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Assessing Nutritional Quality and Shelf life of Broccoli Cultivars

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Abstract: Inadequate knowledge on the nutritional and shelf life of broccoli render growers and consumers to poorly utilize this vegetable. To disseminate proper information on nutrition and storage it's imperative to determine the nutrient content and shelf life of the modern cultivated broccoli cultivars. In this regard, five broccoli cultivars *viz.* Green Magic, Green Giant, Top Green, Early Green and Green Imported were evaluated to determine the nutritional and shelf life quality. A factorial Completely Randomized Design (CRD) with three replicates was used for experimentation. Data were collected on different vitamin, minerals and storage conditions (temperature, packaging). Collected data were statistically analyzed with the help of computer program MSTATC. Outcomes noted that, under fresh condition highest free ascorbic acid content (49.11mg/100g) was recorded in Green Magic. Green Giant had the maximum amount (1.07 mg/100gm) of β-carotene, reducing sugar (4.10 g/100g) and non-reducing sugar (1.53 g/100g). Green Imported had the most content of iron (162.71 ppm), calcium (0.85%) and magnesium (0.33%); while most amount of phosphorus (0.24%) was noted in Green Magic. The peak amount of potassium (0.99 %) and magnesium (0.33%) was found in Green Giant. The longest shelf life was obtained from Green Magic at 4°C (21.83 days) under polyethylene packaging condition. Hence it was noted that, shelf life and temperature had a vice versa relationship.

Keywords: Broccoli, Nutrition, Shelf Life, Vitamin, Minerals, Gazipur

1. Introduction

Broccoli (*Brassica oleracea* L.) is a cole crop rich with nutrients than any other vegetables [1]. Fresh broccoli has nearly double vitamin C level than that of cauliflower. [2]. Per pound of edible portion of broccoli contains protein 9.10 g, fat 0.60 g, carbohydrate 15.20 g, calcium 360.00 mg, phosphorus 211.0 mg, iron 3.60 mg, vitamin-A 970.00 I.U., ascorbic acid 327.00 mg, riboflavin 0.59 mg and thiamine 0.26 mg [3]. According to analytical data presented by Thompson and Kelly [3] broccoli is nutritious than any other cole crops (such as cabbage, cauliflower). Devouring broccoli enriched in antioxidants can reduce the risk of some forms of cancer and heart disease. As a result, broccoli has the potential to significantly improve the nutritional condition of the people of Bangladesh. Vegetables decay after harvest because they are live biological parts. Floral vegetables such as broccoli and cauliflower degrade soon after harvesting from field [4]. Broccoli is a valuable vegetable with short shelf life and increased post-harvest losses which makes the crop less popular; nonetheless, it has a higher potential to enhance our country's nutritional position. Many researchers from across the world have worked hard to release broccoli varieties with a longer shelf

life [5]. Under Bangladeshi conditions, there is sufficient opportunity to reduce post-harvest losses of broccoli and it is most suitable for exporting.

In Bangladesh, a huge proportion of vegetables are wasted owing to high temperatures and humidity during the harvesting time, accounting for over 25% of the total production. There is a dearth of proper storages, as well as insufficient storage knowledge. Consequently, a significant amount of vegetable gets spoiled each year. Fruit and vegetable perishability is related to negative physiological changes, such as weight loss owing to respiration and transpiration, softening of flesh, and decline of defensive strength to pathogen infection. Such spoilage costs both merchants and retailers a huge sum of money [6]. One of the most essential techniques for reducing post-harvest losses in broccoli is to provide optimal quality-controlled store conditions as well as appropriate packaging materials.

Given the foregoing, the current study was designed to evaluate the nutritional content of broccoli at fresh and multiple storage methods, as well as to assess the ideal storage conditions for improving shelf life.

2. Materials and Methods

The investigation was carried out at the Department of Horticulture and Department of Soil Science laboratories, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from January to April, 2016. It was laid in a Completely Randomized Design (CRD) following 3 (three) factors—

Factor A: Temperatures (T_3= 4°C, T_2= 10°C and T_1= 24°C)

Factor B: Packaging materials (Open and Polythene Packaging)

Factor C: Broccoli cultivars (Green Magic, Green Giant, Top Green, Early Green, Green Imported).

Thus, there were 30 treatments combinations altogether. Fresh broccolis were thoroughly cleaned and placed in laboratory room for different vitamin analysis. For mineral analysis fresh broccolis were cut into pieces and dried into oven for 72 hours at 70°C. Then they were grinded into fine powder. For shelf life determination under different storage conditions broccoli were packed with polyethylene pack and open condition and then kept at different temperature. Following data were recorded immediate after harvesting to assess the nutritional quality of broccoli—

i. Ascorbic acid (mg/100g)
ii. β-Carotene (IU/100g)
iii. Calcium (%)
iv. Iron (ppm)
v. Potassium (%)
vi. Phosphorus (%)

The ascorbic acid content was determined as per the procedure described by Pleshkov [7]. β-Carotene was calculated as per the formula provided by Nagata *et al*. [8] with spectrophotometer (Model no. 200-20, Hitachi, Japan) at 663 ηm, 645 ηm, 505 ηm and 453 ηm. Calcium (%), Iron (ppm) and Potassium (%) was measured as per the procedures stated by Piper [9] with Atomic Absorption Spectrophotometer (Model no. 170-30, Hitachi, Japan) under different wave lengths (422.8 ηm for Ca, 248.3 ηm for Fe and 766.5 ηm for K). Phosphorus (%) was determined by Vanadomolybdate yellow colour method as describe by Jackson [10] with double beam spectrophotometer at 440 ηm wave length (Model no. 200-20, HITACHI, Japan). Temperature and packaging treatments were applied by modifying the procedures of Chowhan *et. al.* [6]. The data of various parameters recorded in the experiment were compiled and statistically analyzed through partitioning the total variance with the help of computer MSTATC program. Analysis of variance was done according to Gomez and Gomez [11]. Means were separated using Duncan's Multiple Range Test (DMRT) at 1% or 5% level of probability.

3. Results and Discussion

3.1. Nutritional Qualities

3.1.1. Ascorbic Acid

Variation in free ascorbic acid among the cultivars was statistically significant (Table 1). It ranged between 49.11 and 34.40 mg/100g. The highest content of free ascorbic acid (49.11mg/100g) was recorded in Green Magic which was followed by Green Giant (44.90 mg/100g) and Top Green (42.33mg/100g). The lowest (34.40 mg/100g) was in Green Imported.

3.1.2. β-carotene

Significant variations in the amount of β-carotene were found when considered different cultivar effect. It varied from 1.07 to 0.61 mg/100g (Table 1). Green Giant had the maximum amount of β-carotene (1.07 mg/100gm) which was statistically identical to Green Magic, Top Green and Early Green. Green Imported had the lowest amount of β-carotene (0.61 mg/100gm). Variations in β-carotene may be due to inherent characteristics of the cultivar, climatic and environmental factors.

3.1.3. Reducing Sugar

Variation in reducing sugar content (Table 1) among the cultivars was significant. Highest content (4.10 g/100g) of reducing sugar was found in Green Giant which was statistically similar to other cultivars except Top Green which performed the lowest (3.50 g/100g).

3.1.4. Non-reducing Sugar

Amount of non- reducing sugar content varied significantly (Table 1) among the cultivars. The highest content (1.53 g/100g) of non-reducing sugar was found in Green Giant which was followed by Green Imported (1.42 g/100g) and Green Magic (1.34 g/100g). The lowest (1.07 g/100g) was in Top Green which was statistically at par with Early Green (1.15g/100g).

Table 1. *Effect of cultivars on ascorbic acid, β-carotene, reducing and non-reducing sugar content of broccoli.*

Cultivars	Ascorbic acid (mg/100g)	β-carotene (mg/100g)	Reducing sugar (g/100g)	Non-reducing sugar (g/100g)
Green Magic	49.11 a	1.04 a	3.76 ab	1.34 b
Green Giant	44.90 b	1.07 a	4.10 a	1.53 a
Top Green	42.33 c	1.05 a	3.50 b	1.07 c
Early Green	40.84 c	1.05 a	3.64 ab	1.15 c
Green Imported	34.40 d	0.61 b	3.92 ab	1.42 b
Level of significance	**	**	**	**
CV%	1.48	2.73	1.87	1.69

Means bearing same letter (s) in a column do not differ significantly at 1% level of probability by DMRT. ** - Significant at 1% level of probability.

3.1.5. Iron (Fe)

Significant variations in the amount of iron were found due to effect of different cultivar. It varied from 133.74 to 162.71 ppm (Table 2). Green Imported had the highest iron content (162.71 ppm) which was followed by Green Magic (155.72 ppm), Top Green (152.00 ppm), Green Giant (149.1 ppm) and Early Green had the lowest (133.74 ppm).

3.1.6. Calcium (Ca)

Significant variation in calcium content was observed among the cultivars (Table 2). The maximum calcium (0.85%) was found in Green Imported. The lowest (0.68%) was found in Top Green.

3.1.7. Magnesium (Mg)

There was a significant variation in magnesium content (Table 2). The highest amount of magnesium (0.33%) was found from Green Giant and Green Imported which was statistically identical to Green Magic (0.32%). The lowest (0.28%) amount of magnesium was found from Top Green.

3.1.8. Phosphorus (P)

There was a significant variation in phosphorus content among the cultivars. It ranged between 0.12% and 0.24% (Table 2). The maximum amount (0.24%) of phosphorus was recorded in Green Magic. The lowest (0.12%) was found in Green Giant.

3.1.9. Potassium (K)

Potassium content was also significantly different among the cultivars. The maximum amount of potassium (0.99 %) was found in Green Giant (Table 2). The lowest (0.78%) was found in Early Green.

Table 2. *Effect of cultivars on iron, calcium, magnesium, phosphorus and potassium content in broccoli.*

Cultivars	Fe (%)	Ca (%)	Mg (%)	P (%)	K (%)
Green Magic	155.7 b	0.74 c	0.32 a	0.24 a	0.97 a
Green Giant	149.0 c	0.81 b	0.33 a	0.17 ab	0.99 a
Top Green	152.0 bc	0.68 d	0.28 b	0.18 ab	0.82 b
Early Green	133.7 d	0.76 c	0.29 ab	0.12 b	0.78 b
Green Imported	162.71 a	0.85 a	0.33 a	0.21 ab	0.95 a
Level of significance	**	*	**	**	**
CV%	1.55	3.35	3.96	5.06	3.56

Means bearing same letter (s) in a column do not differ significantly at 1 or 5% level of probability by DMRT. ** and * - Significant at 1% and 5% level of probability, respectively.

Variation in nutritional qualities of the genotypes might be due to genetic characters. Besides weather, soil and climatic factor might also be the cause of differentiation in inorganic chemical properties of the genotypes. Roni et al. [12] observed differences in ascorbic acid content under different fertilization levels. Mukherjee and Mishra [13] reported a variation in Calcium, copper, Iron, Magnesium, Manganese, Selenium and Zinc nutrition content of broccoli genotypes.

3.2. Shelf Life

3.2.1. Effect of Cultivars

Cultivars had a significant influence on the shelf life of curds varied from 9.87 to 12.06 days (Figure 1). The cultivar Green Magic had the longest shelf life (12.06 days) followed by Early Green and Green Giant. The shortest shelf life (9.87 days) was obtained by Green Imported. This was might be due to the inherent control of the genotypes.

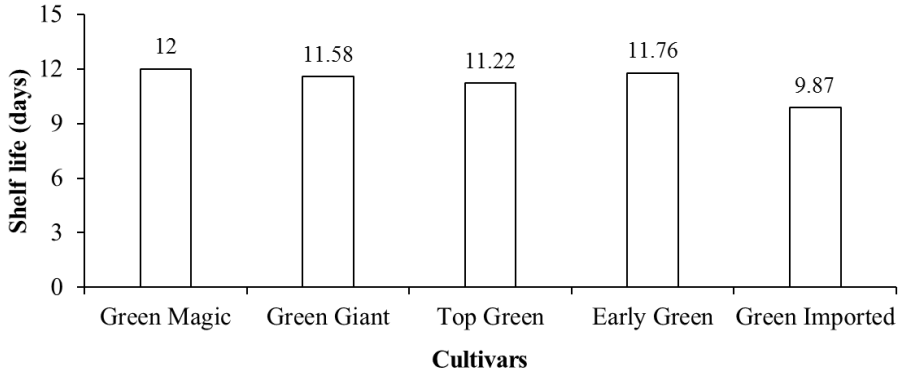

Figure 1. *Effect of cultivars on shelf life of broccoli.*

3.2.2. Effect of Temperature

Different temperature had the significant influence on the shelf life of broccoli varied from 5.08 to 17.97 days **(**Figure 2). The maximum shelf life (17.97 days) was recorded at 4°C (T_3) which was followed by 10°C (T_2) and minimum shelf life (5.08 days) was recorded at 24°C (T_1).

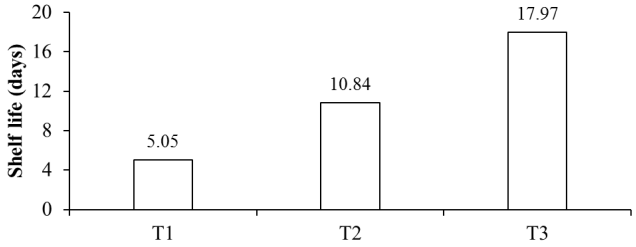

Figure 2. *Effect of temperature on shelf life of broccoli.*

3.2.3. Interaction Effect of Cultivars and Temperature

The interaction effect of broccoli cultivars and temperature on the shelf life of broccoli was found statistically significant varied from 4.40 days to 19.05 days (Table 3). The maximum shelf life (19.05 days) was recorded from Green Magic at 4°C which was followed by Early Green, Green Giant, Top Green and Green imported at 4°C. Minimum shelf life (4.40 days) was recorded from Green imported at 24°C. Roura *et al.* [14] reported that shelf life reduced with increase in temperature which was in agreement with the present findings.

Table 3. *Effect of broccoli genotypes and temperature on shelf life of broccoli after 4 days of storage.*

Cultivars	4°C	10°C	24°C
Green Magic	19.05 a	11.47 e	5.65 i
Green Giant	18.52 b	11.07 f	5.17 jk
Top Green	18.13 c	10.68 g	4.83 k
Early Green	18.73 b	11.23 ef	5.35 ij
Green Imported	15.47 d	9.73 h	4.40 l
Level of significance	**		
CV%	1.95		

Means bearing same letter (s) in a column do not differ significantly at 1% level of probability by DMRT. ** - Significant at 1% level of probability.

3.2.4. Effect of Packaging

Different packaging condition had the significant influence on the shelf life of broccoli varied from 9.49 to 13.10 days (Figure 3). The maximum shelf life (13.10 days) was recorded from the polyethylene package and lowest shelf life (9.49 days) was recorded at open condition.

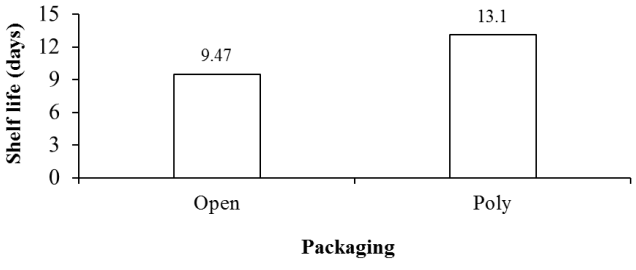

Figure 3. *Effect of packaging on shelf life of broccoli.*

3.2.5. Interaction Effect of Cultivars and Packaging

There was a significant interaction between broccoli cultivars and packaging condition on shelf life of broccoli ranged from 8.38 to 13.92 days (Table 4). The highest shelf life (13.92 days) was found from Green Magic at polyethylene packaging which was followed by Early Green at polyethylene packaging condition. The lowest shelf life (8.38 days) found from Green Imported at open condition. It indicates that good packaging condition can increase the shelf life of broccoli genotypes and polyethylene packaging can increase the shelf life of broccoli.

Table 4. *Effect of cultivars and packing on shelf life of broccoli.*

Cultivars	Open	Poly
Green Magic	10.19 e	13.92 a
Green Giant	9.73 f	13.43 b
Top Green	9.31 g	13.12 c
Early Green	9.86 f	13.67 ab
Green Imported	8.38 h	11.36 d
Level of significance	**	
CV%	1.95	

Means bearing same letter (s) in a column do not differ significantly at 1% level of probability by DMRT. ** - Significant at 1% level of probability.

3.2.6. Interaction Effect of Temperature and Packaging

Shelf life of broccoli was influenced by the interaction effect of temperature and packaging condition (Table 5). The highest shelf life (20.62 days) was found in polyethylene packaging condition at 4°C which was followed by open condition at 4°C, polyethylene packaging condition at 10°C and the lowest shelf life (4.15 days) was recorded from open condition at 24°C.

Table 5. *Effect of temperature and packing on shelf life of broccoli.*

Temperature	Open	Poly
24°C	4.15 f	6.01 e
10°C	9.01 d	12.67 c
4°C	15.33 b	20.62 a
Level of significance	**	
CV%	1.95	

Means bearing same letter (s) in a column do not differ significantly at 1% level of probability by DMRT. ** - Significant at 1% level of probability.

3.2.7. Collective Effect of Cultivars, Temperature and Packing

Combined effects of cultivar, temperature and packaging condition had a significant influence on the shelf life of broccoli cultivars varied from 3.50 to 21.83 days (Table 6). The longest shelf life (21.83 days) was obtained by Green Magic at 4°C under polyethylene packaging which was statistically similar to Early Green at 4°C under polyethylene packaging. The shortest shelf life (3.50 days) was obtained by the genotypes Green Imported at 24°C under open condition. Variation in shelf life may be due to inherent genetic characteristics of the cultivars, different temperature and packaging conditions.

Table 6. *Effect of cultivars, temperature and packaging on shelf life of broccoli.*

Cultivars	Open			Poly		
	4°C	10°C	24°C	4°C	10°C	24°C
Green Magic	16.27 d	9.50 j	4.80 p	21.83 a	13.43 f	6.50 m
Green Giant	15.83 d	9.23 jk	4.13 q	21.20 b	12.90 gh	6.20 mn
Top Green	15.13 e	8.90 k	3.90 qr	21.13 b	12.47 h	5.77 no
Early Green	15.90 d	9.27 jk	4.40 pq	21.50 ab	13.20 fg	6.30 m
Green Imported	13.50 f	8.13 l	3.50 r	17.43 c	11.33 i	5.30 o
Level of significance	**					
CV%	1.95					

Means bearing same letter (s) in a column do not differ significantly at 1% level of probability by DMRT. ** - Significant at 1% level of probability.

Deviation in shelf life of the studied genotypes was mainly due to type of packaging and temperature. Though low temperature had more storing capacity than high temperatures. But, within same treatments some genotypes had better shelf life due to their less water content in the curd. The above findings are in agreement with the reports of Ferdousi *et al.* [15] and Verma *et al.* [16].

4. Conclusion and Recommendations

Among the five cultivars of broccoli, most ascorbic acid was found with Green Magic. β-carotene was same for all the studied cultivars except Green Imported. Sugars were highest in Green giant. Minerals such as Iron and Calcium was most in Green Imported; whereas, Magnesium, Phosphorus and Potassium were lower in the cultivars Top and Early green. In terms of shelf life, Green imported had the lowest shelf life among the cultivars. High temperature reduced the storage capacity of the broccolis. Packaging with polyethylene gave more days of shelf life than open condition. Hence it is recommended to use polyethylene packaging with low temperature (4°C) to enhance storing capacity of broccoli.

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