Determination of the maturity stage and the most suitable age for harvesting of sweet fennel (*Foeniculum vulgare* var. *dulce,* Mill)

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ABSTRACT

Sweet fennel is a native Mediterranean plant and has widely naturalised and escaped from cultivation worldwide. We aimed to study the changes occurred in the physical, chemical and biochemical characteristics during development and under cold storage to determine the maturity stage and the most suitable age for harvesting. Two experiments were carried out on sweet fennel cultivar "Florence" in the winter seasons of 2016-2017 and 2017-2018 at a private farm located in Behiera Governorate. Bulbs of 70, 90, 110, 130, 150 and 170 days age from seed sowing were examined The obtained results showed that there were gradual increases in the bulb fresh weight, size and diameter till the age of 130 days after which a rapid increase took place up to the last examined age of170 days exhibiting statistically a curvilinear pattern. However, the bulb firmness increased gradually with the age proceeding till 170 days age. Moreover, an increase in the T.S.S, ascorbic acid and antioxidant activity was detected up to the age of 130 days then followed by a decline up to the age of 170 days showing statistically a curvilinear shape. Furthermore, storing the developmental stages at 15ºC and 95% RH showed that the bulbs of 130 days age reflected the minimum loss in weight and the lower unmarketable percentage during storage and the highest contents of T.S.S, ascorbic acid and antioxidant activity. From the obtained results, it was clear that the bulb maturity stage of the variety Florence of sweet fennel was reached after 130 days and this age was fortunately the most suitable age for harvesting.

Keywords: Sweet fennel; Maturity; Antioxidant activity; Essential oils.

INTRODUCTION

Sweet fennel belongs to Family *Apiaceae*, which is an annual aromatic herb. It is a hardy, erect, green, with yellow flowers, feathery leaves and grows to heights up to 2.5 m. This plant is considered a native to the Mediterranean region and has widely naturalised and escaped from cultivation worldwide (Lim, 2013). It is extensively grown for its fruits and leaves mainly in the Mediterranean area, western and central Europe, southern and eastern Asia, New Zealand, Ethiopia, South Africa and the Americas. The fruits, seeds, flowers, leaves, stems, sprouted seedlings, swollen leaf bases (bulb) are all edible. The tender shoots, leaves and stems are used in snacks, salads, soups, stews as spices and herbal teas. The yellow flowers and seeds have a mild anise flavor and are used with desserts, cold soups, cakes, bread, biscuits, stuffings, ordinary dishes, sea food dishes, stews and dainties (Lim, 2013). Sweet fennel seed and bulb are excellent sources of vitamins C, A, thiamine, riboflavin, niacin and B-6 that are the body's primary water soluble antioxidant. Moreover, these structures are very good source of dietary fiber, potassium, manganese, folate, phosphorous, calcium, magnesium, iron, copper and amino acids (Barros *et al*. 2010). From the medicinal point of view, it is used to treat dyspepsia, renal colic, constipation, skin disorders, conjunctivitis and blepharitis of the eye. It is recommended for diabetes, bronchitis and chronic coughs. It is used as Hypotensive (El Bardai *et al*., 2001), hepatoprotective (Ozbek *et al*., 2003), Nootropic (Joshi and Parle 2006), antiplatelet (prevented blood clot) (Tognolini *et al*., 2007), Antiobesity (Amin and Nagy, 2009), anti-inflammatory, estrogenic, antifungal and antimicrobial (Kaur and Arora 2009; Pai *et al*., 2010), anticancer (Choo *et al*., 2011) and Anxiolytic (Divekar *et al*., 2011).

It was obvious that there was an accumulation in the T.S.S. and ascorbic acid contents in the sweet fennel bulbs during development till the age of 150 days then terminated by a decline in the following ages (Ahmed, 1999). This picture was seen also on chicory as ascorbic acid content and antioxidant activity increased gradually till they reached the

maximum level at the age of 195 days after seed sowing then decreased rapidly up to the age of 205 days (Petropoulos *et al*., 2018). The essential oil content of garlic bulbs increased with age proceeding up to the age of 185 days after planting (Abouziena and El-Saeid, 2013). In the field of storage it was reported that the strawberry fruits harvested at the white tip stage showed less weight loss and unmarketable percentage than those harvested at red ripe one after 12 d of storage (Shin *et al*., 2008). On tomato, the fruits of breaker and pink stages decreased in firmness with the elapse of storage periods at 10 °C, however, the picked fruits at breaker stage showed less firmness than those picked at pink stage (Davila-Avina *et al*., 2011). On red cabbage, the T.S.S and ascorbic acid contents of the red cabbage heads decreased continuously during storage and the head age of 75 days reserved the highest contents (Hassan, 2018).

Sweet fennel can be harvested at pretty much any stage of growth while it is still tender and after it have reached an acceptable size. If over left, it becomes tough and stringy. Also, when the bulbs are harvested in the early stages of growth, their chemical content becomes minimal, in addition to reduce the total yield.

Good quality bulbs may be affected by the date of harvesting, therefore, we aimed in the present study to determine the maturity stage and the optimum harvesting date of the famous cultivar "Florence" which is the material of this study.

MATERIALS AND METHODS

Sweet fennel bulbs of the cultivar "Florence" were grown at a private farm located at Kom EL-Farag village near Abu EL-Matameer, Behiera Governorate during the two successive winter seasons of 2016-2017 and 2017-2018. The seeds were planted directly in the soil on October 1st in the two seasons. The land was divided to six plots and each plot included three replicates. Every replicate comprised 2 rows. Each plot was 14.4 m^2 in area, and consisted of 6 rows each of 4 meter long and 60 cm width with 25 cm in-row spacing. After 70 d of sowing, the bulb samples have been harvested and continued at 20 days intervals till 170 days. This represented six ages of 70, 90, 110, 130,150 and 170 days. Bulbs of each age were harvested and transferred directly to the laboratory of the vegetable handling department at the Horticultural Research Institute. Sound and uniform bulbs were chosen to determine the physical characteristics, bulb fresh weight, size, diameter and firmness and the chemical and biochemical ones, T.S.S, ascorbic acid, essential oils contents and antioxidant activity. Each of the six developmental stages of the bulbs was stored under cold storage conditions (15°C and 95% RH). Three samples of each age were taken randomly every 3 days and devoted to the physical analysis, loss in weight and unmarketable percentage and the chemical and biochemical ones, T.S.S, ascorbic acid and antioxidant activity before and during storage.

Determination procedures

The bulb length and diameter were estimated in cm by vernier caliper. The bulb fresh weight was determined in g by a balance. The bulb size was measured in cm^3 by immersing the examined part in a container filled with water where the displaced water was measured by a graduated jar. The bulb firmness was determined by using a pressure tester Digital force-Gouge (Model FGV-0.5A to FGV-100A). The percentage of loss in weight was calculated by the equation where loss in weight **%** = loss in weight at sampling date/ the initial weight of the bulbs × 100. The percentage of unmarketable bulbs was determined from the equation where unmarketable bulbs (%) = the total number of unmarketable bulbs at the sampling date / the initial number of bulbs × 100. Total soluble solids content were determined by abbe refractometer as a percentage reported in A.O.A.C., 1990. The ascorbic acid content was determined as mg\100g fresh weight (A.O.A.C., 1980). The antioxidant activity was determined using DPPH (1, 1-diphenyl-2 picrylhydrazyl) radical scavenging method according to Burda and Oleszek (2001).

Statistical analysis:

All obtained data were statistically analyzed using M-State Software (1973) and the Revised L.S.D. test at 0.05 level was used to compare the differences among the means of the various treatment combinations, as illustrated by EL-Rawy and Khalaf-Allah (1980).

RESULTS AND DISCUSSION

Models of developmental stages

The growth of sweet fennel bulb cv. "Florence" had been followed by measuring a number of physical attributes such as bulb fresh weight, size, diameter and firmness as well as the chemical contents including total soluble solids, ascorbic

acid and essential oils beside to biochemical one antioxidant activity.

Physical characteristics

The bulb physical characteristics in the two seasons of 2016-2017 and 2017-2018 are shown in Fig (1). The obtained results exhibited slow gradual increments in the bulb fresh weight and diameter in the initial periods of growth until the age of 130 days then followed by a rapid gradual increase up to 170 days forming statistically a curvilinear type. The figures of bulb size show slow gradual increments in the initial periods of growth until the age of 130 days after which indicated a rapid jump till 150 days followed by a slow increase trend up to 170 days, exhibiting a statistically curvilinear pattern. The obtained data of the bulb firmness exhibited gradual increments in the bulb firmness with age proceed up to the age of 170 days reflecting a statistically a curvilinear shape.

Chemical and biochemical characteristics

The data of the chemical content changes in the bulb during growth are exhibited in Fig. (2). The bulb total soluble solids (T.S.S.) content slowly and gradually increased till the age of 130 days followed by a gradual slow decline up to the last examined age of 170 days reflecting a statistical curvilinear figure. The changes in the bulb ascorbic acid (A.A) content showed slow and gradual increases from the first examined age of 70 days till the age of 130 days in the first season and 150 days in the second one then turned to decline slowly up to the last age of 170 days which suggest a parabola shape. It was clear from the figures of essential oils that the development of the bulb was accompanied by a rapid gradual decrease with the progress of bulb age till the age of 110 days which was followed by a slow gradual decrease till the last tested age of 170 days building from the point of statistics a curvilinear shape. The bulb antioxidant activity showed a very quick increase till the age of 130 days then turned to slowly decrease up to the last examined age of 170 days suggesting statistically a curvilinear type.

The herein increase in the physical characteristics of the bulb may be attributed to the considerable cell expansion after the early period of cell division (Hulme, 1970; Abo El-Hamd, 1981).

In more details, cell division in the first phase of growth consists entirely from the division of meristematic cells. Certain daughter cells are pushed away from the zone of division and produced to the next phase of growth which is cell enlargement. These cells are supplied with large quantities of water and food that may become several times of their former size. From the physiological point of view, the work done on the fruits of watermelon (Pratt, 1971) and tomato (Abd El-Rahman *et al*., 1975; Abo El-Hamd, 1981), related the periods of increase to the changes happened in the levels of IAA, GA_3 and cytokinins. These growth substances may progressively increase in the early periods of head growth then tended to lessen in the latter stages of development. Furthermore, the T.S.S. and ascorbic acid contents increased till the age of 130 days which was followed by a decrease drop till the last examined age of 170 days. The changes in T.S.S. during the bulb growth are the resultant of some aspects such as the movement of water and soluble solids to and from the bulbs, the inversion of insoluble compounds to simpler soluble forms beside respiration. The changes of these factors may add or withdraw the contents. So, the prevalence of one or more of these factors during bulb development may accumulate or lessen these contents (Abu-Zinada, 1988; Emam, 1993). Regarding the content of ascorbic acid, it is known that the fruit synthesis such vitamin from the precursor of hexose sugars which depends on adequate photosynthetic activity (Hulme, 1970). Thus, the increase in this vitamin during the start of bulb development may be attributed to the high synthesis rate of hexose sugars and the decrease occurred due to its exhaustion during respiration and its transfer to the oxidized form (Liao and Sib, 1987). The early increase in antioxidant activity during growth might be due to the production of glycoalkaloids or the metabolism of polyphenolic compounds in the digestive tract resulting in the formation of active metabolites (Ginzberg *et al*., 2009). Another possibility may also be the synergistic interactions between individual components resulting in elevated expression of antioxidant potency (Leo *et al*., 2008).

Storage of the developmental stages

Determination of the proper picking stage of fruits in general depends on the top quality for market accompanied with the ability to be stored for the longest periods. However, the aforementioned basic data showed clearly the features presented in the various developmental ages of the bulbs pertaining to the variety "Florence" of sweet fennel.

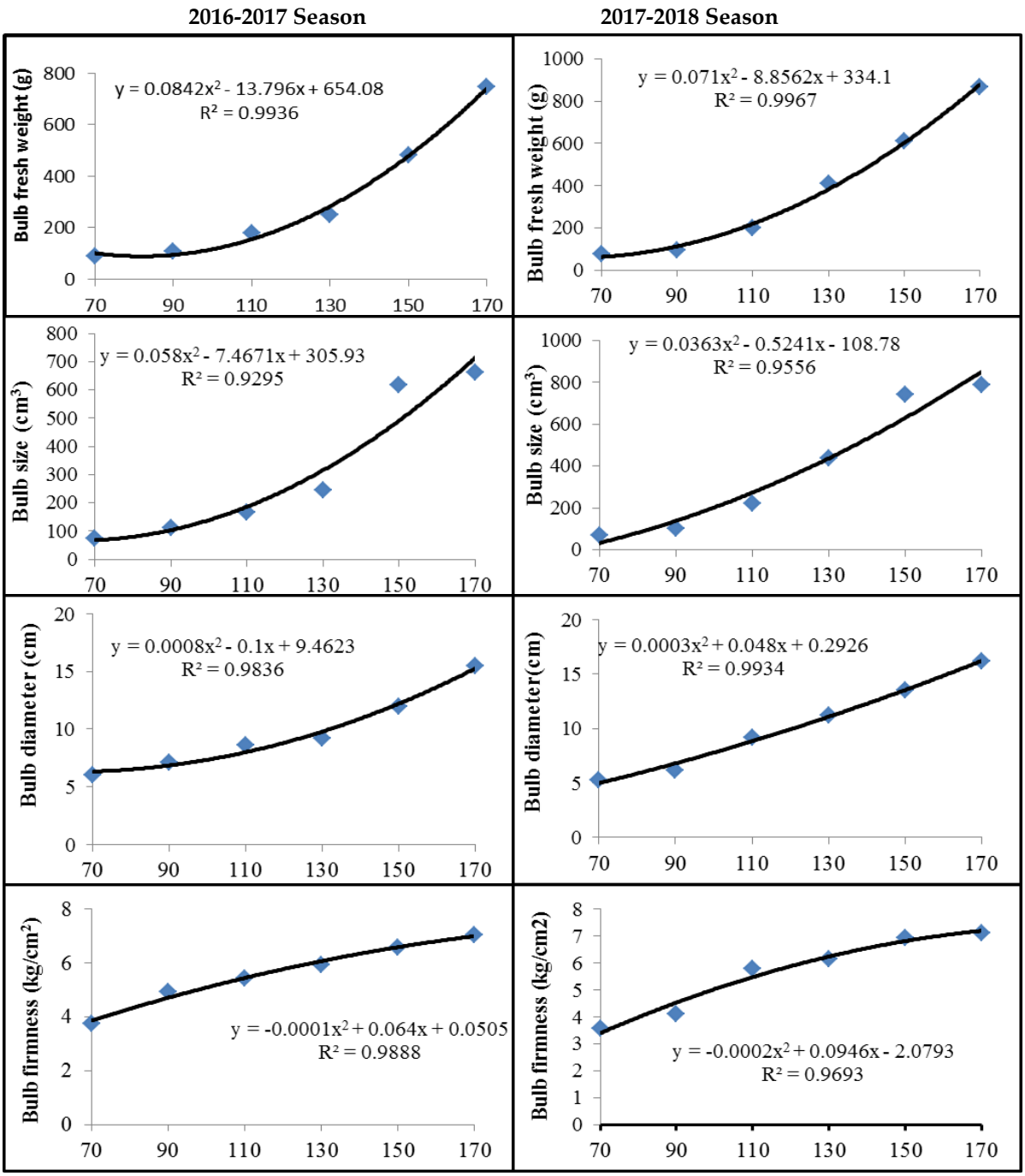

Figure 1. The changes in the different physical characteristics during the bulb various developmental stages in the two seasons of 2016-2017 and 2017-2018.

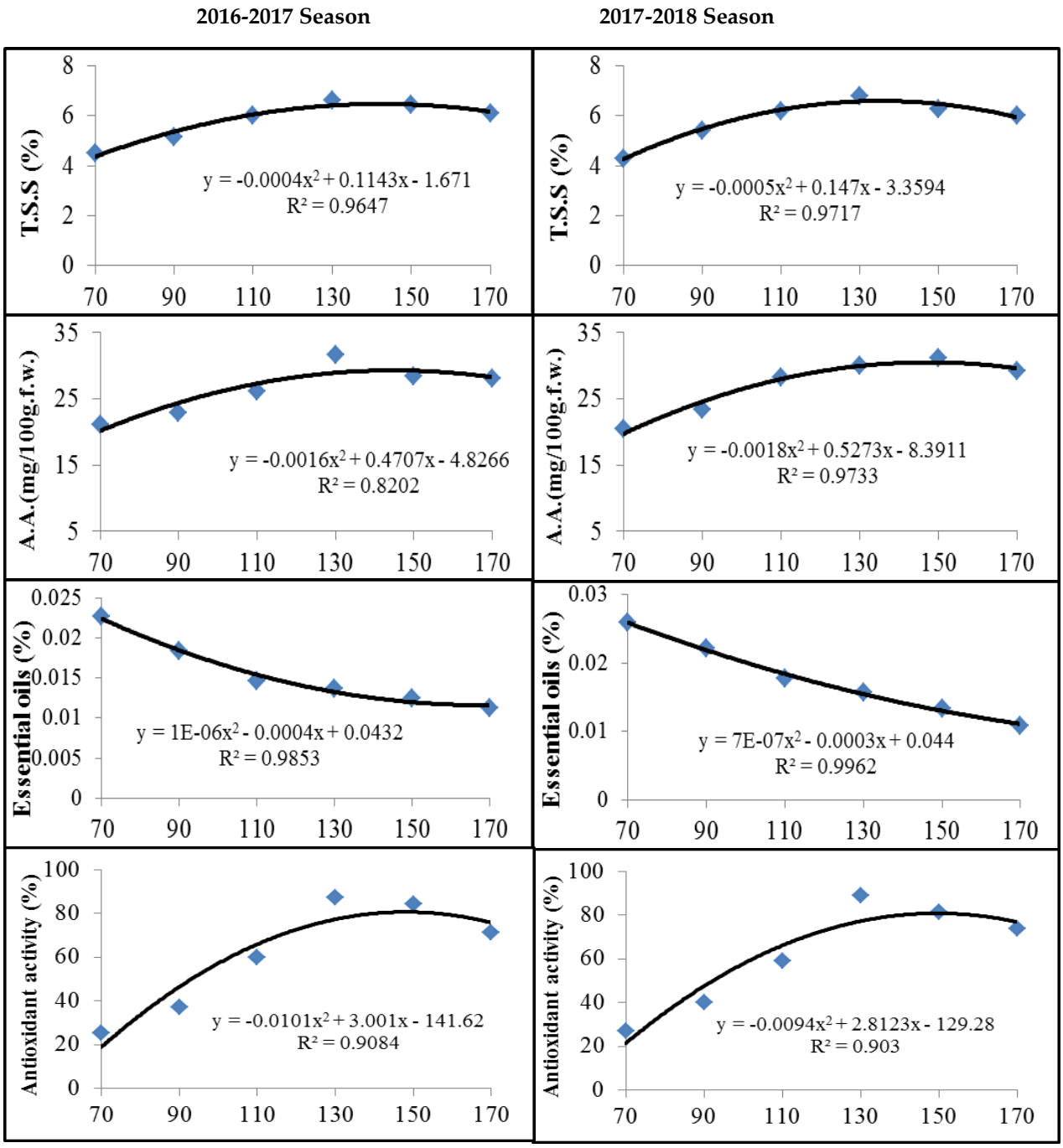

Figure 2. The changes in the different chemical and biochemical characteristics during the bulb various developmental stages in the two seasons of 2016-2017 and 2017-2018.

Physical characteristics

The physical changes in the various stored bulb ages are presented in Table (1). The results of the loss in weight percentage clear that a continuous significant loss in weight happened with the extending of the storage periods in both seasons. However, the bulb ages of 130 and 150 days significantly exhibited the least weight loss meanwhile the age of 70 days and showed the highest significant one in both experimental seasons. Concerning the interaction between the developmental stages and the storage periods, the highest significant weight loss was observed in the

age of 70 days at 9 days of storage while the least one was detected from the ages of 90, 110, 130 and 150 days in the first season and 130 days at 3 days of storage in the second one. The unmarketable percentage gradually increased in all the stored ages till the end of the storage periods. The least significant percentage of unmarketable bulbs were obtained from the age of 130 days in the two seasons during the various storage periods whereas the highest significant one existed from the age of 170 days. Regarding the interaction between the developmental stages and the storage periods, the lowest significant unmarketable bulbs were obtained from the ages of 70, 90, 110, 130 and 150 days at 3 days of storage while the highest significant one was observed from the age of 170 days at 9 days of storage in the two seasons.

Chemical and biochemical characteristics

The obtained data of the changes in the chemical and biochemical contents during storage in the various bulb ages are illustrate in Table (2). The obtained results exhibited that the T.S.S. content in the different bulb ages was decreased significantly with the proceeding of the storage periods in the two seasons. However, the bulb ages of 130 and 150 days had significantly the highest T.S.S. content during the various storage periods, whereas the least significant content occurred in the age of 70 days in the two seasons. With regard to the interaction between the developmental stages and the storage periods, the age of 130 days maintained significantly the highest content of T.S.S at 0 days of storage, whereas the lowest significant content resulted from the age of 70 days at 9 days of storage in both seasons. The obtained figures point to a continuous decrease in ascorbic acid content in all the stored bulb ages with the carry-on of the storage periods during the two seasons. However, the bulb age of 130 days in the first season and both the ages of 130 and 150 days in the second one reserved significantly the highest ascorbic acid content, while the least content resulted from the ages of 70 and 90 days without significant difference between both during storage in the two seasons. The interaction between the developmental stages and the storage periods revealed significantly that the age of 130 kept the highest ascorbic acid content over the other ages during storage meanwhile the age of 70 days reserved significantly the lowest one in the two seasons. The findings of the antioxidant activity showed a decrease trend in all the various ages with the elapse of the storage periods in both seasons. However, the bulb age of 130 days shows significantly the highest antioxidant activity during the various storage periods, whereas the least significant activity resulted from the age of 70 days. The interaction between the developmental stages and the storage periods indicate that the ages of 130 and 150 days in the first season and 130 days in the second one maintained significantly the highest antioxidant activity over all ages during storage while the lowest significant activity resulted from the age of 70 days.

To discuss the effect of the storage periods on the different head ages, it is obvious that the most favorite results came from the bulbs of 130 days age that exhibited the least loss in weight during all these periods. However, this criterion of the general loss in weight with the extend of the storage periods was expected due to the loss of water by transpiration plus the loss in dry matter by respiration (Cabezas *et al*., 2002). The appearance of the unmarketable bulbs of the various developmental stages during storage was also expected. Best results were obtained also from the bulbs of 130 days age as it characterized with the minimum percentage all over the whole storage periods. This feature may be attributed to the continuous chemical and biochemical changes happened in the bulbs during storage which led to moisture condensation and transformation of complex compounds to simple forms of more liability to fungus infection such as the changes from the solid protopectin to soluble pectin form (Raja *et al*., 2011).

Following the chemical and biochemical changes occurred during storage in the various bulb ages, it is evident that a general trend of decrease took place in the contents of T.S.S and ascorbic acid beside the antioxidant activity with the extension of the storage periods. However, the bulb age of 130 days showed the least loss in these contents which may be related to the continuous loss through respiration (Raccuia and Mellilli, 2007**;** Jafri *et al*., 2013). In more detail, the

Table 1. The changes in the loss in weight and unmarketable percentages in the various developmental stages of sweet fennel bulbs stored under cold storage at 15 °C and 95% R.H. in 2016-2017 and 2017-2018 seasons.

Age, days	Storage periods in days							
	2016-2017 season				2017-2018 season			
	3	6	9	Mean	3	6	9	Mean
	Loss in weight (%)							
70	7.32 ^{gh}	19.2 ^{cd}	28.53 ^{a}	18.35 ^{A}	8.25 $^{g-j}$	21.1 ^{bcd}	30.87 ^{a}	20.07 ^{A}
90	5.13 ^{h}	15.66 ^{de}	23.56 ^{b}	14.78 ^{B}	7.46 ^{hij}	16.93 ^{de}	25.28 ^{b}	16.55 ^{B}
110	5.03 ^{h}	11.10 ^{f}	21.20 ^{bc}	12.44 ^{C}	6.45 ^{ij}	12.31 ^{fg}	21.98 ^{bc}	13.58 ^{C}
130	4.58 ^{h}	7.22 ^{gh}	14.76 ^{e}	8.85 ^{D}	4.72 ^{j}	7.56 ^{hij}	15.23 ^{ef}	9.17 ^{E}
150	4.99 ^{h}	8.93 ^{fg}	16.63 ^{de}	10.18 ^{D}	5.31 ^{ij}	9.23 ^{ghi}	17.81 ^{cde}	10.78 ^{E}
170	6.36 ^{gh}	10.11 ^{fg}	19.15 ^{cd}	11.96 ^{C}	5.74 ^{ij}	11.16 ^{fgh}	19.82 ^{cd}	12.24 ^{CD}
Mean	5.61 ^{C}	12.03 ^{B}	20.64 ^{A}		6.32 ^{C}	13.04 ^{B}	21.83 ^{A}	
	Unmarketable bulbs (%)							
70	10 ^{fg}	40 ^{d}	70 ^{b}	40.00 ^{B}	10 ^{hi}	45 ^{de}	70 ^{b}	41.66 ^{B}
90	10 ^{fg}	40 ^{d}	60 ^{bc}	36.66 ^{B}	10 ^{hi}	40 ^{e}	65 ^{b}	38.33 ^{C}
110	5 ^{g}	20 ^{ef}	50 ^{cd}	25.00 ^{C}	10 ^{hi}	20 ^{fg}	55 ^{c}	28.33 ^{D}
130	5 ^{g}	15 ^{ef}	40 ^{d}	20.00 ^{D}	5 ^{i}	15 ^{gh}	40 ^{e}	20.00 ^{E}
150	5 ^{g}	25 ^{e}	50 ^{cd}	26.66 ^{C}	10 ^{hi}	25 ^{f}	50 ^{cd}	28.33 ^{D}
170	20 ^{ef}	45 ^{d}	80 ^{a}	48.33 ^{A}	25 ^{f}	45 ^{de}	80 ^{a}	50.00 ^{A}
Mean	9.16 ^{C}	3.83 ^{B}	58.33 ^{A}		11.66 ^{C}	31.66 ^{B}	60.00 ^{A}	

*The means in a row with a similar superscript are not significantly different ($P > 0.05$).

decrease in ascorbic acid content may be attributed to the important role played as a catalyst in respiration beside the vital part in the biological and biochemical oxidation-reduction reactions during the various processes occurring in the stored fruits (Wang *et al*., 2012). From another view, the gradual decrease in antioxidant activity during storage of bulbs may be due to the breakdown of antioxidant activity such as the polyphenolic compounds during storage by its utilization in respiration, resulting in pronounced decrease in their levels (Tchinda *et al*., 2009).

Determination of the maturity stage and the most suitable age for harvesting

When the previous results of the various stored ages were compared, the bulb of 130 days exhibited the least loss in weight, the minimum percentage of unmarketable bulbs and at the same time dominantly kept the highest concentrations of many compounds (T.S.S., ascorbic acid and antioxidant activity) during storage. The bulb age of 130 days coincided with the maturity stage of the variety "Florence" of sweet fennel. This bulb age was characterized in the two seasons by a range of 288.60 to 307.81 g weight, 246.66 to 440.00 cm^3 size, 9.16 to 11.16 cm diameter, 5.93 to 6.13 kg/cm^2 firmness beside the contents of 6.60 to 6.80% T.S.S, 30.00 to 31.71 mg/100g fresh weight ascorbic acid, 0.0137 to 0.0157% essential oils and 87.15 to 89.05% antioxidant activity. Therefore, the bulb maturity stage of the variety "Florence" of sweet fennel was reached after 130 days and this age was fortunately the most suitable age for harvesting.

CONCLUSION

In seeking to follow the results in this experiment, we can conclude for practical work that sweet fennel ''Florence'' cultivar maturity stage was reached after 130 days from seed sowing. Such age was fortunately the most suitable age for harvesting.

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Table 2. The changes in the chemical and biochemical characteristics in the various developmental stages of sweet fennel bulbs stored under cold storage at (15ºC and 95% R.H) in 2016-2017 and 2017-2018 seasons.

Age, days	Storage periods in days									
	2016-2017 season					2017-2018 season				
	0	3	6	9	Mean	0	3	6	9	Mean
	T.S.S (%)									
70	4.50 d-h	4.03 e-i	3.23 hij	2.10 j	3.46 D	4.30 e-j	4.00 g-k	3.30 jkl	2.23 l	3.46 D
90	5.13 b-f	4.80 c-g	3.83 f-i	2.73 ij	4.12 C	5.40 b-e	4.90 c-h	4.00 g-k	3.03 jkl	4.33 C
110	6.03 abc	5.30 a-e	4.43 d-h	3.33 hij	4.77 B	6.20 abc	5.40 b-e	4.50 d-j	3.53 ijk	4.90 B
130	6.60 a	5.93 abc	4.90 c-g	3.86 f-i	5.32 A	6.80 a	6.00 abc	5.13 b-g	4.16 f-k	5.52 A
150	6.46 ab	5.73 a-d	4.76 c-g	3.63 ghi	5.15 AB	6.26 ab	5.63 a-d	4.56 d-i	3.90 h-k	5.09 AB
170	6.10 abc	5.30 a-e	4.40 dh	3.30 hij	4.77 B	6.00 abc	5.33 b-f	4.50 d-j	3.53 ijk	4.84 B
Mean	5.80 A	5.18 B	4.26 C	3.16 D		5.82 A	5.21 B	4.33 C	3.40 D	
	Ascorbic acid (mg/100g.F.W)									
70	21.16 e-h	20.20 fgh	18.96 fgh	16.86 h	19.29 D	20.36 g-l	19.50 h-l	17.26 jkl	15.73 l	18.21 C
90	22.83 def	21.77 efg	20.13 fgh	18.15 fgh	20.72 D	23.43 e-i	21.21 g-k	18.42 i-l	16.83 jkl	19.27 C
110	26.13 bcd	24.98 cde	23.33 def	21.16 e-h	24.07 C	28.25 a-e	25.19 b-g	23.46 e-i	21.17 g-k	24.51 B
130	31.70a	30.66 ab	28.96 abc	26.76 bcd	29.52 A	31.12 a	29.48 abc	26.75 a-f	24.31 d-h	27.91 A
150	28.31 abc	26.93 bcd	25.26 cde	23.06 def	25.89 B	30.00 ab	28.83 a-d	26.71 a-f	24.75 c-g	27.57 A
170	28.06 abc	26.87 bcd	25.23 cde	23.03 def	25.79 BC	29.14 a-d	26.94 a-f	24.08 d-h	22.21 f-j	25.59 B
Mean	26.48A	25.23A	23.64 B	21.50C		27.05 A	25.19 B	22.78 C	20.83 D	
	Antioxidant activity (%)									
70	25.16 klm	23.64 lm	21.37 lm	18.21 m	22.09 F	26.89 l	25.49 l	22.94 l	19.23 l	23.63 F
90	37.21 i	34.91 ij	32.34 ijk	28.13 jkl	33.14 E	40.23 k	38.73 k	36.41 k	24.14 l	34.87 E
110	59.85 fg	57.80 gh	54.71 gh	51.34 h	55.92 D	58.86 hi	56.82 hij	53.73 ij	50.42 j	54.95 D
130	87.15 a	85.73 a	83.76 ab	81.03 ab	84.41 A	89.05 a	87.70 a	85.36 ab	83.11 abc	86.30 A
150	84.11 a	82.28 ab	79.83 ab	76.02 bc	80.56 B	81.42 abc	79.63 bcd	76.95 cde	73.22 def	77.80 B
170	71.32 cd	69.29 cde	65.88 def	62.11 efg	67.15 C	73.60 def	71.55 ef	68.24 fg	62.31 gh	68.92 C
Mean	60.80 A	58.94 A	56.31 B	52.80 C		61.67 A	59.98 A	57.27 B	52.07 C	

*The means in a row with a similar superscript are not significantly different ($P > 0.05$).

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تحديد درجة أكتمال النمو والعمر المناسب لحصاد الفينوكيا

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الملخص العربي

الشمر الحلو هو نبات من منطقة البحر المتوسط وقد انتشر على نطاق واسع الى جميع انحاء العالم. هدفنا دراسة التغيرات التي حدثت في الخصائص الفيزيائية والكيميائية والبيوكيميائية اثناء النمو وتحت التخزين البارد لتحديد مرحلة النضج والعمر الانسب للحصاد. اجريت تجربتان على صنف الشمر الحلو "فلورنسا" في فصول الشتاء ٢٠١٦-٢٠١٧ و٢٠١٧-٢٠١٨ في مزرعة خاصة تقع في محافظة البحيرة. تم فحص الابصال عند عمر ٧٠ و٩٠ و١١٠ و١٣٠ و١٥٠ و١٧٠ يوما من بذر البذور. اظهرت النتائج التي تم الحصول عليها ان هناك زيادة تدريجية في الوزن والحجم والقطر الطازج للابصال حتى عمر ١٣٠ يوما، وبعد ذلك حدثت زيادة سريعة حتى اخر عمر تم فحصه وهو ١٧٠ يوما، مما يدل على وجود شكل منحني احصائي. ومع ذلك، ازداد صلابة البصلة تدريجيا مع تقدم العمر حتى عمر ١٧٠ يوما. علاوة على ذلك، تم الكشف عن زيادة في نشاط TSS، وحمض الاسكوربيك ومضادات الاكسدة حتى عمر ١٣٠ يوما ثم تلاه انخفاض حتى عمر ١٧٠ يوما يظهر احصائيا على شكل منحني. علاوة على ذلك، اظهر تخزين مراحل النمو عند ١٥ درجة مئوية و٩٥٪ رطوبة نسبية ان الابصال من عمر ١٣٠ يوما عكست الحد الادنى من فقدان الوزن والنسبة المئوية الاقل غير القابلة للتسويق اثناء التخزين واعلي محتوى من TSS وحمض الاسكوربيك ومضادات الاكسدة. من النتائج التي تم الحصول عليها، كان من الواضح انه تم الوصول الى مرحلة نضج البصيلة من مجموعة متنوعة من الشمر الحلو فلورنسا بعد ١٣٠ يوما وكان هذا العمر لحسن الحظ ه وانسب وقت للحصاد.

الكلمات المفتاحية: الشمر الحلو، النضج، النشاط المضاد للاكسدة، الزيوت الضرورية.

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