

## Effect of Some Post-Cold Storage Treatments on Shelf Life of Sweet Potato Roots

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**Abstract:** The experiment was conducted to investigate the effects of hot water treatment, Bio-health and Clean Root as post-harvest bio-fungicide treatments after four cold storage period (13°C and 80:90% RH) on physical and chemical content of ‘Abees’ sweet potato cultivar roots at the end of shelf life (15 days). Results revealed a gradual increase in weight loss and dry matter content and decrease in general appearance score and starch contents with the storage prolongation. No defected roots were found during the first 2 months of storage and no effect on flesh hue angle value during all storage periods. The total carotenoids content remained constant for two months of cold storage plus 15 days shelf-life and then decreased sharply until the end of storage period while total sugars were increased up to 2 months of storage period and then it began to decrease. All applied treatments did not give any defected roots for 2 months of cold storage plus 15 days shelf-life, except roots washed with tap water and untreated roots (control). Roots washed with tap water and control treatments recorded the highest value of defected roots, weight loss and total sugars content, also had the lowest value of general appearance, dry matter and starch content. Hot water + Bio-health and Bio-health treatments had the lowest values of weight loss, defected roots and highest score of general appearance and dry matter. Bio-health and Clean Root treatments exhibited the highest content of total carotenoids while heat water treatments recorded the least value. In brief, immersion in Bio-health as bio-fungicide after hot water treatment or Bio-health only after cold storage up to 4 months and before marketing (shelf life) period, as postharvest treatments and air-dried had more pronounced effect on physical and chemical quality of ‘Abees’ sweet potato cultivar roots.

**Key words:** Sweet potato • Abees • Hot water • Bio-fungicide • Cold storage • Shelf-life

### INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the important vegetable crops in warm countries where it needs a warm growing season of 4-6 months. Such period is less than periods needed for most other root and tuber crops [1]. Sweet potato ranks third of the world root and tuber crops production after potato and cassava [2]. In developing countries, sweet potato is especially valuable because it is a food security crop for the poor that can provide an important part of the dietary carbohydrates of the population [3]. High levels of nutrition, high productivity and low levels of input have made sweet potato a valuable resource in the developing countries. It is a cheap source of carbohydrates and at the same time, the kinds of yellow or orange pulp are rich in

carotenoids which play an important role in human health by acting as sources of pro-vitamin A or as protective antioxidants [4].

In Egypt, less than 6% of sweet potato produced annually is exported. This low export percentage can be attributed to several factors, including inadequate postharvest handling, deficiencies in curing and storage infrastructure, lack of proper packing and grading and inadequate knowledge of EU market requirements and opportunities [5]. Egyptian sweet potato grown varieties are Mabroka, Abees (local varieties) and Beauregard as an important new hybrid progeny. ‘Abees’ is an orange flesh, red skin, low dietary fiber, sweetness taste; rich in vitamin A and carotenoids, but it is difficult to be stored for longer than 1 month and has a short shelf-life [6].

Sweet potato roots are living respiration and biological active organisms. Roots always show a weight loss due to transpiration and respiration [7, 8]. Moreover, sweet potato roots show changes in their physical and chemical quality, especially in the carbohydrate fraction of the roots during storage period [9]. Finally, total weight losses can be increased substantially by storage diseases [8, 10, 11]. The relative important problem is the postharvest weight loss during curing, although curing can heal the skin abrasion and wound inflicted during harvest and handling, reduce moisture loss during storage and minimize microbial decay. Deterioration of sweet potato occurred by some microbial organism during storage and marketing. Also, the decrease in root quality was also affected by sprouting. The spoilage of roots due to invasion by fungi often also occurred and resulting in decreasing quality and large loss during storage [12].

Heat and bio-fungicide treatments have been used as non-chemical means to modify the postharvest quality and reduce pathogens levels and diseases development of a wide variety of horticulture products [13]. Pre-storage hot water treatments (immersion, rinsing and brushing) inhibit ripening, reduce decay incidence and induce resistance against pathogens and against chilling injuries, while they maintain fruit quality during prolonged storage and marketing [14].

Postharvest heat treatment can also, reduce weight loss and undesirable postharvest growth and sprouting and spoilage [15, 16]. Thermal treatment supply a lethal dose of heat to surface pathogens and cauterize eye without damaging the nutritional and processing qualities of sweet potato [17, 12]. Hot water dipping did not have significant effect on sugar level of sweet potato during storage [18]. Transformation of starch to sugar in sweet potato takes place during curing and continues in storage, also  $\alpha$ -amylase in sweet potato roots play a key role in starch degradation during storage [7]. On the other hand, starch content was gradually and continuously decreased with the prolongation of storage period. This reduction could be due to the conversion of starch to sugar which is used in respiration [19, 9].

The objective of this study was to investigate the effects of hot water treatment, Bio-health and Clean Root as a post-storage bio-fungicide treatments after different cold storage periods at 13°C (80:90% RH) and held at room temperature (Shelf life) for 15 days as a simulate retail market on physical and chemical contents of sweet potato 'Abess' as an important local cultivar to extend shelf life and determine the maximum cold storage period at which sweet potato roots can be stored safely.

## MATERIALS AND METHODS

A storage experiment was conducted in the laboratory of Vegetable Handling Research Dept., Horticulture Res. Inst., A.R.C., at Giza, on the tubers of sweet potato 'Abess'. To get these roots, cuttings of this cultivar were planted at distances of 25 cm on rows, 70cm apart at Kaha experimental farm (Kaluobia governorate, Egypt). Planting dates were on the 3<sup>rd</sup> and 8<sup>th</sup> of May in 2011/2012 and 2012/2013 seasons, respectively. Cultural practices of sweet potato production were carried out as recommended by Ministry of Agriculture. Roots of sweet potato were harvested on 18<sup>th</sup> and 23<sup>th</sup> of September in the first and second seasons, respectively.

The harvested roots were left in short heaps at the field for 24 hours in order to lose the major field moisture. Samples of sound roots with the uniform size (200-250 g in weight and 4-5 cm in equatorial diameter) and free of defects were transferred to the laboratory. On arrival, the sweet potato roots were cured at 30°C and 80:90% RH for 10 days. Then, only uniform roots in size, weight, color and free from any visible defects were selected and packed loose in plastic boxes (45 × 35 × 25 cm.) in a single layer, 3 kg for each and stored at 13°C and 85:90% RH up to 4 months. Roots were taken monthly, for four months, from the cold storage room and were subjected to one of the following treatments:

- Dipping in hot water at 55°C for 60 sec.
- Dipping in Clean Root solution (5 g/liter) for 5 min.
- Dipping in Bio-health solution (5 g/liter) for 5 min.
- Dipping in hot water at 55°C for 60 sec. and in Clean Root solution (5 g/liter) for 5 min.
- Dipping in hot water at 55°C for 60 sec. and in Bio-health solution (5 g/liter) for 5 min.
- Washing with tap water.
- Untreated roots (control).

Roots from all treatments were air-dried and held at room temperature (shelf life) for 15 days as simulation for retail market.

- Bio-health is a blend of selected *Trichoderma harzianum* strains, humic acid and seaweed extract. *Trichoderma harzianum* is approx. 10% (approx. 10<sup>7</sup> spores and infection particles). The product type is water soluble granules.
- Clean Root is an experimental product by Central Lab. of Organic Agriculture. It contains different isolates of *Bacillus subtilis*, in addition to amino acids, trace

elements and humic acid. Each gram contains approx.  $30 \times 10^6$  c.f.u. The product type is water soluble granules.

Sweet potato roots quality parameters were analyzed at initial and end of every storage period as follows:

#### **Physical Characteristics**

**Weight Loss:** It was expressed as percentage of weight loss relative to the initial weight as described by Lemoine *et al.* [20].

**Defected Roots Percentage:** It was recorded for all the injured or spoiled roots resulting from fungus or bacterial, shriveling and any visible defects.

**General Appearance (Score):** It was scored as described below according to Kader *et al.* [21].

- Score 9 = Excellent (Field-fresh, no symptoms of deterioration).
- Score 7 = Good (Minor symptoms of deterioration).
- Score 5 = Fair (Deterioration evident, but not serious).
- Score 3 = Poor (Serious deterioration and limit of salability).
- Score 1 = Unmarketable (Not usable under normal condition).

Defects induced root softening, shriveling and decay.

**Flesh Color (Hue Angle):** It was determined by using a Minolta colorimeter type (CR-400/410) for the estimation of a, b and hue angle ( $h^\circ$ ). Hue angle ( $h^\circ$ ) =  $\arctan b^*/a^*$ . Hue angle ( $0^\circ$ = red-purple,  $90^\circ$  = yellow,  $180^\circ$ =bluish-green,  $270^\circ$ = blue), as described by McGuire [22].

**Dry Matter%:** It was determined in dried sample of fresh sweet potato roots, which were dried at  $70^\circ\text{C}$  till constant weight; thereafter it was calculated as dry matter% =  $(B / A) \times 100$ .

Where: A = sample weight before drying. B = sample weight after drying.

#### **Chemical Characteristics**

**Total Carotenoids Content (mg/100 g Fresh Weight):** It was extracted by acetone; thereafter absorbance was read at 470 nm of spectrophotometer (Beckman Du 7400) according to Lichtentaler and Wellburn [23].

**Total Sugars Content (g/100 g Fresh Weight):** It was extracted by ethanol and determined by phenol-sulphuric acid method according to Dubois *et al.* [24]. A standard curve was carried out using pure glucose with a suitable concentration.

**Starch Content (g/100 g Dry Weight):** It was determined by the method of anthrone reagent as described by Ranganna [25]. Prepared glucose anhydrous solution (1000 ppm) was used as standard.

**Statistical Analysis Procedure:** Experiments were performed in completely randomized in factorial design with three replicates. All data were subjected to statistical analysis as described by Snedecor and Cochran [26]. Treatment mean differences were compared using LSD test to evaluate the significant differences of the data at  $p = 0.05$ .

## **RESULTS AND DISCUSSION**

#### **Physical characteristics**

**Weight loss%:** As shown in Table 1 data indicated that the least weight loss percentage was recorded for hot water + Bio-health, Bio-health and hot water + Clean Root treatments with no significant differences between them. On the contrary, untreated roots (control) exhibited the highest weight loss percentage followed by the root washed with tap water in both seasons.

Postharvest heat treatments reduced weight loss as reported by Khalil *et al.* [15] through inactivation the protein and tissue of the surface flesh of sweet potato to retard the evaporation of water through the skin [17, 12]. Moreover, biological fungicide has a good effect on reducing roots weight loss resulting from the infection by micro-organisms on yam [27, 28].

Storage period was also found to be effective in this respect. A gradual increase in weight loss was shown towards the end of the cold storage (4 months) plus 15 days shelf-life; the longer the storage period, the higher weight loss of the roots in both seasons. Respiration contributed more to total weight loss of sweet potato roots during the latter periods of cold storage [29].

The interaction between the used treatments and storage periods had significant effect during the two seasons. Dipping roots in hot water + Bio-health treatment resulted in 8.70% weight loss after 4 months of storage + 15 days shelf life, while washed roots with tap water recorded 14.26% when stored for 4 months at  $13^\circ\text{C}$

Table 1: Effect of immersing in hot water and bio-fungicide as post-storage treatments on weight loss% of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	0.00	6.25	8.32	9.17	10.73	6.89
Clean Root (5g / liter/5 min.)	0.00	6.46	8.52	9.61	10.87	7.09
Bio-health (5g / liter/5 min.)	0.00	6.39	8.01	9.06	10.19	6.73
Hot water (55°C/60 sec.) + Clean Root	0.00	5.90	7.88	8.74	9.51	6.41
Hot water (55°C/60 sec.) + Bio-health	0.00	5.73	7.39	8.09	8.70	5.98
Washed with tap water	0.00	8.94	10.27	12.68	14.26	9.23
Untreated (control)	0.00	8.74	9.99	11.48	12.17	8.48
Mean	0.00	6.91	8.63	9.83	10.92	
2012-2013 Season						
Hot water (55°C/60 sec.)	0.00	6.88	8.52	10.51	11.12	7.40
Clean Root (5g / liter/5 min.)	0.00	7.04	8.97	10.79	11.24	7.61
Bio-health (5g / liter/5 min.)	0.00	5.78	7.48	9.93	10.90	6.82
Hot water (55°C/60 sec.) + Clean Root	0.00	5.94	8.24	10.19	10.99	7.07
Hot water (55°C/60 sec.) + Bio-health	0.00	5.49	7.00	9.12	10.05	6.33
Washed with tap water	0.00	8.32	9.94	12.14	13.82	8.85
Untreated (control)	0.00	8.05	9.05	10.59	11.36	7.81
Mean	0.00	6.79	8.46	10.47	11.35	
Season	A		B		A X B	
LSD at 5%	2011-2012	1.89	1.59		4.22	
	2012-2013	0.94	0.80		2.11	

Table 2: Effect of immersing in hot water and bio-fungicide as post-storage treatments on defected% of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	0.00	0.00	0.00	13.89	16.67	6.11
Clean Root (5g / liter/5 min.)	0.00	0.00	0.00	11.11	13.89	5.00
Bio-health (5g / liter/5 min.)	0.00	0.00	0.00	5.56	8.33	2.78
Hot water (55°C/60 sec.) + Clean Root	0.00	0.00	0.00	8.33	11.11	3.89
Hot water (55°C/60 sec.) + Bio-health	0.00	0.00	0.00	2.78	5.56	1.67
Washed with tap water	0.00	2.78	8.33	25.00	33.33	13.89
Untreated (control)	0.00	0.00	5.56	19.44	22.22	9.44
Mean	0.00	0.40	1.98	12.30	15.87	
2012-2013 Season						
Hot water (55°C/60 sec.)	0.00	0.00	0.00	13.89	19.44	6.67
Clean Root (5g / liter/5 min.)	0.00	0.00	0.00	11.11	16.67	5.56
Bio-health (5g / liter/5 min.)	0.00	0.00	0.00	5.56	11.11	3.33
Hot water (55°C/60 sec.) + Clean Root	0.00	0.00	0.00	8.33	13.89	4.44
Hot water (55°C/60 sec.) + Bio-health	0.00	0.00	0.00	2.78	5.56	1.67
Washed with tap water	0.00	5.56	13.89	27.78	36.11	16.67
Untreated (control)	0.00	0.00	5.56	16.67	25.00	9.44
Mean	0.00	0.79	2.78	12.30	18.25	
Season	A		B		A X B	
LSD at 5%	2011-2012	2.22	1.87		4.96	
	2012-2013	2.78	2.35		6.21	

and 85:90% R.H. plus 15 days at room temperature in the first season. Similar results were noticed in the second season.

**Defected Roots%:** Data presented in Table 2 showed that the hot water + Bio-health followed by Bio-health treatment exhibited the lowest percentage of defected roots, while the washed roots with tap water and untreated roots (control) recorded the highest percentage of defected roots with a significant difference between them.

Generally, the overall quality of fresh product that was treated at optimal hot water and time of exposure was significantly better than that of untreated fruit, as determined by a sharp reduction in decay incidence and several quality traits [13]. It was considered that thermal treatment supplies a lethal dose of heat to surface pathogens and cauterizes sweet potato eyes without damaging the nutritional and processing qualities of sweet potato [30]. Moreover, the use of bio-fungicide against pathogens may be an economically viable way of suppressing postharvest rot. This procedure promises to be an effective way to control postharvest diseases as a cost effective and simple application on yam [27, 28].

Significant differences among overall means of defected roots percentage due to period of storage were detected. The lowest values were recorded after 1 and 2 months and increased rapidly after that.

Concerning the interaction of used treatments and storage periods, data revealed that all applied treatments did not give any defected roots until 2 months of cold storage plus 15 days at room temperature except washed roots with tap water and untreated roots (control). Moreover, dipping in Bio-health after hot water treatment showed the lowest significant defected roots percentage during storage as compared with other treatments.

The changes occurred in roots during storage, which decrease root firmness, as well as transformation of complex compounds to simple forms which more ability to fungus infection.

**General Appearance (Score):** As shown in Table 3 data indicated that untreated roots (control) and roots washed with tap water exhibited significantly lower score of general appearance as compared with other treatments used. Moreover, the hot water + Bio-health; Bio-health and hot water + Clean Root treatments exhibited the highest score of general appearance in both seasons with

Table 3: Effect of immersing in hot water and bio-fungicide as post-storage treatments on general appearance (score) of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	9.00	9.00	9.00	7.33	7.00	8.27
Clean Root (5g / liter/5 min.)	9.00	9.00	9.00	7.67	7.33	8.40
Bio-health (5g / liter/5 min.)	9.00	9.00	9.00	8.33	8.00	8.67
Hot water (55°C/60 sec.) + Clean Root	9.00	9.00	9.00	8.00	7.67	8.53
Hot water (55°C/60 sec.) + Bio-health	9.00	9.00	9.00	8.67	8.33	8.80
Washed with tap water	9.00	8.67	8.00	6.00	5.67	7.47
Untreated (control)	9.00	9.00	8.33	6.67	6.33	7.87
Mean	9.00	8.95	8.76	7.52	7.19	
2012-2013 Season						
Hot water (55°C/60 sec.)	9.00	9.00	9.00	7.33	6.67	8.20
Clean Root (5g / liter/5 min.)	9.00	9.00	9.00	7.67	7.00	8.33
Bio-health (5g / liter/5 min.)	9.00	9.00	9.00	8.33	7.67	8.60
Hot water (55°C/60 sec.) + Clean Root	9.00	9.00	9.00	8.00	7.33	8.47
Hot water (55°C/60 sec.) + Bio-health	9.00	9.00	9.00	8.67	8.33	8.80
Washed with tap water	9.00	8.33	7.33	5.67	4.67	7.00
Untreated (control)	9.00	9.00	8.33	7.00	6.00	7.87
Mean	9.00	8.90	8.67	7.52	6.81	
(9 = Excellent, 7 = Good, 5= Fair, 3 = Poor, 1 = Unmarketable)						
	Season	A		B		A X B
LSD at 5%	2011-2012	0.28		0.23		0.62
	2012-2013	0.33		0.28		0.75

Table 4: Effect of immersing in hot water and bio-fungicide as post-storage treatments on flesh color (hue angle) of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	64.48	66.42	68.36	70.63	71.02	68.18
Clean Root (5g / liter/5 min.)	64.48	65.11	66.32	67.24	67.80	66.19
Bio-health (5g / liter/5 min.)	64.48	66.12	68.17	69.17	69.51	67.49
Hot water (55°C/60 sec.) + Clean Root	64.48	65.76	67.34	68.94	69.41	67.19
Hot water (55°C/60 sec.) + Bio-health	64.48	66.27	68.27	69.90	70.27	67.84
Washed with tap water	64.48	66.49	68.71	69.27	69.60	67.71
Untreated (control)	64.48	66.11	67.51	67.78	68.41	66.86
Mean	64.48	66.04	67.81	68.99	69.43	
2012-2013 Season						
Hot water (55°C/60 sec.)	63.76	65.76	67.79	70.12	70.32	67.55
Clean Root (5g / liter/5 min.)	63.76	64.47	65.77	66.77	67.26	65.61
Bio-health (5g / liter/5 min.)	63.76	65.47	67.60	68.65	68.96	66.89
Hot water (55°C/60 sec.) + Clean Root	63.76	65.11	66.78	68.45	68.79	66.58
Hot water (55°C/60 sec.) + Bio-health	63.76	65.62	67.70	69.39	69.64	67.22
Washed with tap water	63.76	65.93	68.24	68.83	68.99	67.15
Untreated (control)	63.76	65.56	67.05	67.37	67.80	66.31
Mean	63.76	65.42	67.28	68.51	68.82	
Season	A		B		A X B	
LSD at 5%	2011-2012	N.S.	N.S.		N.S.	
	2012-2013	N.S.	N.S.		N.S.	

Table 5: Effect of immersing in hot water and bio-fungicide as post-storage treatments on dry matter% of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons.

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	31.30	30.15	29.04	27.97	26.95	29.08
Clean Root (5g / liter/5 min.)	31.30	30.42	29.56	28.73	27.93	29.59
Bio-health (5g / liter/5 min.)	31.30	30.60	29.92	29.26	28.61	29.94
Hot water (55°C/60 sec.) + Clean Root	31.30	30.36	29.45	28.57	27.72	29.48
Hot water (55°C/60 sec.) + Bio-health	31.30	30.65	30.01	29.38	28.77	30.02
Washed with tap water	31.30	29.79	28.36	27.00	25.70	28.43
Untreated (control)	31.30	29.68	28.14	26.69	25.31	28.22
Mean	31.30	30.24	29.21	28.23	27.28	
2012-2013 Season						
Hot water (55°C/60 sec.)	32.86	31.66	30.50	29.38	28.30	30.54
Clean Root (5g / liter/5 min.)	32.86	31.94	31.05	30.17	29.33	31.07
Bio-health (5g / liter/5 min.)	32.86	32.14	31.43	30.74	30.06	31.45
Hot water (55°C/60 sec.) + Clean Root	32.86	31.89	30.94	30.02	29.13	30.97
Hot water (55°C/60 sec.) + Bio-health	32.86	32.18	31.52	30.87	30.23	31.53
Washed with tap water	32.86	31.27	29.76	28.32	26.96	29.84
Untreated (control)	32.86	31.15	29.54	28.00	26.55	29.62
Mean	32.86	31.75	30.68	29.64	28.65	
Season	A		B		A X B	
LSD at 5%	2011-2012	N.S.	2.48		N.S.	
	2012-2013	0.68	0.57		1.52	

no significant differences among them. Respiration and transpiration contribute to loss in weight and alteration of internal and external appearance [7]. The decrease in quality was also affected by sprouting and external shrinkage symptoms. The spoilage of roots due to invasion by fungi often also occurred and resulted in decreasing quality and large loss during storage [30].

In respect to storage period, data indicate that the general appearance score was significantly decreased with the progress of storage period in the two seasons. Results also revealed that the interaction among all treatments used and storage periods on general appearance score was significant. Hot water + Bio-health followed by Bio-health showed the highest score during all storage periods in both seasons.

**Flesh Color (Hue Angle):** The flesh color of the homogenized samples was measured by recording the hue angle (Table 4). No significant differences were observed between all treatments used. Heat and bio-fungicide treatments have been used as a non-chemical means to modify the postharvest quality, reduce pathogens levels and diseases development and also no significant impact on the internal components 'quality of roots especially flesh color [13, 30]. Also, there was a non-significant increase in flesh hue angle value with the prolongation of storage period in the two seasons. The same results were recorded for the interaction among the used treatments and storage periods.

**Dry Matter%:** Although, dry matter percentage in sweet potato roots was not affected by the post-storage treatments in the first season; significant differences among treatments were detected in the second season in this regard (Table 5). Hot water + Bio-health and Bio-health treatments recorded the highest significant contents of dry matter, while the washed roots with tap water and untreated roots (control) exhibited the least percentage of dry matter content in both seasons. Similar results were reported by Picha [7]; Ress *et al.* [10] and Emam and Attia [29] on sweet potato.

Concerning storage period, a significant difference was detected in both seasons, where a gradual reduction in dry matter content was evident by prolonging the storage period (Table 5).

As respect to the interaction effect between storage period and the used treatments on dry matter content, data showed that the hot water + Bio-health and Bio-health gave the highest contents of dry matter at the

end of all storage periods + the shelf life period in both seasons. Sweet potato roots lose dry matter through natural respiration. Respiration is a chemical process necessary for all living tissue whereby starch and sugars (dry matter) are oxidized to carbon dioxide and water vapor with the liberation of heat [31].

### **Chemical Characteristics**

**Total Carotenoids Content (mg / 100 g Fresh Weight):** Bio-health treatment exhibited the highest content of total carotenoids, while hot water treatments recorded the least content in both seasons (Table 6).

Results also revealed that the interaction among all treatments used and storage periods on total carotenoids content was more pronounced. Bio-health treatments show the higher content of total carotenoids during all storage periods in both seasons. Moreover, dipping roots in hot water recorded, significantly, the lowest content of total carotenoids during all storage periods as compared with other treatments.

**Total Sugars Content (g / 100 g Fresh Weight):** There was a significant difference among treatments in total sugars content of sweet potato roots in the first season. On the contrary, in the second season the roots were not affected by any postharvest treatments (Table 7).

With respect to storage period, data indicate that the total sugars were increased with prolongation storage period up to 2 months then it began to decrease.

The increment in sugar at the first period of storage might due to the moisture loss through transpiration and the conversion of starch to sugars. But the reduction at the end of storage might owe to the utilization of sugars in respiration [32]. Zhang *et al.* [9] found that glucose and sucrose increased early in storage and then remained fairly constant. In sweet potato roots  $\alpha$ -amylase plays a key role in starch degradation during storage. Transformation of starch to sugar in sweet potato takes place during curing and continues in storage [7]. These results are in line with Emam and Attia [29] on sweet potato.

The interaction among all studied factors showed a significant effect on sugars content of sweet potato roots in both seasons. However, after 4 months of storage at 13°C plus 15 days at room temperature (shelf-life), untreated roots (control) or roots washed with tap water exhibited the highest content of total sugars, while Bio-health or Clean Root recorded the least values in the first season.

Table 6: Effect of immersing in hot water and bio-fungicide as post-storage treatments on total carotenoids content (mg / 100 g f. w.) of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons.

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	14.60	12.69	11.26	5.93	1.25	9.15
Clean Root (5g / liter/5 min.)	14.60	14.18	13.90	9.40	5.40	11.50
Bio-health (5g / liter/5 min.)	14.60	14.46	14.44	10.14	6.32	11.99
Hot water (55°C/60 sec.) + Clean Root	14.60	13.44	12.58	7.67	3.32	10.32
Hot water (55°C/60 sec.) + Bio-health	14.60	13.58	12.85	8.04	3.78	10.57
Washed with tap water	14.60	13.91	13.91	9.66	5.86	11.59
Untreated (control)	14.60	13.81	13.56	9.09	5.11	11.24
Mean	14.60	13.73	13.22	8.56	4.44	
2012-2013 Season						
Hot water (55°C/60 sec.)	14.42	12.53	11.12	5.81	1.14	9.00
Clean Root (5g / liter/5 min.)	14.42	14.00	13.74	9.25	5.25	11.33
Bio-health (5g / liter/5 min.)	14.42	14.29	14.27	9.98	6.17	11.83
Hot water (55°C/60 sec.) + Clean Root	14.42	13.27	12.43	7.53	3.20	10.17
Hot water (55°C/60 sec.) + Bio-health	14.42	13.41	12.69	7.90	3.66	10.42
Washed with tap water	14.42	13.74	13.75	9.50	5.72	11.43
Untreated (control)	14.42	13.64	13.40	8.95	4.97	11.08
Mean	14.42	13.55	13.06	8.42	4.30	
LSD at 5%		Season		A		B
		2011-2012		0.77		0.70
		2012-2013		0.71		0.65
						A X B

Table 7: Effect of immersing in hot water and bio-fungicide as post-storage treatments on total sugars content (g / 100 g f. w.) of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons.

Cold storage (Month) + Shelf-life (B)						
Treatments (A)	Initial	1	2	3	4	Mean
2011-2012 Season						
Hot water (55°C/60 sec.)	5.89	6.18	6.44	6.04	5.00	5.91
Clean Root (5g / liter/5 min.)	5.89	6.02	6.15	5.63	4.45	5.63
Bio-health (5g / liter/5 min.)	5.89	5.94	5.99	5.37	4.43	5.52
Hot water (55°C/60 sec.) + Clean Root	5.89	6.10	6.29	5.84	5.06	5.84
Hot water (55°C/60 sec.) + Bio-health	5.89	6.06	6.21	5.71	4.55	5.68
Washed with tap water	5.89	6.31	6.36	6.42	5.14	6.03
Untreated (control)	5.89	6.30	6.38	6.60	5.44	6.12
Mean	5.89	6.13	6.26	5.94	4.87	
2012-2013 Season						
Hot water (55°C/60 sec.)	6.02	6.31	6.36	5.95	4.89	5.91
Clean Root (5g / liter/5 min.)	6.02	6.17	6.21	5.71	4.56	5.73
Bio-health (5g / liter/5 min.)	6.02	6.06	6.11	5.50	4.55	5.65
Hot water (55°C/60 sec.) + Clean Root	6.02	6.24	6.29	5.83	4.72	5.82
Hot water (55°C/60 sec.) + Bio-health	6.02	6.19	6.24	5.72	4.55	5.74
Washed with tap water	6.02	6.45	6.46	6.56	4.61	6.02
Untreated (control)	6.02	6.46	6.43	6.69	4.71	6.06
Mean	6.02	6.27	6.30	5.99	4.66	
LSD at 5%		Season		A		B
		2011-2012		0.39		0.33
		2012-2013		N.S.		0.48
						A X B



Table 8: Effect of immersing in hot water and bio-fungicide as post-storage treatments on starch content (g / 100 g dry weight) of sweet potato roots stored at 13°C and 85:90% RH plus 15 days at room temperature (shelf life) during 2011/2012 and 2012/2013 seasons

		Cold storage (Month) + Shelf-life (B)					
Treatments (A)		Initial	1	2	3	4	Mean
2011-2012 Season							
Hot water (55°C/60 sec.)		64.77	62.39	60.11	57.90	55.78	60.19
Clean Root (5g / liter/5 min.)		64.77	62.96	61.19	59.48	57.82	61.24
Bio-health (5g / liter/5 min.)		64.77	63.34	61.95	60.58	59.25	61.98
Hot water (55°C/60 sec.) + Clean Root		64.77	62.84	60.97	59.16	57.40	61.03
Hot water (55°C/60 sec.) + Bio-health		64.77	63.43	62.11	60.82	59.56	62.14
Washed with tap water		64.77	61.64	58.67	55.84	53.15	58.82
Untreated (control)		64.77	61.41	58.22	55.20	52.34	58.39
Mean		64.77	62.57	60.46	58.43	56.47	
2012-2013 Season							
Hot water (55°C/60 sec.)		66.18	63.75	61.41	59.16	57.00	61.50
Clean Root (5g / liter/5 min.)		66.18	64.32	62.53	60.78	59.08	62.58
Bio-health (5g / liter/5 min.)		66.18	64.73	63.31	61.92	60.56	63.34
Hot water (55°C/60 sec.) + Clean Root		66.18	64.22	62.32	60.48	58.70	62.38
Hot water (55°C/60 sec.) + Bio-health		66.18	64.81	63.48	62.18	60.90	63.51
Washed with tap water		66.18	62.97	59.92	57.01	54.25	60.06
Untreated (control)		66.18	62.72	59.45	56.35	53.42	59.63
Mean		66.18	63.93	61.77	59.70	57.70	
	Season	A		B		A X B	
LSD at 5%	2011-2012	2.97		2.51		6.64	
	2012-2013	3.66		3.10		8.19	

**Starch Content (g / 100 g Dry Weight):** Data illustrated in Table 8 showed that all treatments did not have any significant effect on starch content during cold storage and shelf life condition except roots washed with tap water or untreated roots (control).

Changes in composition and starch properties had significant effect on the eating and processing qualities of sweet potato during storage. However, no comprehensive research has been carried out on the influence of hot water treatment on the physical properties of sweet potato starch and the quality of sweet potato [33].

Concerning storage periods, starch content was gradually and continuously decreased with the prolongation of storage period (Table 8). These results were true in both seasons. This reduction could be found due to the conversation of starch to sugar which used in respiration. These results agree with those obtained by Erturk and Picha [19] and Emam and Attia [29] on sweet potato.

Concerning the interaction among all studied factors, data revealed that there were significant effects on starch content of sweet potato roots in both seasons. However, after 4 months of storage at 13°C plus 15 days at room temperature (shelf-life), dipping in Bio-health + hot water treatment exhibited the highest content of starch followed

by Bio-health treatment, while untreated roots (control) and roots washed with tap water recorded the least values of starch content in both seasons.

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