AGRICULTURAL BIOLOGY,
2024, V. 59, Iss. 1, pp. 22-38
[SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA]

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

*UDC 633.491:581.6:613.2:577.1*

doi: 10.15389/agrobiology.2024.1.22eng
doi: 10.15389/agrobiology.2024.1.22rus

# POTATO JUICE vs. TRADITIONAL POTATO USE — A NEW INSIGHT
(review)

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The authors declare no conflict of interests
Acknowledgement
The review was prepared within the fram s: ework of state assignments "Creation of competitive, high-yielding varieties of grains, legumes, fodder, fruit and berry crops and potatoes of the world level based on promising genetic resources that are resistant to bio- and abiotic factors" (0532-2021-0008) and "Development of biological technologies for managing animal health and intravital formation of the quality of livestock and poultry products" (0532-2021-0009).
*Final revision received October 02, 2023*
*Accepted November 27, 2023*

Abstract

Traditionally, potatoes are consumed in a heat-treated form, e.g., boiled, fried, baked, with a significant part of its beneficial properties lost (A.D. Fabbri et al., 2015; J. Tian et al., 2016). Such processing greatly changes the mineral and vitamin composition of the product, the content of dietary fibre and the activity of secondary metabolites (J. Tian et al., 2016; A.T. Popova, 2019). Freshly squeezed potato juice can be a healthy alternative to heat-treated potatoes. Its use in folk medicine has been known since the early XIX century (J.E. Vlachojannis et al., 2010), while only a few scientific studies describe the physiological effects of potato juice consumption on experimental animals and on humans. One of the unique components of potato juice is resistant starch (L. Copeland et al., 2009). Resistant starch is not digested in the human body (P.J. Butterworth et al., 2011), positively affects the intestinal microbiota (I. Martínez et al., 2010), and normalizes insulin and glucagon-like peptide-1 in blood serum (A.A. Rashed et al., 2022). Of all plant proteins known to date, potato protein is the most balanced in essential amino acids and bioavailable to humans (M. Hussain et al., 2021). Its protease inhibitors are able to regulate digestion and have therapeutic effects in obesity (S. Komarnytsky et al., 2011; S. Nakajima et al, 2011), patatin has hypolipidemic (J. Wu et al., 2021), hypotensive (Y. Fu et al., 2019), antioxidant and antiproliferative properties (Y. Sun et al., 2013). Raw potatoes and their juice contain high concentrations of ascorbic acid (K.A. Beals et al., 2019), B vitamins, potassium, phosphorus, calcium, magnesium, iron and zinc (K. Zaheer et al., 2016; G.I. Piskun, 2023) which are essential for good health. Potato varieties with purple-, red- and yellow-coloured tubers are the richest source of polyphenols, primarily phenolic acids and anthocyanins (E.P. Shanina, 2013; H. Akyol et al., 2016; I.V. Kim et al., 2020). The potato glycoalkaloids solanine and chaconine remain the most controversial in terms of possible health benefits. On the one hand, their average content in potato tubers is low to cause symptoms of poisoning in humans (K. Nishie et al, 1971). On the other hand, experiments with pure extracts of glycoalkaloids proved their anticholinergic, anticholinesterase (V.A. Voronov et al., 2023) and cytotoxic effects o (M. Friedman, 2015; D.K. Zhao et al., 2021; M.L. Lanteri et al., 2023). In the review, we discuss the likely danger of the identified effects for human health vs. the prospects for the immunodeficiency correction, as well as prevention and treatment of cancer diseases (D.K. Zhao et al., 2021; M.L. Lanteri et al., 2023). We also focus on current methods of biodegradation of potato glycoalkaloids (R.C. Hennessy et al., 2020). Selected studies on the biological effects of potato peel extract (N. Singh et al., 2008) and potato juice (R. Muceniece et al., 2008; V. Bartova et al., 2018) are described. The above information shows that potato juice contains all the useful substances of intact raw potatoes. The prospects for using potato juice in functional nutrition are obvious, but it remains to determine the optimal technological methods for its mass production while preserving the biological activity of the components.

Keywords: potatoes, potato juice, starch, protease inhibitors, patatin, polyphenols, flavonoids, phenolic acids, vitamin C, solanine

In dietetics, there has long been controversy about the benefits and harms of potatoes (*Solanum tuberosum* L.) as a food product. In 2018, the World Health Organization (WHO) published healthy eating guidelines that adults should consume daily 400 g of fruits and vegetables, excluding potatoes [1]. As the main arguments that do not allow considering potatoes as a healthy food product, experts cite the following facts: low fiber content [2], high starch content which during long-term storage of potatoes is hydrolyzed to simple carbohydrates (mainly D-glucose, although as a result of cold saccharification, D-fructose also accumulates in tubers) [3, 4], a high glycemic index [5], and the possible presence of the glycoalkaloid solanine which is toxic to humans [6, 7]. Potatoes are not recommended for people suffering from cardiovascular diseases [8], diabetes [9], and obesity [10]. However, to date, the beneficial properties of potatoes have also been cited. These are its unique mineral composition (primarily high potassium content and low sodium content) [11] and protein composition (balanced combination of amino acids, including the essential amino acids arginine, phenylalanine, valine, lysine, unique protease inhibitor proteins and patatin) [12], as well as secondary metabolites (vitamin C, polyphenols, phenolic acids, glycoalkaloids, etc.) [13] which may have a potential therapeutic and preventive effect in a number of socially significant diseases [14].

The first medical records of the use of raw potatoes belong to the Swiss physician M. Bircher-Benner (1867-1939) who discovered the antacid and antispasmodic effects of potato juice in gastrointestinal diseases [15]. Later in the studies of J.E. Vlachojannis et al. [16[ potato juice has been shown to relieve symptoms of dyspeptic disorders. Given the complex multicomponent composition of potatoes, the key factor determining its physiological effects may be the method of consumption of the product and the presence or absence of heat treatment [17]. Traditionally, potatoes are consumed boiled, stewed, fried, baked, steamed, or microwaved [18].

In a review by J. Tian et al. [19] it was noted that during heat treatment, mineral composition of potatoes changes (during the cooking process, up to 50% of potassium is lost as a result of leaching). Water-soluble vitamins (ascorbic and nicotinic acids, thiamine) are lost both as a result of leaching and atmospheric oxidation. Protein denaturation occurs; the content of dietary fiber increases slightly due to the formation of bonds between polysaccharides and proteins. To one degree or another depending on the method of preparing potatoes and the time of thermal exposure, the content and activity of secondary metabolites — polyphenols (including anthocyanins), carotenoids and glycoalkaloids are reduced.

Freshly squeezed potato juice can be a healthy alternative to cooked potatoes. Most of its beneficial properties are preserved with this form of use [18, 19]. The use of potato juice in folk medicine has been known since the beginning of the 19th century [16]. However, only a few scientific studies describe the physiological effects of consuming raw potatoes and its components on the body of experimental animals and humans.

The purpose of this review is to systematize knowledge about the biologically active components of raw potatoes and substantiate the use of potato juice in functional human nutrition.

The search for sources was carried out in PubMed, Google Scholar and eLibrary services for the period from 2013 to 2023. Out of 300 articles found for the key queries "potato juice" and "potato juice," we selected 80 sources devoted to the study of the composition of potato juice and its biological activity in in vitro and in vivo experiments. We did not include publications concerning technologies for obtaining, purifying and concentrating potato juice in the process of starch production, as well as the study of sweet potato juice (sweet potato, *Ipomoea batatas* L.).

Composition and calorie content of raw potatoes. The nutritional value of raw potatoes is determined by the balanced ratio of the most important nutrients. 100 g of tubers contain less than 1 g of fat, 18 g of carbohydrates and 3 g of protein. The calorie content of raw potatoes is about 75 kcal [20]. During thermal cooking of potatoes, ~ 6% of fats, 9% of carbohydrates and 5% of proteins are lost [21].

The main carbohydrate of potatoes, starch [2-4, 7], consists of two fractions, the amylopectin (branched-chain glucose polymer) and amylose (straight-chain glucose polymer) in a constant ratio of 3:1 [22]. Raw starch is practically not digestible by humans [23], but in freshly boiled potatoes more than 95% of all starch is converted into an easily digestible form [24]. The remaining part is so-called resistant starch, it is intensively fermented by the microbiota of the large intestine to produce short-chain fatty acids which lower the pH of the intestinal contents, reduce the toxic effect of ammonia, and act as a prebiotic [20, 25]. Using pyrosequencing technologies, I. MartHnez et al. [26] showed that resistant starch increases the population of *Actinobacteria* sp. and *Bacteroidetes* sp in the intestine whyle *Firmicutes* sp. decreases.

The review by A.A. Rashed et al. [27] describes the positive effect of resistant starch on the patients with type 2 diabetes mellitus, i.e., an increase in the blood levels of insulin and glucagon-like peptide-1 and a 2-fold decrease in postprandial glycemia (the amount of glucose in the venous blood after a meal). The observed effects suggest an antidiabetic effect of resistant starch, although the detailed molecular mechanisms of this action remain to be studied.

Proteins. Plant proteins serve as a source of essential amino acids [28]. Increasing your intake of high-quality plant protein instead of animal protein has been shown to reduce the risk of type 2 diabetes [29]. Because plant proteins are very cheap [30], their consumption by the population has increased over time [31].

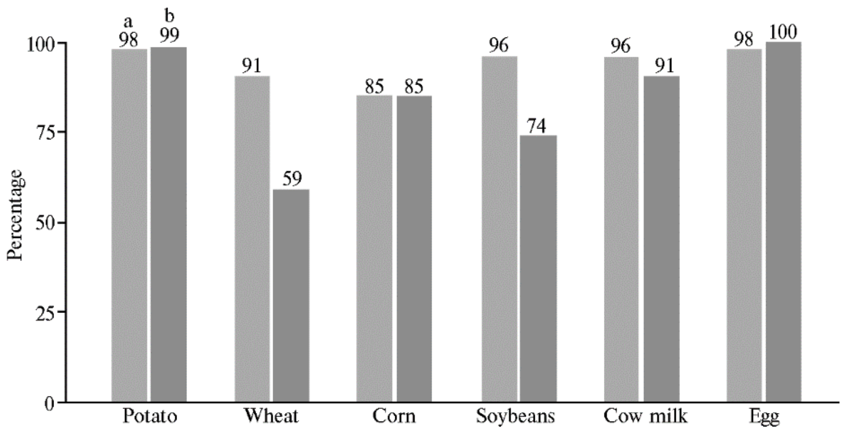


**Fig. 1. Digestibility** (a) **and biological value** (b) **of proteins from various sources.** To construct the diagram, we used the experimental data of M. Hussain et al. [34].

The protein content of potatoes is higher than that of most tubers of other plants [20]. When talking about protein quality, the concept of “biological value” (BV) is often used, taking into account its amino acid composition and bioavailability [32]. Egg albumen is considered the reference protein with biological value taken as 100% [33]. Potatoe BV is relatively high, above 90%. compared to other key plant protein sources (Fig. 1) [34].

Potato protein consists of 19 amino acids, including lysine, methionine, threonine, and tryptophan (Fig. 2) [20, 34-36]. The amino acid composition can vary significantly between varieties. An analysis of 22 varieties and hybrids showed that the content of some amino acids (arginine, tyrosine and phenylalanine) depends on the genotype, and the total protein content in potatoes is directly related to the agroclimatic conditions of cultivation [35]. It was found that in the Leader potato variety grown in the Urals, the protein is $^{1}/_{3}$ essential amino acids arginine (0.644%), phenylalanine (0.430%), valine (0.369%), and lysine (0.340%). The remaining $^{2}/_{3}$ are nonessential amino acids of which aspartic (1.77%) and glutamic (1.44%) are mainly found [35-36].

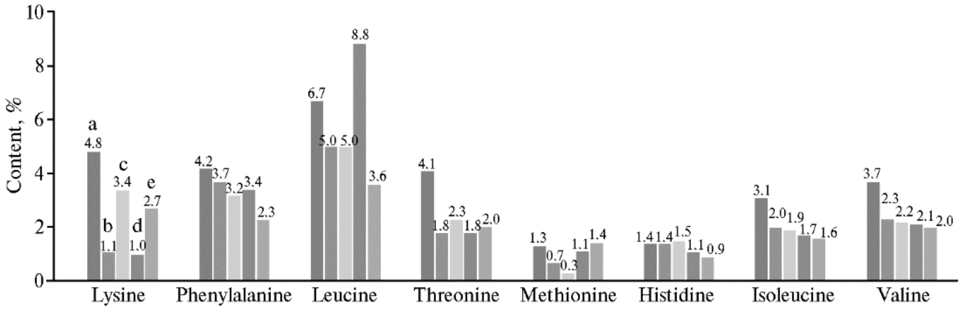


**Fig. 2. Content of essential amino acids** (% of total protein) **in potatoes** (a)**, wheat** (b)**, soybeans** (c)**, corn** (d) **and eggs** (e)**.** We compiled the diagram based on the experimental data of M. Hussain et al. [34].

Potatoes contain protease inhibitors (50% of total proteins), patatin (40%) and other proteins (10%), but their percentage varies greatly depending on the variety and growing conditions [34].

Protease inhibitors are water-soluble 4-25 kDa proteins [37]. There are 7 classes of potato protease inhibitors, the inhibitor I, inhibitor II, serine protease inhibitor, cysteine protease inhibitor, aspartic protease inhibitor, Kunitz type protease inhibitor, carboxypeptidase inhibitor and inhibitors of other serine proteases [38]. All of them actively bind to trypsin, despite the acidic environment of the stomach, presumably due to the large number of β-sheets in the secondary structure of the protein. Trypsin inhibition prevents the proteolytic inactivation of endogenous trypsin-sensitive cholecystokinin-releasing peptides, promoting the release of cholecystokinin [39, 40]. Studying the kinetics of interaction between protease inhibitors and trypsin, Q. Li et al. [41] found a nonspecific type of inhibition. In this type, the inhibitor binds to the ester group outside the active site and does not affect the enzyme-substrate interaction.

Cholecystokinin plays a central role in the regulation of nutritional homeostasis. It is secreted by neuroendocrine cells located in the mucosa of the small intestine [42]. The earliest physiological effect of this hormone is to stimulate contraction of the gallbladder and secretion of the exocrine pancreas. Bile is necessary for the formation of micelles during the digestion of fats, and pancreatic enzymes are involved in the digestion of fats and proteins. In addition, L.J. Miller et al. [43] found cholecystokinin receptors in afferent neurons of the intestinal vagus nerve (cholecystokinin receptor type 1) and on gastric parietal cells (cholecystokinin receptor type 2). Thus, cholecystokinin increases intestinal motility and mediates the secretion of gastric juice. The described mechanisms allow us to consider potato juice protease inhibitors as cholecystokinin agonists and an effective therapeutic agent against obesity (Fig. 3).

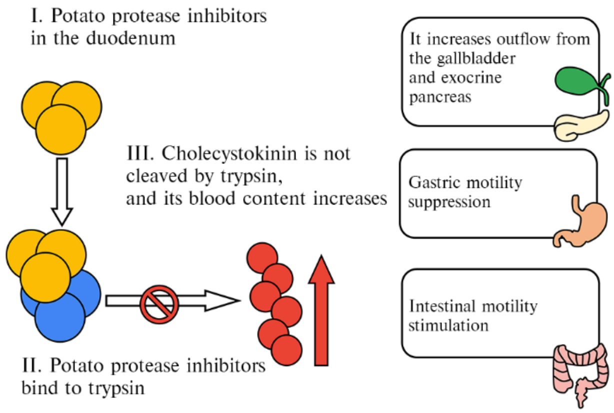


**Рис. 3. The effect of a potato protease inhibitor on the gastrointestinal tract functioning.** We compiled the diagram based on the experimental data from L.J. Miller et al. [43].

Another in vivo study [44] showed that peptides derived from potato protease inhibitors by enzymatic hydrolysis could reduce blood cholesterol and triglycerides through sterol-binding capacity. In the blood serum of rats that consumed this hydrolysate, the amount of total cholesterol, low-density lipoprotein cholesterol and triglycerides decreased compared to animals from the control group [44]. In earlier studies of the biological activity of potato protein hydrolysates, analysis of rat liver mRNA showed increased synthesis of proteins responsible for lipoprotein clearance [45].

Patatin is a glycoprotein with a molecular mass of 40-45 kDa [46]. Purified patatin contains 6 essential amino acids — lysine, phenylalanine, threonine, isoleucine, leucine and valine. The essential amino acid index (EAAI) is 76%. Patatin monosaccharides contains mannose, rhamnose, glucose, galactose, xylose, arabinose, and fucose [47]. The ratio of proteins and carbohydrates in patatin is 64 and 36%, respectively [48]. The biological effects of patatin are interesting. In studies on *Danio rerio* fish, patatin exhibited nonspecific acyl hydrolase activity on triglycerides, activating lipolysis. Moreover, patatin is able to inhibit pancreatic lipase and regulate lipid absorption in the small intestine [47]. The findings suggest that patatin has great potential for use as a functional product in weight loss programs.

In addition, patatin has been assessed in silico [49] as a precursor of angiotensin-converting enzyme (ACE) and renin inhibitory peptides. Such peptides have the ability to bind to ACE and renin, causing their conformational changes through a mixed mechanism [49, 50]. Effective inhibition of two key enzymes of the renin-angiotensin-aldosterone system is one of the promising approaches to the treatment of arterial hypertension [51].

Other biological effects of patatin have also been described. For example, antioxidant and antiproliferative activity against $B_{16}$ mouse melanoma cells, in which pathanin initiated cell cycle arrest in the $G_1$ phase, and against Caco-2 and HT-29 intestinal cancer cells [48, 49, 52].

Potato juice can be used in the diet of people prone to allergies. Compared to gluten, a wheat protein to which children and adults are often allergic, the protein found in potato juice has lower IgE-binding capacity, even at high concentrations. Patatin is the only fraction of potato protein that can provoke an allergy, but its intensity will be significantly lower than for wheat, cow's milk or egg proteins [34]. In 2018, Nestle (Switzerland) patented a formula of milk substitute based on potato proteins for children with an allergy to cow's milk protein [53].

During the thermal processing of food products, a sugar-amine condensation reaction (Maillard reaction) occurs. In 1912, French chemist L.C. Maillard (1878-1936) accidentally discovered that a solution containing sugars and amino acids darkened and acquired a characteristic odor when intensely heated [54]. The brown pigments produced in the Maillard reaction are called melanoidins. They are formed as a result of the interaction of ketone groups of sugars and amino groups of amino acids [55]. Since potatoes are a high-carbohydrate product that contains proteins, prolonged heat treatment produces an extremely undesirable Maillard reaction product, toxic acrylamide [56]. It has been proven that acrylamide has a pronounced cyto- and genotoxic effects [57]. Exposure of cells to acrylamide initiates oxidative stress, leading to mitochondrial-type apoptosis [58]. In experiments on BALB/c mice [59], it was found that dietary fiber from potatoes can reduce the side effects of acrylamide. In a group of animals receiving a potato dietary fiber preparation, ther was a decrease in the negative effects of acrylamide on the histological structure and innervation of the small intestine [58].

Thus, plant proteins contained in potato juice in their native form have high biological activity and are able to regulate digestive processes. In addition, hydrolysates of these proteins have hypolipidemic, hypotensive, antioxidant and antiproliferative properties. However, these effects are characteristic only of native proteins and proteins obtained through enzymatic hydrolysis, while conventional cooking with heating to 100 °C and above destroys native proteins.

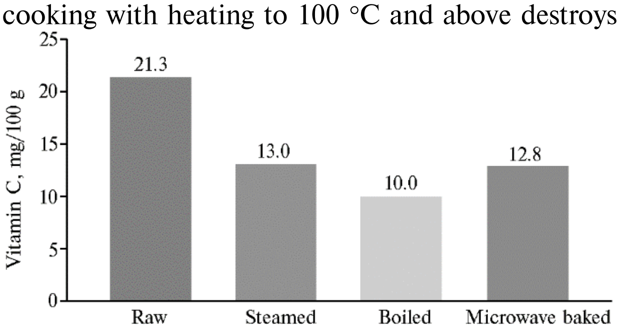


**Fig. 4. Vitamin C content depending on the way to prepare potatoes.** We compiled the diagram based on the experimental data from A.T. Popova [62].

**Vitamins and minerals.** During the heat treatment of potatoes, the activity of many vitamins contained in them is lost [60], in particular vitamin C in the form of ascorbic acid. A medium-sized raw potato (150 g) contains 28 mg of vitamin C [20], or approximately 1/3 of an adult's daily requirement [61].

A.T. Popova [62] investigated how much the vitamin C content decreases depending on the ways of cooking potatoes (Fig. 4).

In addition to ascorbic acid, raw potatoes and potatoe juice are rich in B vitamins ($B_1$, $B_2$, $B_3$, $B_6$) and minerals, the potassium, phosphorus, magnesium, calcium, iron, sodium and zinc [25, 56].

**1. Some vitamins and minerals found in raw potatoes** [20, 61]

| Nutrient | Content, mg/100 g of raw potatoes | Percentage of daily physiological needs for adults per 300 g of raw potatoes |
|---|---|---|
| Vitamin C | 18.3 | 55 |
| Vitamin $B_1$ | 0.08 | 16 |
| Vitamin $B_2$ | 0.02 | 3 |
| Vitamin $B_3$ | 1.09 | 16 |
| Vitamin $B_6$ | 0.14 | 21 |
| Folic acid | 0.0163 | 12 |
| Potassium | 420.6 | 36 |
| Calcium | 13.6 | 4 |
| Magnesium | 22.4 | 16 |
| Iron | 0.75 | 16 |
| Zinc | 0.27 | 7 |

Table 1 shows the contents of some vitamins and minerals in raw potatoes and the percentage of daily physiological needs according to the current Methodological Recommendations MP 2.3.1.0253-21 “Norms of physiological needs for energy and nutrients for various groups of the population of the Russian Federation”) [61] when consuming juice from two medium-sized raw potatoes.

Thus, potato juice, convenient for consuming potatoes raw, retains all the vitamins and minerals contained in potatoes in their native form and in their original concentrations.

P o l y p h e n o l s. Potatoes contain significant amounts of polyphenols. In 150 g of fresh raw potatoes ther are 36 mEq gallic acid, total antioxidant activity is equial to 124.5 mg vitamin C [63]. In addition to ascorbic acid, pigmented potato varieties contain other substances with antioxidant activity, such as carotenoids, flavonoids, tocopherol, and α-linoleic acid [20, 63]. Distribution of polyphenol in potatos uneven, their maximum amount is determined in the peel and gradually decreases towards the center of the tuber [64]. Potato varieties with purple and red pulp possess the highest antioxidant activity, and it is less in varieties with yellow and white tubers [20, 63].

In plants, polyphenols provide the processes of photosynthesis, respiration and protection of the genetic apparatus from ultraviolet radiation, and therefore are continuously synthesized in cells [65].

In the works of S.V. Luca et al. [66] and H.-F. Chiu et al. [67] the effects of using polyphenols are quite fully described experimentally and clinically. In their pure form, polyphenols are widely used as biologically active food additives [68]. The effects of polyphenols in animals and humans are numerous. Thus, in mammals, flavonoids are oxidized into quinones that can interact with functional groups of enzymes, thereby affecting the kinetics of biochemical reactions [69]. In addition, flavonoids have chelating properties. In their active form, they bind transition metal ions, forming chelate complexes [70]. Due to the formation of such complexes in the cell, free radical processes are inhibited [71]. Due to their unique structure, polyphenols have multiple physiological effects, e.g., restorative, anti-inflammatory, hepatoprotective, choleretic, antitumor [71, 72). Moreover, polyphenols can enhance the effect of certain medications. For example, K. Zhai et al. [73] demonstrated the synergistic effects of traditional chemotherapy drugs and some polyphenols (chrysin, catechin, formononetin, hispidulin, icariin, quercetin, rutin, and silibinin) against an aggressive brain tumor glioblastoma.

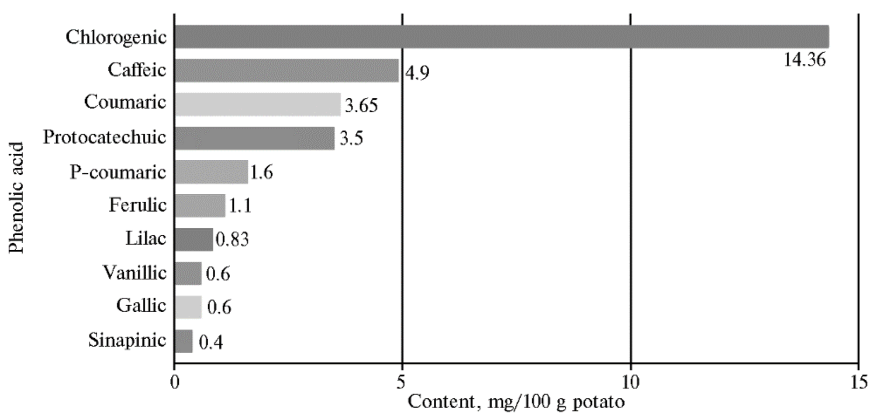


**Fig. 5. Contents of phenolic acids in raw potatoes.** We compiled the diagram based on the experimental data from H. Akyol et al. [74].

All potato polyphenols can be divided into phenolic acids and flavonoids, including flavonols, flavanones and anthocyanins). Potatoes contain the most phenolic acids of which up to 90% are chlorogenic acid (Fig. 5) [74].

Among potato flavonoids, the most common are anthocyanins, as well as catechin, quercetin, kaempferol, and rutin (Table 2) [74]. Thanks to anthocyanins, the peel and pulp are colored purple, red and yellow. Potato anthocyanins include pelargonidin, peonidin, petunidin, and malvidin [74, 75].

**2. Average content of flavonoids in potato dry matter [74]**

| Flavonoid | Concentration, mg/100 g DM |
|---|---|
| Anthocyanins | 283,4 |
| Katekhin | 41,7 |
| Rutin | 2,9 |
| Quercetin | 2,5 |
| Kaempferol | 1,1 |

Thus, the juice obtained from potato tubers with pigmented pulp will have additional biological effects due to high content of flavonoids.

Glycoalkaloids. Glycoalkaloids are secondary plant metabolites that can accumulate in flowers, leaves, fruits, and tubers [76]. Potatoe plants synthesize predominantly two alkaloids, the α-solanine and α-chaconine (chaconine) (77). In chemical structure, both are a compound of the aglycone solanidine with a carbohydrate side chain responsible for interaction with cell membranes [78]. The structure of glycoalkaloids is similar to mammalian steroid hormones [79]. Consumption of large doses of glycoalkaloids may cause an intoxication syndrome [80].

Although the glycoalkaloid content of potatoes varies considerably depending on variety and growing conditions, in general, comparison can be made of the solanine and hakonine contents in fresh raw tubers with the human semi-lethal doses $LD_{50}$ (Table 3) [81, 82).

**3. Content of glycoalkaloids in potato peel and pulp and average semi-lethal dose for humans ($LD_{50}$)** [81, 82]

| Glycoalkaloid | In potato peel, mg/kg | In potato pulp, mg/kg | $LD_{50}$ per or, mg/kg |
|---|---|---|---|
| α-Solanin | 89 | 12 | 2,8 |
| α-Hakonin | 173 | 18 | |

Glycoalkaloids are actively synthesized in tubers in the presence of pests, dueing long-term storage, especially when exposed to light (even artificial) and high temperature [83, 84]. Therefore, to avoid high levels of glycoalkaloids in tubers, potatoes must be properly grown, transported, and stored before consumption [85].

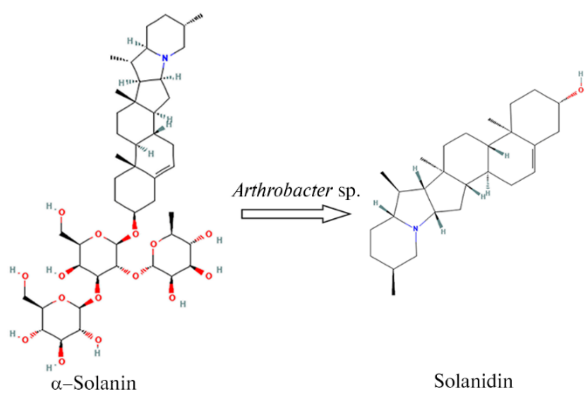


**Fig. 6. Biodegradation of glycoalkaloids on the example of α-solanine.** Formulas are taken from PubChem [91, 92].

However, in addition to toxic effects, therapeutic effects have been described for pure glycoalkaloids from potatoes [86-89]. In vitro and ex vivo, an anticholinergic effect was shown due to antagonistic activity towards $M_3$-cholinergic receptors and an anticholinesterase effect [86], a cytotoxic effect against cells of neuroblastoma SH-SY5Y [87], colon cancer HT-29, liver Hep G2, cervix uterine HeLa and lymphoma U937, cancer of stomach AGS and KATI II [88], prostate LNCaP and PC3, and other cell lines [89]. The data obtained indicate that glycoalkaloids can be considered as promising agents for antitumor therapy.

Biotechnological methods for reducing the toxicity of potato glycoalkoloids are described in the literature. Thus, in the bacteria *Arthrobacter* sp. enzymes capable of biodegrading α-solanine and α-chaconine were discovered. These enzymes can remove the trisaccharide responsible for the interaction of glycoalkaloids with animal cell membranes from α-solanine and α-chaconine molecules. Such biodegradation (Fig. 6) provides formation of low-toxic solanidine [90].

Potato processing products and their biological effects. Potato skin contains the maximum amount of polyphenols [64], so N. Singh et al. [93] proposed studying extracts from it. In an experiment on laboratory rats, researchers showed that potato peel extract was able to significantly reduce acute liver damage due to antioxidant activity.

Potato juice contains compounds that can influence GABAergic activity in the brain, displacing γ-aminobutyric acid (GABA) from its receptors [94]. In addition, V. Bartova et al. [95] found that potato juice, due to its unique proteins, exhibits pronounced antimycotic activity, and the strength of the effect could be modulated by temperature.

Moreover, in a pilot study conducted in 2006, S. Chrubasik et al. [96] used potato juice manufactured by Biotta company (Switzerland) in the treatment of patients with dyspepsia syndrome. The following dosage regimen was recommended: 100 ml twice a day, half an hour before meals in the morning and in the evening before bed. The results of the clinical study showed that at least $^{2}/_{3}$ of the patients had improvement after 1 week, which confirms the promise of using potato juice in clinical gastroenterology.

Prospects for the development of potato juice as a functional food product. Potato juice is the only product that allows preservation of all natural components — proteins, starch, vitamins, minerals, polyphenols, glycoalkaloids (Table 4).

**4. The main components of potato juice and their biological effects**

| Component | Biological effects | References |
|---|---|---|
| Starch | Source of glucose and fructose, the body's most important energy substrate | [2, 3, 20, 22, 23, 25, 26] |
| "Resistant starch" | Intestinal microflora substrate; suppression of the growth of pathogenic flora; antidiabetic effect | [20, 22, 24, 26, 27] |
| Prosthetic inhibitors | Source of essential amino acids; strengthening of digestion processes; obesity prevention; hypolipidemic effect | [37-41, 45] |
| Patatin | Source of essential amino acids; obesity prevention; hypolipidemic effect; antihypertensive effect; antioxidant effect and antiproliferative activity | [34, 47-53] |
| Vitamin C | Antioxidant, immunomodulatory, adaptogenic effects; increased iron absorption; participation in the formation of collagen fibers | [61] |
| Vitamin $B_1$ | Regulation of carbohydrate and energy metabolism | [61] |
| Vitamin $B_2$ | Redox reactions; promotes increased color sensitivity by the visual sensory system and dark adaptation | [61] |
| Vitamin B3 | Regulation of redox reactions; cofactor for several enzymes | [61] |
| Vitamin B6 | Regulation of protein, lipid and nucleic acid metabolism; immunomodulatory effect; regulation of processes of inhibition and excitation of the nervous system; participation in the processes of erythropoiesis | [61] |
| Folic acid | Participation in the exchange of nucleic acids and amino acids | [61] |
| Potassium | The main intracellular ion that maintains membrane potential; participation in electrolyte metabolism | [61] |
| Calcium | Maintaining the structure of bone tissue, participating in the transmission of nerve impulses, muscle contraction, blood clotting processes | [61] |
| Magnesium | Cofactor for a number of enzymes, stabilizer of biomembranes, regulates muscle contractions, maintains homeostasis of calcium, potassium and sodium | [61] |

*Continued Table 4*

| | | |
|---|---|---|
| Iron | Part of hemo- and myoglobin, cytochromes, catalase and peroxidase; regulates the occurrence of redox reactions; depending on the concentration, it has a pro- or antioxidant effect | [61] |
| Zinc | Part of the enzymes involved in the metabolism of carbohydrates, proteins, lipids and nucleic acids; regulates gene expression; | [61] |
| Polyphenols | Antioxidant effect and protection of biomembranes | [20, 63-75] |
| Glycoalkaloids | Intoxication syndrome; antiproliferative effect | [76-89] |

However, for the industrial production of potato juice, it is necessary to resolve a number of issues regarding the requirements for raw potatoes, their processing and packaging the juice. In addition, it is worth considering adding preservatives and antioxidants to the juice. An organoleptic assessment of the resulting product is also necessary to understand whether additional components are necessary to give the juice a more attractive taste. Despite the technological difficulties, potato juice can become a complete functional product to be introduced into the diet of all age groups to maintain and improve public health [97].

The described effects of potato juice in vivo can be achieved due to the synergy of its components, which opens up broad prospects for the use of this product in nutrition and medicine [98-100]. Systematic consumption of potato juice can become an important element in the prevention of such socially significant diseases as malignant neoplasms, diabetes mellitus and arterial hypertension [101, 102]. Potato juice can also be recommended as an adjuvant therapy for people who already have these diseases.

Therefore, potato juice contains all the beneficial substances that make up raw potatoes in their native form, i.e., unique proteins, ascorbic acid, B vitamins, potassium, phosphorus, calcium, magnesium, iron, zinc, polyphenols (primarily phenolic acids and anthocyanins). The accumulated information opens up broad prospects for using potato juice for functional nutrition. Experiments revealed the positive effect of potato juice components on digestive processes, intestinal microbiota, the blood content of insulin and glucagon-like peptide-1. Hypolipidemic, hypotensive, antioxidant and antiproliferative effects have also been described. The most controversial in terms of benefits for human health and requiring further study are the potato glycoalkaloids solanine and hakonine. Potato juice is becoming an attractive product for the food industry and dietetics. The bioavailability and high activity of its components together with the described effects, suggest that this product can be used in the prevention of malignant neoplasms, diabetes, arterial hypertension and other diseases. Further research should determine optimal technological methods for mass production of potato juice while maintaining the biological activity of its components.

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