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Development and quality evaluation of functional apple jam fortified with wheatgrass (*Triticum aestivum* L.) powder

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Abstract

This study aimed to develop a functional apple jam fortified with wheatgrass powder (WGP) and evaluate its physicochemical, nutritional, antioxidant, and sensory properties. Apple jam was prepared by incorporating WGP at 1%, 3%, and 5% (w/w), with an unfortified jam serving as the control. WGP fortification significantly ($p < 0.05$) reduced moisture and total sugars while increasing ash content, titratable acidity, vitamin C, total phenolic content, and antioxidant activity. Total soluble solids remained within the desirable range (68.05–68.61 °Brix), ensuring appropriate gel formation and product stability. Total phenolic content increased from 52.4 to 122.3 mg GAE/100 g, while DPPH radical scavenging activity increased from 26.3% to 74.9%. Sensory evaluation indicated that jam fortified with 3% WGP achieved the highest overall acceptability. Therefore, 3% WGP can be recommended for developing nutritionally enriched functional apple jam with improved antioxidant properties and consumer acceptance.

Keywords: Apple jam; wheatgrass powder; functional food; antioxidant activity; total phenolic content; sensory evaluation

Introduction

Consumer demand for functional foods has increased substantially in recent years, driven by growing awareness of the link between diet and health. Fruit-based products enriched with bioactive plant ingredients have gained considerable attention because they combine consumer acceptability with enhanced nutritional and functional properties [1]. Among these products, jam remains one of the most widely consumed fruit preserves owing to its pleasant taste, convenience, long shelf life, and versatility. However, conventional jams are generally rich in sugars and provide limited amounts of health-promoting phytochemicals, creating opportunities to develop value-added functional jams by incorporating nutrient-dense plant materials.

Apple (*Malus domestica* Borkh.) is one of the most popular fruits used for jam production because of its desirable flavor, natural pectin content, and balanced acidity. Apples are rich in dietary fiber, vitamin C, potassium, and various phenolic compounds, including chlorogenic acid, quercetin, catechin, and phloridzin, which exhibit antioxidant, anti-inflammatory, and cardioprotective properties [2]. Furthermore, the naturally occurring pectin in apples contributes to desirable gel formation, texture, and stability during jam manufacture.

Wheatgrass (*Triticum aestivum* L.), the young shoots of common wheat harvested at the early vegetative stage, has emerged as a promising functional ingredient because of its exceptional nutritional profile. Wheatgrass contains chlorophyll, vitamins A, C, and E, essential amino acids, minerals such as iron, calcium, magnesium, and potassium, dietary fiber, flavonoids, phenolic acids, carotenoids, and antioxidant enzymes. Numerous studies have demonstrated that wheatgrass exhibits antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, hepatoprotective, and detoxifying properties owing to its rich phytochemical composition [3]. Incorporating wheatgrass into fruit-based products, such as jam, offers an effective strategy to improve nutritional quality while maintaining consumer acceptability. Wheatgrass fortification has been reported to enhance total phenolic content, chlorophyll concentration, Antioxidant activity, and mineral composition of food products.

However, its characteristic green color and grassy flavor may influence sensory acceptance, making it essential to optimize the fortification level [3]. Although several researchers have successfully enriched jams and fruit products with natural plant ingredients to improve their functional and antioxidant properties [4], information regarding the development of wheatgrass-fortified apple jam remains limited. Therefore, the present study aimed to develop a functional apple jam fortified with wheatgrass and evaluate its physicochemical, nutritional, antioxidant, textural, microbiological, and sensory characteristics.

Material and methods

Fresh apples (*Malus domestica* Borkh.) were purchased from a local market in Greater Noida, Uttar Pradesh, India. Wheatgrass (*Triticum aestivum* L.) powder was prepared in the laboratory of the Department of Food Science and Technology, School of Engineering and Technology, Sharda University, Greater Noida, Uttar Pradesh, India. All chemicals and reagents used for physicochemical and analytical analyses were of analytical reagent (AR) grade and were procured from standard commercial suppliers.

Preparation of Apple Jam

Apple jam was prepared using fresh apple pulp fortified with wheatgrass (*Triticum aestivum* L.) powder at different concentrations. A control sample (without wheatgrass powder) and three fortified samples containing 1%, 3%, and 5% (w/w) wheatgrass powder were prepared. For jam preparation, 100 g of fresh apple pulp was heated over a low flame, continuously stirred. Granulated sugar was added gradually during cooking to ensure complete dissolution. Appropriate quantities of pectin and citric acid were incorporated to facilitate gel formation and maintain the desired acidity. Wheatgrass powder was added at the respective concentrations (1%, 3%, and 5%, w/w) and mixed thoroughly to obtain a homogeneous mixture.

The mixture was cooked with continuous stirring, and total Soluble solids (TSS) were monitored periodically using an

Abbe handheld refractometer until a final TSS of 68 °Brix was reached. The cooking process was then terminated, and the jam was allowed to cool to room temperature. The cooled jam was filled into clean, sterilized glass jars, sealed immediately, and stored under refrigerated conditions until further physicochemical, antioxidant, microbiological, and sensory analyses.

Physico-chemical analysis

Moisture and ash content were quantified using AAOAC 2000 standards [5]. Titratable acidity, pH, total soluble solids, reducing sugars, non-reducing sugars, and ascorbic acid were quantified according to the standard analytical methods prescribed by the Association of Official Analytical Chemists (AOAC, 2019) [6].

Sensory Analysis

The sensory attributes of the jam samples, including color, texture, taste, and overall acceptability, were evaluated by a panel of 10 trained judges using a nine-point hedonic scale. Sensory evaluation was conducted at 15-day intervals over a 3-month storage period. The panelists assigned scores ranging from 1 (dislike extremely) to 9 (like extremely) for each sensory attribute.

Result and discussion

Physicochemical analysis

Moisture and ash

The incorporation of wheatgrass powder (WGP) significantly affected the physicochemical properties of apple jam. Moisture content decreased ($p < 0.05$) from 31.82% in the control to 29.74% in the 5% WGP treatment, likely due to the high dietary fiber content of wheatgrass, which binds water and reduces free moisture [7]. Conversely, ash content increased significantly from 0.41% to 0.81%, reflecting the mineral-rich nature of wheatgrass (Table 1). Similar trends have been reported in wheatgrass-fortified and other fiber-enriched food products [8].

Table 1: Physicochemical analysis of apple wheatgrass jam

Treatment	Moisture (%)	Ash (%)	TSS (°Brix)	pH	Titrateable acidity (%)
Control (0%)	31.82 ± 0.21 ^a	0.41 ± 0.01 ^d	68.05 ± 0.14 ^a	3.46 ± 0.02 ^a	0.69 ± 0.01 ^c
WGP 1%	31.20 ± 0.18 ^b	0.52 ± 0.02 ^c	68.18 ± 0.16 ^a	3.41 ± 0.03 ^b	0.73 ± 0.01 ^b
WGP 3%	30.41 ± 0.15 ^c	0.66 ± 0.02 ^b	68.43 ± 0.12 ^a	3.36 ± 0.02 ^c	0.77 ± 0.02 ^a
WGP 5%	29.74 ± 0.17 ^d	0.81 ± 0.03 ^a	68.61 ± 0.15 ^a	3.31 ± 0.03 ^d	0.81 ± 0.02 ^a

The results are represented as the means ± standard deviation. Superscripts with different letters in the same column indicate significant differences ($p \leq 0.05$).

TSS and pH

The TSS remained unchanged (68.05-68.61 °Brix) across treatments, indicating that WGP had minimal effect on soluble solids due to standardized sugar concentration (Table 1). The values were within the recommended range for proper gel formation and jam preservation [9]. In contrast, increasing WGP levels significantly decreased pH (3.46-3.31) and increased titrateable acidity (0.69-0.81%), likely due to the presence of organic acids and phenolic compounds in wheatgrass. This enhanced acidity may improve pectin gel formation, microbial stability, and shelf

life, consistent with previous reports on plant-enriched fruit products [10].

Total sugar and Vitamin C content

The incorporation of WGP significantly ($p < 0.05$) influenced the sugar profile and vitamin C content of apple jam. Total sugars and non-reducing sugars decreased progressively with increasing WGP levels, whereas reducing sugars and vitamin C content increased significantly, indicating an improvement in the jam's nutritional quality. Total sugars decreased from 64.82% in the control to 62.65% in the 5% WGP treatment, which may be attributed to the partial replacement of apple pulp with wheatgrass powder. As wheatgrass is rich in dietary fiber, minerals, and bioactive compounds but comparatively lower in soluble sugars, its

incorporation reduced the overall sugar content of the jam. Similar findings have been reported in functional fruit products enriched with fiber-rich plant ingredients ^[11]. Reducing sugars increased significantly from 29.81% to 32.41%, while non-reducing sugars decreased from 35.01% to 30.24% (Table 2). This shift is mainly due to acid-catalyzed hydrolysis (inversion) of sucrose into glucose and fructose during jam processing at high temperatures and

under acidic conditions. The higher acidity observed in WGP-fortified formulations may have further promoted sucrose inversion, resulting in increased reducing sugars and decreased non-reducing sugars. Similar observations have been reported during jam manufacture, where sucrose inversion improves texture, prevents sugar crystallization, and enhances product stability ^[12].

Table 2: Analysis of sugar and vitamin C content

Treatment	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Vitamin C (mg/100 g)
Control	64.82 ±0.31 ^a	29.81 ±0.22 ^d	35.01 ±0.25 ^a	8.82 ±0.31 ^d
WGP 1%	64.14 ±0.27 ^b	30.42 ±0.25 ^c	33.72 ±0.23 ^b	11.84 ±0.42 ^c
WGP 3%	63.36 ±0.24 ^c	31.33 ±0.28 ^b	32.03 ±0.26 ^c	15.71 ±0.38 ^b
WGP 5%	62.65 ±0.30 ^d	32.41 ±0.31 ^a	30.24 ±0.30 ^d	18.46 ±0.40 ^a

The results are represented as the means ± standard deviation. Superscripts with different letters in the same column indicate significant differences ($p \leq 0.05$). Vitamin C content increased significantly from 8.82 mg/100 g in the control to 18.46 mg/100 g in the 5% WGP treatment. This increase is attributed to the naturally high vitamin C content of young wheatgrass, which is also rich in chlorophyll, phenolic compounds, flavonoids, and other antioxidant phytochemicals. Although some ascorbic acid is lost during thermal processing, WGP supplementation significantly enhanced the nutritional and antioxidant value of the jam. Similar improvements have been reported in other wheatgrass-fortified food products ^[13].

Total phenolic content and antioxidant activity”: The

incorporation of WGP significantly ($p < 0.05$) increased the total phenolic content and antioxidant activity of apple jam. Total phenolic content increased from 52.4 to 122.3 mg GAE/100 g, while DPPH radical scavenging activity increased from 26.3% to 74.9% with increasing WGP levels, demonstrating a marked improvement in the antioxidant potential of the jam (Table 3). The enhanced phenolic content and DPPH inhibition are attributed to the rich presence of phenolic compounds, flavonoids, chlorophyll, and other antioxidant phytochemicals in wheatgrass. Despite thermal processing, WGP retained sufficient bioactive compounds, thereby significantly improving the jam's functional quality. Similar findings have been reported in wheatgrass-fortified and other plant-based functional foods ^[7].

Table 3: Determination of antioxidant properties of apple wheatgrass jam

Treatment	Total phenolics (mg GAE/100 g)	DPPH inhibition (%)
Control	52.4 ±1.1 ^d	26.3 ±0.9 ^d
WGP 1%	71.8 ±1.5 ^c	39.8 ±1.1 ^c
WGP 3%	96.4 ±2.0 ^b	58.7 ±1.4 ^b
WGP 5%	122.3 ±2.4 ^a	74.9 ±1.8 ^a

The results are represented as the means ± standard deviation. Superscripts with different letters in the same column indicate significant differences ($p \leq 0.05$).

Sensory analysis

The incorporation of WGP significantly ($p < 0.05$) affected the sensory attributes of apple jam. Colour, aroma, taste, texture, and overall acceptability improved with WGP addition up to 3%, with the highest overall acceptability recorded for the 3% WGP treatment (8.48), followed closely by 1% WGP (8.43). However, further increasing WGP to 5% significantly reduced all sensory scores, with overall

acceptability declining to 7.51. The improved sensory quality at lower WGP levels may be attributed to the pleasant green hue and the contribution of bioactive compounds without adversely affecting flavor or texture. In contrast, higher incorporation (5%) imparted a stronger grassy flavor, a darker color, and slight textural changes, resulting in lower consumer acceptability. Similar trends have been reported in wheatgrass-fortified functional foods, where moderate supplementation improved sensory quality, whereas excessive addition negatively affected consumer preference due to the characteristic taste and aroma of wheatgrass ^[7, 13].

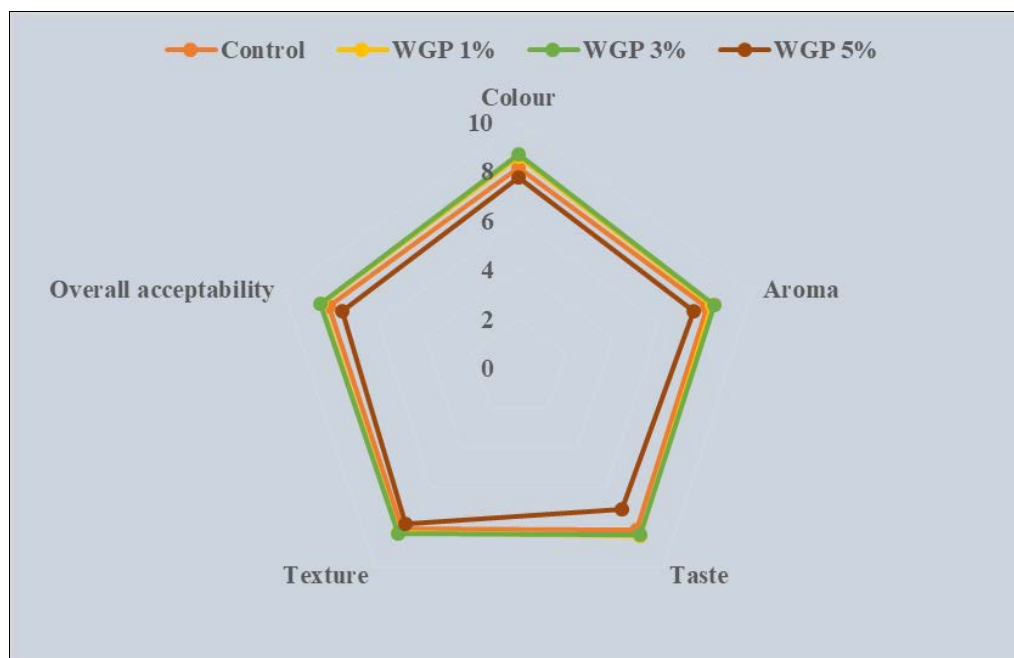


Fig 1: Radar diagram of sensory analysis of apple wheatgrass jam

Conclusion

The present study demonstrated that wheatgrass powder is a promising functional ingredient for the development of nutritionally enriched apple jam. Wheatgrass fortification significantly improved the mineral content, vitamin C, total phenolic content, and antioxidant activity while maintaining desirable physicochemical characteristics. Although higher levels of wheatgrass (5%) further enhanced the nutritional and antioxidant properties, they adversely affected sensory quality due to the characteristic grassy flavor and darker color. Among the formulations, 3% wheatgrass powder provided the best balance between nutritional enhancement and consumer acceptability, achieving the highest overall sensory score and markedly improved antioxidant potential. Therefore, incorporating 3% wheatgrass powder is recommended for producing functional apple jam with improved health-promoting properties and acceptable sensory quality. Further studies on storage stability, bioactive compound retention, and consumer acceptance are recommended to support its commercial application.

Conflict of Interest

Authors declare no competing interests.

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