NUTRACEUTICAL ASPECTS OF STUDYING ZUCCHINI AND ZUCCHINI FRUITS

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Introduction

Nutrition forms the foundation of human life and is one of the key factors in reducing the risk of diet-related diseases. It promotes active longevity and plays a role in developing and utilizing the body's adaptive potential. Poor nutrition is linked to the spread of conditions like atherosclerosis, hypertension, hyperlipoproteinemia, type II diabetes, obesity, osteoporosis, gout, cholelithiasis, and iron deficiency anemia, among others [10].

A feature of the current phase of the pharmaceutical industry's development is the creation of a wide variety of new dietary supplements enriched with biologically active substances that can positively influence physiological processes in the body. When adding essential nutritional factors to the diet, plant-based products play a significant role [10]. One of the unconventional sources of biologically active compounds is the fruit of the zucchini.

Zucchini (Cucurbita pepo L. var. giromontina Alef.) and zucchini (Cucurbita pepo L. var. cylindrica Paris) are annual herbaceous shrub plants of the pumpkin family (Cucurbitaceae), subspecies of the hard-skinned or common pumpkin (Cucurbita pepo L.). The fruit of the zucchini is a multi-seeded false berry. Plant varieties differ in the shape of the fruit (cylindrical, oval-cylindrical, pear-shaped), the surface of the peel (smooth, tuberous, ribbed), the peel color (light green, greenish-yellow), and the pulp (delicate in texture, cream or orange). There is no pulp cavity. Since tsukini is one of the varieties of zucchini, their fruits only differ in shape (more elongated), skin thickness (thinner), and color (green, dark green, almost black, yellow-green, or yellow), they have medium-density pulp, tender with a fresh, specific taste [9]. In Ukraine, zucchini is grown annually on 24-32 thousand hectares, with a gross harvest of 450-630 thousand tons. It is mainly cultivated on private farms. The quality of raw materials is regulated by DSTU 318-91 "Fresh zucchini. Technical conditions," which specifies that 8-12-day-old ovaries with unformed seeds, up to 25 cm in length and 8 cm in diameter, are used. It is known that the fruits of zucchini and zucchini contain phenolic compounds, carbohydrates (polysaccharides, fiber), vitamins (carotenoids, C, B group, K, PP), and minerals (potassium, phosphorus, calcium). These components confer antioxidant, hypoglycemic, anabolic, cytotoxic, immunomodulatory, diuretic, and choleretic effects, among others [9]. Zucchini seeds contain fatty oil, which, similar to pumpkin seed oil, has immunological, antiviral, antiparasitic, antifungal, anti-inflammatory, cardiovascular, and hepatoprotective effects, and positively influences lipid metabolism [2]. Zucchini is recommended for children, especially infants, the elderly, and patients with digestive and metabolic issues. They are used in therapeutic and dietary nutrition for inflammatory bowel conditions, obesity, gout, liver and kidney diseases, among others [2, 9].

The purpose of this work is to study the chemical composition (fatty and amino acids, macro- and microelements) of the fruits of the Aspirant and Zolotinka zucchini varieties to determine their potential as sources of macro- and micronutrients.

Materials and methods

The fruits of Aspirant zucchini and Zolotinka zucchini were used as research objects, which were dried convectively at a temperature of 45-50 °C to a state of air dryness, crushed to a particle size of no more than 1-3 mm. As a result, light cream-colored powders were obtained, and the qualitative composition and quantitative content of fatty acids were determined by gas chromatography-mass spectrometry (GC/MS), amino acids by ion-exchange liquid chromatography, and mineral compounds by atomic emission spectroscopy (NPP).

The analysis of fatty acid composition in raw materials was performed using the GC/MS method according to reference [4]. For this, fatty acids were first converted into their methyl esters. Approximately 0.5 g of the plant raw material sample was placed in a glass vial, to which 3.3 mL of the reaction mixture (methanol : toluene: sulfuric acid in a 44:20:2 v/v ratio) and 1.7 mL of an internal standard solution (undecanoic acid in heptane) were added. The sample was kept at 80 °C for 2 hours, then cooled and centrifuged for 10 minutes at 5000 rpm. From the upper heptane phase, 0.5 mL was taken, containing fatty acid methyl esters. The qualitative composition of the samples was analyzed on a Hewlett-Packard HP-6890 chromatography-mass spectrometer with an HP-5972 mass-selective detector. Separation of mixture components was performed using an HP-5MS capillary column (non-polar, 30 m long, with an inner diameter of 0.25 mm and a stationary phase thickness of 0.25 μm, consisting of 5% biphenyl), with a carrier gas flow rate of 1 cm^3/min, and an HP-INNOWAX polar column (polyethylene glycol) measuring 30 m × 0.25 mm × 0.25 μm, with helium as the carrier gas in temperature programming mode. The column was held at 60 °C for 5 minutes, then heated at 5 °C/min to 280 °C and maintained at this temperature for 10 minutes. The injected sample volume was 1 μL. The evaporator temperature was 250 °C, and the detector temperature was 280 °C. Electron ionization was used at 70 eV, with scanning across the m/z range from 40 to 450.

The qualitative composition of fatty acids was determined by comparing their retention times with those of authentic samples and analyzing full mass spectra against standard spectra of pure substances from the NIST02 and Willey 138k electronic libraries. The analysis of amino acids was performed using an automatic AAA amino acid analyzer T–339M, following the method proposed by V.G. Stein and S. Moore in a

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modern modification [5]. A sample of plant material weighing 100 mg was placed at the bottom of a refractory glass tube. To the tube, 0.5 ml of purified water and 0.5 ml of concentrated hydrochloric acid were added. The tube was cooled in a mixture of dry ice and dimethyl ketone. After cooling, air was evacuated from the tube with a vacuum pump to prevent amino acid oxidation. Proteins were hydrolyzed with hydrochloric acid for 24 hours at a constant temperature of +106 °C in a thermostat. Upon completion of hydrolysis, the tube was opened and cooled to room temperature. The contents were quantitatively transferred to a glass container and placed in a vacuum desiccator over granular sodium hydroxide. Air was then removed using a vacuum pump. After drying, 3–4 ml of deionized water was added, and the drying process was repeated. The samples were dissolved in 0.3–N lithium citrate buffer at pH 2.2 and loaded onto the ion exchange column of the amino acid analyzer, filled with Ostion LGANB cationite. Amino acids in the eluates were detected using the ninhydrin method, which produces colored complexes with a maximum absorption at 560 nm, except for proline and oxyproline, which absorb maximally at 440 nm. The amino acid composition was identified by comparing the chromatograms of standard and sample mixtures [5].

The number of amino acid micromoles in the test sample was calculated using the formula (X, mg):

$$X = \frac{S_{on} \cdot K \cdot Mv}{S_{st}},$$

Where:
Son is the peak area of the amino acid in the test sample,
Sst is the peak area of an amino acid in a standard mixture.
K is a factor that accounts for the mass and dilution of the sample, and
Mv is the molecular weight of an amino acid.

The study of elemental composition using the NPP method with photographic registration was conducted on the DFS-8 spectrophotometer (Asma-Pribor, Ukraine) with a diffraction grating of 600 lines/mm and a three-lens slit illumination system, as well as on the iCE 3500 spectrometer (Thermo Scientific, USA) according to the method [6]. The samples were evaporated from the craters of graphite electrodes in an AC arc discharge. The spectra obtained were recorded on PFS-02 photographic plates using the MF-1 microphotometer (Asma-Pribor, Ukraine). Experimental conditions included an arc current of 16A (source of excitation for spectra of the IVS-28 type), an exposure time of 60 seconds, an ignition temperature of 60°C, an ignition pulse frequency of 100 bits/sec, an analytical gap of 2 mm, and a spectrograph slit width of 0.015 mm. Spectra lines were registered within the range of 230–330 nm. The photographic plates were developed and dried, then the lines (in nm) of the sample spectra, calibration standards, and the background near them were photometrized. Subsequently, a calibration graph was plotted, with coordinates representing the average difference between the line and background blackening as a function of the logarithm of the element content in the calibration standards. This allowed calculation of the percentage of the element in the ash and its quantitative content in the studied raw materials using the formula (X, mg/100 g).

$$X = \frac{a \cdot m}{M},$$

where:
m is the mass of ash (g);
M is the mass of raw materials (g);
a is the content of the element in the ash (%).

The analysis took into account the lower limits of the content of impurities, which were: for Cu – $1 \cdot 10^{-4}$; Co, Cr, Mo, Mn, V – $2 \cdot 10^{-4}$; Ag, Ga, Ge, Ni, Pb, Sn, Ti – $5 \cdot 10^{-4}$; Sr, Zn – $1 \cdot 10^{-2}$ %.

Statistical processing of experimental data was carried out in accordance with the requirements of DFU 2.0 [15] using Microsoft Excel 2016.

Results and discussion

The results of determining the qualitative composition and quantitative content of fatty acids in the fruits of zucchini of the Aspirant variety and zucchini of the Zolotinka variety are given in Table. 1.

Table 1. **Fatty acid content in zucchini and zucchini**

Fatty acid name	Quantitative content of fatty acids, mg/100 mg	
	fruits of zucchini varieties Aspirant	Zucchini fruits of the Zolotinka variety
Myristinova	2,65±0,13	2,79±0,14
Myristolein*	0,69±0,03	0,61±0,03
Palmitic	20,68±1,03	22,06±1,10
Palmitoleic*	0,78±0,04	1,32±0,07
Stearic	5,60±0,28	6,44±0,32
Oleic*	6,56±0,33	10,64±0,53
Linoleum* (ω-6)	18,63±0,93	16,73±0,84
Linolenic* (ω-3)	38,24±1,91	38,84±1,94
Arachidonna*	2,70±0,14	2,72±0,14
Sum of saturated fatty acids	28,92±1,45	31,29±1,56
Sum of unsaturated fatty acids	67,60±3,38	70,84±3,54

Note: * – unsaturated fatty acids

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According to the results of the study, presented in Table 1, the fruits of zucchini contain and have been analyzed for 9 fatty acids, of which 6 are unsaturated and 3 are saturated. Their fatty acid profile was consistent in composition. In terms of quantity, the fatty acids in zucchini fruits were primarily dominated. The fatty acids of the studied raw materials were mostly made up of unsaturated fatty acids, with their content nearly twice as high as saturated ones (70.03% and 69.36% versus 29.97% and 30.64%, respectively). A large portion of the total fatty acid content was contributed by unsaturated acids of the C-18 series—oleic, linoleic, and linolenic. Linolenic acid was the most abundant in both studied fruits, accounting for more than 38%, while linoleic acid was present at nearly half that amount, between 16-19%. It is known that insufficient intake of linoleic and linolenic acids through food causes dysregulation of metabolic processes in cell membranes, as well as in energy production within the mitochondria of the human body [1, 3, 7, 13].

The ratio of linoleic (-6) and linolenic (-3) acids in the raw materials studied was 1:2. Their balance is known to be a key factor in brain development and reducing the risk of coronary heart disease, arrhythmias, hypertension, cancer, diabetes, arthritis, and other autoimmune and neurodegenerative diseases. Both -6 and -3 fatty acids influence gene expression. The levels of -6 and -3 fatty acids in the blood are determined by both endogenous metabolism and dietary intake, making a balanced diet essential for health and disease prevention [1, 3, 7]. It has been found that -3 acids promote anti-inflammatory effects by forming eicosanoids and specialized mediators (resolvins, protectins, and maresins), reduce lipid peroxidation, counteract hypoxia, inhibit immune cell infiltration and inflammation in autoimmune thyroiditis, improve insulin sensitivity, and reduce fat mass. Additionally, -3 acids help alleviate metabolic disorders such as metabolic-associated steatosis of the liver, intestinal dysbiosis, and renal dysfunction. In cardiovascular diseases, they are recommended as secondary prophylaxis for patients at risk of coronary heart disease [1, 3, 7, 13].

Among saturated fatty acids, palmitic acid was the most prevalent, with its content in the studied raw materials exceeding 21%. Stearic and myristic acids were found in small amounts. The results for the qualitative composition and quantitative content of amino acids in the fruits of Aspirant zucchini and Zolotinka zucchini are presented in Table 2.

Table 2. Amino acid content in zucchini and zucchini

Amino acid name	Amino acid content in terms of absolutely dry raw materials, mg/100 mg	
	fruits of zucchini varieties Aspirant	Zucchini fruits of the Zolotinka variety
Glycine	0,82±0,04	1,27±0,06
Alanine	0,78±0,04	1,35±0,07
Valin*	0,38±0,02	0,73±0,04
Leucine*	0,93±0,05	1,40±0,07
Isoleucine*	0,35±0,02	0,49±0,02
Methionine*	0,16±0,01	0,32±0,02
Serine	0,62±0,03	0,93±0,05
Threonine*	0,47±0,02	0,67±0,03
Cystine	0,35±0,02	0,18±0,01
Aspartic acid	1,45±0,07	2,15±0,11
Glutamic acid	2,59±0,13	3,68±0,18
γ-Aminobutyric acid	0,22±0,01	0,61±0,03
Arginine	0,70±0,04	0,99±0,05
Lysine*	0,73±0,04	1,17±0,06
Tyrosine	0,39±0,02	0,55±0,03
Phenylalanine*	0,75±0,04	0,93±0,05
Histidine	0,23±0,01	0,35±0,02
Proline	0,63±0,03	0,92±0,05
Sum of essential amino acids	3,79±0,19	5,70±0,29
Sum of essential amino acids	8,27±0,41	12,64±0,63
Sum of amino acids	12,05±0,60	18,34±0,92

Note: * – essential amino acids

According to the results of the studies shown in Table 2, 18 amino acids were identified in the fruits of zucchini. Their amino acid profile was consistent: 7 essential amino acids, 3 semi-essential, and 8 non-essential. The highest content of total amino acids was found in zucchini fruits (18.34±0.92 mg/100 mg), while the lowest was in zucchini fruits (12.05±0.60 mg/100 mg). It was observed that the raw materials contain significant amounts of glutamic and aspartic acids, leucine, arginine, glycine, lysine, and arginine; small amounts of histidine, methionine, γ-aminobutyric acid, and cystine. Essential amino acids are of particular

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importance to the human body. Their content in the raw materials accounted for nearly one-third of the total amino acids (31.42% and 31.10%, respectively). Among these, leucine, phenylalanine, lysine, valine, and threonine were most abundant, while isoleucine and methionine were present in smaller quantities. Leucine is known to promote hormone production and regulate blood sugar levels; phenylalanine positively affects nervous system functions and has antidepressant effects; lysine plays a role in forming antibodies, hormones, and enzymes, and aids in tissue repair after surgery or injury. Along with valine, lysine is involved in maintaining nitrogen balance [5, 11]. Notably, the essential amino acid levels in zucchini and zucchini fruits slightly exceed the FAO/WHO standards, indicating their high biological value [14].

The results of determining the qualitative composition and quantitative content of mineral compounds in the fruits of Aspirant zucchini and Zolotinka zucchini are shown in Table 3.

Table 3. The content of mineral compounds in zucchini and zucchini fruits

Item Name	Element content, mg/100 g	
	fruits of zucchini varieties Aspirant	Zucchini fruits of the Zolotinka variety
Potassium (K)	4692,00±234,60	9200,00±460,00
Silicon (Si)	586,50±29,33	2300,00±115,00
Calcium (Ca)	2104,50±105,23	2875,00±143,75
Magnesium (Mg)	701,50±35,08	1150,00±57,50
Sodium (Na)	140,30±7,02	86,25±4,31
Phosphorus (P)	281,75±14,09	862,50±43,13
Ferrum (Fe)	11,50±0,58	86,25±4,31
Aluminum (Al)	28,75±1,44	57,50±2,88
Zinc (Zn)	35,19±1,76	34,50±1,73
Manganese (Mn)	7,59±0,38	6,90±0,35
Strontium (Sr)	7,02±0,35	7,13±0,36
Cuprum (Cu)	0,47±0,02	0,43±0,02
Nicole (Ni)	0,46±0,02	0,29±0,01
Molybdenum (Mo)	0,23±0,01	0,43±0,02
Plumbum (Pb)	<0,03	<0,03

Note: Co, Cd, As, Hg<0.01 mg/100 g

According to the results of the studies presented in Table 3, it was found that the examined raw materials have a consistent elemental profile: they contain at least 19 elements (6 macro-, 9 micro-, and 4 ultramicroelements). In terms of mineral compound content, zucchini fruits are nearly twice as low compared to zucchini fruits (8597.77±429.89 mg/100 g and 16667.17±833.36 mg/100 g, respectively). All samples of the studied raw materials accumulated the largest quantities of the following:

• macronutrients: potassium, calcium, silicon, magnesium, and phosphorus,
• trace elements: ferrum, aluminum, zinc, and manganese.

It is known that the predominant macronutrients in the studied raw materials are involved in maintaining water-salt balance, supporting muscle and nerve function, and forming bone tissue [8, 12]. The ratio of calcium, magnesium, and potassium is quite optimal and positively influences metabolism, enhancing the health of the cardiovascular system and skeleton [8, 12].

It should be noted that zucchini fruits contain a relatively high amount of immunoessential elements Mn, Fe, and Zn, which are involved in redox processes and positively influence human immunogenesis [8, 12]. In the studied raw materials, the levels of toxic elements (Pb, Co, Cd, As, Hg) did not exceed the maximum permissible concentrations established by DFU 2.0 (Co, Pb<0.03 mg/100 g; Cd, As, Hg<0.001 mg/100 g) [15]. Therefore, it can be argued that zucchini fruits and zucchini are mainly sources of complete vegetable proteins, fatty acids, and mineral compounds. Based on this, it is possible to develop technologies for preventive treatment of various pathological processes and create biocorrective formulations.

Conclusions

1. In the fruits of zucchini of the Aspirant variety and zucchini of the Zolotinka variety, the qualitative composition and quantity of macro- and micronutrients has been established: fatty and amino acids, macro- and microelements.
2. The results obtained indicate that the studied raw materials are a source of essential polyunsaturated fatty acids, essential amino acids, macro- and immunoessential microelements, which have a preventive focus on the prevention of coronary heart disease, metabolic syndrome, and other chronic diseases..

Prospects for further research. The obtained experimental data allow for assessing the nutraceutical potential of zucchini fruits from various varieties, which opens up opportunities for their further application in pharmacy.

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Nutraceutical aspects of studying vegetable marrows and zucchini fruits

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Introduction. Nutrition forms the foundation of human life and is one of the most vital factors in reducing the risk of developing nutrition-related diseases. It helps ensure active longevity and supports the body's adaptive potential. Poor nutrition contributes to the development of diseases such as atherosclerosis, arterial hypertension, hyperlipoproteinemia, type II diabetes mellitus, obesity, osteoporosis, gout, gallstone disease, iron deficiency anemia, and others. Plant-based foods, including vegetable marrows and zucchini, play a key role in providing essential nutrients in the diet. Vegetable marrows (Cucurbita pepo L. var. giromontina Alef.) and zucchini (Cucurbita pepo L. var. cylindrica Paris) are annual herbaceous bushy plants from the Cucurbitaceae family, subspecies of the common pumpkin (Cucurbita pepo L.). The fruit of vegetable marrows and zucchini is a multi-seeded false berry. Different plant varieties vary in fruit shape, skin surface, and skin and flesh color; they lack a flesh cavity. The quality of raw materials is regulated by DSTU 318-91 "Fresh vegetable marrows. Technical conditions," which states that 8-12-day-old fruits with unformed seeds up to 25 cm long and up to 8 cm in diameter are used. It is known that vegetable marrows and zucchini fruits are sources of phenolic compounds, carbohydrates, vitamins, and minerals. These nutrients confer antioxidant, hypoglycaemic, anabolic, cytotoxic, immunomodulatory, diuretic, and choleretic effects, among others. Vegetable marrows seeds contain fatty oil, which is used similarly to pumpkin seed oil. Vegetable marrows fruits are recommended to be included in the diets of children—especially infants—elderly individuals, and those with digestive or metabolic issues. **The aim of the study** was to investigate the chemical composition (fatty acids, amino acids, macro- and microelements) of Aspirant vegetable marrows and Zolotinka zucchini fruits to determine their potential use as a source of macro- and micronutrients. **Materials and methods.** The objects of the study were vegetable marrows and zucchini fruits, which were dried by convection to an air-dry state and ground. The resulting light cream-colored powders were analyzed to determine the qualitative composition and quantitative content of fatty acids using gas chromatography-mass spectrometry, amino acids through ion-exchange liquid-column chromatography, and mineral compounds by atomic emission spectroscopy. **Results and discussion**. Nine fatty acids were identified and quantified in vegetable marrows and zucchini fruits, with six being unsaturated and three saturated. Their acid profile was consistent in composition. Quantitatively, the fatty acids in zucchini fruits were predominant. Unsaturated fatty acids primarily dominated the overall fatty acid composition of the studied raw materials, with their content nearly twice as high as that of saturated fatty acids. Linolenic acid was the most abundant in both fruits, comprising more than 38%, while linoleic acid was about half as much, at 16-19%. Among saturated fatty acids, palmitic acid was the most prevalent, making up over 21% of the raw material. **Conclusions**. The qualitative composition and quantities of macro- and micronutrients (fatty acids, amino acids, macro- and microelements) in Aspirant vegetable marrows and Zolotinka zucchini fruits have been determined. The results show that the studied raw materials are sources of essential polyunsaturated fatty acids, essential amino acids, macro- and microelements that are important for health. These nutrients have a preventive effect against coronary heart disease, metabolic syndrome, and other chronic illnesses. The experimental data obtained allow us to evaluate the nutritional potential of certain varieties of vegetable marrows and zucchini, opening up opportunities for their future use in pharmacy.

Keywords: vegetable marrows, zucchini, fruits, macro- and micronutrients

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