COMPARATIVE STORAGE STABILITY OF BIOACTIVE COMPOUNDS IN POWDERS FROM DIFFERENT BROCCOLI HYBRIDS

Sherzod .Sh.Nurmatov
PhD Student, Samarkand Institute of Agroinnovations and Research
Samarkand, Uzbekistan
ORCID: 0009-0007-6338-2439
e-mail: nurmatovsherzod1988@gmail.com
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Abstract.

Broccoli powder is a promising functional ingredient due to its high content of biologically active compounds; however, the preservation of these compounds during prolonged storage may depend on the hybrid used as raw material. This study compared the retention of major bioactive compounds in powders produced from seven broccoli hybrids during 12 months of storage. **Agassi F1, Ironman F1, Atlantis F1, Heraklion F1, Naxos F1, Marathon F1, and Tiburon F1** were dried at 55°C using infrared radiation combined with an air velocity of 1.5 m/s. Ascorbic acid, total phenolic compounds, flavonoids, and antioxidant activity were evaluated at 3, 6, 9, and 12 months of storage. A gradual decline in all investigated bioactive parameters was observed, although the rate of degradation differed among hybrids. After 12 months, **Naxos F1** showed the highest retention of ascorbic acid (83.2%), total phenolics (88.7%), flavonoids (87.9%), and antioxidant activity (89.0%). **Agassi F1** ranked second, retaining 82.1, 88.0, 87.1, and 88.3%, respectively. The findings demonstrate that hybrid characteristics significantly influence the long-term preservation of bioactive compounds in broccoli powder and identify Naxos F1 and Agassi F1 as promising raw materials for producing bioactive-rich powdered ingredients with improved storage stability.

Keywords: broccoli, broccoli powder, hybrid, bioactive compounds, storage stability, ascorbic acid, phenolic compounds, flavonoids, antioxidant activity.

1. Introduction

Broccoli (Brassica oleracea var. italica) is an important source of ascorbic acid, phenolic compounds, flavonoids, pigments, and other biologically active constituents. These compounds contribute substantially to the antioxidant and functional properties of broccoli and support its increasing use in the development of functional food ingredients.

Drying and powder production provide an effective approach to extending the utilization period of broccoli and reducing its high perishability. Nevertheless, bioactive compounds may continue to undergo oxidative and chemical degradation even after drying, particularly during prolonged storage. The extent of these changes may be influenced not only by processing and storage conditions but also by the genetic characteristics of the raw material.

Therefore, evaluating different broccoli hybrids under identical processing and storage conditions is important for identifying raw materials capable of maintaining their functional properties over extended storage periods.

The **objective of this study** was to compare the retention of ascorbic acid, total phenolic compounds, flavonoids, and antioxidant activity in powders obtained from seven broccoli hybrids during 12 months of storage and to identify the hybrids with the highest bioactive stability.

2. Materials and Methods

Seven broccoli (Brassica oleracea var. italica) hybrids — **Agassi F1, Ironman F1, Atlantis F1, Heraklion F1, Naxos F1, Marathon F1, and Tiburon F1** — were used in the study. Broccoli florets were dried under the previously optimized conditions of **55°C, infrared radiation, and an air velocity of 1.5 m/s**. The dried material was ground and passed through a 0.5-mm sieve to obtain a uniform powder.

The powders were hermetically packaged and stored under dry, light-protected conditions for **12 months**. Bioactive compound retention was evaluated after 3, 6, 9, and 12 months. The initial concentration of each compound was considered 100%. Ascorbic acid, total phenolic compounds, flavonoids, and antioxidant activity were determined. All measurements were performed in triplicate, and the results were expressed as mean values.

Bioactive compound retention was calculated according to the following equation:

$$\textbf{Retention (\%)} = (C_t / C_0) \times 100$$

where C_0 is the initial concentration and C_t is the concentration after the corresponding storage period.

Results and Discussion

The results demonstrated a progressive decline in the investigated bioactive components during the 12-month storage period. However, the magnitude of these changes differed among broccoli hybrids, indicating that the stability of biologically active compounds was influenced by hybrid-specific characteristics.

During the first three months of storage, degradation was relatively limited. In most samples, more than 94% of the investigated bioactive compounds remained compared with their initial levels. **Naxos F1** exhibited the highest stability during this period, retaining 96.5% of ascorbic acid, 97.8% of total phenolic compounds, 97.3% of flavonoids, and 97.9% of antioxidant activity. These findings indicate that the initial phase of storage had only a minor effect on the functional characteristics of properly dried and packaged broccoli powders.

With increasing storage duration, differences among the hybrids became more pronounced. After six months, Naxos F1 retained **92.5% of ascorbic acid, 95.2% of total phenolics, 94.6% of flavonoids, and 95.3% of antioxidant activity**. Agassi F1 showed a similar trend and remained close to Naxos F1 for most of the evaluated parameters.

After nine months, a more evident decline was observed, particularly in ascorbic acid. Nevertheless, Naxos F1 retained 87.9% of its initial ascorbic acid, 91.9% of total phenolic compounds, 91.2% of flavonoids, and 92.1% of antioxidant activity. Agassi F1 retained 87.0, 91.3, 90.5, and 91.5%, respectively.

The results obtained at the end of the 12-month storage period provided the clearest differentiation among the tested hybrids.

Table 1. Retention of bioactive compounds in broccoli powders after 12 months of storage, %

Broccoli hybrid	Ascorbic acid	Total phenolics	Flavonoids	Antioxidant activity
Agassi F1	**82.1**	**88.0**	**87.1**	**88.3**
Ironman F1	79.4	85.9	84.6	85.8
Atlantis F1	75.9	82.9	81.5	83.2
Heraklion F1	80.2	86.5	85.3	86.6
Naxos F1	**83.2**	**88.7**	**87.9**	**89.0**
Marathon F1	77.6	84.4	82.9	84.7
Tiburon F1	76.8	83.7	82.3	84.0

After 12 months, **Naxos F1 demonstrated the highest retention for all four investigated parameters**. Ascorbic acid retention remained at 83.2%, whereas total phenolic compounds and flavonoids were preserved at 88.7 and 87.9%, respectively. Antioxidant activity showed the greatest stability, with 89.0% of the initial level remaining.

Agassi F1 ranked second and showed only minor differences compared with Naxos F1. It retained 82.1% of ascorbic acid, 88.0% of total phenolics, 87.1%

of flavonoids, and 88.3% of antioxidant activity. This indicates that both hybrids possess comparatively high biochemical stability during prolonged storage.

Heraklion F1 and Ironman F1 showed intermediate retention levels. In Heraklion F1, ascorbic acid retention was 80.2%, while antioxidant activity remained at 86.6%. The corresponding values for Ironman F1 were 79.4 and 85.8%.

Greater degradation was recorded in Marathon F1, Tiburon F1, and Atlantis F1. **Atlantis F1 showed the lowest overall retention**, with ascorbic acid decreasing to 75.9% of its initial value, while phenolics and flavonoids were retained at 82.9 and 81.5%, respectively.

Comparison of individual bioactive components showed that **ascorbic acid was the most sensitive compound to prolonged storage**. Depending on the hybrid, losses after 12 months ranged from 16.8 to 24.1%. In contrast, phenolic compounds showed greater stability, with final retention values ranging from 82.9 to 88.7%.

Flavonoid retention followed a similar pattern to total phenolics. This similarity was also reflected in the antioxidant activity of the powders. Hybrids with higher retention of phenolic compounds and flavonoids generally maintained higher antioxidant activity. Naxos F1 and Agassi F1, for example, showed both the highest phytochemical retention and the highest remaining antioxidant activity after 12 months.

This relationship suggests that the preservation of phenolic and flavonoid fractions is an important factor in maintaining the functional properties of broccoli powder during storage. The comparatively higher stability of antioxidant activity relative to ascorbic acid may also indicate that the antioxidant potential of broccoli powder depends on a combination of different bioactive compounds rather than on a single constituent.

Since all seven hybrids were subjected to the **same drying regime, packaging conditions, and storage period**, differences in bioactive compound retention cannot be explained by processing conditions alone. The results therefore suggest that the genetic and biochemical characteristics of the broccoli hybrid play an important role in determining the long-term stability of the final powdered product.

From a practical perspective, these differences are important when selecting broccoli raw materials for functional powders intended for extended storage. A hybrid that combines high initial biological value with greater retention

of bioactive compounds may provide a more stable ingredient for use in fortified foods, dry mixtures, and other functional food formulations.

Conclusion. The comparative evaluation of seven broccoli hybrids demonstrated that the retention of bioactive compounds in broccoli powder during prolonged storage is significantly influenced by hybrid characteristics. Although gradual losses of ascorbic acid, phenolic compounds, flavonoids, and antioxidant activity occurred in all samples, their rates differed considerably during the 12-month storage period.

Naxos F1 showed the highest overall bioactive stability, retaining 83.2% of ascorbic acid, 88.7% of total phenolic compounds, 87.9% of flavonoids, and 89.0% of antioxidant activity after 12 months. **Agassi F1** demonstrated similarly high stability and ranked second among the investigated hybrids.

Ascorbic acid was identified as the most storage-sensitive of the evaluated components, whereas phenolic compounds and flavonoids showed comparatively higher retention. The similar patterns observed for phenolic compounds, flavonoids, and antioxidant activity indicate that preservation of these phytochemical groups contributes substantially to maintaining the functional properties of broccoli powder.

The results confirm that **selection of the appropriate hybrid should be considered alongside drying and storage conditions when developing broccoli powders for long-term use**. Naxos F1 and Agassi F1 can therefore be regarded as promising raw materials for producing stable, bioactive-rich broccoli powders intended for functional food applications.

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