Research Article

Przemysław Łukasz Kowalczewski*, Joanna Zembrzuska, Agnieszka Drożdżyńska, Krzysztof Smarzyński, Dominika Radzikowska, Marek Kieliszek, Paweł Jeżowski, Zuzanna Sawinska

Influence of potato variety on polyphenol profile composition and glycoalkaloid contents of potato juice

https://doi.org/10.1515/chem-2021-0109
received October 25, 2021; accepted November 25, 2021

Abstract: The results of studies published in recent years indicate the broad biological activity of potato juice (PJ), which is a byproduct of the starch production process. Among the most frequently described activities are anti-inflammatory, antioxidant, and cytotoxic effects. Nevertheless, this waste juice is produced by the processing of many varieties of potatoes with different proportions, which does not allow to conclude on the biological activity of individual varieties. This article is a report on the antioxidant activity of PJ from seven selected potato varieties, their profile of polyphenolic compounds, and the content of glycoalkaloids (GAs). The use of similar cultivation conditions allowed to eliminate the influence of environmental factors on the content of the analyzed compounds. The influence of PJ on the growth of probiotic, commensal, and pathogenic bacteria was also assessed. It was shown that the varieties significantly influenced the differences in antioxidant activity as well as the content of GAs, but despite the observed differences, none of them showed antimicrobial activity. Therefore, it can be concluded that an appropriately selected variety will make it possible to obtain PJ that will be characterized by high antioxidant activity and, at the same time, will be safe from the toxicological point of view.

Keywords: potato juice, antioxidant activity, chaconine, glycoalkaloids, phenolic compounds, solanine, Solanum tuberosum L.

1 Introduction

Among the factors reducing the risk of several types of cancer and cardiovascular diseases, a proper diet rich in plants, being a source of biologically active compounds, is indicated [1]. Plant phenols are a complex group of various secondary metabolite compounds, produced mainly via the shikimic acid pathway from L-phenylalanine and L-tyrosine, they have protective functions in the plant, for example, against UV radiation, competitive warfare against viruses, bacteria, insects, and other plants [2,3]. Their synthesis takes place more intensively in plants subjected to stress factors,
including abiotic and biotic stress [4–6]. In recent years, the
interest of researchers from around the world has been
focused on the influence of free radicals on the human
body, in particular reactive oxygen species. It is believed
that oxidative stress can cause many chronic diseases.
Free radicals can react with proteins, fats, and DNA. The
consequence of these reactions is permanent DNA damage
that can contribute to cardiovascular diseases, in particular
atherosclerosis, age-related macular degeneration, cata-
racts, Parkinson’s and Alzheimer’s diseases, as well as
cancer [7,8]. Numerous literature data [3,9,10] indicate
that there are powerful natural antioxidants that play a
key role in a wide range of biological and pharmacolo-
gical properties, such as anti-inflammatory, anticancer,
antimicrobial, antiallergic, antiviral, anticoagulant, and
hepatoprotective activities.

Potatoes (Solanum tuberosum L.) are one of the most
important cultivated plants intended for food and feed
purposes. Easy cultivation and reasonable climate require-
ments make it grown all over the world [11]. The plant in its
root system produces tubers rich in starch, which is why
often high-starch varieties are used in the starch process,
which results in pure potato starch [12]. The first mentions
of potato cultivation date to 8,000 years ago, and today
more than 5,000 varieties of this plant are cultivated [13].
The dry mass of potato tubers reaches 20–25%, and their
chemical composition, determining the nutritional value,
depends not only on the variety but also on the cultivation
and harvesting conditions [14]. Literature sources indicate
a significant impact of storage conditions on the content of
dry matter of potato tubers, content of reducing sugars, or
amino acid composition [15–17]. Among the nutrients
forming the dry mass of potato tubers, starch, protein,
vitamins, minerals, and fiber should be distinguished.

Potato tubers contain, among other vitamins C, PP, B1,
B2, and B6, iodine, calcium, chlorine, and sulfur. Con-
sumption of one medium-sized potato on skin (approxi-
mately 150 g) provides the recommended daily dose of
vitamin C for an adult (100 mg) [18]. It is worth adding
that potatoes are vegetables with a high iron content
[19,20]. Potatoes are a low-fat raw material (about 0.5%
of fresh weight), containing mainly linoleic (omega-6) and
linolenic (omega-3) acids [21].

Potato juice (PJ) is formed in the production of potato
starch as one of the byproducts. Currently, acidic thermal
coaulation is the most commonly used process of PJ
management. Unfortunately, the protein preparation obtained
in this way is insoluble and enzymatically inactive [22]. Low
emulsifying, foaming, and water-binding abilities significantly
limit the potential use of potato protein in food production
[23]. In starch production factories, acid thermal coagulation
of the PJ protein is commonly used, and the protein mass is
then separated, dried, and used as a feed ingredient [24].
Therefore, new methods of PJ management are sought, and
the directions for the use of PJ described in the literature
include microbiological mediums [25–27] and prohealth food
[28–30]. PJ is gaining increasing interest as a source of nutri-
tional and bioactive compounds. On the one hand, the pro-
teins present in PJ are characterized by high nutritional value
and interesting technological properties [20,31–33]; on the
other hand, nonprotein compounds with anti-inflammatory,
cytotoxic, and antioxidant activities are also present [18,34].
Among the compounds responsible for the antiproliferative
properties of PJ against human skin [35], liver [36], prostate,
and breast [37] cancer cells, glycoalkaloids (GAs) are indicated,
mainly a-solanine and a-chaconine. Isolating the biologically
active ingredients of PJ may allow them to be used in phar-
acy and medicine.

PJ is a seasonal product obtained between August
and December, during the starch production season. Many
different varieties of potatoes are used for process-
ing, so the described biological activity of the juice
obtained may differ depending on the varieties being pro-
cessed at the time. Therefore, this article is a report
on antioxidant activity, polyphenols profile composition,
and GA content in PJ from selected seven potato varieties,
commonly cultivated in Poland.

2 Materials and methods

2.1 Test material

The study used seven potato varieties, grown at the
Experimental Station Gorzyń (52°57′N; 15°89′E), belonging
to the Poznań University of Life Sciences (Poland). The
juice was obtained from seven varieties and denoted as
follows: VR 808 – denoted as PJ1, Saturna – denoted as
PJ2, Toscana – denoted as PJ3, Ditta – denoted as PJ4,
Lord – denoted as PJ5, Denar – denoted as PJ6, and Lady
Claire – denoted as PJ7.

The potatoes were thoroughly washed and peeled,
and then the juice was squeezed out. The obtained juice
was left for an hour in a refrigerator (4°C) for starch sedi-
mentation, and then the juice was decanted, frozen, and
lyophilized. Three times 0.5 L of juice was obtained from
each variety of potatoes, which was then freeze-dried and
unified. The freeze-drying process was performed using Alpha
2–4 LD plus lyophilizer (Martin Christ Gefriertrocknungsanlagen
GmbH, Osterode am Harz, Germany). The process was initiated
with a freezing stage at −35°C for 20 h, followed by the main drying step at a shelf in 5°C for 12 h, and the final drying up at 20°C for 2 h. The obtained dried material was packed in laboratory glass and stored frozen until use.

2.2 Antioxidant activity and polyphenol profile composition

2.2.1 Extraction process of antioxidants

The extraction process was carried out using an 80% solution of methanol using a double extraction from lyophilized samples. The lyophilizate (1 g) was mixed with 20 mL of methanol solution, and then shaken for 15 min using a laboratory shaker S50 (CAT Germany GmbH, Lehrte, Germany). Subsequently, the samples were centrifuged at 6,000×g for 10 min. The supernatant was decanted, and another 10 mL of methanol solution was added to the tube. It was shaken again and centrifuged under the conditions described above. The supernatant was decanted again and mixed with previously collected, then filtered through a 0.22µm filter, and stored in the freezer at −80°C in a glass flask.

2.2.2 Total polyphenol content and antioxidant activity

The total antioxidant activity was assessed against the 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) radical using methods described by Re et al. [38]. Results were presented as Trolox equivalent antioxidant capacity per 1 g of dry matter of the examined sample. The total content of phenolic compounds was determined by the standard Folin-Ciocalteu colorimetric method [39] using a spectrophotometer (Multiskan GO, Thermo Fisher Scientific, Vantaa, Finland) and expressed as chlorogenic acid equivalent per 1 g of dry matter.

2.2.3 Polyphenols profile composition determined by high-performance liquid chromatography (HPLC)

Chromatographic analyses of phenolic compound content were carried out on an Agilent 1260 Infinity II (Agilent Technologies, Inc., Santa Clara, CA, USA) liquid chromatograph equipped with an automatic sample feeder (G7129A), a pump (G7111A), and a diode detector (G7115A) with an overview of the spectrum (190–400 nm). Vanillin and p-hydroxybenzoic acid determinations were made at a wavelength of 280 nm; p-coumaric, sinapic, and ferulic acids at 320 nm; rutin at 360 nm, niacin at 260 nm, and chlorogenic acid at 255 nm. Phenolic compounds were separated by high-performance liquid chromatography on a SB-C18 column (50 mm × 4.6 mm with 1.8 µm particle diameter, Agilent Technologies) at 25°C. The following were used as eluent: A: water:acetic acid (98:2) and B: methanol:acetic acid (98:2) at the flow of 0.75 mL/min in the gradient: 0 min 2% B, 22 min 40% B, 26 min 40% B, 28 min 100% B, 35 min 100% B, and 36 min 2% B. The samples were loaded onto the column in an amount of 10 mL. Quantitative calculations were made using the peak areas (measurement and computer integration using the OpenLab CDS (Agilent Technologies, Inc., Santa Clara, CA, USA) program).

2.3 Glycoalkaloid content

2.3.1 Sample preparation and GA extraction

Extraction and purification of PJ GAs were carried out using methods described by Nielsen et al. [40] with small modification. Briefly, 30 mg of freeze-dried PJ was added to 6 mL 5% acetic acid (Merck Life Science Sp. z o.o., Poznań, Poland), shaken for 15 min and centrifuged (14,000×g, 15 min, 4°C). After that, GAs were extracted from supernatant by solid-phase extraction (SPE) cartridges (HLB Oasis 1cc 30 mg, Waters Corporation, Milford, MA, USA) in vacuum manifold. SPE cartridges were preconditioned according to the manufacturer’s recommendation. The supernatant (2 mL) was added to the column, and then the column was washed with 2 mL of methanol solution (10% v/v). GAs were eluted with 2 mL of methanol with formic acid (0.1% v/v), and then, the elute was filtered (0.22µm) before UHPLC–MS/MS analysis.

2.3.2 UHPLC–MS/MS analysis

The quantitative and qualitative determination of α-solamine and α-chocaine in PJ extracts were performed using the chromatographic system UltiMate 3000 RSLC (Dionex, Thermo Fisher Scientific Inc., Bartlesville, OK, USA) coupled to an API 4000 QTRAP triple quadrupole mass spectrometer with electrospray ionization (from AB Sciex, Foster City, CA, USA) in positive ionization mode ultra-high performance liquid chromatography tandem mass spectrometry (UHPLC–MS/MS). Chromatographic separation was done on a Kinetex 1.7 µm C18 (100 mm × 2.1 mm ID.) column...
from Phenomenex (Torrance, CA, USA). A total of 0.1% formic acid (A) and acetonitrile (B) were used as the mobile phase. Elution was performed using a gradient: 25% B at 0 min, 32% at 3 min, increased to 100% B in 3 min and held for 0.5 min. The flow rate was 0.20 mL/min. The column temperature was maintained at 35°C, and the injection volume was 10.0 μL. A postrun time was set at 4.0 min for column equilibration before the next injection. The operating conditions for mass spectrometry for α-solanine and α-chocaine were as follows: curtain gas 10 psi, nebulizer gas and auxiliary gas 40 psi, source temperature 600°C, ion spray voltage 5,500 V, and collision gas set to medium. Quantitative analysis of the compounds was performed in multiple reaction monitoring (MRM) mode. For analytes was chosen one transitions of the protonated molecular ion and their respective ion product. The first MRM transition was used to quantify, and the second was used to confirm. These transitions (m/z) with associated declustering potentials (V) and collision energies (V) were as follows: α-solanine 869 → 98, 181, 115; 869 → 398, 181, 95 and α-chocaine 852.6 → 98, 201, 119; 852.6 → 706, 201, 97. All compounds were quantified in the potato extracts using the standard addition method.

2.4 Microbiological tests

Antimicrobial activity was determined by the disc diffusion method. In antimicrobial assays, the following strains types were used: Listeria, Salmonella, Yersinia, Clostridium, Escherichia, Enterococcus, Lactobacillus, Bacteroides, and yeast Candida. Specifics about species as well as conditions for the growth of microorganisms are presented in Table S1. The microorganisms were obtained from American Type Culture Collection (Rockville, USA). Antimicrobial activity was determined by point-diffusion method. Agar media suitable for the growth of the investigated microorganisms were inoculated in the logarithmic growth phase in such an amount as to obtain a cell concentration of approximately \(10^6\) CFU/mL. Then, 20 μL of dried PJ at a concentration of 100 mg/mL was applied to solidified agar media. After 24 h incubation, the degree of inhibition of the growth of indicator microorganisms was assessed.

2.5 Statistical analysis

Statistical analysis of the data was performed with Statistica 13 (Dell Software Inc., USA) software. All measurements were studied using one-way analysis of variance independently for each dependent variable. Post hoc Tukey honest significant difference multiple comparison tests were used to identify statistically homogeneous subsets at \(\alpha = 0.05\).

### 3 Results and discussion

#### 3.1 Antioxidant activity and polyphenol profile

The mentioned previously published data indicate that there are also antioxidants in PJ, mainly phenolic compounds, which exhibit antioxidant properties. To compare the properties of the juice obtained from a particular variety, potatoes were grown under similar conditions to eliminate the differences resulting from stress factors. The content of phenolic compounds in the analyzed juices differed between the cultivars (Figure 1). Their lowest content was recorded for PJ7 (8.09 ± 0.19 mg/g), and the highest content was recorded for PJ6 (12.85 ± 0.20 mg/g). This is much higher than the average content in potato tubers of 0.74 mg/g fresh weight [18]. Nevertheless, the polyphenol content is in each form lower than that of the waste PJ obtained in the starch production process [41]. However, the high content of phenols is not associated with high antioxidant activity. The highest

![Figure 1: Antioxidant activities and total phenolic contents of analyzed PJ samples (PJs). PJ1: VR 808, PJ2: Saturna, PJ3: Toscana, PJ4: Ditta, PJ5: Lord, PJ6: Denar, and PJ7: Lady Claire. Mean values with different letters are significantly different at \(\alpha = 0.05\).](image-url)
total antioxidant activity was recorded for PJ5 (3.04 ± 0.11 mM/g) and the lowest for PJ2, PJ1, and PJ7 (1.45 ± 0.27, 1.50 ± 0.03, and 1.63 ± 0.76 mM/g, respectively). It can, therefore, be assumed that PJ contains phenolic compounds in bound form that are linked to cell wall polysaccharides by ester bonds. They are not detected by a simple colorimetric method, but when released in the digestive tract, they can have a beneficial effect on our body. Also, simple heat treatment can release the bound phenols [42–44] and thus increase their bioavailability.

Among the free phenolic acids and polyphenols present in potatoes, the most frequently described are catechin, chlorogenic, caffeic, ferulic, gallic acids, and malvidin [45–47]. However, the analyzed juices showed the presence of chlorogenic, sinapic, coumaric, hydroxybenzoic acids, niacin, rutin, and vanillin. Importantly, PJs from different potato cultivars were characterized by a different profile of the analyzed compounds. PJ4 was the only one that contained chlorogenic acid, which has many health-promoting properties, most of them related to the treatment of metabolic syndrome, including antioxidant, anti-inflammatory, antilipidemic, antidiabetic, and anti-hypertensive effects [48], and PJ4 was the only one that did not contain hydroxybenzoic acid. PJ4 also contained the greatest amount of rutin (3,30,40,5,7-pentahydroxyflavone-3-rhamnoglucoside), which demonstrated a number of pharmacological activities, including antioxidant, cytoprotective, vasoprotective, anticarcinogenic, neuroprotective, and cardioprotective activities [49]. Detailed data on the content of individual phenols are presented in Table 1.

### 3.2 Glycoalkaloid contents

Despite the high nutritional value of potatoes, concern is raised by the presence of GAs, compounds that are widely recognized as toxic [50]. They are formed by combining alkaloids with one or more sugar molecules. GAs are present throughout the plant, but the greatest risk comes from their presence in the edible part, that is, tubers, from which they then pass into the PJ in the starch production process. Almost 95% of the GAs of potatoes are α-solanine and α-chaconine [51]. Due to slight differences in structure, and thus similar physicochemical properties, publications often include the total content of GAs, without distinguishing individual compounds that make up this group of compounds [52]. The use of mass spectrometry allowed to determine the content of both main GAs in the analyzed juices, and the results are presented in Figure 2. It was shown that the juices from PJ4 and PJ3

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**Table 1: Phenolic compounds determined by HPLC**

| Sample  | Chlorogenic acid (μg/g) | Rutin (μg/g) | Niacin (μg/g) | Vanillin (μg/g) |
|---------|------------------------|-------------|--------------|-----------------|
| PJ1     | N/D                    | 1.16 ± 0.01  | 0.95 ± 0.02  | N/D             |
| PJ2     | N/D                    | 1.12 ± 0.01  | 0.90 ± 0.02  | N/D             |
| PJ3     | N/D                    | 1.13 ± 0.02  | 0.98 ± 0.03  | N/D             |
| PJ4     | N/D                    | 1.11 ± 0.01  | 0.93 ± 0.02  | 123.45 ± 0.12   |
| PJ5     | 22.96 ± 0.13           | 1.12 ± 0.02  | 0.97 ± 0.02  | N/D             |
| PJ6     | 18.97 ± 0.12           | 1.11 ± 0.02  | 0.95 ± 0.02  | N/D             |
| PJ7     | N/D                    | 1.12 ± 0.02  | 0.93 ± 0.02  | N/D             |

Mean values with different letters in the superscript are significantly different at α = 0.05.
varieties had the lowest GA content, and the highest levels were observed for PJ1 and PJ6. GAs are essential for the proper growth of the plant. Like phenols, they are secondary metabolites that protect plants against pests and pathogens [53]. However, no relationship was found between the GA and phenol contents. Due to the high toxicity of GAs, an acceptable limit of their content in potatoes has been established, which is 200 mg/kg of fresh potato tubers [54]. It is, therefore, important to monitor the GA content and use varieties with the lowest possible content. For this reason, the PJ4 and PJ3 varieties can be recommended for the production of PJ, on the one hand, due to the low content of GAs and, on the other hand, due to the high content of biologically active phenolic compounds.

### 3.3 Microbiological tests

Substances present in plants, as well as plant extracts, often exhibit antimicrobial properties. The antimicrobial properties of essential oils are the most widely described [23,55–57]. Also, so far few sources indicate the antimicrobial activity of substances present in potato tubers. Among them, proteins and protease inhibitors are most often described [58,59] but also polyphenolic compounds and GAs [53,60–62]. Strains of microorganisms selected for research represent many groups of microorganisms that are important from the point of view of human physiology, both positively influencing our body, but also pathogenic. However, despite the different contents of both phenols and GAs, no antimicrobial activity was found for any of the analyzed juices (data not shown). Therefore, it can be concluded that although PJ will not protect us against the development of pathogenic microflora, its consumption will not interfere with the growth of commensal microflora.

### 4 Conclusion

PJ is of increasing interest as a raw material with a high biological activity. Literature data describe the broad activity of PJ as antioxidant, anti-inflammatory, or even cytotoxic. In this study, the juices obtained from seven potato varieties, grown under the same conditions, were analyzed. It has been shown that both the content and the profile of polyphenolic compounds depend on the variety from which the juice was obtained. The highest content of polyphenols was found in the juice obtained from the Denar, Ditta, and Toscana varieties, and the lowest content was found in the juice obtained from the Lady Claire variety. However, the use of PJ raises toxicological concerns due to the presence of GAs in potatoes. Also in this case, a significant influence of the potato variety on the GA content in the juice was observed. The lowest levels of solanine and chaconine were recorded in juices from Toscana and Ditta. None of the analyzed juices inhibited the growth of the analyzed microorganisms. It can therefore be assumed that the Ditta and Toscana varieties, due to the high content of polyphenols and the low content of GAs, can be recommended for the industrial production of PJ, which is further used in the production of functional food or dietary supplements.

**Acknowledgements:** The authors thank Professor Grażyna Lewandowicz (Poznań University of Life Sciences, Poznań, Poland) for inspiration, consultation, and valuable advice.

**Funding information:** The National Centre for Research and Development of Poland (NCBR) is acknowledged for funding provided within the program LIDER under grant agreement No. LIDER/27/0105/L-11/19/NCBR/2020 (PI: Przemysław Kowalczyński).

**Author contributions:** Conceptualization, P.L.K.; funding acquisition, P.L.K.; formal analysis, P.L.K. and P.J.; investigation, P.L.K., J.Z., A.D., K.S., M.K., and P.J.; methodology, P.L.K., J.Z., and A.D.; project administration,
Conflict of interest: The authors declare no conflict of interest.

Ethical approval: The conducted research is not related to either human or animal use.

Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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