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RESEARCH ARTICLE

Biochemical composition of blackberry varieties cultivated under the climatic conditions of the Samarkand region

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Abstract

This study examined blackberry fruits' biochemical composition and quality at full ripeness. The content of carbohydrates, vitamins, flavonoids and amino acids was analyzed in dried fruits from the following blackberry varieties: Jumbo, Thornfree, Karaka Black, Brazos, Brzezina, Cacanska Bestrna and Chester. The results indicated that the fruits contained relatively high concentrations of the amino acids asparagine, cysteine, alanine and proline. Among the varieties, Chester exhibited the highest amino acid content (22.55 mg/g), closely followed by Thornfree (22.30 mg/g). Carbohydrate content was observed to be the highest in the Cacanska Bestrna variety (9.01 mg/g) and the lowest in the Karaka Black variety (3.37 mg/g). Vitamins (B_2, B_6, B_9, B_{12}, PP and C) and flavonoids (Hypolyethylen, Hypolyethylen 7-O-D-Gly, Rutin, Isorhamnetin and Hyperoside) were also quantified. The analysis revealed that flavonoid content was exceptionally high in the Karaka Black variety (84.116 mg/100 g) and relatively low in the Brzezina variety (35.389 mg/100 g). Regarding vitamin C content, Karaka Black recorded the highest levels (211.321 mg/100 g), whereas Jumbo exhibited the lowest levels (135.265 mg/100 g). These findings could be a valuable resource for the food processing industry and agricultural practices. They provide a basis for establishing quality standards for different blackcurrant varieties and identifying the optimal harvest period for each.

Keywords: amino acids; blackberry; content; flavonoid; thornless varieties

Introduction

In the modern era, one of the most pressing global challenges is the preservation of biodiversity and ensuring food security. Food security encompasses the ability of populations to access safe, nutritious and diverse food in sufficient quantities to support an active and healthy lifestyle at all times. In the context of globalization, providing high-quality, vitamin-rich food products has become a priority for nations worldwide. Blackberries (*Rubus caesius L.*) are cultivated across the globe, with temperate regions characterized by mild winters and extended summers offering the most favourable conditions for their growth. Major blackberry production areas include North America, Europe, Asia, South America, Central America and Africa. The cultivation of blackberries has been enhanced by the introduction of numerous high-quality, high-yielding varieties, which contribute significantly to global agricultural production (1). Worldwide commercial blackberry (*Rubus* sp.) commercial production is estimated to be approximately 154578 tons annually (2). The cultivation and breeding of blackberry varieties adapted to the specific climatic and soil conditions of the Samarkand region hold significant importance. Key factors include identifying highly productive varieties, evaluating vegetation periods, assessing branch development and the ability to form annual shoots and resisting diseases and frost. Additionally, the size of the fruits and the presence of essential biochemical components in their composition are critical considerations in determining the suitability of blackberry varieties for the region.

Approximately 400 blackberry varieties have been developed worldwide, with around 100 being extensively cultivated by gardeners, including 30-40 varieties actively grown in Russia (3). While blackberries are widely consumed fresh, they are also processed into various products such as juices, jams, purees, concentrates and desserts, increasing their commercial and nutritional significance. Fruit quality is a crucial determinant for both consumers and the food industry. Blackberries' external appearance and internal composition are primarily influenced by their primary and secondary metabolites, which are key in determining flavour, texture and shelf life. High-quality fruits command a significant market value, emphasizing optimizing their cultivation, harvesting and postharvest handling (4). Blackberry fruits typically range in weight from 3 to 12 g, depending on the variety and are best described as aggregate fruits composed of multiple drupelets, each containing a seed (2).

Sugars and organic acids are the primary water-soluble constituents in berries, substantially affecting taste, ripening and overall consumer acceptability. The balance between organic acids and sugars and their ratio shapes the fruits' sensory attributes. Furthermore, these compounds, in conjunction with secondary metabolites and aromatic compounds, enhance the organoleptic characteristics of blackberries, making them more appealing to consumers (5). Organic acids contribute to fruit flavour and inhibit microbial growth in fruit juices, thereby preserving product quality and extending shelf life. Typically, these acids are present in their free form but may also be bound to cations such as potassium and sodium.

Additionally, organic acids significantly stabilize anthocyanins, the pigments responsible for the vibrant colouration of many berries. Ascorbic acid, in particular, is vital for extending storage life due to its potent antioxidant properties (6). The acid content is typically higher in unripe fruits and decreases substantially as they mature, influencing taste and consumer preference (7). A specific Blackberry varietys' popularity and consumer acceptability are driven by its high nutritional value, distinctive flavour and aroma and numerous health benefits (8). Blackberries are a rich source of essential vitamins, minerals and bioactive compounds, mainly phenolic compounds. Recent trends indicate a growing demand for foods with elevated phenolic content (9,10), primarily due to their potent antioxidant properties (11). These fruits are notably abundant in anthocyanins, ellagitannins, flavonol glycosides and phenolic acids, all contributing to their powerful antioxidant potential (12, 14). Clinical studies suggest that regular consumption of anthocyanin and phenolic-rich fruits can help mitigate the risks of obesity, cardiovascular diseases, degenerative conditions and certain types of cancer (15, 17). Various factors, including cultivation conditions, the ripening process and the maturity stage, significantly influence fruit quality and taste (18). Blackberry ripening follows a sequential pattern, presenting challenges for harvesting as the entire crop does not mature simultaneously. Determining the optimal harvest time is essential, as blackberries reach peak quality and flavour when fully ripe. However, relying solely on colour as an indicator can be misleading. In practice, blackberries are optimally harvested when their glossy dark colour fades to a duller hue and the fruit detaches effortlessly from the stem.

Given their delicate structure, blackberries should be harvested during the cooler parts of the day and promptly refrigerated to maintain freshness, nutritional quality and extended marketability (19, 20). Blackberry is a fruit of interest because of its high content of anthocyanins and ellagitannins (ETs), as well as other phenolic compounds that contribute to its high antioxidant capacity (20). Several studies document the high antioxidant activity of blackberries based on their oxygen radical absorbance capacity (ORAC) compared to other fruits. Historically, the medicinal properties of blackberries have been recognized since the 16th century in Europe, where they were traditionally utilized for treating oral and ocular infections (21). Epidemiological and clinical research (22, 23, 24) indicates that the consumption of anthocyanins and other flavonoids prevalent in various fruits and vegetables may contribute to a reduced risk of obesity, coronary heart disease, degenerative disorders and multiple forms of cancer. The underlying mechanisms of these health benefits have been extensively investigated through *in vitro* studies and animal models (25-29). This review synthesizes current scientific insights regarding blackberries' chemical composition, metabolic pathways, bioavailability and potential health benefits.

The primary aim of this study is to evaluate the quality parameters of blackberry fruits during ripening and determine the optimal harvest time for each variety. Previous research has examined various ripening stages of blackberries, highlighting their impact on fruit quality. Our analysis focuses on key indicators such as colour, weight, vitamin C content, carbohydrates, amino acids and phenolic compounds in fully ripe fruits from the Jumbo, Thornfree, Karaka Black, Brazos, Brzezina, Cacanska Bestrna and Chester varieties. The findings provide valuable insights into the nutritional composition of these blackberries, aiding producers and the food industry in optimizing harvest timing and assessing internal fruit quality.

Material and Methods

Plant materials

The Samarkand region is located in the central part of Uzbekistan. The climate is continental, characterized by hot and dry summers, with average temperatures ranging from +25°C to +35°C in July, occasionally reaching +40 °C or higher. The winters are moderately cold, with average temperatures in January ranging between -2 °C and -5 °C, sometimes dropping to -15°C. The annual precipitation varies between 250-500 mm and the growing season lasts approximately 200-220 days (30). In 2020, the "Agromeva" farm in the Samarkand region planted several blackberry varieties, including "Karaka Black," "Brazos," "Jumbo," "Thornfree," "Brzezina," "Cacansca Bestrna," and "Chester." The spacing between plants in each row was 2 m, with a 2.5 m distance between rows. The classification of blackberry varieties based on their origin, stem morphology and fruit structure is systematically presented in Table 1.

Determination of fruit weight

Five fruits of each blackberry variety were weighed on 10 replicate scales for each sample. From the obtained weights, we calculated the average weight per fruit. For each sampling, ten replicates of measurements were made for each variety.

Extraction and analysis of sugars and organic acids

The material for the work was the fruits of thornless blackberry varieties Brzezina, Cacansca Bestrna and Chester. grown in the conditions of the farm "Agro Meva" in the Samarkand region. For the analysis, the fruits were collected from different parts of the crown of 8-10 plants at least 0.3 kg. They were selected by standard size, shape and colour and undamaged by pests and diseases.

Table 1. Origin and morphological structure of blackberry varieties

Variety	Origin	Growth habit	Fruit shape
Brazos	USA	Erect	Round-fruited
Brzezina	Poland		
Cacanska Bestrna	Serbia		
Chester	USA		
Jumbo	New Zealand	Semi-Trailing	
Thornfree	USA		
Karaka Black	New Zealand	Trailing	Oblong-fruited

Isolation of free amino acids

The aqueous extract of samples was prepared with proteins and peptides in centrifuge cups. For this, 1 mL (exact volume) of 20 % trichloroacetic acid was added to 1 mL of the studied sample. After 10 minutes, the sediment was separated by centrifugation at 8000 rpm for 15 min. After separating 0.1 mL of the supernatant, it was lyophilized. The hydrolyzate was evaporated and the dry residue was dissolved in a mixture of triethylamine-acetonitrile water (1:7:1) and dried. This operation was repeated twice to neutralize the acid. According to the method, phenylthiocarbamyl derivatives (PTC) of amino acids were obtained by reaction with phenylthioisocyanate (31). The amino acid derivatives were identified using high-performance liquid chromatography (HPLC). The analysis was conducted on an Agilent Technologies 1200 chromatograph with a diode array detector (DAD) and a 75 × 4.6 mm Discovery HS C18 column. The mobile phase consisted of Solution A (0.14 M sodium acetate + 0.05 % triethylamine, pH 6.4) and Solution B (acetonitrile). The flow rate was maintained at 1.2 mL/min and detection was carried out at 269 nm. The gradient program for %B overtime was as follows: 1-6 % (0-2.5 min), 6-30 % (2.51-40 min), 30-60 % (40.1-45 min), 60-60 % (45.1-50 min) and 60-0 % (50.1-55 min).

Extraction and analysis of Vitamins C

Blackberry fruits were ground into a fine pulp using a mortar cooled with liquid nitrogen to extract bioactive compounds. Three grams of fruit sample was extracted with 9 mL of 2 % meta-phosphoric acid (32). The extraction process was conducted at 4°C for 30 min. The obtained extracts were subsequently centrifuged and filtered through 0.20 µm cellulose mixed ester membrane filters (Chromafil PP/MV A-20/25, Macherey-Nagel, Düren, Germany) into vials. Vitamin C analysis was performed using a UV detector set at 210 nm and a Rezex ROA - Organic Acids H+ (8 %) column (Phenomenex), maintained at 20°C. The mobile phase consisted of 4 mM sulfuric acid at a 0.6 mL/min flow rate. The concentration of vitamin C was quantified and expressed as mg per 100 g of fresh blackberry sample.

Extraction and analysis of phenolic components

For analysis, the fruits were collected at the stage of biological maturity in 2024. The fruits were selected according to a standard size, shape and colour, were not damaged by pests and diseases and were at least 0.3 kg from 8-10 plants from different crown parts. To check the quality of medicinal forms based on blackberry plov, a spectrophotometric method was used to quantitatively determine the amount of flavonoids in the tincture in terms of rutin and in the dry tablet extract, the total content of vitexin-2-O-rhamnoside and hyperoside was quantitatively determined by HPLC (33,34). A chromatographic column with a C18 stationary phase was used, with a mixture of phosphoric acid, isopropyl alcohol: tetrahydrofuran: water (1:5:20:80; vol. %) as an eluent and an analytical detection wavelength of 340 nm. Studies of the qualitative and quantitative determination of hypolaetin, rutin, isorhamnetium and hyper azide in blackberry fruits were carried out using HPLC with spectrophotometric detection (34).

Statistical analysis

All measurements and nutrient content values are presented as mean ± standard error of the mean (SEM) based on 10 replicates. Significant differences between sampling dates and blackberry varieties were determined using a two-way analysis of variance (ANOVA) performed with the Origin 86 statistical software. Post-hoc comparisons for all measurements and nutrient compositions were conducted using Duncans' multiple-range test. Statistical significance was established at $P < 0.05$.

Results and Discussion

The experiment was conducted on the following blackberry varieties grown in the conditions of the Samarkand region: Jumbo, Thornfree, Karaka Black, Brazos, Brzezina, Cacansca Bestrna and Chester. The fruits of all these varieties are suitable for fresh consumption, freezing and processing. The ripening period of the blackberries typically occurs between June and July. During this period, we collected fruit samples and monitored various quality parameters. Fruit weight and size were measured and a chemical analysis was performed on all samples to determine the content of carbohydrates, amino acids, vitamin C and phenolic compounds.

Fruit colour and weight

Generally, fruit weight declines relatively late in the season, particularly in August and September. (Table 2). This reduction in fruit weight is primarily attributed to increased transpiration and the obstruction of phloem flow as the berries reach their maximum size (35). The variety with the highest average fruit weight is Karaka Black. Studies have shown that Karaka Black is characterized by its large size and high fruit weight (Fig. 1). Among the visual parameters, fruit colour is critical in influencing consumer purchasing decisions. Consumers tend to favour deep, dark and vibrant fruits, as lighter hues often indicate that the fruit is under-ripe (36,37). The fruits' colour is influenced by various factors, including genotype, growing conditions, harvest timing, climatic and soil conditions and storage practices (38).

The content of sugar and amino acids

The total sugar content in the Cacansca Bestrna (9.04 mg/g) and Thornfree (8.97 mg/g) varieties is significantly higher than in the other varieties (Table 3). The primary sugars present in the fruits are glucose and fructose, which, in a roughly 1:1 ratio, make up 90-96 % of the total sugar content. The remaining sugars are sucrose and maltose, with concentrations ranging from 0.01 to 0.16 mg/g. Since fructose is generally sweeter than

Table 2. Size of blackberry fruit varieties

Blackberry species	Fruit height (cm)	Fruit width (cm)	Fruit weight (g)
Jumbo	2.27±0.42	1.62±0.42	2.91±0.24
Thornfree	2.47±0.58	1.6±0.66	3.81±0.99
Karaka Black	2.53±0.89	2.1±0.81	4.93±0.59
Brazos	2.17±0.79	2.36±1.24	4.39±2.69
Brzezina	2.22±0.67	1.8±0.35	3.6±0.74
Cacansca Bestrna	1.88±0.68	1.32±0.61	3.11±1.65
Chester	1.75±0.86	1.42±0.62	1.89±0.69

Table 3. Amino acid and carbohydrate content in the fruits of blackberry varieties

Blackberry varieties	Essential amino acids (mg/g)	Non-essential amino acids (mg/g)	Total	glucose (mg/g)	fructose (mg/g)	sucrose (mg/g)	maltose (mg/g)	Total
Jumbo	3.09	10.03	13.12	2.51	3.36	0.05	0.06	5.98
Thornfree	3.54	18.76	22.3	4.22	4.44	0.16	0.15	8.97
Karaka Black	2.38	4.88	7.26	1.71	1.62	0.03	0.01	3.37
Brazos	3.35	9.69	13.04	2.28	2.62	0.01	0.08	4.99
Brzezina	2.2	6.66	8.86	3.14	4.25	0.06	0.13	7.58
Cacansca Bestrna	3.85	12.92	16.77	3.42	5.51	0.06	0.05	9.04
Chester	4.16	18.4	22.56	1.45	3.05	0.02	0.06	4.58

Fig. 1. Blackberry fruit size (Karaka black).

glucose and sucrose, its higher concentration contributes to the sweetness of the fruit, which most consumers favour. The fructose content in the fruits ranges from 1.62 to 5.51 mg/g. Glucose content varies from 1.71 to 4.22 mg/g (Fig. 2). research indicates that similar sugar concentrations have been reported (39). Slightly higher glucose and fructose contents in blackberries (40). This results from different environmental conditions, site locations and technological measures in blackberry production. Blackberries are known for their characteristic sour taste, which is attributed to the low ratio of sugars to acids. The plant protein-to-carbohydrate ratio is significant for several ecological, physiological and nutritional reasons, including plant growth, metabolism, nutrient distribution, ecological interactions, stress tolerance and agricultural and nutritional value. This ratio plays a key role in blackberries' growth, adaptation and nutritional value, making it an essential indicator in natural ecosystems and agricultural systems. Among the varieties studied, the Chester variety exhibited the highest amino acid-to-carbohydrate ratio (4.92), while the Jumbo variety had the lowest (0.89). The ratios for other varieties were as follows: Thornfree (2.48), Brazos (2.62), Karaka Black (2.15), Cacansca Bestrna (1.86) and Brzezina (1.16) (Table 4).

Vitamin C content in blackberry varieties

Vitamin C analysis revealed that Karaka Black contained the highest concentration of vitamin C at 211.321 mg/100 g. Jumbo had the lowest at 135.265 mg/100 g, 36 % lower than Karaka Black. The Thornfree and Brzezina varieties showed similar values, ranging from 193.236 to 193.521 mg/100 g. (Table 5). The vitamin C content in the Chester variety differed from that of Karaka Black by only 1.7 %. In contrast, the vitamin C content in wild blackberries ranges from 20.4 to 28.1 mg/100 g. (41). The vitamin C content in the Cacansca Bestrna variety was reported to range from 10.27 to 12.25 mg/100 g in fresh weight. In contrast, our results show that the vitamin C content in this variety was 183.574 mg/100 g in dry weight (Fig. 3). In addition to genotype, various environmental factors, including plant location, climate, weather, soil conditions and the season and stage of maturity, significantly influence the vitamin C content (42).

The content of phenolic compounds

Among the samples studied, hypolaetin was present in the *Chester, Cacansca Bestrna and Thornfree varieties.* Its content in the *Cacansca Bestrna and Thornfree* varieties was almost identical, at 2.141 and 2.114 mg/100 g, respectively. In contrast, the *Chester* variety contained 1.29 mg/100 g less

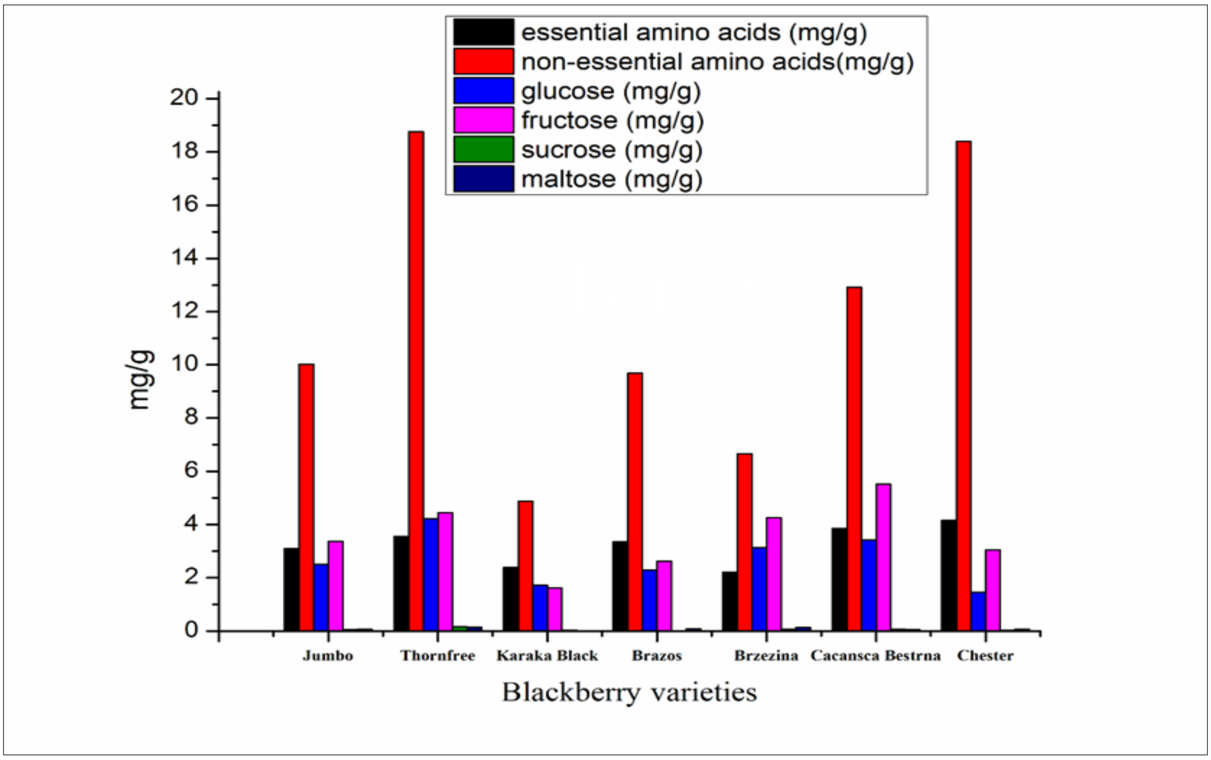

Fig. 2. Amino acid and carbohydrates content of blackberry varieties.

Table 4. Amino acid content in the fruits of blackberry varieties

	Jumbo	Thornfree	Karaka Black	Brazos	Brzezina	Cacansca Bestrna	Chester
				Essential amino acids			
Histidine	0.274	0.345	0.086	0.085	0.171	0.411	0.567
Isoleucine	0.186	0.091	0.253	0.641	0.065	0.196	0.305
Leucine	0.32	0.205	0.519	0.289	0.327	0.318	0.321
Lysine	0.025	0.077	0.034	0.024	0.02	0.086	0.078
Methionine	0.046	0.139	0.046	0.064	0.035	0.058	0.099
Phenylalanine	0.106	0.266	0.107	0.094	0.067	0.129	0.288
Threonine	0.759	0.957	0.198	0.77	0.428	0.867	1.115
Tryptophan	1.06	1.256	1.028	1.212	0.897	1.498	1.098
Valine	0.315	0.206	0.105	0.171	0.19	0.288	0.285
Total	3.091	3.542	2.376	3.35	2.2	3.851	4.156
				Non-essential amino acids			
Alanine	2.457	3.921	1.018	1.688	1.42	2.199	4.324
Arginine	0.17	0.319	0.241	0.116	0.12	0.243	0.37
Asparagine	1.739	3.573	0.724	1.161	1.267	3.066	4.055
Aspartic acid	0.116	0.688	0.076	0.181	0.123	0.2	0.308
Cysteine	0.769	2.572	0.118	1.483	0.214	1.061	2.385
Glutamic acid	0.188	0.289	0.103	0.307	0.115	0.14	0.312
Glutamine	0.105	0.248	0.049	0.117	0.142	0.121	0.153
Glycine	0.849	1.794	0.364	0.579	0.629	1.536	2.031
Proline	2.734	3.388	1.638	3.151	1.899	3.578	3.206
Serine	0.463	1.421	0.43	0.732	0.529	0.405	0.687
Tyrosine	0.436	0.55	0.12	0.178	0.204	0.372	0.565
Total	10.026	18.763	4.881	9.693	6.662	12.921	18.396
Total sum	13.117	22.305	7.257	13.043	8.862	16.772	22.552

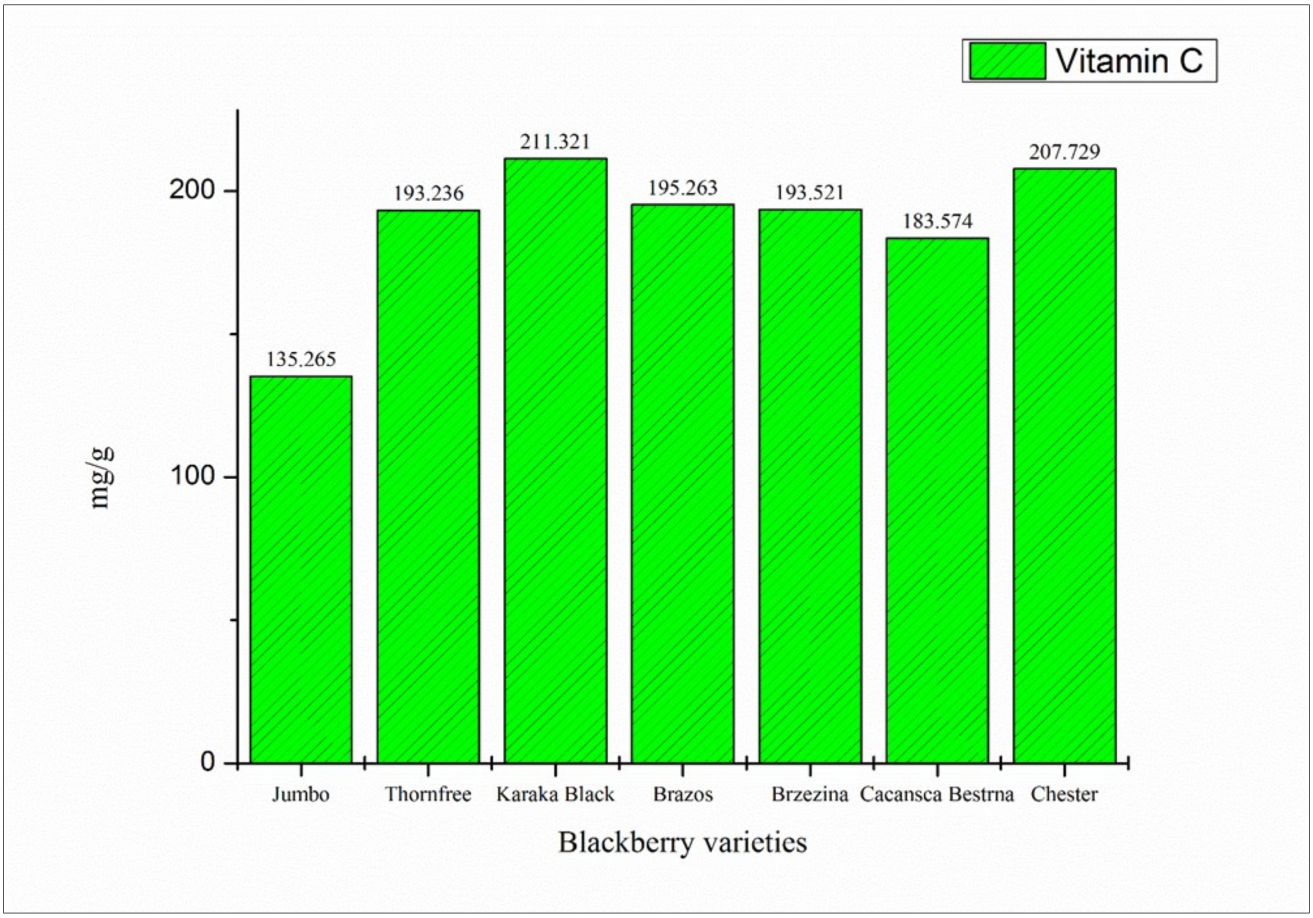

Fig. 3. Vitamin C content in blackberry varieties.

Table 5. Flavonoid content in the fruits of blackberry varieties

Blackberry variaties	Hypolaetin	Hypolaetin 7-O-D-Gly	Rutin	Isorhamnetin	Hyperoside	Total flavonoids	Vitamin C
Jumbo	0	0	32.541	3.584	16.224	52.349	135.265
Thornfree	2.114	4.521	31.251	2.551	42.541	82.978	193.236
Karaka Black	0	3.989	25.665	2.204	52.258	84.116	211.321
Brazos	0	7.231	35.261	3.854	14.856	61.202	195.263
Brzezina	0	0	18.977	2.141	14.251	35.369	193.521
Cacansca Bestrna	2.141	0	26.854	1.987	12.541	43.523	183.574
Chester	0.854	0	19.258	4.521	17.521	42.154	207.729

hypolaetin (Table 5). Rutin is a glycoside that combines the flavonoid quercetin with the sugar rutinose. It has been suggested that while all four free hydroxyl groups of cyanidin have varying glucuronidation capacities, the glucuronidation of cyanidin-3-glucoside occurs most readily at the 3-position (43, 44). Quercetin glycosides, which are also abundant in blackberries, are converted to glucosides, resulting in rapid absorption possibly via glucose transporters in the gut (44, 45, 46) found in the *Brazos* variety (35.261 mg/100 g) and the lowest in the *Brzezina* variety (18.977 mg/100 g). The difference between these two varieties is 46 %. Smaller differences were observed in the following varieties: 8 % in Jumbo (32.541 mg/100 g), 11 % in Thornfree (31.251 mg/100 g), 23 % in Cacansca Bestrna (26.854 mg/100 g), 27 % in Karaka Black (25.665 mg/100 g) and 45 % in Chester (19.258 mg/100 g). Our research has demonstrated that the Jumbo (62 %), Cacanska Bestrna (62 %), Brazos (58 %), Brzezina (54 %) and Chester (46 %) cultivars exhibit a high concentration of rutin flavonoids (Fig. 4). It was found that the Karaka Black (62 %) and Thornfree (51 %) varieties exhibit a high concentration of hyperoside (Fig. 5).

A study demonstrated that isorhamnetin reduced oxidative stress markers in animal models by enhancing the activities of antioxidant enzymes, such as superoxide dismutase (SOD). This compound can protect tissues from oxidative and inflammatory damage, positioning it as a potential therapeutic agent for chronic inflammatory diseases (47). A clinical trial explored isorhamnetins' effects on endothelial dysfunction. The results showed improved blood vessel function and reduced LDL cholesterol levels in participants with early-stage atherosclerosis. (48). Isorhamnetin has significant cardiovascular protective effects by enhancing lipid metabolism and reducing vascular inflammation. Research revealed that isorhamnetin suppressed colon cancer cell proliferation by modulating the PI3K/AKT signalling pathway, suggesting its potential as a complementary therapy in cancer treatment, targeting tumour growth and metastasis. An animal study demonstrated that isorhamnetin mitigated cognitive decline and oxidative stress in a mouse model of Alzheimers' disease, highlighting its therapeutic potential for neurodegenerative disease (49). The highest isorhamnetin content was found in the Chester variety (4.521 mg/100 g), while the lowest was

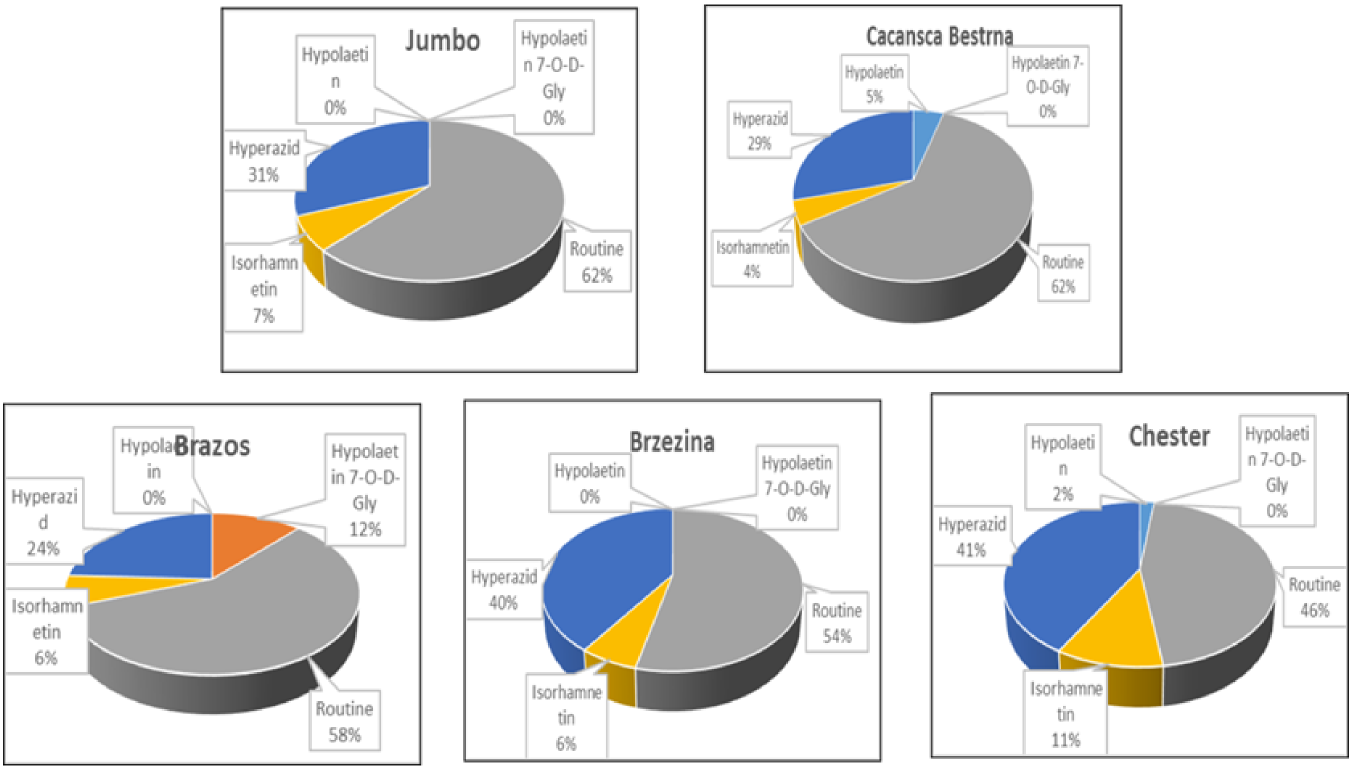

Fig. 4. Amount of flavonoids in blackberry cultivars.

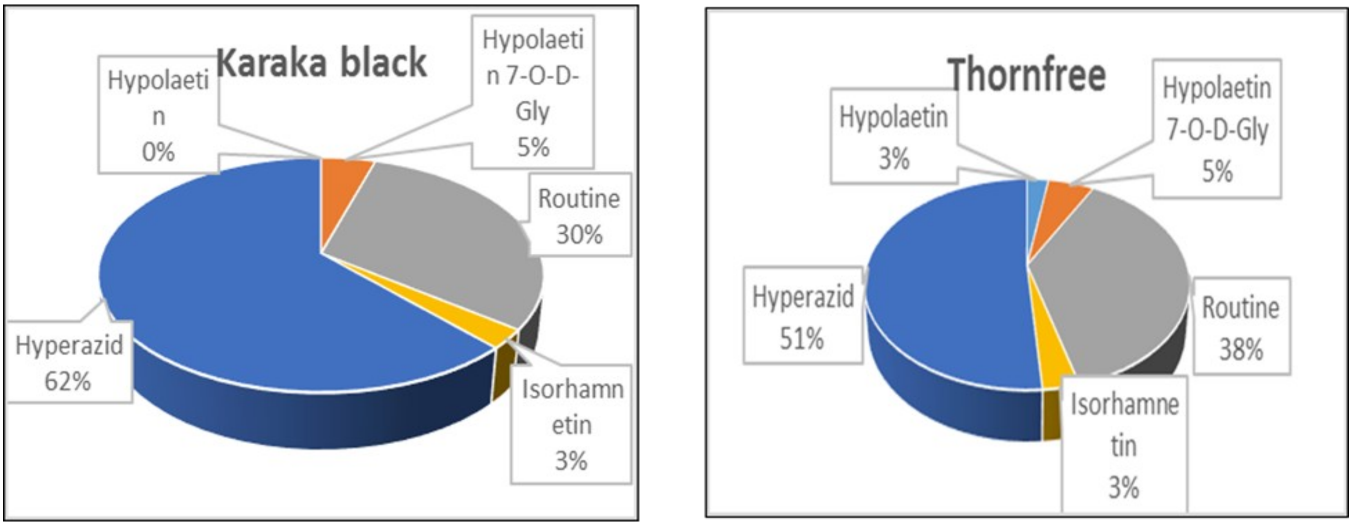

Fig. 5. Amount of flavonoids in blackberry cultivars.

observed in Cacansca Bestrna (1.987 mg/100 g). The content in Brazos and Jumbo varieties was nearly identical, at 3.854 and 3.584 mg/100 g, respectively. The values for Thornfree, Karaka Black and Brzezina varieties were also close, ranging from 2.551 to 2.141 mg/100 g.

The highest content of hyperazide was found in the Karaka Black variety (52.258 mg/100 g), while the lowest content was observed in Cacansca Bestrna (12.521 mg/100 g). The hyperazide content in the Thornfree variety was 9.717 times lower than in the Karaka Black variety (42.541 mg/100 g). The content in the Chester, Jumbo, Brzezina and Brazos varieties was relatively similar, ranging from 14.251 to 17.521 mg/100 g. The Karaka Black, Thornfree and Brazos varieties were found to contain the flavonoid hypolaetin 7-O-D-Gly, which distinguishes them from the other varieties. This flavonoid represents 4.74 % of the total flavonoids in Karaka Black, 5.45 % in Thornfree and 11.81 % in Brazos. Hypolaetin 7-O-D-glucoside is a glycosylated flavonoid that may offer significant health benefits, including antioxidant, anti-inflammatory, cardioprotective and neuroprotective effects. It is commonly found in various plants and consumed through foods or supplements containing flavonoid-rich ingredients. This study comprehensively analyzed the biochemical composition of various blackberry (*Rubus caesius*) cultivars grown under the climatic conditions of the Samarkand region. The findings highlight the significant variability in vitamin C, flavonoids, amino acids and carbohydrates across different cultivars, which is primarily influenced by genetic differences and environmental factors.

Among the studied cultivars, Karaka Black exhibited the highest vitamin C content (211.321 mg/100 g), significantly greater than that of Jumbo, the cultivar with the lowest vitamin C concentration (135.265 mg/100 g). The high vitamin C content in Karaka Black suggests that this cultivar has superior antioxidant potential, which may contribute to its extended shelf life and potential health benefits. These findings align with previous research on Rubus species, showing that vitamin C content varies due to genetic factors, ripening stages and postharvest conditions. Additionally, compared with other berry species such as raspberry (*Rubus idaeus*, 26.2 mg/100 g), blackcurrant (*Ribes nigrum*, 181 mg/100 g), blueberry (*Vaccinium corymbosum*, 9.7 mg/100 g) and goji berry (*Lycium barbarum*, 48 mg/100 g), the vitamin C levels in blackberries, particularly in Karaka Black, were found to be substantially higher. This highlights blackberries' potential as a valuable vitamin C source in human nutrition.

Flavonoid content also varied significantly among the cultivars. Karaka Black contained the highest flavonoid concentration (84.116 mg/100 g), whereas Brzezina exhibited the lowest (35.389 mg/100 g). Flavonoids play a crucial role in plant defence mechanisms and are recognized for their health-promoting properties, particularly their antioxidant and anti-inflammatory effects. Notably, the flavonoid levels recorded in Karaka Black were comparable to those reported in Blackberry Agavam (72.7-56.6 mg/g) and Blackberry Agavam Klon (81.6-65.7 mg/g) (50). The variations in flavonoid content may be attributed to differences in cultivar genetics, environmental conditions and agronomic practices, emphasizing the importance of selecting optimal cultivars for cultivation in specific regions. Amino acid analysis revealed Chester had the highest amino acid concentration (22.552 mg/g), whereas Karaka Black contained the lowest (7.257 mg/g). Amino acids are vital for protein synthesis and play essential roles in metabolic functions. The observed differences in amino acid composition among cultivars suggest that Chester may have more excellent nutritional value concerning protein content.

Carbohydrate analysis indicated that Cacanska Bestrna had the highest carbohydrate content (9.01 mg/g), while Karaka Black exhibited the lowest (3.37 mg/g). Carbohydrates are a primary energy source and their fruit content directly affects taste, sweetness and overall consumer preference. The variations observed in carbohydrate concentration may be linked to differences in fruit ripening stages, environmental conditions and metabolic pathways of individual cultivars. Additionally, storage conditions and postharvest treatments have been reported to affect sugar composition in berries, which should be considered in further research. Overall, the findings of this study contribute to the existing body of knowledge regarding the biochemical composition of blackberries and reinforce the importance of cultivar selection in optimizing nutritional and functional properties. Further Research is needed to investigate the impact of postharvest processing and storage conditions on the stability of these bioactive compounds. Genetic and agronomic studies could provide deeper insights into different blackberry cultivars' mechanisms underlying nutrient accumulation.

Conclusion

Among the studied cultivars, Karaka Black exhibited the highest concentrations of vitamin C (211.321 mg/100 g) and flavonoids (84.116 mg/100 g), indicating its potent antioxidant potential. In contrast, Jumbo and Brzezina contained the lowest levels of vitamin C (135.265 mg/100 g) and flavonoids (35.389 mg/100 g), respectively. The Chester cultivar was the richest in amino acids (22.552 mg/g), while Cacanska Bestrna had the highest carbohydrate content (9.01 mg/g). These results highlight different blackberry cultivars' nutritional potential and suitability for fresh consumption and processing. The high vitamin C and flavonoid levels in Karaka Black make it a promising candidate for health-oriented food products. Future research should explore the impact of storage conditions and postharvest processing on the stability of these bioactive compounds to enhance blackberries' commercial value.

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Authors' contributions

JN carried out a biochemical analysis and wrote an article, AM analyzed the results of the biochemical analysis and made recommendations on the results, FK checked the writing and structure of the article and gave directions, AKh helped with the tables and checked the correctness of the research. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

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