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Chemical and Physical Quality of Snap Bean Pods duringStorage and Shelf Life as Affected by Some Natural Safety compounds.

Tahany A. A. Ghanaym[1], Zaki, M. El-Said[2], M.I . Ragab[3], Manal M. Attia[1], Mostafa. H.M. Mohamed[2] and Ahmed S. Mohamed[4]*

1 Horticulture Research Institute, Agriculture Research Center, Egypt

2 Horticulture Department, Faculty of Agriculture, Benha University, Egypt.

3 Horticulture Dept., Faculty of Agriculture, University of Ain Shams, Egypt.

4 Horticultural Crops Technology Dept., National Research Centre, Dokki, Giza, Egypt

Abstract

Snap bean pods are highly susceptible to post-harvest damage which limits their storage as well as shelf life periods. This investigation was carried out to study the effect of using some natural safety compounds i.e., algae extract, chitosan, potassium silicate and moringa leaves extract as pre-harvest foliar application on quality attributes of snap beans pods during storage and shelfe life periods. Data revealed that weight loss percentage, reduction in general appearance, snappiness, decay percentage, reduction protein and fiber of snap bean pods were increased significantly and consistent with the prolongation of storage period in the two seasons. Meanwhile, pods obtained from treated plants with the algae (4 cm/L) and leaves moringa extract (6 cm/l) were the most effective treatment for these paremters. It can be concluded from this study that treating snape bean plants on field with the algae (4 cm/L) and leaves moringa extract (6 cm/l) and then packing in polypropylene bags improved storability, maintained pod quality attributes, and gave good appearance of pods after 28 days of storage at 5°C + 2 days at 10°C (shelf life).

"Keywords: Phaseolus vulgaris, snap bean, algae, potassium silicate, nano chitosan, moringa, Storage, shelf life, weight loss."

1. Introduction

Snap bean *(Phaseolus vulgaris L.)* is superior to the rest of the legume vegetable crops in terms of economic importance in Egypt for its domestic consumption and export. The cultivation area of green snap bean plants in Egypt was 65671 fed. and the productivity was 284299 tons with an average of 4,327 tons / fed.**[1].**

Quality attributes of snap beans pods such as weight loss percentage, general appearance (GA) and snappiness as well as chlorophyll, protein, fiber and carbohydrate contents of snap bean pods might be considerably and consistently affected with the prolongation of storage period during storage and shelf life conditions **[2, 3, 4, 5, 6, 7]**. These may be attributed to transpiration, respiration and other senescence related metabolic processes during storage**[8, 9, 2, 10]**. Plant nutrition before harvest is one of the main factors affecting the quality of fruits and vegetables during the storage period **[11]**.

Snap bean pods are highly susceptible to post-harvest damage which limits their storage and shelf life, therefore some pre-harvest treatments have been suggested for use in maintaining the quality and improving the storability of snap bean pods such as treatment with seaweed extract, chitosan, potassium

*Corresponding author e-mail: aq.mohamed@nrc.sci.eg.; (Ahmed S. Mohamed).

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silicate and leaves moringa extract which decreases respiration rate, weight loss, decay and maintains the overall quality and prolongs the shelf life of snap bean pods **[12, 13, 5, 14, 10]**. Spraying plants with seaweed extract significantly maintained crude protein percentage and total chlorophyll content as well as the minimum values of crude fiber in green pea seeds during storage at 0°C **[15]**. The enhancement effect might be attributed to that seaweed extract organic compounds **[16]**, macro and micro elements **[17]**and rich in both organic and mineral substances **[18]**, these minerals (potassium, calcium, iron, manganese and magnesium) may reduce weight loss percentage and maintain green color during storage **[7]**. Also, spraying snap bean plants with chitosan at 1.5 % produced pods with better storage qualities. Where, the dimenshing rate of vitamin C, chlorophyll and water contents as well as the rise rate of cellulose content were lower than those of untreated fruits**[19]**. The protection in plants by silicon could be due to its accumulation and polymerization in the plant cells to form a mechanical barrier as silica – cuticle double layers that difficult to be attacked by the insect pests **[20, 21, 22]**. Furthermore, mechanical barriers are not the only defense mechanism against external agents. The moringa leaf extract is considered as a natural plant growth regulator as mentioned by **[23, 24, 25, 26, 27, 28]** thus, its effect on the storage capacity of vegetable crops could be studied. The main aim of this investigation is evaluation of several natural safety compounds i.e., algae extract, chitosan, potassium silicate and moringa leaves extract as foliar application on quality attributes and storability of snap beans green pods.

2. Methods

This experiment was conducted to study the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extract (4 cm and 6/L) as a pre-harvest application as compared with untreated plants (control) on keeping quality of snap bean green pods during storage. These foliar spray treatments were applied three times during the growing period of snap bean plants at 21, 35, 50 days after sowing. Snap bean pods obtained from the previous treatments were harvested in the suitable maturity stage of marketing on 7th and 4th of Mayo in the first and second seasons, respectively; then delivered to the laboratory of Handling of Vegetable Crops Department, Agricultural Research Center, Giza. Pods uniform in length, diameter and color and free from blemishes were selected for storage experiment.

Marketable green snap bean pods packed in polypropylene bags (which are used for exporting the Egyptian green beans), and each bag had 200 g as one replicate, then bags packed in carton box. The experimental design was completely randomized design with three replicates. Three replicates from each treatment were taken at random and examined immediately after harvest and after 7, 14, 21 and 28 days at 5°C and 90-95% relative humdity plus 2 days at 10°C (shelf life) for the following properties: weight loss percentage, general appearance as well as snappiness scores, total chlorophyll contents and total soluble solids percentage, decay, protein and fiber percentages were examined immediately after harvest and after 7, 14, 21 and 28 days at 5°C plus 2 days at 10°C (shelf life).

For storage experiments the following properties were recorded:

1.Weight loss percentage as estimated according to the following equation:

$$\text{Weight loss percentage} = \frac{\text{initial weight - weight at each inspection interval}}{\text{initial weight}} 100$$

2.General appearance as evaluated using a scale from 9-1, where 9=excellent, 7=good, 5=fair, 3=poor, 1=unsalable; pods rating 5 or below were considered as unmarketable as described by **[29**. It was recorded for both of the shriveling, wilting, color change and decay or any their visible deterioration.

3. Snappiness as evaluated using a subjective scale of 5-1, where 5=full typical snappiness, 4=moderately full, 3=moderate, 2=slight, 1=low.

4. Decay percentage was measured using a subjective scale of 5 to 1, where 5=extreme, 4=severe, 3= moderate, 2= slight, 1= none.

5.Total soluble solids percentage (TSS) as determined by using refractmeter as described in **[30]**.

6. Total chlorophyll content as determined according to **[30]**.

7.Protein percentage in dry matter of pods: it was calculated by multiplying the total nitrogen by the factor 6.25, it was determined according to **[30]**.

8.Fiber percentage in dry matter of pods: it was determined according to **[31]**. The statistical analysis for obtained data was analysis by the methods of Duncan's multiple range tests **[32]**.

3. Resultsand discussion

1.Weight loss percentage

Data in Table 1 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extracts (4cm and 6/L) as a pre-harvest foliar application compared with untreated plants (control) on weight loss % of produced snap bean pods during storage and shelf life. Data reveal that weight loss percentage of snap bean pods was increased significantly and consistently with the prolongation of storage period in the two seasons. These results are in agreement with those obtained by **[2, 5, 6, 7]**on snap beans. The loss in weight may be attributed to transpiration, respiration and other senescence related metabolic processes during storage period**[8]**.

Concerning the effect of pre-harvest treatments, data show that most pre-harvest treatments indicatesignificant lower weight loss percentage of pods as compared with untreated plants (control); however, snap bean pods obtained from plants treated with moringa extract at 4 cm/L surpassed those obtained from the other treatments or untreated control in minimizing pod weight loss percentage during storage and shelf life with significant differences between them in both seasons.

Snap bean pods obtained from the other treatments were less effective in reducing the loss of weight percentage. On the contrary, pods obtained from untreated plants gave mostly highest values of weight loss percentage especially in second season. These results were achieved in the two seasons and were in agreement with those obtained by **[15]**for algae extract. Such results may be due to the beneficial effect of seaweed extract **[33]**; on vegetative growth and chemical composition of snap bean pods which in turn maintained the metabolic homeostasis after harvest and reduce dehydration of pods.

In general, the interaction among pre-harvest treatments and storage periods was significant in both seasons. Snap bean pods obtained from plants treated with the extract of moringa showed the least weight loss percentage either after 0, 7, 14, 21 or 28 days of storage periods, while those obtained from untreated plants gave the highest values of weight loss percentage.

Table 1.Effect of some growth stimulants on weight loss % of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0+2 days	7+2 days	14+2 days	21+2 days	28+2 days	Mean	0+2 days	7+2 days	14+2 days	21+2 days	28+2 days	Mean
Control	4.4^{su}	4.8^{qt}	7.6^{jq}	10.7^{ek}	12.4^{dh}	8.9^{CD}	6.5^{hk}	7.3^{fk}	10.2^{ak}	13.1^{ak}	18.5^{ac}	12.3^{B}
Algae 2 cm/L	6.7^{mr}	6.7^{mt}	9.9^{gm}	13.9^{ce}	19.7^{a}	12.5^{A}	6.4^{hk}	6.6^{hk}	8.7^{ei}	12.9^{ak}	15.9^{ah}	11.0^{B}
Algae 4 cm/L	7.4^{lt}	8.0^{iq}	9.9^{gm}	14.3^{bd}	17.2^{ab}	12.4^{A}	6.2^{hk}	6.9^{gk}	8.3^{ei}	12.4^{ak}	14.9^{ai}	10.7^{B}
Potassium silicate 2 cm/L	5.2^{pt}	6.4^{nt}	9.0^{ip}	10.8^{ek}	13.4^{ce}	9.9^{BC}	6.7^{hk}	8.5^{ei}	10.5^{ak}	13.1^{ak}	16.1^{ag}	12.0^{B}
Potassium silicate 4 cm/L	4.0^{tu}	4.4^{su}	7.5^{jq}	8.8^{ip}	11.1^{ei}	7.9^{D}	15.4^{ah}	19.3^{a}	10.9^{ak}	15.3^{ah}	19.0^{ab}	16.1^{A}
Nano chitosan 60 mg/L	4.2^{su}	4.6^{su}	9.2^{io}	13.0^{cg}	15.5^{bd}	10.6^{BC}	5.9^{ik}	7.4^{fk}	10.7^{ak}	13.4^{ak}	17.5^{ad}	12.3^{B}
Nano chitosan 90 mg/L	4.3^{su}	4.6^{su}	8.7^{ip}	13.4^{bd}	15.9^{bc}	10.7^{B}	5.6^{ik}	7.0^{gk}	9.7^{bk}	13.8^{ak}	16.3^{af}	11.7^{B}
Moringa 4 cm/L	2.2^{u}	2.4^{u}	4.9^{qu}	7.8^{lr}	9.7^{in}	6.2^{E}	5.2^{k}	6.4^{hk}	9.4^{ck}	12.2^{ak}	14.4^{bh}	10.6^{B}
Moringa 6 cm/L	1.8^{u}	1.9^{u}	5.8^{pt}	10.1^{fk}	15.0^{bd}	8.2D	4.9^{k}	6.2^{hk}	10.1^{ak}	12.5^{ak}	15.2^{ah}	11.0^{B}
Mean	4.5^{D}	4.9^{D}	8.0^{C}	11.4^{B}	14.4^{A}		7.0^{D}	8.4^{CD}	9.8^{C}	13.2^{B}	16.4^{A}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test.

2. General appearance

Data in Table 2 show the effect of the extracts of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa (4cm and 6/L) as a pre-harvest application compared with untreated plants (control) on general appearance where 9equal poor appearance, meanwhile 5 scores or below are considered as unmarketable snap bean pods during the storage and shelf life periods. Data reveal that

there was a significant reduction in general appearance of snap bean pods with the prolongation of storage period and shelf life in both seasons. Similar results were reported by **[7]** on snap bean pods. The decreases in scores of snap bean pods during storage period might be due to shriveling, wilting, color change and decay **[2]**. In this respect, all pre-harvest growth stimulants treatments showed higher scores of general appearance when compared with the untreated control plants during the storage and shelf life periods. However snap bean pods obtained from plants treated with the highest rate of algae (4 cm/l) followed by nano chitosan (90 mg/L) gave the highest score of pods. The worst appearances scores of green pods were recorded for the untreated control. These results were achieved in the two seasons and were in agreement with those obtained by **[15]** for algae on pea. The reminder used growth stimulants lay in between enhancement effects in this regard might be attributed to that algae materials contained more nutrient elements and organic compounds **[16]**, macro and micro elements **[17]** and rich in both organic and mineral substances **[18]**. In this respect **[7]**mentioned that minerals i.e, potassium, calcium, iron, manganese and magnesium reduced weight loss percentage and maintained green color during storage.

The interaction between pre-harvest treatments and storage periods was significant in the two seasons; the results revealed that snap bean pods obtained from plants treated with either algae (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) potassium silicate (2 and 4 cm/L) did not exhibit any changes in their appearance till 7 days and gave good appearance after 14 up to 21 days. While, pods which obtained from untreated control rated the unsalable appearance at the end of storage (21 days) in the two seasons.

Table 2. Effect of some growth stimulants on general appearance (score) of snap bean pods at storage periodat 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	9.0^{a}	7.7^{bc}	5.0^{fg}	4.3^{gh}	2.3^{i}	5.7^{C}	9.0^{a}	7.0^{bd}	6.3^{cd}	5.7^{de}	5.0^{e}	6.6^{B}
Algae 2 cm/L	9.0^{a}	9.0^{a}	9.0^{a}	7.0^{cd}	5.0^{fg}	7.8^{B}	9.0^{a}	8.0^{ab}	8.0^{ab}	7.0^{bd}	7.0^{bd}	7.8^{AB}
Algae 4 cm/L	9.0^{a}	9.0^{a}	9.0^{a}	8.3^{ab}	6.3^{de}	8.3^{A}	9.0^{a}	9.0^{a}	9.0^{a}	7.7ac	7.0^{bd}	8.3^{A}
Potassium silicate 2 cm/L	9.0^{a}	9.0^{a}	9.0^{a}	7.7^{bc}	3.3^{hi}	7.6^{B}	9.0^{a}	9.0^{a}	8.3^{ab}	7.7^{ac}	7.0^{bd}	8.2^{A}
Potassium silicate 4 cm/L	9.0^{a}	9.0^{a}	9.0^{a}	7.0^{cd}	3.0^{i}	7.4^{B}	9.0^{a}	9.0^{a}	7.7^{ac}	7.7^{ac}	7.0^{bd}	8.1^{A}
Nano chitosan 60 mg/L	9.0^{a}	9.0^{a}	9.0^{a}	7.0^{cd}	7.0^{cd}	8.2^{A}	9.0^{a}	9.0^{a}	8.3^{ab}	7.7^{ac}	7.0^{bd}	8.2^{A}
Nano chitosan 90 mg/L	9.0^{a}	9.0^{a}	9.0^{a}	7.7^{bc}	7.0^{cd}	8.3^{A}	9.0^{a}	9.0^{a}	7.0^{bd}	7.0^{bd}	7.0^{bd}	7.8^{B}
Moringa 4 cm/L	9.0^{a}	8.3^{ab}	7.0^{cd}	6.3^{de}	2.3^{i}	6.6^{C}	9.0^{a}	8.0^{ab}	7.0^{bd}	7.0^{bd}	6.3^{cd}	7.5^{B}
Moringa 6 cm/L	9.0^{a}	8.3^{ab}	7.0^{cd}	5.7^{ef}	2.7^{i}	6.5^{C}	9.0^{a}	8.0^{ab}	8.3^{ab}	7.7^{ac}	6.3^{cd}	7.9^{AB}
Mean	9.0A	8.7^{A}	8.1^{B}	6.8^{C}	4.3^{D}		9.0^{A}	8.4^{B}	7.8^{C}	7.2^{D}	6.6^{E}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test. **(**9= excellent, 7=good, 5=fair, 3= poor, 1= unsalable).

3. Snappiness

Data in Table 9 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andMoringa extract (4 cm and 6/L) as pre-harvest treatments on snappiness (score) of snap bean pods where 5 equal full snappiness, 4 equal full snappiness during storage and shelf life. Data show that snappiness of snap bean pods decreased with the prolongation of storage period in the two seasons. Similar results were obtained by **[7]**on snap bean pods.

Concerning the effect of pre-harvest treatments, data reveal that there was significant difference among all pre-harvest treatments in pod snappiness during storage; pods obtained from all pre-harvest treatments maintained snappiness as compared with untreated control. Moreover, pods obtained from the algae (4 cm/L) was the most effective treatment for reducing the loss of snappiness, followed by potassium silicate (2 cm/L) in the two seasons.

Concerning the interaction between pre-harvest treatments, and storage periods after 7 days of

storage and still up to the end of the experiment, data indicated that snap bean pods obtained from plants treated with either algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) ormoringa (4cm and 6/L) in a descending order were the most obvious in maintaining pod snappiness with significant differences between them in the two seasons, meanwhile those obtained from untreated plants which showed the lowest scores with significant differences between them at the same period..

Table 3. Effect of some growth stimulants on snappiness (score) of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	3.3^{ad}	2.7^{cd}	2.3^{de}	1.7^{e}	1.7^{e}	2.3^{E}	5.0^{a}	3.3^{df}	2.7^{f}	3.0^{ef}	2.3^{f}	3.3^{F}
Algae 2 cm/L	4.0^{ab}	3.5^{ac}	3.0^{bd}	3.0^{bd}	3.0^{bd}	3.3^{AB}	5.0^{a}	4.0^{bd}	4.0^{bd}	4.0^{bd}	4.0^{bd}	4.2^{AB}
Algae 4 cm/L	4.0^{ab}	4.0^{ab}	3.7^{ac}	3.3^{ad}	3.3^{ad}	3.7^{A}	5.0^{a}	4.7^{ab}	4.7^{ab}	4.3^{ac}	4.0^{bd}	4.5^{A}
Potassium silicate 2cm/L	4.0^{ab}	3.7^{ac}	3.3^{ad}	3.0^{bd}	3.0^{bd}	3.4^{AB}	5.0^{a}	4.3^{ac}	4.3^{ac}	4.0^{bd}	4.0^{bd}	4.3^{AB}
Potassium silicate 4cm/L	4.0^{ab}	3.7^{ac}	3.7^{ac}	2.3^{de}	2.3^{de}	3.2^{BC}	5.0^{a}	4.0^{bd}	3.0^{ef}	3.0^{ef}	4.0^{bd}	3.8^{DE}
Nano chitosan 60 mg/L	4.0^{ab}	3.3^{ad}	3.3^{ad}	2.7^{cd}	2.7^{cd}	3.2^{BC}	5.0^{a}	4.0^{bd}	3.7^{ce}	3.0^{ef}	3.0^{ef}	3.7^{E}
Nano chitosan 90 mg/L	3.7^{ac}	3.3^{ad}	3.0^{bd}	2.3^{de}	2.3^{de}	2.9^{CD}	5.0^{a}	3.3^{df}	3.0^{ef}	3.0^{ef}	3.0^{ef}	3.5^{F}
Moringa 4 cm/L	4.0^{ab}	2.7^{cd}	2.7^{cd}	2.3^{de}	2.3^{de}	2.8^{D}	5.0^{a}	4.0^{bd}	3.3^{df}	4.0^{bd}	3.7^{ce}	4.0^{CD}
Moringa 6 cm/L	4.3^{a}	3.0^{bd}	3.0^{bd}	2.7^{cd}	2.7^{cd}	3.1^{BC}	5.0^{a}	4.3^{ac}	4.0^{bd}	4.0^{bd}	3.3^{df}	4.1^{BC}
Mean	3.9^{A}	3.3^{B}	3.1^{B}	2.6^{B}	2.6^{C}		5.0^{A}	4.0^{A}	3.6^{B}	3.6^{B}	3.5^{C}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test. **(**5= full typical snappiness, 4= moderately full, 3= moderate, 2= slight, 1= low).

4. Decay percentage

Data presented in Table 4 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extract (4cm and 6/L) as pre-harvest treatments on decay percentage of snap bean pods during the storage and shelf life in both seasons. Results show clearly that the decay percentage was significantly increased with extending the storage period up to 28 days of storage.

Table 4.Effect of some growth stimulants on decay % of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season						Second Season					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	1.0^{b}	1.0^{b}	1.7^{a}	1.7^{a}	1.7^{a}	1.4^{A}	1.0^{d}	1.0^{d}	1.7^{cd}	2.3^{ab}	2.7^{a}	1.7^{A}
Algae 2 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.5^{cd}	2.0^{bc}	1.3^{B}
Algae 4 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.3^{cd}	1.7^{cd}	1.2^{B}
Potassium silicate 2 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.3^{cd}	2.0^{bc}	1.3^{B}
Potassium silicate 4 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.3^{cd}	2.0^{bc}	1.3^{B}
Nano chitosan 60 mg/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.3^{cd}	1.7^{cd}	1.2^{B}
Nano chitosan 90 mg/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.3^{cd}	1.3^{cd}	2.0^{bc}	1.3^{B}
Moringa 4 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.3^{cd}	1.7^{cd}	1.2^{B}
Moringa 6 cm/L	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{b}	1.0^{B}	1.0^{d}	1.0^{d}	1.0^{d}	1.7^{cd}	2.0^{bc}	1.3^{B}
Mean	1.0^{B}	1.0^{B}	1.1^{A}	1.1A	1.1^{A}		1.0^{C}	1.0^{C}	1.1^{C}	1.5^{B}	2.0^{A}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test. **(**5= extreme, 4= severe, 3= moderate, 2= slight, 1= none**)**

Such results are more obvious during the second season of study. The pre-harvest foliar spray of snap bean plants with either algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) ormoringa extract (4cm and 6/L) decreased the decay percentage of pods compared with the control treatment during both seasons of study. As for the effect of the interaction, results reveal that pre-harvest spray with any one of the used growth stimulants exhibited the lowest decay percentage of pods.

5. Total soluble solids percentage

Data in Table 5 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extract (4 cm and 6/L) as pre-harvest treatments on total soluble solids (TSS) % of snap bean pods during both storage and shelf life periods. Data indicate that total soluble solids of snap bean pods were increased with the prolongation of storage period in first season, while in the second one, total soluble solids of snap bean pods were not affected until 7 days and then were decreased till the end of storage periods as well as shelf life. These results are in agreement with those obtained by **[2]** on snap beans. This increase in TSS % may be due to water loss during storage period **[34]** and may possibly be due to hydrolysis of starch into sugars. As the hydrolysis of fruit starch is completed, no further increase in TSS could be detected and subsequently, a decline in this parameter predictable since sugars along with other organic acids are primary substrates used for respiration **[35]**. Concerning the effect of pre-harvest treatments, data revealed that there were significant differences between all pre-harvest treatments and untreated control on TSS % of pods during storage and shelf life. Snap bean pods obtained from plants treated with algae (4 cm/L), potassium silicate (4 cm/L) were the most effective treatments in maintaining TSS % without significant differences between them in the two seasons, while the lowest values in this concern were recorded for pods obtained from untreated plants. These results were achieved in the two seasons.

Table 5. Effect of some growth stimulants on total soluble solids (%) of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	3.9^{ik}	4.3^{gj}	5.4^{ac}	5.5^{ab}	5.6^{ab}	4.9^{AC}	4.9^{di}	5.1^{bg}	4.2^{il}	4.0^{kl}	4.0^{kl}	4.4^{C}
Algae 2 cm/L	4.5^{fi}	4.6^{fi}	4.8^{bf}	5.5^{ab}	5.5^{ab}	5.0^{AB}	5.3^{ag}	5.8^{ac}	4.7^{fk}	4.0^{kl}	4.0^{kl}	4.8^{AC}
Algae 4 cm/L	4.5^{fi}	4.9^{bf}	4.4^{gj}	5.5^{ab}	5.5^{ab}	5.0^{AB}	6.0^{a}	5.7^{ad}	4.6^{gk}	4.1^{jl}	4.4^{hl}	4.9^{AB}
Potassium silicate 2 cm/L	4.3^{gj}	4.2^{ik}	5.4^{ac}	5.1^{af}	5.2^{ae}	4.8^{BC}	5.3^{ag}	4.6^{gk}	5.0^{dh}	4.7^{fk}	3.7^{l}	4.7^{BC}
Potassium silicate 4 cm/L	4.2^{ik}	5.6^{ab}	5.4^{ac}	5.2^{ae}	5.2^{ae}	5.1^{A}	5.8^{ac}	5.2^{ag}	4.9^{di}	4.1^{jl}	4.1^{jl}	4.8^{AC}
Nano chitosan 60 mg/L	4.2^{ik}	4.6^{fi}	4.2^{ik}	5.1^{af}	5.1^{af}	4.6^{C}	5.2^{ag}	5.6^{ad}	4.8^{ej}	4.0^{kl}	3.7^{l}	4.7^{BC}
Nano chitosan 90 mg/L	3.9^{ik}	4.7^{eh}	4.3^{gj}	5.3^{ad}	5.4^{ac}	4.7^{BC}	5.5^{af}	5.5^{af}	4.8^{ej}	4.1^{jl}	4.9^{di}	4.9^{AB}
Moringa 4 cm/L	3.6^{k}	4.2^{ik}	4.8^{bf}	5.4^{ac}	5.4^{ac}	4.7^{BC}	5.9^{ab}	5.3^{ag}	4.9^{di}	4.9^{di}	4.1^{jl}	5.0^{A}
Moringa 6 cm/L	4.2^{ik}	3.9^{jk}	5.4^{ac}	5.7^{a}	5.5^{ab}	4.9^{AC}	5.1^{bg}	4.7^{fk}	4.8^{ej}	5.0^{dh}	4.1^{jl}	4.8^{AC}
Mean	4.2^{C}	4.6^{B}	4.9^{B}	5.4^{A}	5.4^{A}		5.5^{A}	5.3^{AB}	4.7^{B}	4.3^{B}	4.1^{C}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test.

In general, the interaction between pre-harvest treatments, and storage periods plus shelf life was significant in the two seasons. Snap bean pods obtained from plants treated with Moringa extract (6 cm/L) after 21 days and algae (4 cm/L) after 0 days gave the highest value of TSS % in first and second seasons, respectively, while the lowest ones were found in those obtained from plants treated with moringa extract (4 cm/L) after 0 days and potassium silicate (2cm/L) as well as after 28 days.

6. Total chlorophyll content

Data in Table 6 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extract (4 cm and 6/L) as pre-harvest treatments on total chlorophyll content of snap bean pods during storage and shelf life. Data reveal that chlorophyll content of snap bean pods was gradually decreased during storage and shelf life. Obtained results are in agreement with those obtained by **[2, 5, 7]**, on snap bean pods. This decrement in chlorophyll content

could be attributed to the gradual increase in of destruction by chlorophyll degrading peroxidase activity and also to the transformation of chloroplasts to chromoplasts by chlorophyllase activity **[36]**. Concerning the effect of pre-harvest treatments, data reveal that snap bean pods obtained from plants treated with potassium silicate (2 and 4cm/L in the first and second season, respectively) had significantly the highest value of total chlorophyll content as compared with the other treatments or untreated plants during storage and shelf life. These results were in agreement with those reported by **[33]**for algae on snap bean.

Also, the stimulative effect of the studied treatments on total chlorophyll might be due to that algae or potassium silicate acts as a source of cytokinins **[33, 15]**, which, delay the degradation of chlorophyll via the inhibition of chlorophyllase activity **[37]**. In general, the interaction between pre-harvest treatments, and storage periods was significant in the two seasons. However, snap bean pods obtained from plants treated with potassium silicate (2 and 4cm/L in the first and second season) had the highest values of chlorophyll content, while the lowest values were found in those obtained from treated plants with moringa extract (4 cm/L) after 28 days of storage in both seasons.

Table 6. Effect of some growth stimulants on total chlorophyll content (mg/100g fresh weight) of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	35.7^{ch}	40.0^{ae}	35.3^{di}	34.4^{di}	32.9^{ej}	35.7^{BD}	38.1^{ej}	38.7^{ej}	46.0^{bc}	42.7^{be}	35.5f^{j}	40.2^{BC}
Algae 2 cm/L	33.7^{ej}	33.4^{di}	33.2^{e}j	31.7^{fk}	30.2^{gk}	32.4^{DE}	41.8^{cf}	42.1^{be}	41.0^{dg}	39.5^{dh}	41.2^{cf}	41.1^{B}
Algae 4 cm/L	33.3^{ej}	34.7^{di}	31.1^{fk}	30.4^{gk}	28.9^{hk}	31.7^{E}	36.7^{ej}	37.7^{ej}	36.8^{ej}	41.9^{cf}	34.5^{hk}	37.5^{D}
Potassium silicate 2 cm/L	47.7^{a}	44.4^{ab}	43.6^{ac}	42.8^{ad}	42.4^{ad}	44.2^{A}	39.8^{dh}	38.7^{ej}	37.2^{ej}	37.5^{ej}	37.6^{ej}	38.2^{CD}
Potassium silicate 4 cm/L	43.2^{ac}	35.9^{ch}	36.5^{bh}	36.6^{bh}	35.6^{ci}	37.6^{B}	52.5^{a}	47.3^{b}	46.6^{bc}	45.2^{bd}	46.9^{bc}	47.7^{A}
Nano chitosan 60 mg/L	30.2g^{k}	28.8^{hk}	26.9^{jl}	24.3^{kl}	24.4^{kl}	26.9^{F}	38.2^{ej}	34.9^{gk}	33.2^{jk}	33.4^{ik}	32.6^{jk}	34.5^{E}
Nano chitosan 90 mg/L	40.7^{ae}	37.9^{bg}	31.5^{fk}	30.9^{gk}	29.3^{gk}	34.1^{CE}	39.9^{dh}	37.8^{ej}	37.4^{ej}	36.6^{ej}	36.4^{ej}	37.6^{D}
Moringa 4 cm/L	25.7^{jl}	23.7^{kl}	29.9^{gk}	23.3^{kl}	20.7^{l}	24.7^{F}	34.1^{hk}	29.2^{kl}	24.6^{l}	27.0^{l}	25.8^{l}	28.1^{F}
Moringa 6 cm/L	38.0^{bf}	36.5^{bh}	36.0^{ch}	35.3^{ci}	34.6^{di}	36.1^{BC}	41.3^{cf}	39.6^{dh}	38.6^{ej}	38.0^{ej}	38.1^{ej}	39.1^{BD}
Mean	36.5^{A}	35.0^{AB}	33.8^{BC}	32.2^{CD}	31.0^{D}		40.3^{A}	38.4^{AB}	37.9^{B}	38.0^{B}	36.5^{B}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test.

7. Protein percentage

Data in Table 7 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andmoringa extract (4 cm and 6/L) as pre-harvest treatments on protein % of snap bean pods during storage and shelf life. Data reveal that protein content of snap bean pods was decreased in a descending order with the prolongation of storage period and shelf life. Obtained results were achieved in the two seasons and are in agreement with those obtained by **[6]** on snap bean.Concerning the effect of pre-harvest treatments, the results showed that snap bean pods obtained from plants treated with algae (2 cm/L) had significantly the highest protein content and was the super treatment in maintaining protein content of pods in the two seasons, while the lowest values of protein content was recorded for pods obtained from the other treatments and untreated plants. These results were achieved in the two seasons and were in agreement with those obtained by **[15]**for algae on pea.The enhancement effect of algae application on pod protein content may be due to their important role in the biosynthesis of chlorophyll molecules which in turn may positively affect total carbohydrates content by increasing photosynthetic substances transformation from its origin source leading to the increase of different growth substances **[38]**and then maintained protein content during storage **[15]**. Concerning the interaction between pre-harvest treatments, and storage periods, the results reveal that snap bean pods obtained from plants treated with algae (2cm/L) in both seasons and moringa extract (4 cm/L) in the second one had the highest values of total protein content with significant differences between them in each storage period and shelf life, while the lowest ones were found in those obtained from treated plants with potassium silicate (4cm/L) after 21 days from storage period in the two seasons.

Table 7.Effect of some growth stimulants protein % of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	15.4^{ae}	15.2^{ag}	15.0^{ag}	14.9^{ah}	14.7^{a}i	15.0^{B}	15.6^{ch}	15.4^{dj}	15.0^{fm}	15.0^{fm}	14.7^{gn}	15.1^{C}
Algae 2 cm/L	16.8^{a}	16.5^{ab}	16.7^{a}	15.7^{ad}	15.3^{ag}	16.2^{A}	16.9^{ac}	16.3^{ae}	16.0^{bf}	15.4^{dj}	15.0^{fm}	16.1^{A}
Algae 4 cm/L	13.3^{dj}	13.0^{ej}	12.8^{fj}	12.3^{hj}	12.1^{hj}	12.7^{D}	13.8^{mr}	13.5^{os}	13.0^{rt}	12.6st	12.4^{t}	12.9^{E}
Potassium silicate 2 cm/L	14.1^{aj}	14.0^{aj}	13.6^{cj}	13.5^{dj}	12.7^{gj}	13.6^{CD}	15.2^{fm}	14.8^{gn}	14.2^{jp}	13.9^{kq}	13.6^{nr}	13.9^{D}
Potassium silicate 4 cm/L	14.2^{aj}	13.8^{cj}	13.0^{ej}	12.4^{hj}	11.8^{j}	13.0^{D}	14.4^{io}	14.2^{jp}	14.0^{nr}	13.7^{nr}	13.5^{ps}	13.5^{D}
Nano chitosan 60 mg/L	14.3^{aj}	14.9^{ah}	14.7^{ah}	14.4^{aj}	14.1^{aj}	14.5^{BC}	14.8^{gn}	14.4^{i}o	13.9^{kq}	13.4^{ps}	13.2^{ps}	14.2^{D}
Nano chitosan 90 mg/L	16.0^{ac}	14.8^{ah}	14.2^{aj}	13.9^{bj}	13.6^{cj}	14.5^{BC}	16.0^{af}	15.6^{ch}	15.3^{ek}	14.8^{gn}	14.5^{io}	14.8^{D}
Moringa 4 cm/L	16.3^{ad}	15.8^{ad}	15.3^{ag}	14.8^{a}h	11.9^{ij}	14.8^{B}	17.3^{a}	17.0^{ab}	16.6^{ac}	16.4^{ad}	15.8^{cg}	15.6^{B}
Moringa 6 cm/L	15.8^{ad}	15.3^{ag}	14.8^{ah}	14.3^{a}j	13.6^{cj}	14.8^{B}	16.3^{ae}	16.0^{bf}	15.4^{ek}	15.1^{fm}	14.7^{gn}	15.1^{C}
Mean	15.1^{A}	14.8^{AB}	14.5^{B}	14.0^{C}	13.3^{D}		15.6^{A}	15.2^{B}	14.8^{C}	14.5^{D}	14.2^{E}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test.

8. Fiber percentage

Data in Table 8 show the effect of algae (2 and 4 cm/L), potassium silicate (2 and 4 cm/L), nano chitosan (60 and 90 mg/L) andMoringa extract (4 cm and 6/L) as pre-harvest treatments on fiber % of snap bean pods during storage and shelf life periods. Data reveal that fiber content of snap bean pods increased slowly with the prolongation of storage period in first season and the differences mostly did not reach to 5% of significance in the second season, these results are in agreement with those obtained by **[2, 3]**on snap beans. The increase in fiber % during the increase in storage period may be due to moisture loss during storage **[9]**.

Concerning the effect of pre-harvest treatments, data show that some of the various applied treatments showed significantly lower fiber percentages as compared with untreated plants in both seasons. Snap bean pods obtained from plants treated with moringa (4 cm and 6/L) gave the least values of fiber content during storage in the both seasons, while the highest ones were obtained from other treatments and untreated control in the two seasons. These results are in agreement with those obtained by **[15]** for olgae on pea.

In general, the interaction between pre-harvest treatments and storage periods was significant in both seasons, whereas snap bean pods obtained from plants treated with moringa extract (4 cm and 6/L) had the lowest values of fiber percentage after 0, 7, 14, 21 and 28 days of storage in both seasons, while pods obtained from plants treated with other stimulants and untreated plants had the highest ones with significant differences between them in both seasons.

Table 8.Effect of some growth stimulants fiber % of snap bean pods at storage period at 5°C, with additional 2 days at 10°C as shelf life during both seasons (2019 and 2020).

Treatments	First Season (2019)						Second Season (2020)					
	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean	0 + 2 days	7 + 2 days	14 + 2 days	21 + 2 days	28 + 2 days	Mean
Control	11.0^{dk}	10.7^{dk}	11.0^{dk}	11.3^{ck}	11.4^{ck}	11.1^{BD}	12.1^{dk}	12.4^{bj}	12.5b^{j}	12.7^{aj}	12.8^{ai}	12.5^{CD}
Algae 2 cm/L	9.8^{fk}	10.0^{ek}	10.2^{dk}	10.5^{dk}	10.8^{dk}	10.3^{CD}	11.5^{dm}	11.6^{dm}	11.8^{dm}	11.9^{dm}	12.1^{dk}	11.8^{D}
Algae 4 cm/L	9.2^{gk}	7.3^{k}	21.9^{a}	18.9^{af}	15.5^{ak}	14.6^{B}	14.9^{ae}	15.7^{ab}	15.7^{ab}	15.8^{ab}	15.9^{a}	15.6^{A}
Potassium silicate 2 cm/L	17.5^{aj}	17.9^{ai}	18.4^{ah}	18.3^{ah}	18.8^{af}	18.2^{A}	14.0^{af}	15.0^{ad}	12.6^{bj}	10.8^{hp}	11.3^{ho}	12.7^{BD}
Potassium silicate 4 cm/L	11.6^{bk}	13.1^{ak}	13.5^{ak}	13.6^{ak}	13.9^{ak}	13.1^{BC}	13.3^{ah}	13.6^{ag}	14.2^{af}	14.5^{af}	14.2^{af}	14.0^{B}
Nano chitosan 60 mg/L	20.1^{ac}	20.5^{ab}	20.9^{a}	21.3^{a}	21.5^{a}	20.9^{A}	12.9^{ai}	13.2^{ah}	13.4^{ah}	13.5^{ah}	13.6^{ag}	13.3^{BC}
Nano chitosan 90 mg/L	18.7^{af}	21.6^{a}	19.3^{ae}	19.5^{ae}	19.8^{ad}	19.8^{A}	10.2^{hp}	10.4^{hp}	10.3^{hp}	10.5^{hp}	10.6^{hp}	10.4^{E}
Moringa 4 cm/L	6.9^{k}	7.9^{k}	8.4h^{k}	8.9^{hk}	9.2^{gk}	8.3^{D}	8.7l^{p}	9.1^{kp}	9.4^{kp}	9.6^{ip}	9.6^{ip}	9.3^{EF}
Moringa 6 cm/L	8.2^{ik}	9.0^{ik}	9.2^{gk}	9.8^{fk}	9.7^{gk}	9.2^{D}	7.3^{p}	8.2^{op}	8.3^{op}	8.5^{mp}	8.5^{mp}	8.2^{F}
Mean	12.6^{B}	13.1^{B}	14.8^{A}	14.7^{A}	14.5^{A}	13.9	11.7^{A}	12.1^{A}	12.0^{A}	12.0^{A}	12.1^{A}	

Values with the same capital letters in the column and the row are not statistically different. The same small letters in the interaction are not statistically different, according to Duncan's Multiple Range test.

4. Conclusions

It can be concluded from this study that foliar spray snap bean plants three times during the growing period at 21, 35, 50 days after sowing in the field with the algae (4 cm/L) and moringa leaves extract (6 cm/l) and then produced green pods were packed in polypropylene bags improved storability, maintained pod quality attributes, and gave good appearance of pods up to 28 days of storage at 5ºC + 2 days at 10ºC as shelf life.

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