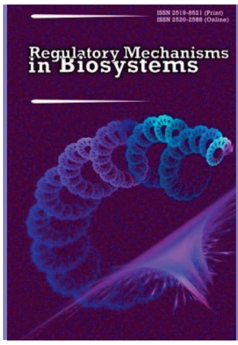

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The content of microelements in fruits of the oriental persimmon (*Diospyros kaki*) and its dietary role in remedying micronutrient deficiency in the region

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The relevance of the problem under study lies in the need to develop innovative approaches to the introduction of fruit crops into the diet to avoid the loss of nutrients and thus help prevent micronutrient deficiency in the human body. In this regard, the purpose of this article is to study the content of biologically active substances in the products of promising persimmon varieties and their effect on the normal functioning of the thyroid gland. The following results were obtained during the study: soil and climatic conditions affecting the nutritional value of the agricultural product were presented. It was established that Shaki-Zagatala economic region is an iodine deficiency endemic area and belongs to the zone of moderate iodine (I) deficiency. The quantity of macro- and microelements in fruits of 20 varieties of Oriental persimmon (*Diospyros kaki*) bred by folk selection growing in Shaki-Zagatala economic region was studied and compared by regions; the use of persimmon plants in the food industry as a way of increasing the amount of iodine in the human body was substantiated. It has been proved that in order to eliminate iodine deficiency, it is advantageous to eat more food enriched with iodine from fruits of the Oriental persimmon (*D. kaki*), which is rich in microelements. The role of awareness – raising activities among the population regarding health disorders associated with iodine deficiency was revealed. The practical value of the article materials consists in obtaining detailed information about biochemical composition of Oriental persimmon fruit (*D. kaki*) for the purpose of iodine deficiency prevention. The technologies of processing and storage of the product in fresh and processed form to preserve the useful properties of persimmon have been proposed in order to increase the profitability of production and increase the level of sales of products in the Shaki-Zagatala economic region of Azerbaijan.

Keywords: plant fruit; biochemical composition; nutrients; thyroid gland; iodine deficiency; Oriental persimmon; micronutrients.

Introduction

The biology of persimmon crops has been studied sufficiently, however, there are no detailed studies on the influence of environmental factors on the nutrient content of fruits grown in the Shaki-Zagatala economic region. These studies are of significant value to specialists in agriculture, medicine and food industry, since the nutritional value of the product consists of many nutrients necessary for the human body. This fruit contains a large number of trace elements and vitamins: copper, calcium, potassium, magnesium, iron, manganese, phosphorus, ascorbic acid, tocopherol, carotene (Azizov et al., 2020). This content of biologically active substances allows the use of persimmon fruit for the treatment and prevention of many diseases. For example, persimmon contains iodine, which is well assimilated by the human body, which makes it possible to combat the problem of iodine deficiency in mountainous areas as well as areas remote from the sea (Ryabova, 2013). The study of varietal properties of Oriental persimmon (*Diospyros kaki*) was conducted by Korol & Shulga (2020), Santos et al. (2021), Tardugnoa et al. (2022).

The study by Rabelo Vaz Matheus et al. (2022) reports that, according to the UN, in 39% of cases, the cause of any disease is a deficiency of trace elements in the human body. According to this study, more than 30 microelements are vital to a person for normal life. These include: bromine, iron, iodine, cobalt, manganese, copper, molybdenum, selenium, fluorine, chromium, zinc, boron, vanadium, silicon. Deficiency of these trace elements leads to the development of cardiovascular diseases, mental disorders, and cancer. Thus, some of these trace elements are part of biologically active compounds, for example, iodine plays a structural role in the composition of thyroid hormones, cobalt is part of vitamin B_{12}, iron is part of haemoglobin, and magnesium is part of chlorophyll. Therefore, a lack of molybdenum leads to nervousness, fainting, impotence, or a cancerous tumour. With a lack of manganese, the growth of hair, nails and the work of the gastrointestinal tract slow down, the risk of uterine bleeding increases and, in some cases, the development of schizophrenia occurs. Calcium deficiency leads to hyperactivity in children, problems with the cardiovascular system, and eczema. A lack of chromium leads to diabetes, high cholesterol levels, decreased thyroid function, and an increased risk of thrombosis. Insufficient iron levels cause a decrease in appetite, stunting in children, and confusion. The lack of copper affects the work of the heart, and magnesium deficiency leads to the loss of balance when moving. And selenium deficiency leads to malfunctions in the liver, can lead to the appearance of multiple sclerosis, skin cancer, the development of alcoholism, cataracts and lupus erythematosus. Insufficient amount of sodium and zinc leads to disturbances in the urinary system.

In general, it can be noted that in all regions located in the southern part of the Greater Caucasus, iodine deficiency and thyroid diseases caused by it are fairly frequent. The elimination of iodine deficiency diseases has become a serious problem of our time. Iodine deficiency has become an urgent problem in medical and socio-economic aspects. People of all ages are exposed to this disease, including at the stage of intrauterine development, which has a detrimental effect on the intellectual, educational, professional spheres of people, as well as on public health (Hassen et al., 2019). The problem of micronutrient deficiencies can be solved with the help of comprehensive measures to ensure regular and effective, from the standpoint of human health, consumption of vegetables, fruits, and seafood. Therefore, the problem of combating the lack of trace elements in the human body can be solved by balancing the diet with natural foods with a multivitamin composition. Particularly effective in such preventive measures are the fruits and berries of the climatic zone familiar to the organism of the inhabitants. Thus, for the USA it is apples and plums, for Canada it is the Canadian serviceberry, for India it is pomegranate and cherry plum, for France it is peach and apricot, for Azerbaijan it is Oriental persimmon.

The study by Diaz et al. (2020c) found that 51.7% of children aged 11 to 12 years in the European region do not get enough iodine, protein, micro- and macronutrients from food. In 20% of these children, mild to moderate frequency of iodine deficiency was revealed. Thus, it can be argued that iodine deficiency is a problem directly related to nutrition.

In Azerbaijan, the Oriental persimmon is widespread in areas of the eastern and western Greater Caucasus. In the northern regions of the Lesser Caucasus, in the mountainous part of Talysh, on the Lankaran and Kura-Araz lowlands, in the Alazan-Eirichai valley and on the Bozgir plateau, the Caucasian persimmon variety (*Diospyros lotus* L.) is distributed at 700–1200 m above sea level. At high altitudes, it is distributed singly in damp areas near dwellings, along river banks, on less sunny slopes and ravines (Azizov et al., 2020). It is protected in Girkan National Park and Zagatala State Nature Reserve. The process of cultivation of this variety is complicated and costly; it is necessary to create shelters in the areas of natural distribution of the plant. Because of its tendency to wilting and sensitivity to negative influences, Caucasian persimmon (*D. lotus* L.) is included in the "Red Book" of Azerbaijan.

Oriental persimmon (*D. kaki*) is sometimes called Japanese persimmon. It typically reaches 10–12 m. It is a deciduous, subtropical fruit tree widely cultivated in many countries; in Azerbaijan it is cultivated in the plains and foothills (Azizov et al., 2020). In the north-western region of Azerbaijan, due to the large areas of land where the Oriental persimmon is cultivated, a fruit drying factory "Balhurma", in line with modern standards, started to work in 2017 in the village of Kateks, Balakan district. The persimmons in this factory are mainly exported. A study conducted by scientists from Brazil showed that 70% of the world's population suffers from thyroid disease (Marques et al., 2019). Women and adolescents are at risk. Iodine deficiency occurs in more than 3 billion people on all continents. Such iodine deficiency diseases are widespread as endemic goitre, mental retardation, cretinism. Iodine deficient areas are considered to be uplands, mountainous areas, areas remote from the sea. Soils in these regions are iodine deficient . Therefore, the population of Shaki-Zagatala economic region must be fully provided with iodine-containing products. It has been proven that people who eat seafood and fruits enriched with iodine suffer less from iodine deficiency (Ryabova, 2013).

Oriental persimmon (*D. kaki*) fruits are round, dark red, yellow or bluish black, waxy, with yellow, edible peel, seeds are thinly sheathed, with a very hard endosperm, the embryo is flat or wedge-shaped and slightly curved (Gunduz et al., 2020). It should be eaten after the fruit is fully ripe. In folk medicine, an alcoholic infusion of persimmon fruit is used to treat the thyroid gland, bekmez made from its fruit is used as a tonic for weakness, as a stimulant for diseases of the nervous system, as a means to suppress appetite, as a depressant for hypertension, as an anti-edema agent, as a coughing agent in case of bronchitis. Oriental persimmon (*D. kaki*) ranks first among plants growing in the Shaki-Zagatala region (Azizov et al., 2020). Up to 40% of sugar is collected from this plant in dried fruits, and molasses, dried products and alcoholic beverages are made from its fruits. Dried fruits are crushed and added to flour in baking sweet breads (Asmy & Fitri, 2021).

Persimmon is not widely distributed in Azerbaijan, reproduction occurs generatively. Considering the abovementioned material, the aim of this article is to empirically study the indicators of biochemical composition of Oriental persimmon and its impact on iodine deficiency the example of the population living in the economic region of Azerbaijan.

Materials and methods

This study was conducted in accordance with the Declaration of Helsinki for research involving human participants. Informed consent was obtained from all participants or their parents/guardians, in line with CONSORT guidelines for clinical trials. Participants were informed of the study purpose, procedures, risks and benefits, and their right to withdraw at any time, per the Declaration of Helsinki. Confidentiality was maintained by assigning unique code numbers to de-identify participant data and samples, in keeping with principles outlined in the Declaration of Helsinki. Urine samples were obtained from willing participants and labelled only with the code number.

Fructose and glucose are easily digestible organic substances that are found in large quantities in fruit (Diaz et al., 2020a). Tannins are involved in anti-inflammatory, hypoallergenic, anti-viral and anticarcinogenic processes. Oriental persimmon varieties in Qakh district have the highest content of these substances. The daily diet of a person should contain 5–6 grams of pectin substances. They take part in iron forming, protective processes. Varieties in Zagatala, Qakh and Balakan districts are the most enriched in pectin substances. Vitamin C has the properties of a strong antioxidant. Regular intake of persimmon fruits with high content of vitamin C in sufficient quantities (50–100 mg/day) will meet the human body's needs for this organic substance. A more detailed study of the content of vitamin C and other biochemical components in Oriental persimmon varieties is presented in the study of Bakhshalieva et al. (2023). All micro- and macronutrients, which were studied in this experiment play an important role in the metabolic processes of the human body, as well as prevent immunodeficiency. However, one of the most important trace elements providing high performance and high human health indicators is iodine (I) (Krela-Kazmierczak et al., 2021). Iodine deficiency causes thyroid disease and goitre formation. After the age of 12, a person should consume 150 mcg/day of iodine.

The following theoretical methods were used during the study: analysis, synthesis, generalization of scientific research on the content of nutrients in fruits of Oriental persimmon (*D. kaki*) and their role in the prevention of iodine deficiency. During the empirical study, an X-ray fluorescence method was used on an Omega-4000 device (INNOV-x, USA) (Jafarova, 2020). This method is used to study the elemental composition of the substance. Using this modern spectroscopic method, the content of trace elements in the composition of Oriental persimmon fruits was analysed at the Azerbaijan National Nuclear Center. For this purpose, the studied material was irradiated with X-rays. In this case, the atoms of the material under study go into an excited state under the influence of high-energy photons. The electron moves from lower orbitals to higher energy levels, resulting in ionization of the atom and thus determining the most predominant chemical element in persimmon fruits.

Also, a portable Sonoscape S9 ultrasound device with a 15 mHz linear transmitter was used to diagnose the condition of the thyroid gland (Jarząb & Placzkiewicz-Jankowska, 2018). The experiment was continued for a year in Balakan, Qakh, Zagatala, Gabala, and Shaki districts. Twenty varieties of fully ripened fruits of *D. kaki* common in Shaki-Zagatala economic region were selected as study material, and the amount of macro- and micronutrients present in fruits was studied for the five regions. In order to study the prevalence of thyroid diseases in endemic regions, studies were conducted among adolescents in April-May 2022. A total of 273 students aged 15–17 years (144 girls, 129 boys) studying in Shaki, Gabala and Quba secondary schools were included in the study. After registering anthropometric indicators of students (height, weight) on specially prepared forms in the school medical center, the thyroid gland was examined by palpation method recommended by the World Health Organization (Syvolap & Hura, 2019). The examination was then performed using a Sonoscape S9 portable ultrasound device with a 15 mHz linear transmitter (Jarzab & Placzkiewicz-Jankowska, 2019).

Because the most appropriate and reliable method for determining the frequency and severity of iodine deficiency is the determination of urine iodine content, participants in the experiment were advised to take urine samples first thing in the morning in closed plastic containers for two months, and the containers were labelled. Urine samples from 189 respondents were evaluated for iodine content, while 84 participants did not take a urine sample. Urine readings ranged from <70 µg/L, acute deficiency; 70–99 µg/L, mild deficiency; 100–300 µg/L, normal; and ≥300 µg/L, excess.

Refinement of theoretical and practical conclusions, generalization and systematization of the results were carried out using methods of mathematical statistics and graphical representation of the results. The information displayed within the tables is expressed as x ± SD (representing the mean ± standard deviation). For the purpose of contrasting the mean attributes between the control and experimental groups, the Tukey test was employed. Notably, statistical significance was acknowledged at a $P < 0.05$ across all the provided data.

Results

A comprehensive examination encompassing 26 trace elements within *D. kaki* was conducted. It can be seen that the amount of many elements in fruits varies by region. Micronutrients such as vanadium (V), tin (Sn), iodine (I), selenium (Se), zinc (Sn), molybdenum (Mo), potassium (K), calcium (Ca), iron (Fe) were present in large amounts. It is also determined that such amount remains constant in all regions. The Filichai deposits can be called the reason for the high iron content. The values of trace elements in fruits collected in Balakan and Zagatala districts show that the element was more abundant in the rocks of these regions. Furthermore, the quantum of elemental content within fruits is shown to exhibit a notable correlation with the mineralogical composition of the regions where the plants are cultivated. Additionally, this relationship is further nuanced by the intrinsic biochemical attributes specific to distinct varieties and forms of the plants. The detailed biochemical profile of *D. kaki* is illustrated, with specific reference to different regions (Table 2). For instance, Oriental persimmon in Balakan district displays a pulp weight of 127.4 g, accompanied by diminutive seeds measuring 1.1 cm in length and 0.6 cm in width. Contrarily, Qakh district showcases a fruit composition with 138.4 g of pulp mass and seeds measuring 1.7 cm in length. In Zagatala district, the pulp mass is augmented to 156.2 g, and correspondingly, larger seeds ranging from 1.7 to 2.8 cm in length are observed. A comparable trend continues with variations observed in other districts, such as Gabala, where a pulp mass of 165.2 g coexists with seeds measuring 0.9 to 1.5 cm in length. Conversely, in Shaki district, the persimmon fruit exhibits a pulp weight of 187.8 g, accompanied by seeds ranging from 0.7 to 1.5 cm in length (Table 1).

Table 1
The amount of macro- and microelements in the fruits of Oriental persimmon (*D. kaki*) common in Shaki-Zagatala economic region (x ± SD, n = 6)

Element	UoM by regions, %				
	Balakan	Qakh	Zagatala	Gabala	Shaki
K	0.478 ± 0.059^{a}	0.718 ± 0.035^{b}	0.608 ± 0.030^{c}	0.787 ± 0.039^{d}	0.615 ± 0.031^{c}
Na	0.494 ± 0.025^{a}	0.473 ± 0.024^{a}	0.511 ± 0.026^{ab}	0.557 ± 0.028^{b}	0.532 ± 0.027^{b}
Mg	0.695 ± 0.034^{a}	0.693 ± 0.035^{a}	0.739 ± 0.037^{a}	0.747 ± 0.037^{a}	0.702 ± 0.035^{a}
Ca	0.087 ± 0.004^{a}	0.107 ± 0.005^{b}	0.100 ± 0.005^{c}	0.105 ± 0.005^{bc}	0.091 ± 0.005^{ab}
Ti	0.053 ± 0.003^{a}	0.063 ± 0.003^{b}	0.065 ± 0.003^{b}	0.052 ± 0.003^{a}	0.057 ± 0.003^{ab}
V	0.0041 ± 0.0002^{a}	0.0041 ± 0.0002^{a}	0.0042 ± 0.0002^{a}	0.0041 ± 0.0002^{a}	0.0041 ± 0.0002^{a}
Cr	0.011 ± 0.001^{a}	0.013 ± 0.001^{a}	0.011 ± 0.001^{a}	0.010 ± 0.001^{a}	0.012 ± 0.001^{a}
Mn	0.019 ± 0.001^{a}	0.014 ± 0.001^{b}	0.015 ± 0.001^{b}	0.015 ± 0.001^{b}	0.014 ± 0.001^{b}
Fe	0.027 ± 0.001^{a}	0.024 ± 0.001^{b}	0.027 ± 0.001^{a}	0.023 ± 0.001^{b}	0.023 ± 0.001^{b}
Ni	0.027 ± 0.001^{a}	0.030 ± 0.001^{b}	0.030 ± 0.001^{b}	0.029 ± 0.001^{b}	0.027 ± 0.001^{a}
Cu	0.027 ± 0.001^{a}	0.032 ± 0.002^{b}	0.027 ± 0.001^{a}	0.029 ± 0.001^{b}	0.030 ± 0.001^{b}
Zn	0.0063 ± 0.0003^{a}	0.0071 ± 0.0004^{b}	0.0062 ± 0.0003^{a}	0.0063 ± 0.0003^{a}	0.0071 ± 0.0004^{b}
Ga	0.0022 ± 0.0001^{a}	0.0022 ± 0.0001^{a}	0.0012 ± 0.0001^{b}	0.0023 ± 0.0001^{a}	0.0020 ± 0.0001^{a}
Sn	0.0011 ± 0.0001^{a}	0.0011 ± 0.0001^{a}	0.0011 ± 0.0001^{a}	0.0012 ± 0.0001^{a}	0.0011 ± 0.0001^{a}
Sr	0.0082 ± 0.0004^{a}	0.0089 ± 0.0004^{b}	0.0099 ± 0.0005^{c}	0.0081 ± 0.0004^{a}	0.0082 ± 0.0004^{a}
I	0.0023 ± 0.0001^{a}	0.0021 ± 0.0001^{a}	0.0021 ± 0.0001^{a}	0.0022 ± 0.0001^{a}	0.0023 ± 0.0001^{a}
Se	0.0009 ± 0.0001^{a}	0.0010 ± 0.0001^{a}	0.0010 ± 0.0001^{a}	0.0011 ± 0.0001^{a}	0.0010 ± 0.0001^{a}
Al	0.133 ± 0.006^{a}	0.156 ± 0.008^{b}	0.143 ± 0.007^{c}	0.156 ± 0.008^{b}	0.145 ± 0.007^{c}
Si	0.053 ± 0.003^{a}	0.056 ± 0.003^{a}	0.053 ± 0.003^{a}	0.055 ± 0.003^{a}	0.054 ± 0.003^{a}
P	0.246 ± 0.012^{a}	0.256 ± 0.013^{a}	0.239 ± 0.012^{a}	0.253 ± 0.013^{a}	0.246 ± 0.012^{a}
S	0.050 ± 0.003^{a}	0.044 ± 0.002^{b}	0.043 ± 0.002^{b}	0.045 ± 0.002^{b}	0.044 ± 0.002^{b}
Ba	0.042 ± 0.002^{a}	0.045 ± 0.002^{a}	0.040 ± 0.002^{a}	0.041 ± 0.002^{a}	0.041 ± 0.002^{a}
Pb	0.0042 ± 0.0002^{a}	0.0049 ± 0.0002^{b}	0.0043 ± 0.0002^{a}	0.0031 ± 0.0002^{c}	0.0022 ± 0.0001^{d}
Mo	0.0010 ± 0.0001^{c}	0.0011 ± 0.0001^{c}	0.0011 ± 0.0001^{c}	0.0010 ± 0.0001^{c}	0.0011 ± 0.0001^{c}
Nb	0.0139 ± 0.0007^{a}	0.0142 ± 0.0007^{a}	0.0137 ± 0.0007^{a}	0.0138 ± 0.0007^{a}	0.0142 ± 0.0007^{a}
Rb	0.0042 ± 0.0002^{a}	0.0033 ± 0.0002^{b}	0.0031 ± 0.0002^{b}	0.0041 ± 0.0002^{a}	0.0030 ± 0.0002^{b}

Note: different letters show a significant difference between the groups within a line (with a significance $P < 0.05$), determined by the Tukey test.

This discernible interrelation between the dimensions of the fruit's pulp and its seeds is evident. It is deduced that fruits with lower pulp weight inherently tend to possess shorter and wider seeds. In contrast, fruits characterized by higher pulp weights tend to have longer and comparatively narrower seeds. The emergence of this correlation underscores the distinctiveness of vegetative attributes among the studied plant varieties. This divergence is significantly influenced by factors encompassing distribution range, cultivation conditions, and even the effects of hybridization and mutation within the cultivated species of the plant genera (Table 2). The consumption patterns of persimmons predominantly encompass raw consumption, followed by less frequent utilization in various processed forms, such as marmalade, jam, jelly, and baked goods. The roasted form of Oriental persimmon seeds is embraced as an alternative to coffee. Remarkably, the utilization of raw persimmons and its derivative products assumes dietary significance, attributing a positive impact on cardiovascular and digestive systems while enriching the body with essential micronutrients.

As indicated in Table 2, the examined persimmon varieties demonstrate a low sucrose content, rendering this fruit suitable for dietary consumption. The diverse levels of titratable acids denote varying metabolic pathways engaged in the synthesis of biocomponents, potentially influencing the fruit's limited shelf life. Disparities in the accumulation of iodine were discerned among the different Oriental persimmon varieties, accentuating the status of Balakan district as an iodine-deficient area (Table 3). Within the context of this investigation, it was ascertained that *D. kaki*, cultivated in the Shaki-Zagatala region, exhibited a discernible iodine content of 0.002%. The inclusion of Oriental persimmon fruit and its derived products is underscored by the substantial iodine presence within these fruits, thus making them nutritionally relevant. The plant *D. kaki* showcases a widespread distribution throughout the Shaki-Zagatala region, encompassing both domestic settings and agricultural premises. It is conceivable that a promising avenue for future research endeavours lies in the creation of a comprehensive map illustrating the spatial distribution of iodine concentrations across Azerbaijan. Currently available studies have primarily focused on iodine concentrations in subterranean aquifers, revealing ranges of 0.49–146.4 µg/L, as well as surface water sources, which indicate concentrations within the span of 0.49–55.78 µg/L. Furthermore, within the purview of this study, a careful examination brought to light the presence of grade I goitre in three adolescents, constituting 1.5% of the examined cohort, ascertained through both palpation and ultrasound assessment. Encouragingly, no instances of grade II goitre were identified, with gender being a non-contributory factor in this regard. Notably, nodular goitre was found in a substantial subset of students, totalling 20.5%, among whom 26 individuals manifested discernible alterations in glandular dimensions. Efficacious evaluation of iodine insufficiency was undertaken by analyzing urine iodine levels (Table 3). The ensuing analysis revealed that acute deficiency prevailed in 12.2% of cases, while mild deficiency was observed in 21.2% of instances. Conversely, 49.7% of the participants exhibited iodine levels within the expected range, and 16.9% evinced an excess of iodine.

Table 2
Organic matter content (%) of *D. kaki* varieties (x ± SD, n = 6)

Biocomponents	Balakan	Qakh	Zagatala	Gabala	Shaki
Sugar	0.081 ± 0.004[a]	0.067 ± 0.014[b]	0.093 ± 0.002[c]	0.082 ± 0.002[a]	0.067 ± 0.004[b]
Titratable acids	0.068 ± 0.003[a]	0.075 ± 0.004[b]	0.085 ± 0.005[c]	0.075 ± 0.004[b]	0.069 ± 0.005[ab]
Tannins	0.075 ± 0.007[ab]	0.083 ± 0.002[b]	0.069 ± 0.003[a]	0.071 ± 0.004[a]	0.067 ± 0.006[a]
Pectinaceous substances	0.082 ± 0.004[a]	0.083 ± 0.002[a]	0.080 ± 0.002[a]	0.068 ± 0.001[b]	0.074 ± 0.002[c]
Average for the region	0.076 ± 0.014[a]	0.075 ± 0.009[a]	0.081 ± 0.004[a]	0.073 ± 0.001[a]	0.068 ± 0.022[a]

Note: see Table 1.

Table 3
The urine iodine levels observed in participants of the experiment who consumed *D. kaki* sourced from various districts

Iodine content in urine	Balakan	Gabala	Quba	Shaki	Total
Acute deficiency <70 μg/L	2 (2.4%)	10 (15.4%)	12 (21.1%)	1 (1.5%)	25 (9.2%)
Mild deficiency 70–99 μg/L	20 (24.4%)	7 (10.8%)	24 (42.1%)	9 (13.4%)	60 (22.2%)
Norm 100–300 μg/L	34 (41.5%)	34 (52.3%)	17 (29.8%)	43 (64.2%)	128 (47.2%)
Excess ≥300 μg/L	26 (31.7%)	14 (21.5%)	4 (7.0%)	14 (20.9%)	58 (21.4%)
Total	82 (100.0%)	65 (100.0%)	57 (100.0%)	67 (100.0%)	271 (100.0%)

A comprehensive appraisal of iodine deficiency, carried out as part of this study, unveiled a prevalence of normal iodine levels in a significant portion, accounting for 70% of the respondents. Of particular significance, within the confines of Shaki, this figure was notably lower, standing at 9.9%. Consequently, the meticulous investigation into iodine sufficiency is distinctly pivotal. The intricate interplay of sugars, titratable acids, pectin and tannins, vitamin C, and both micro- and macronutrients within Oriental persimmons is demonstrably influenced by the nuanced conditions in which the plants are cultivated, as well as the prevailing storage environments. In addition, this inquiry embarked upon a comprehensive assessment of the impact imparted by rapid freezing at –30 °C and protracted cold storage at –18 °C, sustained over a six-month period, on the biochemical composition of Oriental persimmon fruits. The detailed findings and outcomes of this evaluation are presented in detail in Table 4.

Table 4
Micronutrient content in fruits of fresh *D. kaki*, during low-temperature treatment (–30 °C) and long-term cold storage (–18 °C) (x ± SD, n = 6)

Micronutrients	Indicators		
	fresh persimmon	low-temperature treatment (-30 °C)	long-term cold storage (-18 °C)
Sugar, %	18.24 ± 0.91[a]	18.31 ± 0.92[a]	17.74 ± 0.89[a]
Titratable acids, g/dm³	0.79 ± 0.04[a]	0.78 ± 0.04[a]	0.77 ± 0.04[a]
Tannins, %	1.35 ± 0.07[a]	1.30 ± 0.07[a]	1.27 ± 0.06[a]
Pectin substances, %	1.56 ± 0.08[a]	1.44 ± 0.07[b]	1.48 ± 0.07[ab]
Vitamin C, mg%	12.10 ± 0.61[a]	10.92 ± 0.55[b]	9.20 ± 0.46[c]

Note: see Table 1.

The results presented in Table 4 indicate that the sugar fraction values decreased during prolonged cold storage. It could be due to the action of hydrolytic and transport enzymes not inhibited by cold stress, the damaging effect of low temperatures on cell walls and the loss of micronutrients during thawing. Titratable acid values decreased due to dissociation between oxidation and phosphorylation reactions, which did not stop after cold treatment. The decrease in pectin substances is explained by the transition of insoluble protopectins to a soluble state after the destructive changes caused by thawing. In addition, the content of macronutrients in fruits of Oriental persimmon under low-temperature treatment (-30 °C) and long-term cold storage (-18 °C) was analysed (Table 5).

Table 5
Macronutrients in fruits of *D. kaki* under low-temperature treatment (–30 °C) and long-term cold storage (–18 °C) (mg%, x ± SD, n = 6)

Macronutrient content	Low-temperature (–30 °C)	Long-term cold storage (–18 °C)
K	222.8 ± 11.1	222.3 ± 11.1
Na	17.6 ± 0.9	17.4 ± 0.9
Ca	114.4 ± 5.7	114.0 ± 5.7
Mg	61.3 ± 3.1	61.0 ± 3.1
P	46.7 ± 2.3	46.1 ± 2.3

Note: significant differences between the cells in the table within a line were not found (P < 0.05).

As can be observed from the results presented in Table 5, low-temperature treatment provides high preservation of potassium, calcium, sodium, magnesium and phosphorus. Indicators of trace elements such as iron, zinc and iodine decreased to a small extent. Thus, the method of rapid freezing and 6-month storage is an effective method of preserving the food quality of Oriental persimmon (Table 6).

Table 6
Indicators of trace elements (mg%) in fruits of *D. kaki* under low temperature treatment (–30 °C) and long-term cold storage (–18 °C) (x ± SD, n = 6)

Micronutrient content	Low temperature (–30 °C)	Long-term cold storage (–18 °C)
Iron	728.5 ± 36.4	725.9 ± 36.3
Zinc	82.8 ± 4.1	81.2 ± 4.1
Iodine	1.88 ± 0.09	1.85 ± 0.09

Note: see Table 5.

Discussion

Since the late 19th – early 20th century, scientists have been conducting research contributing to the formation of ideas about the pathophysiology of iodine deficiency diseases. The formation of thyroid function disorders is due to the lack of iodine intake in the diet. The compensatory response of this organ is to increase its size in order to obtain as much iodine as possible (Lisco et al., 2023). An experienced physician can use palpation to examine neoplasms in the thyroid gland. That is why one of the informative diagnostic methods used in the study for this article was the palpation method. Iodine deficiency disease is a common problem not only in Azerbaijan, but also in the United States, Switzerland, Sweden, Finland, Norway, Austria, and the United Kingdom (Asmy & Fitri, 2021). Reputable international organizations dedicated to the elimination and prevention of iodine deficiency diseases have been active in these countries for many years. The success of these programs is evidenced by the minimal incidence of endemic goitre in economically developed countries (Syvolap & Hura, 2019). One common measure to prevent iodine deficiency is the use of foods with iodised dietary salt. However, this measure cannot fully meet the body's need for iodine. Krela-Kazmierczak et al. (2021) explain this by the fact that the thyroid gland requires an additional trace element involved in iodine assimilation – selenium (Se). Severe forms of iodine deficiency diseases are common in regions with high deficiency of selenium and iodine. Thus, mass iodine prophylaxis with the use of vitamin supplements, pharmaceutical preparations, and especially foodstuffs rich in iodine are a priority that will lead to improvement of public health.

Functional nutrition, a concept studied in detail by Bayramov et al. (2022), consists in eating foods that favourably affect the human body. It has been proved that this is the key to longevity, stress resistance, normal development and improving the quality of life of the population of the planet. Within this concept, a functional component of a healthy person's diet (depending on the age group) is a bioactive food supplement that reduces the risk of disease through the micronutrients it contains, which are involved in the optimal absorption of iodine. Functional diets are based on eating foods that have been technologically processed and enriched with nutrients and phytocomponents, such as seafood, eggs, persimmon, seaweed, potatoes, dairy products and cereals. Another important factor in functional nutrition is the consumption of foods with reduced amounts of harmful components for human health. It has been proven that optimal iodine absorption requires the optimal content of micronutrients presented in Table 1. The prophylactic measure in the concept of functional nutrition is the intake of supplements. The biotransformed form of such supplements is successfully absorbed by the human body, because the process of iodine release from this food supplement occurs after the breakdown of milk casein by liver enzymes, triggered by the thyroid when there is insufficient iodine in the body (Dominguez et al., 2020b). The research of Bakhshalieva et al. (2023) proved that at an altitude of 600–800 m above sea level, the content of vitamin C and sugars in the fruit of Oriental persimmon is lower than in those varieties of Oriental persimmon plants that grow at an altitude of 200–300 m above sea level.

Bayramov et al. (2022) conducted a study on the benefits of non-traditional herbal supplements as iodine-containing foods. The nutritional and biological value of spices (ginger, turmeric, dried persimmon, and watercress seeds), amino acids, and the content of major minerals, especially iodine, were studied. The biological value of these spices in the composition of bakery, pasta and flour confectionery products was also tested, together with losses of iodine in the production process in the finished product and during storage. The optimal proportions of the introduction of spices (5–42 μg/100 g of product) in the process of manufacturing the product were calculated. This experiment proved that the introduction of iodine-enriched spices in food formulation is the creation of additional sources of iodine (Dominguez et al., 2020b). The iodine content reaches 15–20 μg/100 g when turmeric and ginger are added to prepared gingerbread and cookies. In addition, one of the biological properties of these spices is an inhibitory effect on microbiological processes, which increases the shelf life of the product enriched with iodine. In this research, technological requirements were developed for the use of spices enriched with iodine in the recipe for the preparation of bakery and pasta products. This example of an innovative approach in the use of non-traditional iodine-containing herbal supplements can become one of the components of the concept of functional nutrition. A study by Dominguez et al. (2020b) shows the awareness of subjects about the consequences of iodine deficiency. When asked about awareness of the consequences of iodine deficiency in the human body, 43.2% answered "thyroid diseases", 13.6% – "mental retardation", 11.7% – "metabolic disorders", 0.3% – "fatigue", 8.7% – "other diseases", 5.8% – "immunodeficiency", 1.8% – "diabetes mellitus". To the question "Is there a problem of iodine deficiency": 59.7% of respondents answered "yes", 6.1% – "no", and 34.2% – "difficult to answer". To the question "Reasons why people neglect the prevention of iodine deficiency": 27.5% named the reason "lack of available information about iodine-containing products"; 44.9% – "low financial situation, which does not allow people to purchase iodine-containing products or preparations"; 14.8% – "do not realise the consequences of iodine deficiency for the body"; 10.8% – "difficult to answer." To the question "What foods should be consumed to prevent iodine deficiency?": 25.8% answered "iodised salt", 23.8% – "seaweed", 19.4% – "seafood", 17.1% – "products, containing iodine", 13.9% – "drugs". To the question "What foods enriched with iodine do you know?": 24.7% of respondents answered "seaweed", 26.1% – "seafood", 2.2% – "persimmon", 1.2% – "nuts, water, and bread", 14.8% – "iodised salt", 30.9% – "difficult to answer". To the question "Is the use of iodised salt enough to prevent iodine deficiency?": 27.5% answered "yes", 57.2% – "no", 34.6% – refrained from answering. To the question "Is it necessary to provide extended information on the content of iodine in the product on the package?": 26.1% answered "yes", 42.1% – "no", 31.8% – "difficult to answer". Only 46% of those surveyed were taking any measures to prevent iodine deficiency. As can be seen from this research, the results of which are presented, education about the importance of iodine in the human body and the ways to obtain it is an important part of prevention of iodine deficiency and thyroid disease. Until 10 years ago, the most common way to prevent iodine deficiency was to eat iodised salt. However, over time, people began to note the irrationality of using this method for a number of reasons. Firstly, the shelf life of such salt does not exceed 6 months; secondly, it must be added to already cooked dishes, since its mineral properties are lost under the influence of heat processing during cooking. And third, in countries such as Switzerland and the United States, the excessive use of iodised salt in food has led to the development of thyrotoxicosis due to a lack of proper education.

Various measurement methods recommended by the World Health Organization are used to assess iodine deficiency. Among them, palpation of the thyroid gland is the widely used and preferred method in epidemiological studies (Syvolap & Hura, 2019; Azizov et al., 2020). According to World Health Organization and United Nations Children's Fund criteria, school children in Quba and Gabala had 9–11 times more cases of acute iodine deficiency than school children in Shaki. Thus, the measure of iodine deficiency prevention with iodised salt has lost relevance due to the ineffectiveness of this method in controlling thyroid disease. However, in Great Britain, the USA, Switzerland, Austria, Sweden, Norway and Finland, a unique product recommended for prevention of iodine deficiency, which eliminates the risk of iodine overdose, is being developed and created. This product acts as a dietary supplement, which includes iodine synthesis with casein protein. This compound is broken down only under the action of liver enzymes in the case of iodine deficiency in the body naturally. At that, when the human body produces a sufficient amount of iodine, the decomposition of the compound does not occur. Given this feature of the preparation, Dominguez et al. (2020c) called it "smart iodine".

Direito et al. (2021) presented scientific data on the role of iodine and selenium deficiency in the functioning of the thyroid gland, namely, in the development of thyroid disorders. It has been proven that the use of selenium (75 mg/day) and iodine (150 mg/day) helps reduce the severity of pathological processes in the thyroid gland. According to the cartographic data of the World Health Organization, which were analysed for this study, throughout Europe, there is a mild or moderate iodine deficiency in people of working age, and, accordingly, of reproductive age. Therefore, monitoring the functional state of the thyroid gland is one of the conditions for the prevention of microelement deficiency. In this study, the determination of the level of thyroglobulin in the blood is considered a reliable method for determining the individual status of iodine in the human body. This protein is concentrated only in the tissues of the thyroid gland and is a carrier of iodine. The concentration of thyroglobulin was determined by isolating a protein from human blood serum, the indicator of which was less than 10 ng/mL, which indicates the norm, since the sharp increase in this indicator signifies the development of goitre. This method of determining iodine deficiency shortens the study procedure, since the method that was used in this study requires a 24-hour monitoring to assess the iodine status of the subject and at least 10 urine samples. Thus, the marker for determining the level of thyroglobulin concentration is the most sensitive and effective.

One of the factors in the development of thyropathies is a decrease in the level of selenium in the blood serum. This fact is recognised by experts from Greece, Turkey, Egypt, Brazil, Sri Lanka, China, and Japan. Conducted studies indicate that selenium deficiency leads to such diseases of the thyroid gland as an increase in volume, changes in echogenicity, the presence of nodular or colloid formations, and lymphoid infiltration. Moreover, selenium contributes to the effective course of the process of antioxidant protection of thyrocytes and the activation of thyroid hormones, regulates the processes of apoptosis. The study by Direito et al. (2021) proved that even with sufficient intake of iodine in the human body, a lack of selenium leads to necrosis and fibrosis of the thyroid gland. Thus, the interaction of iodine and selenium is involved in the metabolism of thyroid hormones, and therefore adding iodine to the diet is not enough to correct the problem of iodine deficiency, since selenium is involved in the synthesis of enzymes necessary for the production of thyroid hormones.

According to a study conducted by the European Organization for the Promotion and Prevention of Cancer, in 10 European countries (502 subjects took part in the experiment), selenium levels in the blood range from 63 to 100 µg/L, which indicates a moderate selenium deficiency. In this regard, monitoring the content of selenium in the blood is an important component in the treatment and prevention of thyroid disorders in iodine-deficient regions.

As it can be seen from the analysis of scientific and methodological literature, modern medicine needs to develop new methods, ways of treatment and prevention of iodine deficiency in humans. Since there have been studies stating that humans can obtain iodine from three sources – water, air and food (the body itself does not produce this microelement) (Dominguez et al., 2020b) – it is necessary to develop the most effective ways of iodine replenishment. Ryabova (2013) considers one of these ways to be eating food enriched with iodine, in which iodine is accumulated naturally. According to the degree of iodine accumulation, the persimmon fruit is the most iodine-containing product. In her study, the researcher estimated the amount of iodine in persimmon after heat treatment. Since this fruit is a perishable product, researchers are faced with the task of developing storage methods that preserve the useful nutrients. For example, persimmon fruits of Hachia variety preserved iodine in the amount of 2.11 µg/100 g after freezing, Hiakume variety contained 2.04 µg/100 g, and Zenji Maru variety contained 1.97 µg/100 g. And when making jam, marmalade or candied fruits, the highest combination of iodine is retained in candied fruits at 1.56 µg/100 g. This research indicates that the natural conditions in which persimmon grows in Abkhazia (subtropical podzolic soils), contribute to the accumulation of the necessary microelements, so that this fruit can be used in the formulation of functional food products or as a source of natural iodine that is absorbed naturally.

Conclusions

Many countries are studying iodine deficiency, since iodine plays a key role in human health and lack of this micronutrient can lead to serious diseases, especially among people living in iodine-deficient regions. In choosing an effective way to restore and maintain the balance of trace elements in the human body, it is necessary to focus on the daily intake of food not only in terms of its energy value, but also in terms of the complex of necessary nutrients that have a regulating and normalizing effect on certain organs and their functions. As shown in the research for this article, the studied varieties of persimmon can be successfully used in functional nutrition as a product with a natural source of iodine, nutrients, vitamins and trace elements. It was found that among the trace elements contained in persimmon fruits, the amount of vanadium (V), tin (Sn), iodine (I), selenium (Se), zinc (Sn), molybdenum (Mo) did not change and remained stable in all districts. The content of iodine (I) in fruits of *D. kaki* widely spread in Shaki-Zagatala region did not change by regions and amounted to 0.002%.

In Shaki, acute deficiency of iodine (I) was 1.5%, moderate deficiency occurred in 13.4% of cases, a normal amount was observed in 64.2%, and excess – in 20.9%. Shaki-Zagatala region is an iodine deficiency endemic region and belongs to the zone of moderate iodine deficiency (I). Oriental persimmon is widespread in this region. Therefore, to eliminate this problem, residents of the region are recommended, among other measures, to use food made from the fruits of *D. kaki*, which is rich in iodine and other micronutrients. The amount of iodine in the soil, on which the plant grows, depends on the amount of iodine absorbed by the plant. Therefore, the prospect of further studies may lie in calculation of iodine in the composition of fertilizers used for crop cultivation.

The authors declare there is no conflict of interest in this study.

Informed consent was obtained from all participants or their parents/guardians.

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