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Formulation and Quality Assessment of Brownie Enriched with Black Grapes Raisin Pomace Powder

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Abstract

Black grape raisin pomace powder (BGRPP) is a by-product from fruit processing. It is rich in dietary fiber and phenolic antioxidants. This study added BGRPP to brownies to create a healthier bakery product and promote the sustainable use of fruit processing waste. We looked at how adding BGRPP affected the sensory, nutritional, physicochemical, antioxidant, and microbiological features of brownies. We made brownie recipes by replacing refined wheat flour with BGRPP at 5%, 10%, and 15% levels. We evaluated the products through sensory analysis, proximate composition, physicochemical measurements, Total flavonoid content, DPPH radical scavenging activity and total plate count. Among all formulations, the brownie containing 15% BGRPP (T3) achieved the highest sensory scores for appearance (8.20), taste (8.67), odor (8.37), and mouthfeel (8.67). Fortification with BGRPP significantly improved dietary fibre content (11.64%), antioxidant activity (45.37 mg/g AAE), and total flavonoid content (64.60 mg QE/100 g) compared with the control. The fortified brownie also exhibited a lower pH (5.9), higher total soluble solids (12.4 °Brix), and reduced microbial load (1.23×10^4 CFU/g), indicating enhanced functional quality and microbiological stability. Overall, incorporation of BGRPP improved the nutritional and functional attributes of brownies without compromising sensory acceptability, with the 15% fortification level identified as the optimum formulation for the development of a value-added functional bakery product.

Keywords: Black grape raisin pomace powder, functional brownie, dietary fibre, antioxidant activity, flavonoids, Bakery food sensory evaluation.

INTRODUCTION

Grapes *(Vitis vinifera L.)* are among the most widespread cultivated fruit crops in the world, with an annual yield of more than 75.8 million tonnes per year (Ramla Khairi et al., 2018). The grape berries undergo a range of physiological changes as they mature, leading to the development of a typical coloration, an increase in sugar levels, and the formation of a natural waxy coating on the surface of the fruit, making them desirable for fresh consumption and processing. The grapes, after harvest, are subjected to cleaning, grading, and pre-treatment to ensure better drying and improve the quality of the produce (Jin et al., 2017). The grapes are dried to make raisins or processed to develop other value-added products. Generally raisins are

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dried grapes which are different varieties of *Vitis vinifera L.* and among the range of dried fruits, raisins are one of the most preferred. Based on the cultivar of grape used to manufacture them, the raisins are categorized into black raisins, golden raisins, sultanas, and currants. Black raisins are famous for their nutritional and health benefits and are rich in polyphenols, which have a high antioxidant potential (Harshita Gupta et al., 2025). The wine industry generates a significant quantity of by-products during wine production, which create a disposal problem, especially for small and medium-sized enterprises. Grape pomace, the residue left after extracting juice from grapes, constitutes around 20-25% of the weight of the processed grapes and is the major by-product among others generated during wine production. The waste material utilization in the production of functional foods and nutraceuticals is a novel area with a bright future and immense potential for valorising agro-industrial waste in the context of a circular economy (Charalampia et al., 2016). Grape pomace is a good source of fiber, flavonoids, phenolic compounds and other phytonutrients with antioxidant, antimicrobial, anti-inflammatory, and prebiotic activities. The addition of grape pomace to food goods can enhance the nutritional value, moisture content, texture, oxidative stability, and functionality due to the valuable compounds present. Consequently, grape pomace has been utilized in a variety of food products, including bakery goods, dairy products, beverages, and meat analogs, to improve their physicochemical, technological, and nutritional properties (Kohajdová, 2018; Tseng et al., 2013). Recently, there has been a surge in the utilization of grape pomace as a functional food ingredient to produce value-added products in line with the circular economy's principles by transforming agro-industrial food waste into more valuable products while offering enhanced nutritional and functional benefits (Temkov et al., 2021).Grape pomace, primarily grape skins and seeds, along with other discarded portions, can be dried and ground into a fine powder and added to a variety of food products, including bakery products, cookies, cereals, pasta, beverages, and dietary supplements. Brownies are one of the most popular baked items, with a unique flavor and soft texture, and have gained worldwide recognition and acceptability among consumers. However, traditional brownies are high in carbohydrates and fat, while fiber and healthy phytonutrients are low, making them nutritionally unbalanced. As a result, the addition of black grape raisin pomace powder could improve the nutritional and antioxidant content of brownies while also enhancing their technological qualities and overall sensory appeal. Thus, the current study aimed to develop and evaluate functional brownies as a value-added product made from black grape raisin pomace powder with enhanced nutritional, antioxidant, and functional properties.

2. Materials and Methods

2.1 Study Design

The experimental study was carried out in the Food Science Analysis Laboratory, Department of Food and Nutrition, School of Home Science, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India. The process included preparation of black grape raisin pomace powder (BGRPP), development of fortified brownies and the evaluation of sensory, nutritional, physicochemical, antioxidant and microbiological properties of the developed samples in the laboratory conditions

2.2 Materials

Refined wheat flour, and other materials needed for this research such as preparation of brownies were purchased from the local market of Lucknow, Uttar Pradesh, India. Black grape raisins, used for the production of black grape raisin pomace powder (BGRPP) were also obtained from the local market. The required chemicals and analytical grade reagents for proximate, physicochemical, antioxidant and microbiological analyses were purchased from laboratory suppliers.

2.3 Preparation of Black Grape Raisin Pomace Powder

Black grape raisins were subjected to handpicking to remove defective and undesirable materials. The produce was then washed with running water and soaked in distilled water for 4-6 h. The soaked sample was blended with a laboratory blender to form a paste. The obtained paste was filtered using muslin cloth to separate the liquid from the pomace. The pomace was dried in a laboratory dryer at 50-55 o C to obtain a constant weight. The dried matter was ground into a powder, sieved, and stored in an airtight container until further use in brownie production.

2.4 Formulation of Brownies

Four brownie samples were prepared by replacing different percentages of refined wheat flour with black grape raisin pomace powder. The control sample (T0) was prepared using 100% refined wheat flour, while T1, T2 and T3 were made using 5, 10 and 15% BGRPP respectively with the other ingredients being held constant.

2.5 Preparation of Brownies

The methodology of brownie production using the BGRPP is demonstrated in Figure 1. All ingredients were weighed using an analytical balance. The dry components were mixed together, and the wet ingredients were added to the resultant mixture. The dough was placed into well-greased molds and baked at 180 °C for 25-30 min. in a preheated oven. After cooling to room temperature, the brownies were stored in airtight containers and kept until the analyses were performed.

Fig.1 Preparation of brownie

2.6 Proximate Analysis

The composition of the formulated brownies was determined by standard analytical procedures as described by AOAC (2019). Moisture content was determined using hot air oven method at 105ºC. Ash content was determined by incinerating the samples in a muffle furnace at 550ºC. On the other hand, determination of the crude protein was by kjelhdahl digestion analysis which was calculated by a factor of 6.25 for the nitrogen content. Extraction of crude fat was done using Soxhlet apparatus with petroleum ether as the solvent. The total crude fibre in the samples was analyzed by enzymatic-gravimetric AOAC method while the carbohydrate content was determined by calculation. Finally, calculation of the energy value of the various formulated brownie samples was done using Atwater's coefficients.

2.7 Physicochemical Analysis

The physicochemical analysis such as pH of brownie samples was determined using a calibrated digital pH meter after homogenizing the sample in distilled water. Total soluble solids (TSS) were measured using a digital refractometer and expressed as °Brix.

2.8 Determination of Antioxidant Activity and Total Flavonoid Content

The antioxidant activity of the brownie samples was assessed with the help of 2, 2-Diphenyl1-picrylhydrazyl radicals. In detail, 100 µL of the sample extract was mixed with 3 mL of a freshly prepared 2,2-diphenyl-1-picrylhydrazyl solution. This mixture was allowed to stand for 30 min in the dark at room temperature. After this, the absorbance of the solution was measured at 517 nm in a UV–Vis spectrophotometer and the antioxidant activity was calculated from the results in mg ascorbic acid equivalent per gram of the sample. The total amount of flavonoids present in the brownies was determined by a standard spectrophotometric assay and reported as mg of quercetin equivalent (QE) per 100 g of brownie sample.

2.9 Sensory Evaluation

Sensory evaluation of brownie samples was conducted using a semi-trained panel. Appearance, colour, aroma, taste, mouthfeel, texture, and overall acceptability were evaluated using a nine-point hedonic scale, where 9 represented "like extremely" and 1 represented "dislike extremely."

2.10 Microbiological Analysis

Microbiological quality was evaluated by determining the total plate count using the spread plate technique on nutrient agar. Samples were analysed immediately after preparation and during storage. Plates were incubated at 35–37 °C for 24–48 h, and results were expressed as colony-forming units per gram (CFU/g).

2.1.1 Statistical Analysis

Each test was performed three times and the results are presented as mean ± standard deviation. IBM SPSS Statistics (version 21) was used for statistical analysis. Significant differences between the treatments were analyzed by one-way analysis of variance (ANOVA) and Tukey's multiple comparison test. Differences were regarded as statistically significant at $p<0.05$.

3. Results and Discussion

3.1 Sensory Evaluation

The sensory evaluation results of the brownie samples fortified with black grape raisin pomace powder are presented in Figure 2. All brownie samples had an acceptable score which proves that the addition of BGRPP did not affect the overall acceptability of the product. Among the treatments evaluated, brownie sample with 15% BGRPP (T3) had the highest scores for appearance (8.20 ± 0.66), taste (8.67 ± 0.48), aroma (8.37 ± 0.49) and mouthfeel (8.67 ± 0.48) while the lowest scores were recorded for control sample (T0). The improved sensory properties of T3 may be attributed to the incorporation of fruit flavour and colour and the enhancement of chewiness of the brownie due to the high content of dietary fibre and phenolic compounds of black grape raisin pomace. The one-way ANOVA revealed significant differences ($p < 0.05$) between the treatments for all the sensory attributes studied, indicating that the level of BGRPP addition had a significant effect on the organoleptic qualities of the brownie. Additionally, our findings are consistent with previous studies showing the positive effect of grape pomace supplementation on the sensory properties of baked goods (Pio Ávila et al., 2019; Poiana et al., 2023; Alshawi, 2024).

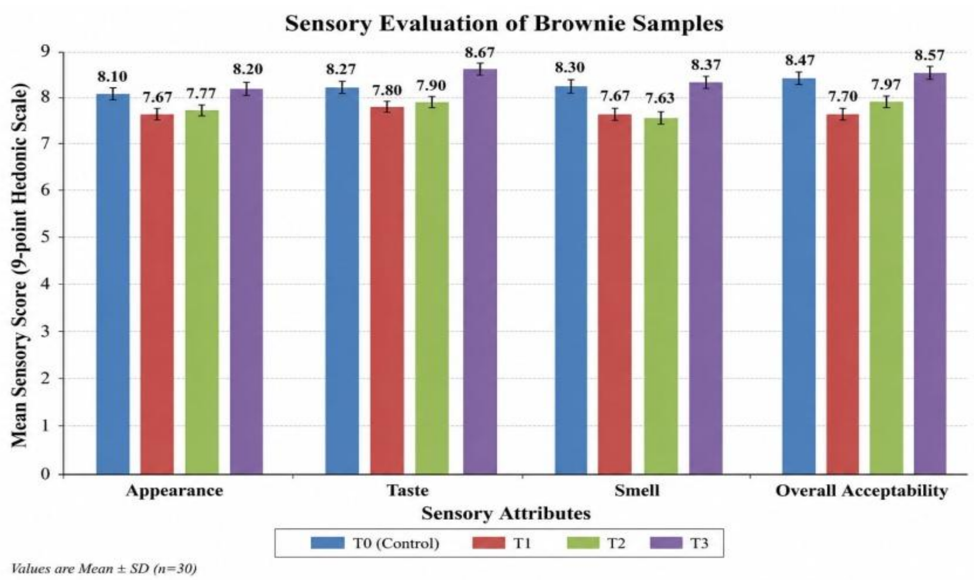

Fig. 2 Sensory evaluation score statistical analysis using one-way ANOVA

3.2 Proximate Composition

The proximate composition of the control and black grape raisin pomace powder (BGRPP) fortified brownies is shown in Table 1. Adding BGRPP significantly affected the proximate composition of the brownies ($p < 0.05$). The moisture and ash contents increased from 26.17% to 26.81% and from 3.61% to 3.73%, respectively. This change is likely due to the BGRPP's high water-holding capacity and its rich mineral content. There was a marked increase in dietary fiber, rising from 2.00% to 11.64%. On the other hand, there were slight decreases in fat, protein, and energy content. The control brownies and the experimental brownies did not show any significant difference in carbohydrate content. In conclusion, the BGRPP fortification significantly improved the nutritional properties of the brownies without harming their proximate composition. Similar findings were noted by Bender et al. (2017), Shih et al. (2020), Poiana et al. (2023), Alshawi (2024), and Kausar et al. (2024) for grape pomace-fortified baked goods.

Table 3.2 Effect of Black Grape Raisin Pomace Powder on Proximate Composition of Brownies

Parameters	Control Brownie (T0)	Fortified Brownie (T3)
Moisture (%)	26.17	26.81
Ash (%)	3.61	3.73
Fat (%)	25.12	24.96
Crude Fibre (%)	2.73	2.39
Dietary Fibre (%)	2.00	11.64
Protein (%)	8.60	8.35
Carbohydrate (%)	36.05	36.15
Energy Value (kcal/100 g)	406.48	402.64

3.3 Physicochemical Properties

Physicochemical evaluation revealed that the incorporation of BGRPP significantly influenced both pH and total soluble solids (TSS) of the brownies. The pH decreased from 6.8 ± 0.02 in the control sample to 5.9 ± 0.03 in the T3 formulation, which can be attributed to the naturally occurring organic acids present in grape pomace. This reduction in pH may enhance microbial stability and potentially extend the product's shelf life. In contrast, TSS increased from 10.2 to 12.4 °Brix with increasing levels of BGRPP, reflecting a greater concentration of soluble constituents, including sugars and phenolic compounds. The elevated TSS may contribute to improved flavour perception and overall product quality in the fortified brownies.

3.4 Antioxidant Activity and Total Flavonoid Content

The addition of black grape raisin pomace powder (BGRPP) strongly and significantly ($p < 0.05$) improved the brownies' antioxidant properties. It reported an increase in antioxidant activity from 35.86 to 45.37 mg AAE/g and a dramatic increase in total flavonoids from 23.80 to 64.60 mg QE/100 g when higher amounts of BGRPP were used. This effect is likely caused by the high quantity of phenolic compounds and flavonoids which naturally have strong antioxidant activity in black grape raisin pomace. These results correlate with Nakov et al. (2023), who showed high antioxidant activity and increased flavonoid content in bakery products with the addition of grape pomace and further suggested grape by-products as functional food ingredients.

3.5 Microbiological Quality

The addition of 15% black grape raisin pomace powder (BGRPP) in the brownie formulation showed reduced total plate count (1.2310 4 CFU/g) as compared to control sample (3.5610 4 CFU/g) indicating an improved microbiological stability upon incorporation of BGRPP. The decrease in microbial load can be due to the antimicrobial activity of phenolic compounds and other bioactive components naturally present in black grape raisin pomace which can inhibit the evolution of microbes and extend the shelf life of the product. Sunarmani and P. Luna (2022) have also observed that microbial growth in brownies is highly sensitive to moisture content and water activity during storage, and highlighted the importance of formulation in enhancing microbiological quality.

4. Conclusion

Black grape raisin pomace powder (BGRPP) is a promising functional component for improving the nutritional and functional qualities of brownies, according to the results of this study. Without sacrificing sensory quality, partially substituting BGRPP for refined wheat flour greatly enhanced dietary fibre, antioxidant activity, total flavonoid concentration, and mineral content. With dietary fibre rising from 2.00% to 11.64%, antioxidant activity rising from 35.86 to 45.37 mg AAE/g, and total flavonoid content rising from 23.80 to 64.60 mg QE/100 g, the brownie containing 15% BGRPP (T3) had the best overall sensory acceptability and nutritional profile of all the formulations. Better microbiological stability and product quality were also demonstrated by the enhanced brownie's lower pH and decreased total plate count. The incorporation of BGRPP represents a sustainable strategy for the valorization of agro-industrial by-products by converting grape processing residues into a functional food ingredient with added nutritional value. The findings indicate that a 15% substitution level of BGRPP is optimal for producing nutritionally enhanced brownies with improved antioxidant potential while maintaining high sensory acceptability. Future studies should investigate the long-term storage stability of BGRPP-enriched products, the bioavailability and bioaccessibility of phenolic compounds, comprehensive texture profile characteristics, and consumer acceptance under commercial manufacturing conditions to support large-scale industrial implementation.

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