*Original Research Article*

A comparative study on the Morphological & Biochemical characteristics of three types of Broccoli (*Brassica Oleraceae*) produced in Chittagong region Bangladesh

# ABSTRACT

Broccoli is a green vegetable (*Brassica oleracea var.italica*) plant which is characterized by green flower heads arranged in a tree like branches are attached with a thick, edible stalk.

It is a popular vegetable crop with a good source of various remarkable nutritional composition like rich source of antioxidant including Vitamin C, K and A ,also contains several important minerals including potassium, calcium and iron and numerous health benefits. Morphological Parameter such as, leaf area, node density, bud number change etc.in many plant species in response to factors such as light availability, soil compaction ,organic matter removal etc. are compared.Recently, it has just started cultivating in Bangladesh. In this study, three varieties of Broccoli have been selected, named as BC1 (BARI-1), BC2 (Crown Green) and BC3 (a hybrid variety of Broccoli) for experimental analysis.

As shown in, three varieties of Broccoli identified from the morphological and physico-chemical characters such as- Plant Height (cm), Vegetable weight (g), Vegetable Floret weight (g), Vegetable Stem Weight (g), Head Length (L), Stalk Diameter (Ds), Shape, Color, and Compactness.

The aim of this work is to evaluate effect of conventional mineral fertilizers, which are considered as a major source of plant nutrients and wastewater on vegetative growth in addition to Biochemical properties of the Broccoli plants.

The data which was obtained from the chemical characters of three varieties of broccoli such as pH (6.23 to 6.55), moisture (86.22to 89.32%), Ash (0.80 to 0.83 %), TA (0.41 to 0.54 %), TSS (7.32 to 9.63°Brix), Total Sugar (6.04 to 5.60 %), Reducing Sugar (4.22 to 4.58%), Non-Reducing Sugar (0.92 to 1.46%), Lipid (0.30 to 0.33%), Water Soluble Protein (2.12 to 2.22 %), Vitamin-C (84.3 to 88.6%).

In this Experiment, nine important minerals content were analyzed. It was observed that, among the three varieties of Broccoli high sources of Iron and its amount was varied between 17.8 to 24.5 mg%. Potassium and Calcium are also considered as good sources of broccoli. In conclusion, all the three promising varieties, BC1 cultivar is much better than BC2 and BC3 in the context of nutrient contents.

*Keywords: Broccoli; Morphological Character; Biochemical Composition****;*** *Mineral content*

**1. INTRODUCTION**

Plants are used traditionally not only for nutrition, but also for therapy of diseases, as they contain pharmacological active substances [1]. Broccoli is very similar to cauliflower, but unlike it, its floral buds are well-formed and clearly visible. The inflorescence grows at the end of a central, thick stem and is dark green. However, there are dozens of types of broccoli, and colors range from green to purple to white. Each type of broccoli has different flavors, and different-sized stalks, leaves, and florets, while they all have similar health benefits but there are some subtle nutritional differences worth noting [2]. Broccoli is a nutrient-dense power house packed with vitamin C, vitamin K, minerals, fibers and antioxidants that offer remarkable biological benefits. The cruciferous vegetable is known for its ability to support heart health, improve digestion, strengthen bones, and even enhance brain function.It also boasts more protein than most other vegetables.

 Broccoli is known as the “Crown Jewel of Nutrition” since it possess all the nutrients namely vitamins, minerals, secondary metabolites and fiber proclaiming its exceptional health benefits [3].Further, broccoli might be consumed both as fresh and consumed food, so it is regarded as the dual use plant food. Typically, it is processed as dried or frozen, for retail sale in the market or canned for instant soup preparation. By the booming number of health – conscious consumers, who prefer salad, side dish, entrée component, or a nutritious dietary supplement, broccoli offers great advantage and hence enhances its share of the market.

Fresh broccoli is exceptionally rich source of vitamin C (91% of Daily value, DV), Vitamin K (77% of DV) and Folate 15% of DV) (Health line, Broccoli – 101: Nutrition Facts and Health Benefits). It is also a good source of minerals such as Ca, Mn, Fe, Mg, Se. Zn and P. In addition to that it is also good sources of electrolytes [4].Broccoli is gradually becoming popular among the urban people of Bangladesh and the Chinese restaurants together with the grand hotels. They are using broccoli for making soup and other delicious foods.

Bangladesh Agricultural Research Institute (BARI) has developed a variety, named BARI Broccoli-1 [5]. It has just started cultivating in Bangladesh. Growers' level extension of broccoli farming can bring a new horizon to the agriculture sector in Bangladesh. Broccoli cultivation is gaining popularity in Bangladesh, particularly in in the northern region for the last couple of years. Farmers are increasingly growing broccoli due to its high market price and growing demand, especially from urban areas and restaurants. Broccoli is a winter vegetable, and studies have indicated that planting in late November can be optimal for production.

In Bangladesh, only a few varieties of broccoli are being cultivated, besides there are some other genotypes too, which have higher yield potential as compared to the released varieties. Early curd bearing, flower initiation, more curd weight, size, shape etc., are inherent characters; all of these contribute to yield.

**2. METHODS AND MATERIALS**

**2.1 Collection of the sample**

The three varieties of Broccoli namely BC1 (BARI-1), BC2 (Crown Green) & BC3 (Yellowish Green) were selected for the experimental analysis.

**2.2 Collection of BC1 (BARI-1)**

The BC1 **(Fig-1**)were collected from the Bangladesh Agriculture Research Institute (BARI-1), Khulshi, Chittagong, which is Light Green Color, the major diameter is 15 cm, minor diameter is 7.5 cm, head length is 13 cm, stalk diameter 8 cm, shape: Light green, spearheads with less thick stems, Compactness: Less compact bud [6]

**2.3 Collection of BC2 (Crown Green)**

The BC2 **(Fig-1**) were also collected from Khagrachari hill tracts, which is Dark Green color, the vegetable Shape is Dense, well-domed tight heads with thick stems on stout plants, Compactness: compact bud. The BC2 plants are growing quickly and the plant height is about 60-65cm. [8]

**2.4 Collection of BC3 (Hybrid Variety of Broccoli)**

This variety of Broccoli **(Fig-1**) was collected from Super shop and local vegetable market in Chokoria, Cox’s Bazar which is available at the specific time period in the month of October to December.

Some morphological characters are as follows: Average vegetable size is730-850 grams, Shape is Dense, Large spear heads with thick stems and the vegetable color is Yellowish Green which is less compact bud.

 **  **

 **BC1 BC2 BC3**

 **Fig. 1: Three Experimental Varieties of Broccoli**

* 1. **Sample Preparation**

The fresh broccoli were washed in running tap water and spread on different trays. The sample then chopped in small sizes and allowed for drying under sunlight for 6/7 days. Again, they were dried for 24 hours at 37°C in an incubator.

Then fine powders from dry chopped broccoli were prepared by using high speed blending machine for several times until powder was formed. Powders were stored in dark airtight box. Powder or fresh broccoli was used for experimental purpose. All the morphological & biochemical tests were done in triplicate and the results of each value is average of three determinations.

* 1. **Morphological & Physico-chemical properties**

Morphological & Physical properties such as origin, plant height, longest diameter, Length, shape, Color, Compactness, and Proximate analysis.

* 1. **Diameter**

The major diameter (D) & minor diameter (d) of broccoli was measured by Vernier caliper in cm. The determinations were done in triplicate and the results of each value is average of three determinations.

* 1. **Length**

The Length of broccoli was measured by Vernier caliper in cm. The determinations were done in triplicate and the results of each value is average of three determinations.

* 1. **Weight**

The weight of broccoli was determined by digital weighing balance. The result of each value is average of three determinations.

**2.10 Color**

Three Experimental Varieties of Broccoli color was determined by spectrophotometric ally at different wavelength.

**2.11 Proximate Composition**

Different types of chemical properties of Broccoli were analyzed for pH, moisture, ash, dry matter content, titratable acidity, total soluble solids, total sugar, reducing sugar, non-reducing sugar, water soluble protein, Vitamin C, lipid content, phenolic compound, flavonoid compound. All the parameter were done in triplicate and the results of each value is average of three determinations.

**2.12 Determination of pH**

At first 4 gm of dry broccoli powders were homogenized well with 30 ml of distilled water and then filtered through Whatman’s No.1 filter paper. The filtrate was centrifuged for 10 minutes at 5000 rpm and the clear supernatant was used for pH determination using pH meter (AOAC, 2010).

**2.13 Determination of Total Soluble Solids (TSS)**

TSS was determined by Refractometer as degree brix (°B). At first 4 g of fresh broccoli was

Taken into a mortar and smashed well. Then a drop of juice was squeezed on the prism

Of the Abbe Refractometer and the percent of TSS obtained from the direct reading of the

Instrument as recorded.

**2.14 Determination of Titratable Acidity (TA)**

The TA is a total amount of acid present in the juice and determined by titration using standard solution of sodium hydroxide, which can be expressed as equivalence of any organic acid such as citric acid, malic acid. All the parameter was done in triplicate and the results of each value is average of three determinations.

**2.15 Determination of Moisture Content**

At first 4g of Broccoli was weighed in a porcelain crucible and heated in an electrical oven for about six hours at 100° C. It was then cooled in desiccators and weighed again. For a constant

Weight, the crucible with sample was heated repeatedly and weighed after cooling. Moisture content was determined by the standard IUPAC Method, 1979 as following:

 Amount of moisture obtained

 % moisture= --------------------------------------------× 100

 Weight of Broccoli

**2.16 Determination of Dry Matter Content**

Percent dry matter content of the broccoli powder was calculated from the data obtained during moisture estimation using the following formula:

 %of Dry Matter= 100 - % moisture content

**2.17 Determination of Ash Content**

4 gm of edible part of broccoli were weighted in a porcelain crucible (which was previously cleaned and heated at about 1000C, cooled and weighted). The crucible with sample content was placed in a muffle furnace for 4 hours at 6000 C this was then cooled in desiccators and weighted. To ensure completion of ashing .The crucible was again heated at the same temperature in the muffle furnace for an hour, cooled and weighted again. The procedure was repeated till two consecutive weights were the same and the ash formed almost white in color**.** Ash content of broccoli was determined by the following method of A.O.A.C. (1980)

 Amount of Ash obtained

 % Ash =----------------------------------------- × 100

 Weight of Broccoli

**2.18 Determination of Total Sugar Content**

Total Sugar content of edible part of the Broccoli was determined colorimetrically by the Anthrone Method (Jayaraman,1981). [8]

 Amount of Sugar obtained

 % Total Sugar =-----------------------------------------× 100

 Weight of Broccoli

**2.19 Determination of Reducing Sugar content**

Reducing Sugar content of edible portion of the broccoli was determined by Dinitrosalicylic acid method (Miller.G.L.,1972).[9]

 Amount of Reducing Sugar obtained

 % Reducing Sugar =------------------------------------------------------- × 100

 Weight of Broccoli

**2.20 Determination of Non-Reducing Sugar**

Non-Reducing Sugar (Sucrose) content of edible portion of the broccoli was determined by the methods of Ranganna (Ranganna,1979). [10]

% Non-Reducing Sugar = (% of Total sugar **-** % of Reducing sugar)

**2.21 Determination of Water soluble protein content**

Water Soluble protein contents of edible part of the Broccoli juice were determined by the method of Folin-Lowry (Lowry et al.1951).[11]

 Amount of water soluble protein obtained

 % protein =----------------------------------------------------------× 100

 Weight of Broccoli

**2.22 Determination of Lipid content**

About 4 gm of edible part of the broccoli was first grounded in a mortar with about 10 ml of distilled water. The grounded flesh was transferred to a separating funnel and 30 ml of chloroform – ethanol mixture was added. The mixture was mixed well and then kept overnight at room temperature in the dark. At the end of this period 20 ml of chloroform and 20 ml of water were further added and mixed well. Generally three layers were seen. A clear layer of chloroform containing all the lipids, a colored aqueous layer of ethanol with all water-soluble materials, and a thick pasty inner phase were seen.

The chloroform layer was carefully collected in pre-weighted beaker (50 ml) and then placed on a steam bath for evaporation. After evaporation of the chloroform, the weight of the beaker was determined again. The difference in weight gives the amount of lipid. Lipid contents of edible part of Broccoli was determined by Bligh and Dyer (1959) method [12]

 Amount of Lipid obtained

 % Lipid =--------------------------------------× 100

 Weight of Broccoli

**2.23 Determination of Vitamin C content**

10ml of Standard vitamin C solution was taken in a conical flask and then titrated it with the dye solution.4 grams of edible part of broccoli was pested in a mortar and homogenized well with 3% metaphosphoric acid (approximately 20 ml) and filtered it through double layer muslin cloth. The filtrate was centrifuged at 3,000 rpm for 10 minutes and the clear supernatant was titrated with 2,6dichlorophenol indophenol solution. The amount of vitamin C present in the extract was determined by comparing with the titration result of standard vitamin C solution. Vitamin C content of edible part of Broccoli were determined by the Bessey’s titrimetric method (1933)[13]

 mg of Vitamin C obtained

 % Vitamin C =------------------------------------× 100

 Weight of Broccoli

**2.24 Detection of Phenolic compound presence**

The presence of phenolic content determines by Folin-Ciocalteu’s methods with slight modification. 0.2MlL of the diluted sample extract was taken into test tube containing 1.0 mL of a 1/10 dilution of Folin- Ciocalteu’s reagent in water. After waiting for 10 minutes, 0.8Mlof a sodium carbonate solution (7.5%W/V) was added to the sample. The tubes were then allowed to stand at room temperature for 30 min with intermittent shaking for color development. The color change showed the presence of phenols in Broccoli Juice.[14]

**2.25 Detection of flavonoid presence**

The presence of total flavonoid content of Broccoli extract was determined by the aluminium chloride colorimetric method .1ml of sample was mixed with 1 ml Methanol AlCl3.6H2O solution in a 1:1 ratio. Blank solution was also prepared by distilled water with methanolic Solution in a 1:1 ratio. Both the mixtures were incubated for 20 minutes at room temperature in a dark place. The color change showed the presence of flavonoid compounds. [15]

**3. RESULT AND DISCUSSIONS**

**3.1 Morphological analysis**

The visible physical features of plant are crucial for understanding and utilizing vegetable crops. These characters are vital for plant identification, classification, and understanding their ecological and genetic diversity. In vegetables, morphology impacts aspects like consumer preferences (appearance, flavor, texture etc.), seed/fruit identification, and even plant adaptation to environmental conditions [16].

It has been known that most of the vegetables are low in calories with a water content of over 70 percent, an average of 3.5 percent protein and less than 1 percent fat but they are very good sources of minerals, especially calcium, and iron, vitamins etc., as well as rich in dietary fiber and antioxidants [17]. Broccoli floret of Greater Chittagong district are first time used for physico-morphological analysis and then after proper processing, various chemical analysis of the crushed floret are performed triplicate. In this study, we have selected 3- types of broccoli based on floret color from different locations: BC1- light green from Khulshi (BARI - 1), Chittagong, BC2 – dark green from Chittagong hill tract and BC3 – yellowish green from Chokoria, Cox’s Bazar, Chittagong Division. As reported, floret color is a crucial phenotypic trait in broccoli, serving as an indicator of maturity and determining its market value but the mechanisms underlying color variation remain unclear[18]**.** As given in the **(Table -1),** the plant height of the experimental broccolis collected from three different fields was 53 to 65 cm. These values are very much similar as reported [19, 20] found the plant height ranging from 53.93 to 58.11 cm that are also within the range of present findings. Among the morphological characters analyzed, weight of the vegetable as well as floret were varied widely among the types, and BC3 variety showed the maximum weight of vegetable (730 – 850 gm) and that of floret was 440 – 580 gm. Again, the varieties could also be possible to identify from their other studied characters such as diameter, head length, stalk diameter, major and minor diameter, shape etc. of the vegetables.

**Table 1: Morphological Parameter of different types of Broccolis**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | BC1 | BC2 | BC3 |
|  Origin | Khulshi, Chittagong | Khagrachari, Hill Tracks, CTG | Chokoria, Cox’sBazar |
|  Plant Height(cm) | 55-60cm | 60-65cm | 53-63cm |
| Vegetable weight (g) | 470 - 530 g | 560 - 680g | 730-850 g |
| Vegetable Floret weight(g) | 230-340 g | 280-410g | 440-580g |
| Vegetable Stem Weight(g) | 170-210g | 180-260g | 210-350g |
| Major diameter (d) | 15 cm | 18 cm | 15 cm |
| Minor diameter (D) | 7.5 cm |  9 cm |  8.5 cm |
| Head Length(L) | 13 cm | 15 cm | 13 cm |
| Stalk Diameter (Ds) |  8 cm | 12 cm |  9 cm |
| Shape | Spear heads with less thick stems |  Well-domed tight heads with thick stems on stout plants | Large spear heads with thick stems |
| Color | Eye - visible | Light green | Dark green | Yellowish Green |
| Spectrophoto-meter | 460-500 nm | 480-530 nm | 561-580nm |
| Compactness | Less compact bud  | Compact bud | Less compact bud  |

Each value is average of three determinations.

**3.2 Biochemical analysis**

The data pertaining to the chemical compositions of experimental broccoli varieties such as pH, moisture, Ash, TA, TSS, Total Sugar, TA, Lipid, Water Soluble Protein, Vitamin-C etc., were determined and the average values are presented in the (**Table-2)**. As shown, broccoli solution were found to be mildly acidic and pH was varied between 6.23 to 6.55.

Moisture content in vegetables is a critical factor that influences their quality, storage life, economic value, and safety. Maintaining optimal moisture levels is essential for preserving the freshness, texture, and overall appeal of vegetables, as well as preventing spoilage and ensuring food safety. Our findings indicated that moisture content 3- types broccoli was varied between 86 -88%. As published in Health line (2023), raw broccoli contains 90% water while [21]results showed that moisture content broccoli was 86.36%. Among the other nutrient contents of floret, TSS composition was varied between 9.29 to 9.63, Soluble Protein was found to slightly higher than 2 gm% while Vitamin C contents was varied between 84 to 89 mg%. It may be mentioned that [22] reported that Broccoli contained 80.54 mg% Vitamin C which is slightly lower than our reported values. The present findings also indicated that broccoli is also good sources of water soluble protein (higher than 2%), which is very similar to the reports available in Health line [23]

Further, qualitative detection confirmed the broccoli is also good sources of antioxidants especially Phenolic- and Flavonoid-compounds.

**Table 2: Biochemical Compositions of different types of Broccolis**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | BC1 | BC2 |  BC3 |
| BC1 Floret | BC1 Stem | BC2 Floret | BC2 Stem |  BC3 Floret | BC3 Stem |
| pH | 6.55 ± 0.01 | 6.23±0.01 | 6.35±0.01 | 6.12±0.01 | 6.32±0.01 | 6.25±0.01 |
| Moisture (%) | 88.31±0.03 | 86.22±0.03 | 89.32±0.02 | 87.34±0.03 | 88.32±0.02 | 89.34±0.03 |
| Ash (%) | 0.80±0.01 | - | 0.83±0.01 | - | 0.81±0.01 | - |
| Dry-matter (%) | 11.69±0.01 | 13.29±0.01 | 10.52±0.01 | 12.42±0.01 | 12.12±0.01 | 11.42±0.01 |
| Titratable acidity,TA (g citric acid /100g) | 0.54±0.02 | 0.43±0.01 | 0.45±0.01 | 0.41±0.01 | 0.45±0.01 | 0.43±0.01 |
| Total Soluble Solids (TSS)(0Brix) | 9.63±0.02 | 7.32±0.03 | 9.29±0.02 | 7.58±0.02 | 9.58±0.02 | 7.63±0.02 |
| Total Sugar (gm %) | 6.04±0.02 | 5.88±0.01 | 5.60±0.02 | 4.20±0.01 | 5.46±0.02 | 4.56±0.01 |
| Reducing Sugar (gm %) | 4.58±0.01 | 4.26±0.01 | 4.32±0.01 | 3.28±0.01 | 4.22±0.01 | 3.33±0.01 |
| Non-Reducing Sugar (gm%) | 1.46±0.01 | 1.62±0.01 | 1.28±0.01 | 0.92±0.01 | 1.24±0.01 | 1.23±0.01 |
| Total Lipid (gm %) | 0.30±0.01 | - | 0.33±0.01 | - | 0.32±0.01 | - |
| Water Soluble Protein (gm %) | 2.22±0.01 | - | 2.18±0.01 | - | 2.12±0.01 | - |
| Vitamin C (mg %) | 84.3±0.01 | - | 88.6±0.01 | - | 84.3±0.01 | - |

 Each value is average of three determinations.

**3.3 Mineral Compositions of broccoli**

Taking mineral rich foods in the diet daily can significantly enhance our overall health and well-being and from the reports available so far, it can be suggested that broccoli vegetable is also very good sources of minerals. Key minerals in broccoli include potassium, calcium, iron, magnesium, phosphorus etc. those are vital for bone health, maintaining fluid balance, supporting nerve and muscle function, and aiding in various metabolic processes [23]

The present data **(Table-3)** demonstrated that all the e- types of broccoli is a good source of Iron and its amount was varied between 0.7 to 0.8 mg%. Potassium and Calcium are also considered as good sources of broccoli.

**Table 3: Mineral Compositions of different types of Broccolis**

|  |  |  |  |
| --- | --- | --- | --- |
| Name of the Mineral (mg %) | BC1 | BC2 |  BC3 |
| Calcium  | 0.81± 0.01 | 0.62± 0.01 | 0.66± 0.01 |
| Magnesium  | 0.21± 0.01 | 0.20± 0.01 | 0.20± 0.01 |
| Potassium  | 0.95± 0.03 | 0.95± 0.01 | 0.98± 0.01 |
| Copper  | 0.09± 0.01 | 0.04± 0.01 | 0.06± 0.01 |
| Iron  | 0.7± 0.02 | 0.8± 0.01 | 0.8± 0.01 |
| Zinc  | 0.19± 0.01 | 0.18± 0.02 | 0.18± 0.02 |
| Phosphorus  | 1.9± 0.01 | 1.6± 0.01 | 1.7± 0.01 |
| Sodium | 20.9± 0.01 | 15.4± 0.01 | 18.4± 0.01 |
| Chloride | 0.0 | 0.0 | 0.0 |

 Each value is average of three determinations

**CONCLUSION**

In the final investigation, our results clearly indicated that BARI-1 cultivar is much better that Green Crown and Yellowish Green in the context of nutrient contents.Agriculture is the main source of livelihood for the people in Bangladesh. Although Bangladesh is a tropical country, the climate and the soil of many parts of Bangladesh are much suitable for broccoli Production. Generally, it is grown almost all over Bangladesh especially in hilly and high land where there is no water stagnation. Vegetable cultivation is one of the crop farming enterprises that ensures the country’s food and nutritional security.

In Bangladesh nearly four million people, including over a million women, work in commercial or, homestead vegetable cultivation. Broccoli is rapidly becoming an important fresh market and processing vegetable crop in many parts of the world including Bangladesh.

Some countries of the world have been now broccoli vegetables in two seasons per but we produce it only time throughout the year. Broccoli is one of the most costly vegetables in the world and many people like it as a salad also.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that no generative AAI technologies such as (ChatGPT, COPILOTS, etc.) and text- to- image generators have been used during the writing or, editing of this manuscript.

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