Nutrient Composition and Toxic Factor Content of Four Wild Species of Mexican Potato

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The nutrient composition and toxic factor content of four wild species of Mexican potato were determined to compare the nutritional and toxic potentials with those of a cultivated variety. The nutrient composition did not show wide differences, but the true protein contents of wild species did. As expected, starch was the principal component, free sugars were found in very low levels, and the amylose/amylopectin ratio (20:80 average) did not indicate any special difference between the wild species and the cultivated one. Sulfur amino acids were deficient in all of the samples, and the cultivated species showed the highest chemical score. All of the samples showed low content of lectins and trypsin inhibitors, but two wild species showed >20 TUI/mg. Alkaloids were present in higher quantities in the wild species than in the cultivated one.

Keywords: *Wild potato; nutrient composition; antinutritional factors; starch; protein quality*

INTRODUCTION

One of the most important genera in the Solanaceae family is without doubt *Solanum*, which includes species of nutritional, agricultural, chemical, and toxicological importance (Macrae et al., 1993). *Solanum tuberosum* is one of the most important varieties of cultivated potatoes, which according to the Potato Investigation Center, in Lima, Peru, can play an important role in the diet of many developing countries since its nutritional value and protein quality are superior to those of cereals; thus, it ranks first among vegetables in per capita consumption in many countries and is the second crop in protein production after soybean (FAO, 1990; Van der Zaag, 1983). Wild potato species are totally distributed throughout the American continent and can be found from Patagonia up to the southern states of the United States (Luna Cavazos, 1987). In Mexico, wild species of *Solanum* appear in maize fields as weeds, many of which are not edible. There are about 33 wild species distributed within the Mexican territoy, and in some regions, mainly the central part of Mexico, *Solanum cardiophyllum* and *Solanum ehrenbergii*, known as "papitas güeras" (blonde potatoes), are used as food and commercialized in the community markets (Galindo, 1982; Camacho, 1986). However, in the same area grow other species that are not edible. Historical reports of most of the wild species indicate that these tubers are bitter and their consumption can result in severe gastrointestinal disturbances and vomiting. To combat the toxic effects of these potatoes, native people usually consume them with edible clays. Geophagy appears to be an effective means of adsorbing the glycoalkaloids of these potatoes (Johns, 1986; Johns and Galindo, 1990). There is not enough information about the nutritional value of wild potato tubers, and the toxicological point of view seems to be of major interest. Lectins, protease inhibitors, saponins, and phenolic compounds are present in potatoes, but alkaloids are the most studied toxic factor since they are responsible for the acute toxicity exhibited by these tubers (Bushway et al., 1980; Dao and Friedman, 1994; Hellenas et al., 1995). This paper attempts to show nutritive characteristics besides toxic potential of some wild Mexican potato species frequently found in the central part of Mexico, in comparison with a cultivated variety of *S. tuberosum*.

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MATERIALS AND METHODS

Wild potato species were collected in different regions in the Mexican states of San Luis Potosí, Zacatecas, and Guanajuato; the four wild species were *Solanum polytrichon, S. cardiophyllum, S. erhenbergii*, and *S. stoloniferum*. *S. tuberosum* (var. Alpha) was cultivated by INIFAP in Toluca; all of the wild species were botanically classified at UNAM FES Zaragoza, and all were prepared in the same way for analysis. The samples were peeled and fractionated into little pieces and freeze-dried (freeze-dryer model 5, Labconco Co., Kansas City, MO); the samples were then milled, and the analyses were carried out with the flours.

The proximate analysis was carried out according to the technique described by the AOAC (1990). The true protein content was determined according to the technique described by Lucas et al. (1988): a heavy metal salt was used to precipitate the soluble protein, and the resulting precipitate and the insoluble protein were separated by filtration; finally, the nitrogen content was determined according to the micro-Kjeldahl method (nitrogen factor = 6.25). The vitamin C content was determined by using the dichlophenol indophenol titration procedure (AOAC, 1984). For this analysis fresh tuber samples were used, and vitamin C was extracted by using an acetic acid solution. The total starch content was determined, as recommended by Southgate (1991), by the extraction of starch from the sample by a treatment with 80% ethanol and solubilization with perchloric acid. The isolated starch was then determined as the total content of carbohydrates according to the phenol−sulfuric acid procedure of Dubois et al. (1956).

The amylose content was determined according to the method of Knutson and Grove (1994), including the modifica-

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Table 1. Proximate Analysis and True Protein and Vitamin C Contents of the Wild Potato Tubers and Cultivated Potato (Grams/100 g of Sample)[a]

	S. polytrichon[b]	*S. stoloniferum*[c]	*S. ehrenbergii*[c]	*S. cardiophyllum*[c]	*S. cardiophyllum*[d]	*S. tuberosum* (cultivated potato)
moisture	88.91 ± 1.02[a]	77.00 ± 1.64[c]	83.90 ± 1.08[b]	72.24 ± 1.95[d]	75.26 ± 1.16[c,d]	79.01 ± 1.00[c]
dry basis						
ash	4.40 ± 0.27[c]	5.40 ± 0.18[b]	5.64 ± 0.03[a]	4.35 ± 0.08[c]	4.14 ± 0.16[d]	4.24 ± 0.14[c,d]
total lipids	0.25 ± 0.04[d]	0.37 ± 0.03[c]	0.58 ± 0.06[b]	0.17 ± 0.04[e]	0.14 ± 0.09[e]	0.68 ± 0.05[a]
crude fiber	2.62 ± 0.97[a]	2.22 ± 0.91[a]	2.11 ± 0.87[a]	1.74 ± 0.56[d]	1.79 ± 0.91[d]	1.83 ± 0.93[a]
crude protein	8.50 ± 0.05[e]	11.26 ± 0.07[a]	10.73 ± 0.05[b]	11.27 ± 0.04[a]	9.52 ± 0.04[d]	10.0 ± 0.05[c]
CHOs[e]	84.23	80.75	80.94	82.47	84.41	83.27
true protein	4.40 ± 0.55[e]	6.49 ± 0.72[b]	9.58 ± 0.81[a]	6.03 ± 0.43[c]	5.62 ± 0.71[d]	9.50 ± 0.65[a]
% protein N	51.76 ± 0.61[f]	57.63 ± 0.64[d]	89.28 ± 0.82[b]	53.50 ± 0.58[e]	59.03 ± 0.61[c]	95.00 ± 0.73[a]
fresh sample						
mg of vitamin C/100 g of sample	5.87 ± 0.58[c]	2.93 ± 0.62[d]	2.36 ± 0.81[d]	5.78 ± 0.58[c]	9.15 ± 1.18[b]	17.18 ± 1.23[a]

[a] Values are expressed as means ± standard deviation ($n = 3$). Different superscripts mean significant difference ($p < 0.05$). [b] From Zacatecas State. [c] From San Luis Potosí State. [d] From Guanajuato State [e] CHOs, carbohydrates calculated by difference.

tions proposed by Chrastil et al. (1987). Samples of freeze-dried potatoes were placed in a volume of $CaCl_2$ and allowed to gelatinize; a volume of a solution of iodine in dimethyl sulfoxide (DMSO) was then added, and aliquots from each tube were diluted with water. The blue complex formed was determined spectrophotometrically. The amylose content was corrected as percent of starch content, and amylopectin was calculated by subtracting amylose from the total starch value.

The presence of free sugars was determined by using the dinitrosalicylic acid procedure for reducing sugars (Southgate, 1991).

Amino acid analysis was performed by high-performance liquid chromatography (HPLC) by means of a Waters chromatograph with a scanning fluorescence detector and following the technique recommended by the Millipore Corp. (1993) (Iwaki et al., 1987). This method is based on a derivatizing reagent (6-aminoquinolyl-*N*-hydroxysuccinimidyl carbamate) that converts both primary and secondary amino acids to stable fluorescent derivatives. The acid hydrolysates of each sample were prepared as described by Lucas and Sotelo (1982). The tryptophan content of each sample was determined by alkaline hydrolysis (Lucas and Sotelo, 1980) and colorimetric reaction with 4-(dimethylamino)benzaldehyde (Ras et al., 1974).

The chemical score was calculated by using the FAO/WHO amino acid pattern for high-quality protein according to the method of Pellet and Young (1980). The antinutritional factors investigated were hemagglutinins (lectins) and trypsin inhibitors. For the determination of hemagglutinins the technique described by Jaffé et al. (1974) was employed with rabbit red blood cells. The trypsin inhibitor activity was determined according to the method of Kakade et al. (1974) by using benzoyl-DL-arginine *p*-nitroanilide (BAPNA) as a substrate and reported as trypsin units inhibited. One trypsin unit corresponds to an increase of 0.01 absorbance unit at 410 nm per 10 mL of the reaction mixture under the conditions defined by Kakade et al.

The alkaloids analyzed were α-solanine and α-chaconine; the two alkaloids used as standard were obtained from Sigma Chemical Co., St. Louis, MO. This analysis was accomplished by employing the HPLC technique described by Dao and Friedman (1996) with the help of a Waters chromatographic system. A C_{18} column was employed, and some modifications were done: 0.10 M ammonium phosphate buffer/acetronitrile (65:35) at pH 6.5 was used as eluent. This modification was validated for linearity, specificity, and accuracy (Lang and Bolton, 1991).

All of the analytical tests were done in triplicate, and an analysis of variance was made.

RESULTS AND DISCUSSION

Table 1 shows the proximate analysis on a dry basis and vitamin C content in fresh sample. Moisture ranged between 88.91 and 72.24% as expected since fresh tubers contain large amounts of water. Vitamin C was low in wild potato tubers, showing the lowest values in *S. stoloniferum* and *S. ehrenbergii*; *S. cardiophyllum* from Guanajuato presented the highest value among the wild potato species studied. *S. tuberosum* presented the highest vitamin C content of all the samples analyzed. The proximate composition on a dry basis and the true protein contents are presented in the same table. The ash and lipid contents showed small differences between wild potatoes and cultivated potato *S. tuberosum*. The crude protein content showed differences between wild potatoes: *S. polytrichon* had the lowest content (8.50%), and *S. stoloniferum* and *S. cardiophyllum* from San Luis Potosí the highest (11.26 and 11.27%, respectively), which were higher concentrations of crude protein than that of *S. tuberosum* (10%). The true protein contents indicate that the wild potatoes, except *S. ehrenbergii*, have large amounts of nonprotein nitrogen since only 51−59% of the total nitrogen content corresponds to proteins; therefore, *S. tuberosum* had the highest true protein content (95% of protein nitrogen), and *S. ehrenbergii* was the wild potato tuber with the highest protein content (89.28% of protein nitrogen). These results could be also due to the presence of nonprotein amino acids, free protein amino acids [which are common in *Solanum* tubers (Synge, 1977)], alkaloids, and other nitrogen compounds that have higher incidence in wild species than in cultivated potatoes, possibly as a response of different environmental conditions. However, *S. eherenbergii*, which is a wild species, showed a high content of protein nitrogen; hence, these changes between potatoes might be due to the stage of ripeness (Flores, 1997).

Starch and sugar contents are shown in Table 2. The total starch content was very high as expected in all tubers, ranging from 74.8% in *S. ehrenbergii* to 84.08% in *S. cardiophyllum* from Guanajuato. The free sugars were present in all samples in very small amounts: *S. ehrenbergii* had the highest content and is statistically different from the others. If we consider that free sugars may be an indicator of maturity, these differences might be due to different physiological stages among the potato species studied (Dao and Friedman, 1994; Hellenas et al., 1995). The amylose content of wild Mexican potatoes and *S. tuberosum* ranged between 16 and 20% (starch basis); in all cases amylopectin is the highest starch component and agrees with the amylose and amylopectin contents reported for other *Solanum* tubers. No differentiation between wild and

Table 2. Total Starch Content, Free Sugars, and Amylose/Amylopectin Ratio in the Wild Potato Tubers and Cultivated Variety[a]

	total starch (g/100 g of dry matter)	reducing sugars (g/100 g of dry matter)	amylose, amylopectin[b] contents (g/100 g of starch)	amylose/amylopectin ratio
S. polytrichon, Zacatecas	83.53 ± 0.92[a]	0.70 ± 0.04[d]	18.16 ± 0.33[b], 81.84	0.221
S. stoloniferum, San Luis Potosí	80.11 ± 0.16[c]	0.65 ± 0.06[d]	16.70 ± 0.27[c], 83.30	<0.200
S. ehrenbergii, San Luis Potosí	74.80 ± 0.54[d]	5.55 ± 0.91[a]	21.53 ± 1.04[a], 78.47	0.274
S. cardiophyllum, San Luis Potosí	81.58 ± 0.48[b]	1.03 ± 0.13[c]	20.44 ± 1.00[a], 79.56	0.256
S. cardiophyllum, Guanajuato	84.08 ± 0.56[a]	0.63 ± 0.08[d]	19.02 ± 0.61[ab], 80.90	0.235
S. tuberosum var. Alpha	81.09 ± 0.10[b]	2.50 ± 0.73[b]	20.72 ± 0.86[a], 79.28	0.261

[a] Values are expressed as means ± standard deviation ($n = 3$). Different superscripts mean significant difference ($p < 0.05$). [b] Amylopectin = total starch − amylose.

Table 3. Amino Acid (AA) Content in Wild Potato Tubers and in Cultivated Potato (Grams of AA/16 g of N)[a]

AA	*S. polytrichon*	*S. stoloniferum*	*S. ehrenbergii*	*S. cardiophyllum*	*S. cardiophyllum*	*S. tuberosum*[b]	FAO/WHO pattern 1973
aspartic acid	24.5 ± 2.01	21.4 ± 1.06	23.6 ± 1.24	22.3 ± 1−02	14.8 ± 1.67	12.4 ± 2.03	
glutamic acid	10.1 ± 0.97	11.7 ± 1.20	11.3 ± 1.08	9.4 ± 1.00	7.4 ± 0.31	10.2 ± 1.81	
serine	3.0 ± 0.32	2.5 ± 0.91	2.3 ± 0.18	2.8 ± 0.14	4.7 ± 0.78	4.1 ± 0.92	
glycine	3.2 ± 0.35	2.5 ± 0.18	2.3 ± 0.21	2.7 ± 0.17	3.6 ± 0.51	3.8 ± 0.45	
histidine	2.5 ± 0.24	1.5 ± 0.10	1.5 ± 0.17	2.0 ± 0.16	2.3 ± 0.10	1.5 ± 0.38	
arginine	8.5 ± 0.61	6.3 ± 0.56	10.4 ± 0.40	12.4 ± 1.08	7.8 ± 0.28	5.0 ± 0.17	
alanine	3.4 ± 0.31	2.3 ± 0.81	2.1 ± 0.17	2.3 ± 0.19	2.8 ± 0.36	4.4 ± 0.31	
proline	5.9 ± 0.46	8.8 ± 0.62	5.8 ± 0.41	5.2 ± 0.21	3.7 ± 0.18	3.8 ± 0.56	
sulfur AA[c]	1.5 ± 0.17	1.5 ± 0.10	1.4 ± 0.10	1.3 ± 0.12	1.2 ± 0.51	1.9 ± 0.78	3.5
aromatic AA[d]	6.8 ± 0.62	5.0 ± 0.14	4.6 ± 0.51	5.8 ± 0.71	4.8 ± 0.61	6.7 ± 0.61	6.0
isoleucine	3.5 ± 0.31	3.1 ± 0.26	2.9 ± 0.62	3.4 ± 0.16	2.9 ± 0.76	3.8 ± 0.42	4.0
leucine	6.6 ± 0.21	5.3 ± 0.31	4.7 ± 0.21	5.2 ± 0.30	4.3 ± 0.17	6.0 ± 0.71	7.0
lysine	4.2 ± 0.40	4.9 ± 0.61	4.8 ± 0.30	5.0 ± 0.17	4.4 ± 0.34	4.8 ± 0.21	5.4
threonine	4.0 ± 0.37	2.3 ± 0.18	2.1 ± 0.17	2.6 ± 0.13	2.4 ± 0.18	3.7 ± 0.26	4.0
tryptophan	1.9 ± 0.08	1.5 ± 0.09	1.5 ± 0.14	1.5 ± 0.20	1.4 ± 0.26	1.7 ± 0.34	0.96
valine	5.1 ± 0.46	3.9 ± 0.28	3.9 ± 0.18	3.9 ± 0.31	4.0 ± 0.35	4.7 ± 0.31	4.9
chemical score[e]	42	42	39	36	34	53	
limiting AA	sulfur AA in all studied species						

[a] Values are expressed as means ± standard deviation ($n = 3$). [b] Cultivated potato. [c] Cysteine + methionine. [d] Phenylalanine + tyrosine [e] Chemical score = (g of amino acid in sample/g of amino acid in FAO pattern) × 100.

Table 4. Antinutritional Factors and Alkaloids Present in Wild Potato Tubers and Cultivated Potato (Dry Basis)

	lectins (titer)[a]	trypsin inhibitors[b,c] (TUI/mg of sample)	α-solanine[c] (mg/100 g of sample)	α-chaconine[c] (mg/100 g of sample)
S. polytrichon, Zacatecas	4	5.4 ± 1.06[d]	116.51 ± 5.24[c]	208.67 ± 2.75[c]
S. stoloniferum, San Luis Potosí	8	22.5 ± 2.05[a]	103.46 ± 3.90[d]	94.21 ± 3.71[d]
S. ehrenbergii, San Luis Potosí	6	23.7 ± 2.31[a]	54.28 ± 1.93[e]	54.32 ± 4.28[e]
S. cardiophyllum, San Luis Potosí	6	11.3 ± 1.09[c]	243.00 ± 11.43[b]	257.00 ± 15.37[b]
S. cardiophyllum, Guanajuato	4	12.0 ± 2.17[c]	273.85 ± 12.89[a]	281.94 ± 22.99[a]
S. tuberosum (alpha variety)[c]	8	16.1 ± 1.40[b]	6.94 ± 0.40[f]	16.71 ± 0.62[f]

[a] Titer = maximal dilution at which agglutination is observed. [b] TUI, trypsin units inhibited per mg of sample. [c] Values are expressed as means ± standard deviation ($n = 3$). Different superscripts mean significant difference ($p < 0.05$).

cultivated potatoes can be established on the basis of total starch content. In addition, no differentiation may be established by taking the amylose/amylopectin ratio as a basis since this parameter did not show any special profile in wild potatoes or in *S. tuberosum*; differences found may be due to different stages of maturity (ripeness).

Table 3 shows the amino acid content in the studied potatoes. All samples showed an interesting essential amino acid profile with acceptable content of methionine, lysine, and tryptophan that can be compared to legume amino acid profiles (beans, peas, chickpea). The chemical score (CS) was calculated by using the FAO pattern of 1973. The sulfur amino acids turned out to be the limiting ones in all cases, with CS ranging between 34 and 53 including *S. tuberosum*. It is important to note the high amount of lysine and tryptophan in all samples. The highest CS was that of *S. tuberosum* (53), and if we compare it to that of legumes, the CS of this potato is higher than the CS of many of them. On the whole, the amino acid profile of *S. tuberosum* looks better than that of wild potatoes. Both samples of *S. cardiophyllum* presented the lowest chemical scores (34 and 36).

The toxic factor analysis is shown in Table 4. The highest lectin content was observed for *S. stoloniferum* and *S. tuberosum*, and the lowest contents were those of *S. polytrichon* and *S. cardiophyllum* from Guanajuato. The trypsin inhibitor contents of *S. stoloniferum* and *S. ehrenbergii* were the highest ones, and *S. polytrichon* showed the lowest content. In this case no difference was observed between *S. cardiophyllum* samples collected from different regions. No differentiation can be made between cultivated potato and wild ones on the basis of lectin and trypsin inhibitor content, perhaps due to handling conditions or different stages of ripeness, since physical damage and physiological state are very important in the production of these two antinutritional factors. The wild species presented a higher content of the two alkaloids α-solanine and

α-chaconine than *S. tuberosum* did, and they also showed the presence of other compounds (small peaks, possibly alkaloids not studied here); *S. cardiophyllum* presented the highest amount of α-solanine and α-chaconine, as can be observed in Table 4. According to Johns and Galindo (1990) *S. cardiophyllum* and *S. ehrenbergii* are edible wild species, but in this study *S. cardiophyllum* did not seem to be, because of the high alkaloid content. The differences found could be due to the soil, the season, and the stage of development when they were collected. It is convenient to continue the study of the other Mexican wild potatoes since some of them with low alkaloid content could be important as animal feed. From these results it is concluded that further research on the toxic effects of these potatoes should be done to enhance the current toxicological information about *Solanum* genera.

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