



Importance of using tomato serum in the development of functional food products

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ABSTRACT

Background: The significance of incorporating tomatoes in the development of functional food products is due to their content of vitamins, carotenoids, and minerals. In industrial tomato processing, a considerable amount of tomato serum (clarified tomato juice) is produced. For instance, during tomato paste production, serum constitutes 80% of the total volume of processed tomatoes. Tomato serum contains essential organic, phenolic, and polyphenolic compounds, water-soluble vitamins, macro- and microelements. One promising application is the use of tomato serum in yeast bread technology. A specific application is using it as a growth stimulator for baker's yeast, as well as for microorganisms in sourdoughs, including Type 1 and wheat-based sourdough. This is an effective method to enhance the biotechnological characteristics of sourdoughs, as well as the organoleptic and physico-chemical quality indicators of bakery products, including enriched and functional products. The aim of the study is to investigate the mineral composition of tomato serum from red-fruited, yellow-fruited, and dark-hued tomatoes, as well as flour from various industrial producers of premium-grade baking wheat flour, for their potential combined use in the production of enriched and functional bakery products.

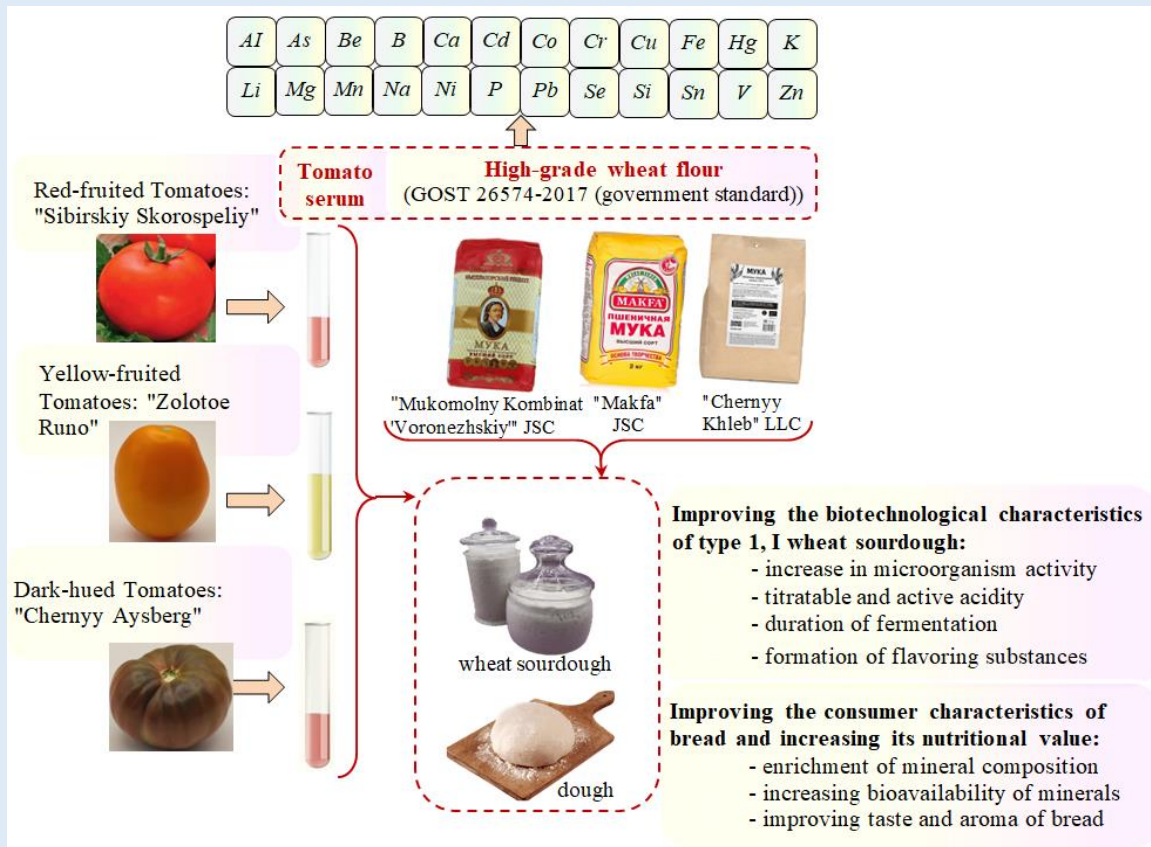
Objective: Tomato serum was obtained under laboratory conditions by centrifuging pre-crushed and thermally processed fruits of the red-fruited variety "Sibirskiy Skorospeliy," yellow-fruited variety "Zolotoye Runo" and dark-hued variety "Chernyy Aysberg." The tomatoes were grown in 2023 in open fields in the village of Nikonovo, Voronezh Voronezh region, Russian Federation. The mineral composition of tomato serum from various tomato varieties and premium-grade wheat flour from different industrial producers (JSC "Mukomolny Kombinat 'Voronezhskiy'", JSC "Makfa", and LLC "Chernyy Khleb", Russia) was investigated.

Methods: The mineral content was determined using inductively coupled plasma mass spectrometry with a quadrupole mass spectrometer, Nexion 300 D. The basic physicochemical quality indicators of the high-grade wheat flour were rapidly assessed using the "Chopin Technologies Infraneo chopin" device.

Results: The dry matter content in tomato serum ranges from 4.8% to 6.1%. All tomato serum samples exhibited an acidic reaction: the "Sibirskiy Skorospeliy" variety was the most acidic at pH 3.90, "Chernyy Aysberg" had a pH of 3.99, and "Zolotoye Runo" was the least acidic at pH 4.37. The content of 24 mineral elements was determined in both tomato serum and premium-grade wheat flour. Tomato serum from various tomato varieties contains a broad range of minerals. Potassium is the most abundant (2,755.5-3,274.5 mg/kg), with its content being 1.3-2.1 times higher than in premium-grade wheat flour. Significant amounts of phosphorus (275.8-279.0 mg/kg), magnesium (116.3-146.4 mg/kg), and calcium (63.88-91.61 mg/kg) are also present in the serum. Iron content varies from 2.533 mg/kg (variety "Chernyy Aysberg") to 17.630 mg/kg (variety "Sibirskiy Skorospeliy"). In premium-grade wheat flour from JSC "Mukomolny Kombinat 'Voronezhskiy'" and JSC "Makfa", iron content is 9.109-9.643 mg/kg, while in the sample from LLC "Chernyy Khleb," it is 2.29-2.43 times higher. Zinc content in tomato serum and industrial wheat flour ranges from 1.921-2.685 mg/kg and 8.12-9.429 mg/kg, respectively. Consuming 100 g of tomato serum can meet 7.9-9.4% of the daily potassium requirement, 2.8-3.5% of magnesium, 4.7-9.8% of iron, and 3.9-4.0% of phosphorus. Sodium content in tomato serum is minimal, ranging from 23.74 to 68.11 mg/kg, which is 0.2-0.5% of the daily requirement for an adult.

Conclusion: Incorporating tomato serum into food products, including bakery goods, can enrich their composition with deficient macro- and microelements and improve the bioavailability of minerals in flour. A specific application of tomato serum could be as a growth stimulator for wheat sourdough microorganisms (including type 1, I), which is an effective way to enhance the biotechnological properties of baker's sourdoughs, thereby improving their functionality and the organoleptic and physico-chemical quality of bakery products.

Keywords: tomato serum, clarified tomato juice, wheat flour, micro- and macro-element composition, functional properties.



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INTRODUCTION

The last 5-10 years have been marked by significant achievements in the field of functional food science. This progress has been made possible by the vast number of studies conducted in thousands of organizations across various regions of the globe. Both traditional approaches to developing functional food recipes [1-3] and innovative ones, such as those combining the possibilities of quantum and tempus theories of functional food science, are being utilized [4]. A mandatory attribute that qualifies a food product as functional is the presence of substances or compounds with biological activity that contribute to the prevention of specific diseases [4, 5]. Sources of biologically active compounds can include not only "pure" preparations obtained through

microbiological or chemical synthesis but also processed products from various fruits, berries, and vegetables, including tomatoes [6-11].

The importance of tomatoes in developing functional food products is primarily due to their content of vitamins (particularly vitamin C), carotenoids (such as lycopene and lutein), and minerals (notably potassium, calcium, magnesium, and phosphorus) [8, 9, 11-17]. Additionally, it's important to consider that tomatoes are used to produce popular and commercially successful products such as tomato juice, paste, and various sauces. By-products from tomato processing, such as pomace consisting of seeds, skins, and minimal pulp, also hold interest for the food industry, with various recommendations for their use or processing [18, 19].

One traditional tomato-processing product is tomato juice, which always contains a certain amount of pulp. Some industrial tomato processing methods produce serum (clarified juice, cell juice, or juice without pulp), which has not yet achieved widespread commercial popularity as a standalone product. The volumes of tomato serum produced during processing are substantial; for example, in tomato paste production, serum can make up to 80% of the processed tomato volume. Tomato serum typically contains 6.0-8.0% dry matter, including sugars, organic and phenolic acids, polyphenolic compounds, water-soluble vitamins, and macro- and microelements. One of the first steps in developing functional food products is justifying the choice of raw materials based on the presence of specific biologically active compounds [1, 2].




The aim of the study is to investigate the mineral composition of tomato serum from red-fruited, yellow-fruited, and dark-hued tomatoes, as well as flour from

various industrial producers of premium-grade baking wheat flour, for their potential combined use in the production of enriched and functional bakery products.

MATERIALS AND METHODS

Materials: The subjects of the study were fruits of the red-fruited tomato variety "Sibirskiy Skorospeliy," the yellow-fruited variety "Zolotoe Runo," and the dark-fruited variety "Chernyy Aysberg" (Table 1). The tomatoes were grown in 2023 in open fields in the village of Nikonovo, Voronezh Region, Russian Federation. Tomato serum was obtained under laboratory conditions by centrifuging pre-chopped and thermally processed tomato fruits. For comparison, the mineral composition of high-grade wheat flour (GOST 26574-2017 (government standard)) from JSC "Mukomolny Kombinat 'Voronezhskiy'", JSC "Makfa," and LLC "Chernyy Khleb" (Russia) was also analyzed.

Table 1: Characteristics of tomatoes used in the work.

Variety	Fruit Appearance	Fruit Characteristics
Red-fruited Tomatoes: "Sibirskiy Skorospeliy"		The fruits are bright red in color, with a flat-round and round shape. They are medium-sized, weighing 65-114 g. The variety is maturing early. The originators are the Federal Scientific Center for Vegetable Growing (Moscow Region, Odintsovo District, VNISSOK Settlement, Russia); Agrofirma Aelita LLC (Moscow, Russia); and Gavriush Breeding Company LLC (Moscow, Russia).
Yellow-fruited Tomatoes: "Zolotoe Runo"		Unripe fruits are light green, while ripe fruits are yellow. The shape is oval. The fruit weighs 90-100 g. The variety matures early. The originators are Agrofirma Poisk LLC (Moscow Region, Ramensky District, Vereya Village, Russia) and Tsentri-Ogorodnik LLC (Moscow Region, Ramensky District, Vereya Village, Russia).
Dark-hued Tomatoes: "Chernyy Aysberg"		Unripe fruits are green with a spot, while ripe fruits are purple, brown. The shape is flat-round and moderately ribbed. The fruit weighs 220-280 g. The variety is maturing early. The originator is Agrofirma Aelita LLC (Moscow, Russia).

Methods: Determination of dry matter content was performed using a refractometric method; active acidity was measured with a pH-150MI device (manufactured by LLC "Izmeritelnaya Tekhnika," Russia); and the quantity of mineral substances was determined by inductively coupled plasma mass spectrometry using a quadrupole mass spectrometer Nexion 300 D. The basic physicochemical quality indicators of the high-grade wheat flour were rapidly assessed using the "Chopin Technologies Infraneo chopin" device.

RESULTS AND DISCUSSION

All analyzed tomato serum samples were clear liquids, with colors corresponding to the tomato variety: bright yellow for serum from "Zolotoe Runo" tomatoes, pink for "Sibirskiy Skorospeliy," and light brownish pink for "Chernyy Aysberg." The dry matter content in tomato serum also varied: it increased in the order of "Zolotoe Runo", "Sibirskiy Skorospeliy", and "Chernyy Aysberg", with values of 4.8%, 6.0%, and 6.1%, respectively. All tomato serum samples had an acidic reaction: "Sibirskiy Skorospeliy" was the acidic at pH 3.90, "Chernyy Aysberg" was intermediate at pH 3.99, and "Zolotoe Runo" was the least acidic at pH 4.37.

Among the wide variety of chemical elements (currently 118 elements are known), about 20 are considered crucial for the proper biological functioning of the human body [20]. Mineral substances are one group of functional ingredients used in the production of functional foods due to the undeniable importance of macro- and micro-elements in supporting the life processes of all human body systems: they act as cofactors for enzymatic systems and participate in the catalysis of numerous chemical reactions. They are

necessary for normal metabolism of proteins, fats, and carbohydrates, prevent damage from free radicals, are part of DNA, regulate hormone levels, strengthen bones, and support skin function and appearance, among other roles [20-23]. We determined the content of 24 chemical elements in tomato serum and high-grade wheat flour.

Since agricultural soils are at risk of contamination with toxic metals/metalloids due to anthropogenic activities, excessive accumulation of arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) in food crops can occur [24, 25]. Therefore, it is important to consider that several chemical elements are crucial for assessing food safety due to their potential toxic effects on human health [26]. Among the ten major chemical substances of serious public health concern recognized by the World Health Organization, four are particularly hazardous: arsenic, cadmium, lead, and mercury [27]. Other international organizations, such as the Agency for Toxic Substances and Disease Registry (ATSDR), the United Nations Environment Programme (UNEP), and the U.S. Environmental Protection Agency (US EPA), also classify toxic heavy metals as substances with the highest risk to human health [28]. Accumulation of toxic elements in the human body disrupts essential metabolic processes. Comparison of the mechanisms of action of these toxic elements reveals similar pathways causing their toxicity: generation of reactive oxygen species, weakening of antioxidant defenses, enzyme inactivation, and oxidative stress [29, 30]. In addition to inducing oxidative stress, toxic heavy metals act as "molecular mimics" of certain endogenous intracellular molecules and inhibit several metabolic processes; they can cross the placenta and interfere with fetal development [28].

Table 3: Results of determining the content of toxic elements in tomato serum and wheat flour of the highest grade.

Elements	Content, mg/kg:					
	in the serum from the pulp of tomatoes			in high-grade bakery wheat flour production		
	"Sibirskiy Skorospeliy"	"Chernyy Aysberg"	"Zolotoe Runo"	"Mukomolny Kombinat 'Voronezhskiy' JSC"	"Makfa" JSC	"Chernyy Khleb" LLC
As	0.00545± 0.0002	0.00554± 0.0009	0.00709± 0.0007	0.00542± 0.00006	0.01137± 0.0013	0.01264± 0.0008
Cd	0.00434± 0.0008	0.0023± 0.0002	0.01421± 0.0005	0.01039± 0.0011	0.00428± 0.0006	0.00685± 0.0006
Cr	0.03193± 0.0061	0.02109± 0.0010	0.02316± 0.0026	0.02304± 0.0017	0.02561± 0.0038	0.056± 0.0034
Co	0.00332± 0.0005	0.0024± 0.0003	0.0103±0.001	0.00319± 0.0008	0.00446± 0.0004	0.01053± 0.0006
Cu	0.4592± 0.0459	0.3273± 0.0327	0.8174±0.0817	1.62±0.162	2.687±0.2687	3.438± 0.3438
Hg	0.00373± 0.0005	0.00266± 0.0002	0.00442± 0.0004	0.01114± 0.0008	0.00723± 0.0004	0.00928± 0.0007
Mn	0.5497±0.026	0.4554± 0.0261	0.8574±0.0736	5.486±0.0751	6.001±0.5855	16.20± 0.29
Ni	0.04087± 0.0028	0.07379± 0.0659	0.1558±0.007	0.06576± 0.0044	0.1105±0.0202	0.2067± 0.0055
Pb	0.00762± 0.0006	0.01195± 0.0025	0.00905± 0.0003	0.01247± 0.0006	0.01355± 0.0003	0.02045± 0.002
Sn	0.4066± 0.0189	0.1003±0.001	0.2233±0.0151	0.03655± 0.0468	0.01545± 0.0017	0.00561± 0.00003

Comparison of experimental data (Table 3) with regulatory requirements (Table 2) shows that all analyzed samples of tomato serum and high-grade wheat flour meet safety standards for toxic heavy metals content.

In addition to the elements mentioned above, nickel (Ni), copper (Cu), manganese (Mn), cobalt (Co), chromium (Cr), and tin (Sn) also require attention and control [35-38]. There is evidence of a correlation between Ni and the development of breast cancer, chronic bronchitis, and allergic reactions [35, 37]. Although Cu, Mn, and Ni are trace elements necessary for normal life functions and homeostasis, in high doses they exhibit toxic properties. Additionally, Co^{2+} can substitute for Zn^{2+} in the zinc finger DNA-binding domain of the estrogen receptors (ERs) to associate with the estrogen response [35, 39]. It is reported that chromium (Cr) may

contribute to the development of diabetic complications [37], and tin (Sn) can lead to a decrease in calcium levels in serum [38].

The data in Table 3 indicate the safety of the analyzed products in terms of toxic element content.

The determination of elements such as potassium, sodium, and calcium in juice products is important due to their dietary significance. For example, recent studies have confirmed that excessive sodium in food products is a factor contributing to cardiovascular diseases; sodium can either promote protective immunity (for example, by enhancing the body's response to skin pathogens) or contribute to immune dysregulation and the development of autoimmune diseases [40]. Calcium is essential for the human body but can pose problems for patients with renal insufficiency. Potassium is also

