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A study of biochemical profiles and antioxidant potential in fresh apple genotypes

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Abstract: Apple (Malus domestica) is a widely consumed fruit, known for its nutritional and health benefits. This study investigates the biochemical profile and antioxidant activity of fresh fruits from different apple genotypes, focusing on key components such as sugars, organic acids, phenolic compounds, and antioxidant capacity. A total of five apple genotypes (G1, G2, G3, G4, and G5) were selected, and the fruit samples were analyzed for their biochemical composition using high-performance liquid chromatography (HPLC) and spectrophotometric methods. The results showed significant variability in sugar content, with fructose and glucose being the predominant sugars. Organic acids, such as malic acid, were found in varying concentrations across genotypes. Phenolic compounds, including flavonoids and phenolic acids, demonstrated antioxidant activity, which was highest in Genotype G3. The study highlights the genetic variation in apple fruits that affects their nutritional composition and antioxidant potential, providing valuable information for breeding programs aimed at enhancing fruit quality.

Keywords: Biochemical Profiles, Antioxidant Potential, Apple Genotypes, Phytochemical Composition, Phenolic Compounds, Flavonoids, Ascorbic Acid (Vitamin C), Total Antioxidant Capacity (TAC), Free Radical Scavenging Activity, DPPH Assay, FRAP Assay.

Introduction: Apple (Malus domestica) is one of the most widely consumed fruits globally, appreciated for its taste, versatility, and health benefits. Apples have been studied extensively due to their rich nutritional profile, which includes essential vitamins, dietary fibers, and a wide range of bioactive compounds, particularly antioxidants. The consumption of apples has been linked to various health benefits, such as reduced risks of cardiovascular diseases, certain types of cancer, and oxidative stress-related conditions (Basu et al., 2010). The primary components contributing to the apple's health-promoting properties are its sugars, organic acids, phenolic compounds, and other antioxidants.

The sugar composition in apples consists mainly of fructose, glucose, and sucrose, which contribute to the fruit's sweet flavor and provide a source of quick energy. Organic acids, primarily malic acid, are responsible for the fruit's tart taste and are associated with several health benefits, including their role in improving digestion and acting as a natural preservative in fruits. Phenolic compounds, such as flavonoids, phenolic acids, and tannins, are particularly important for their antioxidant properties. These compounds help neutralize free radicals in the body, reducing oxidative stress, which is linked to a variety of chronic diseases, including cardiovascular diseases and neurodegenerative disorders (Sasaki et al., 2012).

Recent studies have emphasized the role of apple genotypes in determining the biochemical composition of the fruit. Genetic variation among apple cultivars leads to differences in the concentrations of sugars, acids, phenolic compounds, and antioxidant activity, which in turn influence their taste, nutritional value, and health benefits. As such, selecting specific apple genotypes with optimal levels of these bioactive compounds has become a key focus in apple breeding programs. In addition to the traditional emphasis on yield, size, and flavor, apple breeders now aim to produce cultivars with enhanced antioxidant capacity to meet the growing demand for functional foods that promote health and prevent disease.

While many studies have assessed the biochemical composition and antioxidant activity of apples, there is a need for more research on the variation of these properties among different apple genotypes, especially in the context of fresh, unprocessed fruits. Understanding how different genotypes perform in terms of their nutritional and antioxidant profiles can provide valuable insights into the selection of cultivars for both commercial production and health promotion.

The objective of this study is to investigate the biochemical profile and antioxidant activity of fresh fruits from five distinct apple genotypes. By analyzing the sugar content, organic acids, phenolic compounds, and overall antioxidant capacity, this research aims to highlight the genetic diversity in apples that affects their nutritional quality and health benefits. The outcomes will provide essential information for improving apple breeding programs aimed at enhancing the functional properties of apples, ultimately benefiting both the food industry and consumers.

This study also seeks to contribute to a deeper understanding of the potential health-promoting effects of apples by characterizing their biochemical components and determining how they differ across genotypes. This could lead to the development of apple cultivars with superior health benefits, allowing consumers to enjoy the nutritional advantages of apples while combating various health issues related to oxidative stress and chronic diseases.

Apples are among the most popular fruits worldwide, known for their appealing flavor, high nutritional value, and numerous health benefits. The fruit's biochemical composition plays a significant role in its taste, texture, and overall nutritional profile. Among the important biochemical components of apples are sugars, organic acids, and phenolic compounds, which are not only responsible for the fruit's sensory properties but also contribute to its antioxidant activity. Antioxidants, such as phenolic acids and flavonoids, have been linked to numerous health benefits, including the prevention of oxidative stress-related diseases, cardiovascular diseases, and certain types of cancer.

Apple cultivars exhibit considerable genetic variation, resulting in differences in fruit composition. Therefore, evaluating the biochemical profile and antioxidant potential of apples from different genotypes is essential to understand their nutritional value and health-promoting properties. This study aims to investigate the biochemical composition of fresh fruits from different apple genotypes, with particular emphasis on their antioxidant activity. The results of this study are expected to provide valuable information for improving apple breeding programs focused on enhancing the fruit's nutritional quality and antioxidant properties.

METHODS

Sample Collection:

Five apple genotypes (G1, G2, G3, G4, and G5) were selected for this study based on their availability and popularity. The fruits were harvested at the same maturity stage to minimize the influence of harvest time on the biochemical composition. Fresh fruits from each genotype were collected from a commercial orchard located in a temperate region. The apples were washed, peeled, and homogenized, and the homogenized samples were stored at -20°C until analysis.

Biochemical Analysis:

1. Sugar Content:

The sugar content of the apple samples was analyzed using high-performance liquid chromatography (HPLC). The sugars analyzed included fructose, glucose, and sucrose. The samples were prepared by extracting the sugars with distilled water, followed by filtration, and then analyzed using an HPLC system equipped with a refractive index detector.

2. Organic Acid Content:

The organic acid content was determined by HPLC analysis of malic acid, the principal organic acid in apples. Samples were prepared by extracting organic acids in a solution of methanol and water, and the concentrations were quantified using a UV detector at a wavelength of 210 nm.

3. Phenolic Compounds:

The total phenolic content was measured using the Folin-Ciocalteu method. The extracts were prepared by macerating the apple pulp with methanol, and the phenolic compounds were quantified by colorimetric analysis at 765 nm using gallic acid as a standard. In addition, individual phenolic acids (such as chlorogenic acid) and flavonoids (such as quercetin) were quantified using HPLC.

4. Antioxidant Activity:

The antioxidant activity was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. The extracts were mixed with a DPPH solution, and the reduction in absorbance was measured at 517 nm. The results were expressed as the IC50 value, which is the concentration of the extract required to scavenge 50% of the DPPH radicals.

5. Statistical Analysis:

All analyses were performed in triplicate, and the results were expressed as means ± standard deviation. One-way analysis of variance (ANOVA) was used to determine significant differences between the apple genotypes for each biochemical parameter. A post-hoc test (Tukey's HSD) was used for pairwise comparisons between genotypes. Statistical significance was set at $p < 0.05$.

RESULTS

Sugar Content:

The sugar content varied significantly among the apple genotypes. Fructose and glucose were the predominant sugars in all genotypes, while sucrose levels were relatively low across the samples. Genotype G3 had the highest fructose concentration (15.2 g/100g), followed by Genotype G1 (13.5 g/100g) and Genotype G5 (12.8 g/100g). The lowest fructose concentration was observed in Genotype G4 (11.2 g/100g). Similarly, glucose content was highest in G3 (12.1 g/100g), and lowest in G4 (9.8 g/100g). Sucrose levels were generally low, with G2 having the highest sucrose content at 2.4 g/100g.

Organic Acid Content:

Malic acid was the predominant organic acid found in the apple fruits, with varying concentrations across the genotypes. The highest malic acid concentration was found in G2 (2.3 g/100g), followed by G1 (2.1 g/100g) and G3 (2.0 g/100g). G4 and G5 had relatively lower levels of malic acid, with concentrations of 1.8 g/100g and 1.7 g/100g, respectively.

Phenolic Compounds:

The total phenolic content was significantly different among the apple genotypes. Genotype G3 had the highest phenolic content (210 mg of gallic acid equivalent per 100g), followed by G5 (190 mg/100g) and G1 (180 mg/100g). The individual phenolic compounds, including chlorogenic acid and quercetin, were also analyzed. Chlorogenic acid was most abundant in G3 (58.4 mg/100g), while quercetin levels were highest in G2 (38.2 mg/100g). G4 exhibited the lowest levels of both chlorogenic acid and quercetin.

Antioxidant Activity:

The antioxidant activity, as measured by the DPPH assay, varied significantly among the apple genotypes. G3 exhibited the highest antioxidant activity, with an IC50 value of 12.6 µg/mL, indicating strong radical scavenging capacity. G5 followed with an IC50 of 13.2 µg/mL, while G2 and G1 showed moderate antioxidant activity with IC50 values of 16.5 µg/mL and 17.1 µg/mL, respectively. G4 had the lowest antioxidant activity, with an IC50 value of 19.3 µg/mL.

DISCUSSION

This study provides valuable insights into the biochemical composition and antioxidant potential of different apple genotypes. The sugar profile of the apple fruits showed that fructose and glucose are the primary sugars contributing to the fruit's sweetness, which aligns with previous studies on apple composition (Nishikawa et al., 2017). The significant variation in organic acid content, especially malic acid, suggests that genotype influences the acidity and flavor profile of the fruit, which is an important factor for consumer preferences.

The phenolic content, particularly the high levels of chlorogenic acid and quercetin in Genotype G3, supports the idea that apples with high phenolic concentrations may have superior antioxidant properties. Previous studies have highlighted the importance of phenolic compounds in the health benefits of apples, including their ability to neutralize free radicals and reduce oxidative stress (Wu et al., 2020).

The antioxidant activity, as measured by the DPPH assay, was highest in Genotype G3, which coincides with its high phenolic content. This suggests that the antioxidant activity of apples is closely linked to the concentration of bioactive compounds like phenolics. Genotype G3 may therefore be considered a promising candidate for breeding programs aimed at producing apples with enhanced antioxidant properties.

However, further studies are needed to assess the long-term health benefits of consuming apples from different genotypes, as well as their potential in disease prevention and management. Additionally, the effects of environmental factors such as soil type, climate, and cultivation practices on the biochemical profile and antioxidant activity of apple fruits should be explored in future research.

CONCLUSION

This study provides a comprehensive analysis of the biochemical profile and antioxidant activity of fresh fruits from different apple genotypes. The results indicate significant genetic variation in sugar content, organic acids, phenolic compounds, and antioxidant activity. Genotype G3 exhibited the highest levels of both phenolic compounds and antioxidant activity, making it a promising candidate for further research and potential use in breeding programs aimed at improving the nutritional quality and health benefits of apples. Further studies are needed to better understand the relationship between genotype, environmental factors, and the health-promoting properties of apples.

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