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Agrobiological characterization and variation of vitamin C and anthocyanins in Armenian eggplant landraces from the national eggplant collection

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ABSTRACT

Background: The importance of our scientific studies on landrace forms of eggplant lies in the fact that for a wide circle of society, Armenian cuisine is distinguished by the abundance of the fruits of this plant. On farms across Armenia, one can find numerous ancient landrace varieties of this plant, distinguished by their unique qualities, organoleptic properties, and taste. Historical data show that the Armenian people have been cultivating ancient landrace forms of eggplant for approximately 350–400 years. Landraces, ancient varieties of eggplant, due to their excellent growth and fruiting properties, have spread across various soil and climatic conditions, and their fruits are used for fresh consumption, canning, drying, and the preparation of other products. They are rich in various biologically active substances.

Objective: Study the content of vitamin C and anthocyanins in the fruits of locally valuable eggplant varieties.

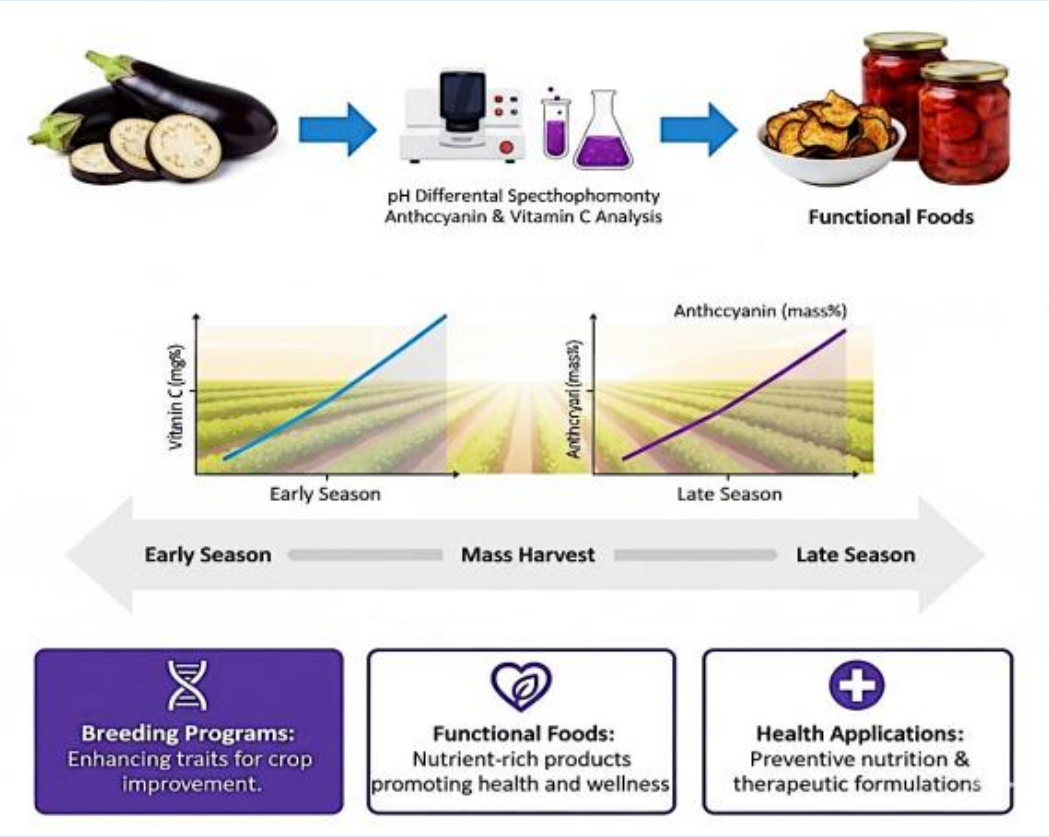
Methods: In our experiments, we used several genetic resources of the local valuable eggplant collection. The amounts of vitamin C and anthocyanins were determined by standard spectrophotometric methods.

Results: Vitamin C in fresh eggplant fruits at the beginning of the harvest was 4.25 – 5.35 mg%, at the middle of the harvest – 6.25 – 7.35 mg%, at the end of the harvest – 6.15 – 7.85 mg%, and Anthocyanin at the beginning of the harvest was 3.25 – 6.32 (mass%), at the middle of the harvest – 6.63 – 7.18 (mass%), at the end of the harvest – 4.28 – 5.87 (mass%).

Novelty and Innovative Announcements: Our research was conducted for the first time and made it possible to obtain local, valuable forms of eggplant with high bioactive compounds for functional food. The novelty of the research lies in the fact that by crossing the best selected landraces with different eggplant varieties, we can create new varieties with high vitamin C and anthocyanin content.

Conclusion: Among the valuable local landrace forms Yerevani bambak, Apagayi teghakan, Haykakan erkar, Haykakan sev, Teghakan sev, Teghakan khorovaci, Teghakan khaviari, Teghakan pahacoyi stood out for their high content of vitamin C and anthocyanin. These are valuable forms for breeding new eggplant varieties and hybrids used as functional foods.

Keywords: Eggplant; Landraces; Vitamin C; Anthocyanins; Functional food; Armenia



Graphical Abstract: Agrobiological Characterization and Nutrient Dynamics in Armenian Eggplant Landraces

INTRODUCTION

Scientific research on functional foods is being conducted rapidly worldwide. These studies have revealed several traditional and modern recipes, making the use of functional foods even more applicable. Functional foods are an excellent source of bioactive compounds, including vitamins, anthocyanins, and phenolic compounds, which are directly related to the prevention of many diseases. Various fruits, berries, and vegetables, including eggplant, are rich in the above-mentioned biologically active compounds, both fresh and cooked, as well as dried and processed products [1-5].

Recently, a very interesting direction has emerged in the science of functional food related to quantum mechanics and the concept of time. Quantum and Tempus theories have opened new avenues for modern research in functional foods. Functional food science offers an opportunity to better understand the relationship between food, chronic diseases, and health. Quantum theory, in turn, studies the interactions among a number of substances and bioactive compounds in functional foods, thereby optimizing their development and use for chronic diseases and health, and Tempus theory increases the effectiveness of functional food in promoting health and preventing diseases [6]. The results from these two theories served as the basis for our scientific research, which revealed that the balanced use of antioxidants in eggplant-based foods can increase the body's resistance, especially to cancer.

Eggplant, also known as aubergine, common eggplant, or brinjal (*Solanum melongena* L.), is a warm-climate crop, mainly cultivated in tropical and subtropical climates. All species are annual vegetables that produce fleshy fruits, mainly used fresh and dried in fried and cooked dishes, often mixed with spices, oil, meat, or other vegetables. Eggplant is a global crop, especially widespread in Asia and the Mediterranean. The plant is rich in bioactive compounds [7]. This plant is classified based on its high phenol content in the pulp, its acids, and anthocyanins in the peel [8]. Such antioxidants are known for their many beneficial health properties [9].

The selection the eggplant quality production assumes the solution of a task relevant for all cultures: to ensure a high level of synthesis in the production of valuable biologically active substances, including vitamins, carbohydrates, and organic acids [10-11].

Phenolic compounds belong to the group of natural heteroaromatic molecules that play a major role in plants. According to various authors [12-13], over 4,000 types of polyphenols have been isolated from plants. Among the polyphenolic compounds commonly found in plants, flavonoids and phenolic acids are intensively studied. Many studies show that flavonoids are effective antioxidants that are involved in the chemical processes of many oxidative systems. The anticancer properties of flavonoids have been the subject of numerous clinical and experimental studies. It was found that their antiproliferative effect is similar to the effect of modern anticancer drugs [14-15]. After studying the total phenolic content of several eggplant varieties, it was found that *S. melongena* varieties show significant variations in this indicator. Local varieties had higher phenol content compared to commercial and wild varieties. This highlights the crop's high potential for phenolic compounds. Eggplant peel, which contains the main component anthocyanins, has a high antioxidant capacity [16-17].

Numerous studies have been conducted on anthocyanins. The literature reports on anthocyanins' antioxidant, antimutagenic, and anticancer activities [18-19].

The most common anthocyanin in eggplant fruit is nasunin. Nasunin was first isolated from fruit peel in 1933 by Kuroda and Wada, and its structure was determined as delphinidin-3-glycoside, cylated with p-coumaric acid [20-21]. This compound nasunin, is largely contained in the skin of eggplant fruits

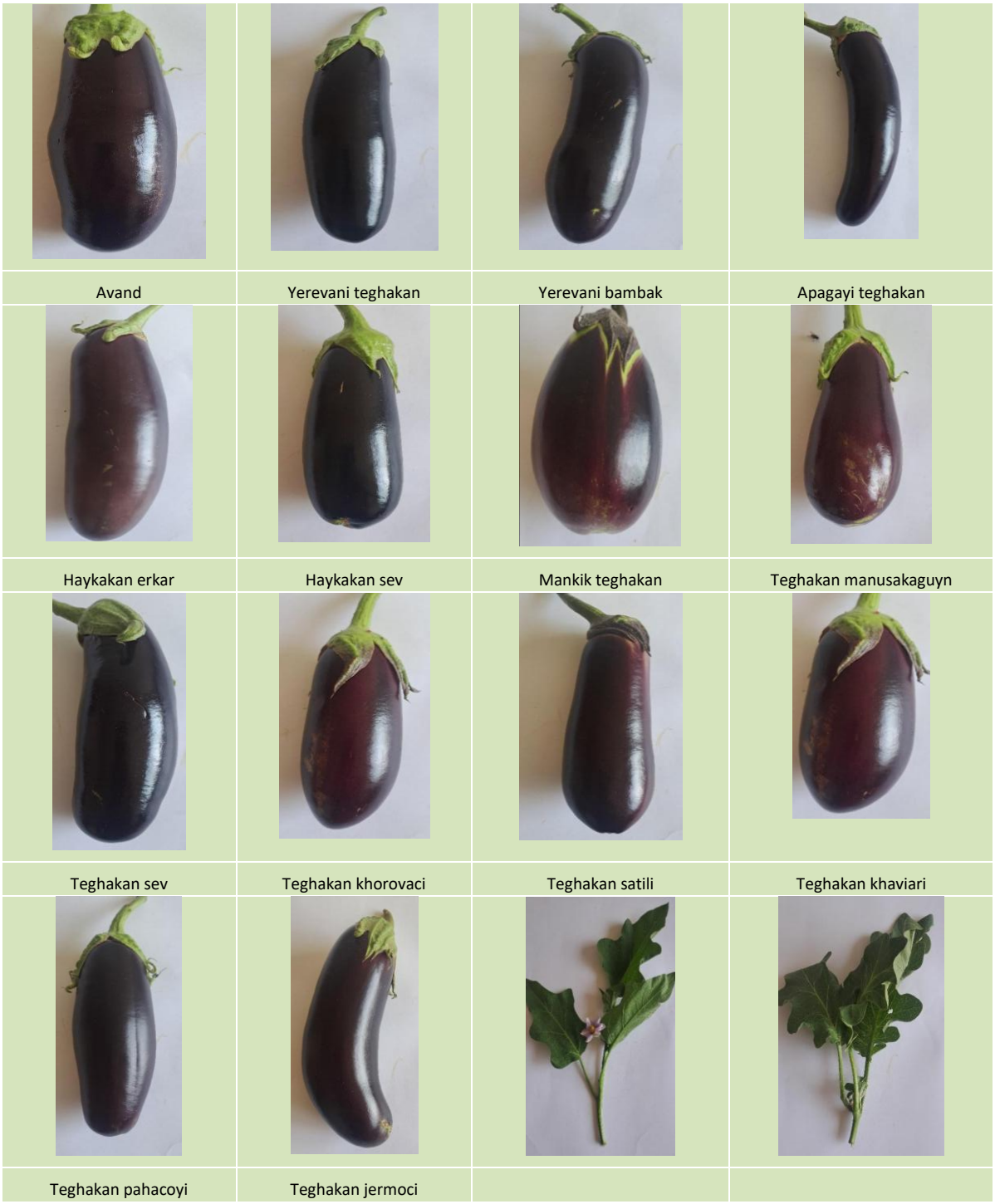
Studies conducted by different scientists confirm significantly higher antioxidant activity of nasunin, compared to other anthocyanins of eggplant. The high

antioxidant activity of nasunin relates to the presence of the p-coumaroyl group in its structure [22-24].

MATERIAL AND METHODS

Genetic resources: In our experiments, we used local landrace forms: Yerevani teghakan, Yerevani bambak, Apagayi teghakan, Haykakan erkar, Haykakan sev, Mankik teghakan, Teghakan manusakaguyn, Teghakan sev, Teghakan khorovaci, Teghakan satili, Teghakan khaviari, Teghakan pahacoyi, and Teghakan jermoci landraces (Figure 1). The local Avand variety served as a control.

Figure 1. The landraces of eggplant.



The agrotechnical conditions of the experimental plot, the methods of conducting experiments, determining the content of bioactive compounds in fresh and dried eggplant fruits, and statistical data processing are described in our previous article [25-27].

The fruit was dried in the traditional way, in a shady environment, as the local population does. The technically ripe fruits were peeled, split lengthwise, and 6 fruit parts were obtained, which were hung on threads and dried. The fruits were dried for 10 days, packed in paper, and then the vitamin and anthocyanin content was determined using modern spectrophotometric methods.

RESULTS AND DISCUSSION

Experiments by several scientists have shown that levels of bioactive indicators in technically ripe fruits of many agricultural crops vary across the early, middle, and late vegetative stages of harvesting. All this affects the use of fresh, dried fruits as functional foods [28-30]. Since people use only technically ripe fruits to eat eggplant, we have attached importance to the correct determination of these dates in our soil and climatic conditions.

The results (Figure 2) showed that the period from mass seed germination to the beginning of fruit harvest was 112-128 days, the middle of the harvest was 120-139 days, and the end of the harvest was 138-151 days. In terms of agrobiological properties, the following eggplant varieties gave the best results: Yerevani teghakan, Yerevani bambak, Apagayi teghakan, Haykakan sev, Teghakan sev, Teghakan khorovaci, Teghakan satili, and Teghakan khaviari. These varieties are the best compared to the Avand variety ($P < 0.05$).

Since the human body cannot synthesize or store vitamin C, it must be obtained through daily food. One of its main properties is its antioxidant activity. It is also important for collagen synthesis, in which case it plays a beneficial role in the production of the structural proteins of the skin, muscles, bones, and blood vessels, as well as in wound healing. Since heat treatment reduces the vitamin C content, it is best to eat vegetables raw or lightly cooked. The recommended daily allowance (RDA) for vitamin C is 75–90 mg, and 85–120 mg for pregnant and lactating mothers [31–32].

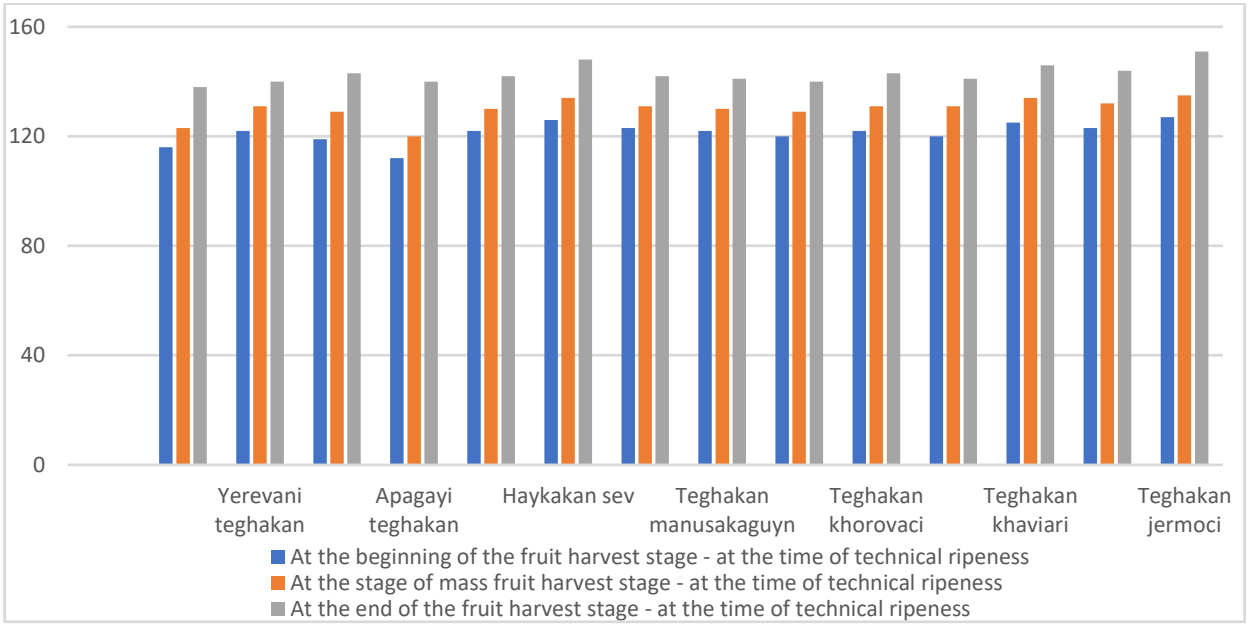


Figure 2. Agrobiological characterization of the eggplant landraces considered in this study

The results obtained in fresh eggplant fruits (Figure 3) were: 4.25 – 5.5 mg% at the beginning of the harvest, 6.25 – 7.35 mg% in the middle of the harvest, and 6.15 – 7.85 mg% at the end of the harvest. The following local

eggplant varieties produced the best results: Yerevani bambak, Apagayi teghakan, Haykakan erkar, Teghakan sev, Teghakan khaviari, and Teghakan pahacoyi. These varieties outperformed the Avant variety ($P < 0.05$).

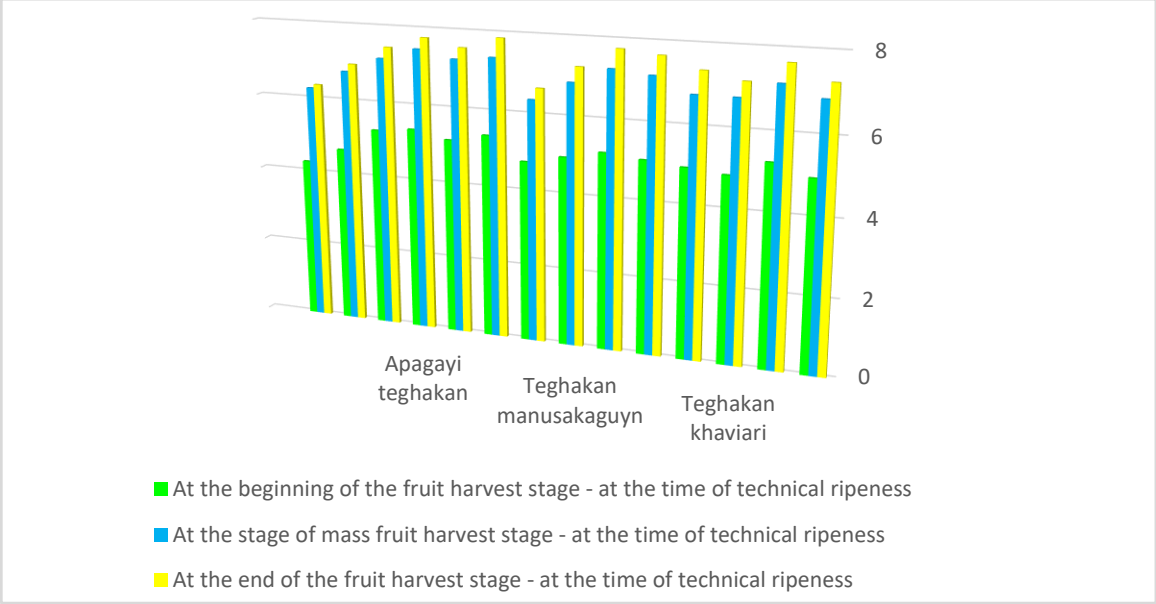


Figure 3. Dynamics of Vitamin C (mg%) eggplant local sorts studied at time of technical ripeness

The vitamin C content in dried eggplant fruits (Fig. 4) at the beginning of the harvest was: 4.45 – 5.55 mg%, in the middle of the harvest – 5.75 – 6.45 mg%, and at the end of the harvest – 5.85 – 6.95 mg%. The varieties Yerevani bambak, Apagayi teghakan, Haykakan erkar, Haykakan sev, Teghakan sev, Teghakan khaviari, and Teghakan pahacoyi stood out, which exceeded the Avand variety ($P < 0.05$).

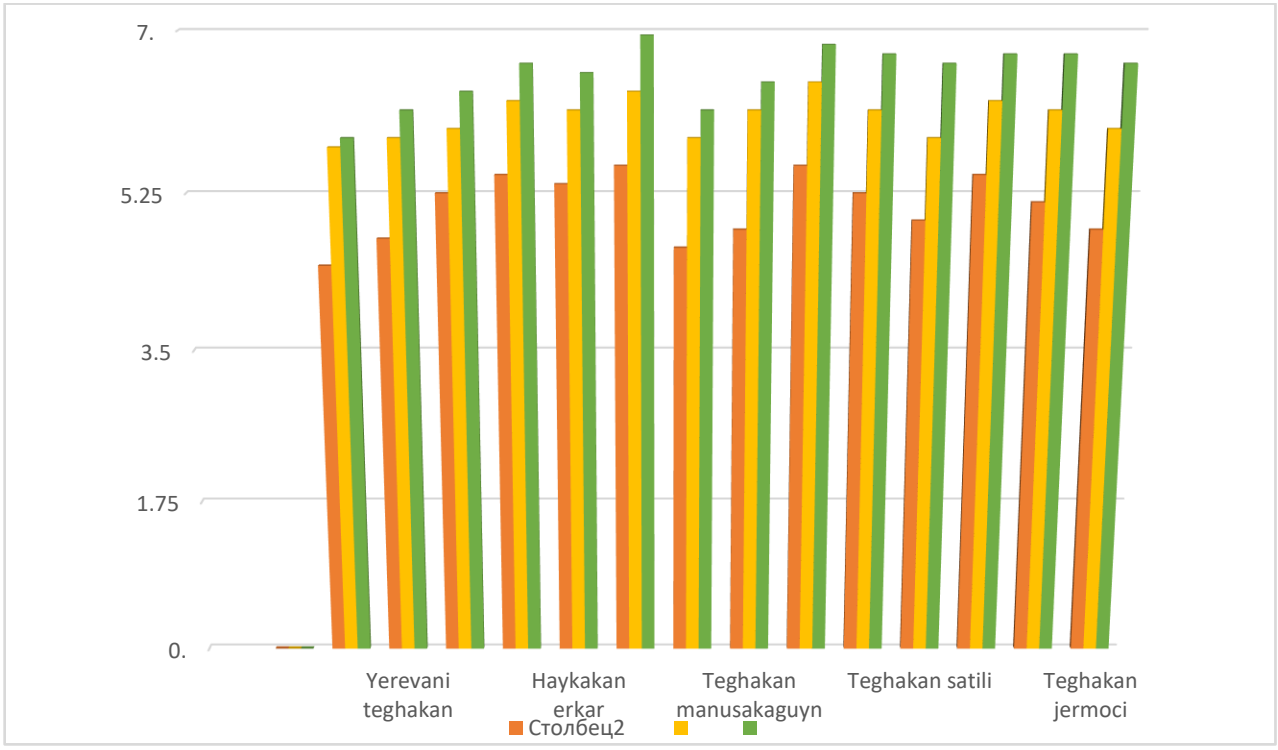


Figure 4. Vitamin C (mg%) content in ripe dried and ground eggplant fruits

Numerous studies have shown that anthocyanins, which have antioxidant activity, have beneficial effects on human health. The recommended daily intake for humans is 185-215 mg. However, the qualitative composition of anthocyanins varies greatly between plant species and varieties. A study of more than 100 food products showed that aglycones (cyanidin, pelargonidin, delphinidin, etc.) are present in all foods, but not all contain sugar residue (they were acylated). At the same time, it is known that the antioxidant activity of acylated anthocyanins is much higher than that of non-acylated ones [33-34].

The composition of anthocyanins has been studied in many collections worldwide, but it is still unknown for most cultivated and wild eggplant species from different countries. It is possible that these collections contain other types of anthocyanins, which, among other things, have higher antioxidant activity than nasunin and delphinidin 3-caffeoylrutinoside-5-glucoside. Increasing the anthocyanin content in the skin of cultivated eggplants is possible by crossing them with other species that synthesize other types of anthocyanins [35-37].

In fresh eggplant fruits Anthocyanin (Table 1) at the beginning of the harvest was 3.25 – 6.32 (mass%), at the middle of the harvest – 6.63 – 7.18 (mass%), at the end of the harvest – 4.28 – 5.87 (mass%), in dried eggplant fruits at the beginning of the harvest was: 1.26 – 3.32 (mass%), at the middle of the harvest: 4.67 – 5.45 (mass%), at the end of the harvest: 3.35 – 5.93 (mass%). The best ones are: Yerevani bambak, Apagayi teghakan, Haykakan erkar, Haykakan sev, Teghakan sev, Teghakan khorovaci, Teghakan khaviari, which have surpassed the Avand variety ($P < 0.05$).

Table 1. Anthocyanins (mass%) content in the landraces from the Eggplant.

Eggplant LD	Anthocyanin (mass%) content					
	In fresh fruits eggplant			In ripe dried and ground fruits eggplant		
	at the beginning of the harvest	in the middle of the harvest	at the end of the harvest	at the beginning of the harvest	in the middle of the harvest	at the end of the harvest
Avand, control	3.25	6.63	4.32	1.28	4.67	3.55
Yerevani teghakan	3.35	6.77	4.28	1.23	4.86	3.35
Yerevani bambak	5.18	7.05	4.94	2.26	5.28	5.63
Apagayi teghakan	5.36	7.10	5.65	3.15	5.32	5.72
Haykakan erkar	5.87	6.98	5.72	3.20	5.35	5.81
Haykakan sev	5.80	7.18	5.80	3.25	5.45	5.90
Mankik teghakan	3.46	6.70	4.30	1.34	4.74	3.89
Teghakan manusakaguyn	4.87	6.81	4.33	1.78	4.79	4.27
Teghakan sev	6.32	7.15	5.87	3.30	5.42	5.93
Teghakan khorovaci	6.18	7.09	5.75	3.32	5.40	5.52
Teghakan satili	6.20	6.97	5.24	3.24	4.90	4.61
Teghakan khaviari	6.30	6.98	5.80	3.22	5.41	5.82
Teghakan pahacoyi	6.25	7.12	5.73	3.17	5.35	5.90
Teghakan jermoci	5.46	6.87	5.15	2.76	4.78	4.65

Scientific Innovation and Practical Implications

The novelty of this research lies in the comprehensive biochemical characterization of Armenian eggplant landraces across different harvest stages and processing conditions (fresh and dried fruits). The study identifies significant variation in vitamin C and anthocyanin content

among genotypes, highlighting valuable breeding material with enhanced antioxidant potential. Selected landraces such as Yerevani bambak, Apagayi teghakan, Haykakan erkar, Haykakan sev, Teghakan sev, Teghakan khorovaci, Teghakan khaviari, and Teghakan pahacoyi represent promising genetic resources for the development of nutritionally improved eggplant varieties.

This study also aligns with the Functional Food Center's 17-step model for functional food development. Specifically, the biochemical characterization supports Step 2 (determination of relevant bioactive compounds) and Step 7 (identification of an appropriate food vehicle), as the quantified levels of vitamin C and anthocyanins provide foundational compositional data. These findings support the potential of selected landraces as dietary sources of antioxidant compounds and establish a scientific basis for future investigations corresponding to Step 8 (preclinical studies) and Step 9 (clinical trials), which will be required to further evaluate biological efficacy and safety [6].

CONCLUSION

The present study demonstrates significant agrobiological and biochemical variability among Armenian eggplant landraces. The vegetation period—from mass germination to fruit harvest—ranged from 112 to 151 days depending on genotype, reflecting substantial differences in earliness and adaptation potential.

A distinct dynamic pattern in the accumulation of bioactive compounds was observed across harvest stages. Vitamin C and anthocyanin contents increased from early to middle harvest stages, followed by minor fluctuations at the late harvest stage in both fresh and traditionally dried fruits. These results confirm that harvest timing is a critical factor influencing antioxidant composition.

Several landraces—notably Yerevani bambak, Apagayi teghakan, Haykakan erkar, and Haykakan sev—consistently exhibited higher levels of vitamin C and anthocyanins compared to the control variety Avand. These genotypes represent valuable genetic resources for breeding programs aimed at enhancing nutritional quality.

In conclusion, these findings underscore the importance of conserving local germplasm. Selected Armenian landraces of *Solanum melongena* serve as promising genetic resources and raw materials for the development of antioxidant-rich functional foods.

Authors' Contributions: K.S. and P.T. designed the research; K.S., G.Sh., M.G., and A.Z. provided fresh and dried fruits in the landraces from the National Eggplant Collection of Armenia for research. A.Zh. and G.S. performed biochemical analysis; G.K. and V.V. performed statistical analyses; K.S. and G.K. wrote the manuscript; K.S., P.T., and A.C. edited the article. All authors read and approved the final version of the manuscript.

List of Abbreviations: S., Solanum; mg%, milligram percent; mass%, Percentage by mass.

Competing Interests: There are no conflicts of interest to declare.

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