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Food Chemistry 99 (2006) 698–701
Food Chemistry
www.elsevier.com/locate/foodchem

Balance between nutrients and anti-nutrients in nine Italian potato cultivars

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Received 23 May 2005; received in revised form 22 August 2005; accepted 22 August 2005

Abstract

Nine commercial potato cultivars have been analyzed in order to detect differences in nutritional quality, considering the balance between nutrients and anti-nutrient compounds present in each. The most important nutrients studied in this paper were: water, starch, free sugars, such as glucose, fructose and sucrose, malic acid, citric acid, ascorbic acid and chlorogenic acid. The anti-nutrients measured included α-solanine, α-chaconine and asparagine. This last compound was added to the anti-nutrient compounds because it is involved in the formation of acrylamide during thermal food processes. From this study, by considering the nutritional quality of each cultivar, we can divide the potato cultivars into three groups, each being suitable for a different technological processes.

Keywords: Potato; Acrylamide; Nutrients; Anti-nutrients; Technological processes

1. Introduction

The most important nutrients present in potatoes are: carbohydrates, such as the starch and free sugars, organic acids, ascorbic acid, and the antioxidant phenols, such as chlorogenic acid and its polymers. These molecules are involved in pathogen resistance in plants, and the chlorogenic acid concentration represents about the 90% of the total phenolic compounds in the potatoes (Bell, 1980; Friedman, 1997; Mondy & Gosselin, 1988).

These parameters are important, not only for human nutrition but also in food processes. The concentration of these parameters could be influenced by different cultivars, farming system techniques and climatic conditions.

In order to evaluate the nutritional quality of different potatoes it is also important to include the concentrations of anti-nutrients, such as glycoalkaloids solanine and α-chaconine. α-Solanine and α-chaconine are the two major glycoalkaloids present in potato. They appear to be unaffected by food processing (baking, cooking and frying). The toxicity, of these compounds may be due to adverse effects on the central nervous system, with disruption of the cell membranes, on the digestive system and general body metabolism (Friedman, Roitman, & Kozukue, 2003). For these reasons there are informal guidelines, limiting the total glycoalcaloid concentration in potato to 200 mg/kg fresh weight of potatoes (Souci-Fachmann-Kraut, 2000).

Beside these classic parameters, other compounds present in potatoes, are very important for evaluating the nutritional quality, e.g., the potential to form acrylamide.

During the recent years, acrylamide has been detected in many foods heated during their production or preparation. Acrylamide is a probable carcinogen (IARC, 1994) formed by heating glucose or fructose with asparagine by the Maillard reaction at temperatures of 120–170 °C (Mottram, Wedzicha, & Dodson, 2002). Particularly high concentrations (>1 ppm) were found in products of plant origin heated to high temperatures (Amrein et al., 2003).

Potato chips and french fries are probably major sources of acrylamide for humans, because potatoes are rich in carbohydrates and heat-treated foods are necessary for acrylanide production (Friedman, 2003). Different agronomical systems do not influence the amounts of free sugars,

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doi:10.1016/j.foodchem.2005.08.046

such as glucose and fructose, or free asparagine in the potato and this reduces the risk of acrylamide production during food processing (Mottram et al., 2002).

In our opinion, nutritional quality is the *balance* between nutritional and anti-nutritional compounds. For this reason we have studied, the concentration of: water, starch, free carbohydrates (glucose, fructose and sucrose), malic acid, ascorbic acid, citric acid, chlorogenic acid, α-solanine, α-chaconine and asparagine in nine widespread Italian potato cultivars, in order to find if there are nutritional quality differences between them and, if possible, to choose appropriate cultivars for different food processes.

2. Materials and methods

2.1. Potatoes

The potato samples were kindly offered by Quality Seed s.r.l. (Minervio, Bologna, Italy) and harvested during the same period. The samples were stored at 4 °C. Some were lyophilized and stored at room temperature in a vacuum dryer. The determinations of water, ascorbic acid, malic acid and citric were performed on fresh samples. The concentrations of starch free carbohydrates, chlorogenic acid, asparagine, α-solanine and α-chaconine were obtained on the lyophilized samples.

2.2. Water

Water amount were determined measure according to AOAC methods at 105 °C (Nancy & Wendt Thiex, 2003).

2.3. Starch

Total starch content was determined, using 100 mg dry samples, by a Diffchamb Enzy Plus Starch kit (Diffchamn AB Sweden) (Beutler, 1984).

2.4. Carbohydrates

One gramme of fresh potato sample was extracted by 10 ml of acetonitrile/water (80:20 v/v), the sample was stirred and centrifuged at 3000 rpm for 10 min. Aliquots of this solution were filtered through a 0.45 μm Millex filter (Millipore) prior to injection into the HPLC.

A Beckman 342 HPLC model (Palo Alto, Ca USA), equipped with R.I. detector, and an INERTSIL NH2 4 × 250 mm (GL Sciences Japan) column, was used. Fifty microliters were injected into the column. An isocratic mode elution with a mobile phase of acetonitrile/water (80:20 v/v) at a flow rate of 0.5 ml/min was used (Chrompack application note no. 186).

2.5. Organic acids

Ten gramme of fresh sample were diluted with sodium phosphate dihydrate buffer 0.2 M, pH 2.8 (by saturated solution of metaphosphoric acid), stirred for 10 min and centrifuged at 4500 rpm for 5 min. Aliquots of this solution were filtered through a 0.45 μm Millex filter (Millipore) prior to injection into the HPLC.

Chromatographic conditions: (Beckman 342 HPLC model Palo Alto, CA, USA), equipped with an UV–Vis detector and a Supelcosil C18 column (Supelco Bellefonte Ca, USA), isocratic mode. Mobile phase was sodium phosphate dihydrate buffer 0.2 M, pH 2.8 (by saturated solution of metaphosphoric acid), wavelength 214 nm, flow rate 1 ml/min (Kontron application note no. 0511).

2.6. Asparagine

The lyophilized sample (about 100 mg) was deproteinized by 50 ml of a 0.3 M sulfosalicylic acid solution. The sample was stirred and centrifuged at 10,000 rpm for 5 min. The supernatant was recovered and 250 μl injected into Beckman 118 BL aminoacid analyzer (Mondino, 1972).

2.7. Chlorogenic acid

One or three grammes of fresh sample were extracted by a methanol:water (50:50 v/v) solution, stirred and heated to 100 °C for 30 min. The sample was cooled and filtered through a 0.45 μm Millex filter (Millipore) prior to injection into the HPLC.

2.8. Chromatographic conditions

(A Beckman 342 HPLC model Palo Alto, CA, USA), equipped with a UV–Vis detector and a Supelcosil C18 4.6 × 250 mm column (Supelco Bellefonte CA, USA), isocratic mode was used. Mobile phase wavelength was 310 nm, and flow rate 1.2 ml/min (Lucas & Develaar, 1996).

2.9. α-Solanine, and α-chaconine

The samples were prepared according to Friedman et al. (2003) and the glycolalkaloids detected by HPLC (Beckman 342 model, Palo Alto, CA, USA) equipped with a UV–Vis detector using an Inertsil NH_2 column 5 μM, 4.0 × 250 mm (GL Science, Japan). Acetonitrile/20 mM KH_2PO_4 (80:20 v/v) as mobile phase was used, in isocratic mode at 208 nm. The flow rate was 1.0 ml/min, sample size 20 μl. The α-solanine and α-chaconine were identified by comparison to a standard chromatogram of both glycoalkaloids (Friedman et al., 2003).

2.10. Statistical analysis

The results were expressed as weighted means and, for each value, the standard deviation were calculated. The ANOVA test used to determine the statistical differences. The criterion for statistical significance was $P \leqslant 0.05$. Data

presented in Tables show the calculated means and the different letters indicate significant differences at $P \leqslant 0.05$ using Duncan's test.

3. Results and discussions

In Table 1 shows the values of water, glucose, fructose, sucrose and starch. All values found are in accordance with literature data (Souci-Fachmann-Kraut, 2000). In particular, the Sponta cultivar showed lowest values of water glucose and fructose, the Jelli and Agria cultivars showed low values of all free carbohydrates, and the Primura showed a low concentration of sucrose. The free sugars involved in the Maillard reaction form acrylamide. They are potential precursors for acrylamide formation and the cultivars with low sugar concentrations are more suitable than others in high temperature food processes. The cultivar Marabel has the highest value of sucrose and starch, probably due to a better storage process (Amrein et al., 2003).

In Table 2 shows the values of malic, citric, and ascorbic acids. All the samples have good concentrations of these compounds, which means a good nutritional value. In detail, the Primura cultivars are more rich than others in malic acid, the Merit presents high values of ascorbic acid and the Sponta and Agria have the highest concentration of citric acid, but this last cultivar also has a very low concentration of ascorbic acid. Compared with the literature data (Souci-Fachmann-Kraut, 2000) only the Merit, Primura and Agria cultivars had good amounts of chlorogenic acid; the others had a low concentration of this compound.

In the Table 3 shows the values of asparagine, α-solanine and α-chaconine. The Agata and Arinda cultivars had the lowest asparagine concentrations. Since asparagine is an important precursor of acrylamide formation, these two cultivars are more suitable, than others, for use in high temperature food processes. Other cultivars had different amounts of asparagine with highest values in Frinka, Sponta and Primura. The same Table also shown the amounts of α-solanine and α-chaconine in each potato cultivar studied. The sum of both glycoalcaloids, in all cultivars studied, was acceptable for human nutrition (Morgan & Coxon, 1987).

4. Conclusions

The nutrition parameters, such as water, starch, free sugars and citric acid, in the cultivars studied, are in accordance with the literature data. The malic acid concentrations appear to be high in the Agata, Primura, Arinda, Marabel, Sponta and Agria cultivars. The ascorbic acid concentration is low in the Agria, Arinda and Frinka cultivars.

The Agata, Primura and Arinda cultivars present the lowest values of α-solanine and α-chaconine and Agata and Arinda have very low concentrations of asparagine.

Table 1
Water and sugars (g/100 g of fresh product)

Cultivars	Water	±	Glucose	±	Fructose	±	Sucrose	±	Starch	±
Agata	81.00cd	1.10	0.23c	0.01	0.17e	0.01	0.53cd	0.01	12.22a	0.07
Primura	80.86cd	1.12	0.21de	0.02	0.13d	0.01	0.35a	0.01	12.44b	0.15
Arinda	81.83d	1.00	0.34f	0.03	0.08c	0.01	0.57d	0.05	12.54b	0.02
Merit	79.03bc	1.00	0.18d	0.01	0.13d	0.01	0.78e	0.03	13.34c	0.14
Marabel	81.70d	1.60	0.12c	0.01	0.11d	0.01	1.39f	0.14	18.63g	0.18
Jelli	77.70b	1.50	0.02a	0.01	0.05b	0.01	0.33a	0.02	14.30d	0.16
Frinka	79.40bcd	0.50	0.22e	0.01	0.18e	0.01	0.46c	0.04	15.09e	0.02
Sponta	75.23a	1.12	0.03a	0.01	0.00a	0.01	0.45bc	0.02	17.06f	0.07
Agria	80.13cd	2.06	0.07b	0.03	0.05b	0.02	0.36ab	0.02	15.15e	0.12
F ANOVA	8.15***		108.43***		80.43***		116.02***	1053.30***		

Each value is the mean of three determinations; different letters indicate significant differences at $P \leqslant 0.05$ (Duncan's test).

Table 2
Organic acids and chlorogenic acids (mg/100 g of fresh product)

Cultivars	Malic acid	±	Ascorbic acid	±	Citric acid	±	Chlorogenic acid	±
Agata	125d	1.50	19.2f	0.64	425.6e	1.10	4.75c	0.32
Primura	140e	1.67	9.98c	0.08	389d	40.53	10.1e	1.09
Arinda	123cd	6.56	8.06b	0.10	256a	4.98	3.45b	0.14
Merit	97.6a	1.01	24.2g	0.63	479f	7.21	12.1f	0.08
Marabel	161f	3.42	17.5e	0.54	286b	5.14	6.42d	0.39
Jelli	100a	1.62	13.3d	0.60	424e	4.81	1.40a	0.15
Frinka	127d	1.07	8.51b	0.19	320e	1.81	7.07d	0.04
Sponta	106b	1.01	18.5f	0.21	656h	1.67	4.26c	0.06
Agria	118c	0.90	3.68a	0.08	625g	0.17	10.5e	0.12
F ANOVA	164.77***		760.88***		297***		222.11***	

Each value is the mean of three determinations; different letters indicate significant differences at $P \leqslant 0.05$ (Duncan's test).

Table 3
α-Chaconine, α-solanine and asparagine (mg/100 g of fresh product)

Cultivars	Asparagine	±	α-Chaconine	±	α-Solanine	±	α-Chaconine + α-solanine	±
Agata	15.6a	0.90	0.89a	0.005	0.15a	0.005	1.04a	0.001
Primura	392f	17.0	1.51b	0.01	0.33c	0.001	1.84b	0.01
Arinda	50.4b	2.40	1.71c	0.04	0.29b	0.005	2.00c	0.05
Merit	154c	6.20	2.16d	0.16	0.74f	0.01	2.90d	0.15
Marabel	183d	9.30	3.54g	0.01	0.68e	0.005	4.22h	0.02
Jelli	238e	10.9	2.95e	0.15	0.59d	0.01	3.54e	0.14
Frinka	458g	14.7	3.26f	0.06	0.56d	0.01	3.81f	0.05
Sponta	458g	20.5	4.09h	0.03	1.01g	0.027	5.10i	0.01
Agria	147c	6.40	3.39fg	0.11	0.67e	0.03	4.07g	0.09
F ANOVA	620.50***		470.16***		825.26***		817.51***	

Each value is the mean of three determinations; different letters indicate significant differences at $P \leqslant 0.05$ (Duncan's test).

Even if all cultivars have a safe concentration of α-solanine and α-chaconine,the gap between storage and the processing could imply passage of time and the amount of these compounds could increase. In conclusion, the potato cultivars studied could be divided into three groups, each suitable for different technological processes (Quaderni di Filiera, 2003).

4.1. 1st Group: agata and arinda

These two cultivars are suitable for high temperature food processes, such as chips, snacks, french fries and fried food, because they have very low asparagine concentrations; thereby reducing the possibility of acrylamide formation and also have a good amount of ascorbic acid, that will protect the food from oxidation during the high temperature processes. The low concentrations of α-solanine and α-chaconine allow cooking of these cultivars with the peel.

4.2. 2nd Group: sponta and marabel

These cultivars have a good quality of starch and organic acids, but a low water content. However, they have high values of asparagine; for these reasons, it is better to employ them in low temperature processes such as minimally processed foods and stir-fry foods, but they have to be peeled, because they have high concentrations of α-solanine and α-chaconine that could increase during the storage period.

4.3. 3rd Group: primura, merit, jelli, finka, agria

These cultivars should not be used in high temperature processes and should be cooked without the peel. We suggest their use for domestic purposes and home cooking.

Acknowledgements

The authors thank Prof. Elliot M. Berry (Director, Department of Human Nutrition and Metabolism, Faculty of Medicine, Hebrew University-Hadassah Jerusalem, Israel) for his kind revision.

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