% fresh weight) soluble in 80% ethanol is carbohydrate in nature and is likely in the form of mono-, di-, and oligosaccharides. The nature of this material is unknown at present.

Because nonessential amino acids predominate (Table II), the nutritional quality of the amino acids of *A. priceana* is poor in comparison to other major root crops. There are significant amounts of arginine and aspartic acids with smaller amounts of glutamic acid and proline also present. Among the essential amino acids, only valine and aromatic amino acids are present in the tubers in levels exceeding the FAO (1973) recommendation. The protein

**Table II. Amino Acid Content[a] of *Apios priceana* Tubers and Alcohol-Insoluble Solids**

| | tubers | alcohol-insol solids | FAO |
|---|---|---|---|
| | Essential | | |
| threonine | 3.10 | 2.84 | 4.0 |
| valine | 5.09 | 6.81 | 5.0 |
| methionine | 0.61 | 0.71 | |
| half-cystine | ND | ND | |
| isoleucine | 3.76 | 4.67 | 4.0 |
| leucine | 5.83 | 8.22 | 7.0 |
| tyrosine | 3.55 | 2.51 | |
| phenylalanine | 3.95 | 5.11 | |
| lysine | 4.95 | 9.25 | 5.5 |
| | Nonessential | | |
| aspartic acid | 18.60 | 12.90 | |
| serine | 3.89 | 2.12 | |
| glutamic acid | 7.67 | 8.87 | |
| proline | 7.20 | 6.86 | |
| glycine | 3.47 | 4.24 | |
| alanine | 3.40 | 4.01 | |
| histidine | 3.00 | 3.93 | |
| arginine | 33.20 | 23.10 | |

[a] Grams of amino acid in 16 g of nitrogen.

appears to be almost totally deficient in sulfur-containing amino acids, with 0.61 g of methionine in 100 g of crude protein. Half-cystine was not detected.

Extraction of dried *A. priceana* with 80% ethanol removed 32.7% of the nitrogen, suggesting that this was low molecular weight material. Determination of the NPN fraction with TCA gave a similar value of 36.1% for the percentage of nitrogen present as low molecular weight material (i.e., nonproteinaceous). Apparently both 80% ethanol and 13% TCA solution solubilize the same nitrogenous fraction. This has been shown to be the case for white potatoes (Li and Sayre, 1975) and sweet potatoes (Purcell and Walter, 1980). The nitrogen of the AIS fraction thus is probably proteinaceous. When the amino acid content of the AIS fraction was measured, it was observed (Table II) that compared to the amino acid content of whole dried material the amounts of the most abundant nonessential amino acids (aspartic acid and arginine) declined, while the relative amounts of the essential amino acids (valine, isoleucine, leucine, lysine) all increased to such an extent that they were no longer limiting with respect to the FAO standard pattern. Apparently the nonprotein nitrogen fraction, which is soluble in alcohol, contains fairly large amounts of aspartic acid and arginine as free amino acids and, thus, lowers the nutritional quality of the protein. When these amino acids are removed by alcohol extraction, a clearer picture of the amino acid pattern of the protein is obtained. Thus, the

protein is limiting only with respect to threonine and total sulfur.

SUMMARY

*A. priceana* tubers are unique in their large size and ability to grow in highly alkaline, wooded habitats. To obtain a protein that can be useful in human nutrition, the nonprotein nitrogen of the tubers can be extracted by alcohol. *A. priceana* would appear to be a better germplasm source for breeding with other *Apios* species to expand their habitats.

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# Effect of Chain Length and Concentration on the Degree of Dissociation of Phosphates Used in Food Products

Graham R. Trout[1] and Glenn R. Schmidt*

A sodium ion selective electrode was used to determine the degree of dissociation of six different sodium phosphates commonly used in food products. The phosphates investigated had number average chain lengths between 1.0 and 20.8. All phosphates were analyzed at pH 6.0 and at four concentrations between 0.15 and 0.60%. The results showed that the concentration had no significant ($p > 0.05$) effect on the degree of dissociation of the phosphates, whereas the chain length had a large significant effect ($p < 0.001$). The degree of dissociation decreased as the chain length of the phosphate increased; the rate of decrease was proportional to the square of the chain length. The values for the degree of dissociation ranged from 91.6% for the shortest chain length phosphate to 38.0% for the longest.

## INTRODUCTION

Phosphates are used in processed meat products to reduce the amount of water lost during cooking and to improve the texture of the product (Ellinger, 1972). Although phosphates are very effective at increasing both of these functional properties, it is not fully understood how they achieve this. As a result, it has been difficult to determine which type of phosphate and what conditions are required for the phosphates to produce the maximum increase in either of these functional properties.

Phosphates increase the functional properties of meat products by one or more of the following ways: (a) by increasing the pH of the product; (b) by increasing the ionic strength of the product; (c) by dissociating actomyosin, the main structural protein of muscle, into actin and myosin; (d) by binding to the meat proteins (Hamm, 1970). But it is not known how important each of these factors are because the exact ionic strength of the phosphates cannot be calculated. This is because the ionic strength of the phosphates is determined by their degree of dissociation, which in turn is determined by the type and concentration of phosphate (Van Wazer and Callis, 1958). And to date, the values obtained for the degree of dissociation of the phosphates commonly used in food products have been quite variable (Wall and Doremus, 1954; Schindewolf, 1953; Schindewolf and Bonhoeffer, 1953; Batra, 1965). The values for the degree of dissociation of the phosphates must be known accurately because a small error in the degree of dissociation produces a large error in the value calculated for the ionic strength.

The sodium ion electrode is the most useful instrument available for measuring the degree of dissociation of phosphates at the concentrations typically found in meat products (0.1%-0.6% in the aqueous phase) (Gardner and Nancollas, 1969). In several previous studies, however, these electrodes have been used as concentration probes (Rechnitz and Brauner, 1964; Batra, 1965) rather than activity probes. When they are used as concentration probes, they produce erroneous results because at high phosphate concentrations the activity of the sodium ion

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