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Changes in Some Physical and Chemical Fruit Properties During Fruit Development Stage of Some Olive Oil Cultivars

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Abstract: This work was carried out through 2004 and 2006 seasons on three olive oil cultivars, namely (Arbequina, Bouteillan and Koroneiki). Trees were 12 years old, grown in sandy soil, planted at 5x5 meters apart under drip irrigation system. The investigation aimed to study the changes in some physical and chemical fruit properties in relation to fruit development stage. Results proved that fruit of the three cultivars exhibited a cycle growth pattern: Growth was rapid during the first fruit growth stage (8-10 weeks), slow during the second stage (6-8 weeks). The third stage is again one of rapid growth and coincides with the change in fruit skin color. The increment in fruit size prior to fruit coloration comes mainly from increased moisture content of the fruit. Oil begins to accumulate in the fruit and increases gradually through July, August and reaches the maximum as fruit become completely black.

Kew words: Olive (*Olea europaea*) · Arbequina · Bouteillan · Koroneiki · Growth curve

INTRODUCTION

The olive tree (*Olea europea* L.) is one of the most important plants which have a great economic value in new reclaimed land in Egypt. The fruit of *Olea* species is a drupe, the term "stone fruit" expresses the fact that the seed is surrounded by a hard shell or stone, the endocarp. This stone develops from the inner part of the ovary wall and the soft flesh from the outer part. When the fruit is very young the stone is soft but after a few weeks it begins to harden. The seed of the mature fruit is the embryo and the large halves. Hartmann and Opitiz [1] reported that olive fruit exhibits a cyclic growth pattern. Growth is rapid during the first stage, slower during the second stage, in (July and August). The third stage, just before fruit starting to color, is again one of rapid growth and coincides with the color changes from green to straw to red to black. After few weeks from fruit set, oil begins to accumulate in the fruit.

The amount of oil increases gradually through summer and fall and reaches its maximum as fruits become completely black. Oil production, quantity and quality is greatly affected by many factors i.e., cultivar, oil accumulation and harvesting stage etc. The fruit weight and fruit volume showed continuous increase from the beginning of fruit development till fruit reached it's full weight when it was 26 weeks old (180 days from fruit set) in Hamed variety and about 28 weeks old (195 days from fruit set) in Chemlali variety. However, moisture content in development olive fruits remained constant during the first two weeks. This was followed by intermittent variations until fruit starting to color (reddish-green). At this stage, the moisture content remained constant until the blacking of the fruit [2]. The oil began to appear in Chemlali olive fruits after 60 days from fruit setting and reached its maximum (22%) after 185 days [3]. The fruit weight and fruit volume of eight seedling olive cultivars increased through the season with a reduced rate of growth in the middle period development [4]. The average flesh weight of olive fruit increased from the age of 60 days till the end of the sampling with a slow rate of increase during the middle stages of growth [5].

MATERIALS AND METHODS

The present study was conducted on twelve olive trees of the three cultivars (Arbequina, Bouteillan and Koroneiki). The trees were 12 years old, grown in a sandy soil at planting distance of 5x5 meters apart under drip irrigation system in El-Kassassen Experimental Station, belonging to the Horticulture Research Institute, Ministry of Agriculture, Egypt. The trees were almost similar in

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vigor, free from any visible pathogenic symptoms and at the same bearing phase. Experimental trees were subjected to the ordinary horticultural practices and the work was conducted during 2004 and 2006 seasons, because of reasons beyond control (unfavorable weather conditions prevailing in the 2005 season) results of this season were eliminated. For somewhat, similar trees of each olive cultivar were selected. Study the changes in some physical and chemical fruit properties during fruit development stages of the three olive cultivars has a great importance for olive growers to modify some horticultural practices during fruit development such as fertilization, irrigation etc. Fruit sample (100 fruit per tree) was randomly collected at two weeks intervals (from May 11, 2004 and May 24, 2006) until the early September of each season, thereafter fruit samples were weekly collected till the harvest date (October 30, 2004 and November 7, 2006). For each studied olive cultivar only healthy fruits, without any kind of infection or physical damage were subjected to the following physical and chemical fruit characteristics determination as follows:

Fruit Weight: It was determined by weighing the samples (100 fruits) by ordinary balance with 0.01 gm sensitivity and average weight per fruit was calculated.

- Moisture content and dry matter content were determined by drying the flesh in an oven at 60-80°C until a constant weight [6].

Oil Percentage: Fruit oil content was determined by means of the Soxhelt fat extraction apparatus using Hexan of 60-80°C boiling point as described by A.O.A.C. [6].

Statistical Analyses: The data were subjected to analysis of variance and Duncan's multiple rang test was used to differentiate means at 5% [7].

RESULTS AND DISCUSSION

Fruit Weight: A considerable rapid increase in fresh fruit weight was noticed during the first stage of fruit development (from May 11 until June 26) (Tables 1- 6). This increase in fresh fruit weight was mainly due to cell division and cell enlargement prevailing in this early stage. Therefore, vigor of tree, adequate nutrients, availability of soil moisture, crop density and fruit leaf ratio has been shown to influence fruit weight. At the end of this stage fruit weight attained (0.71 and 0.78 gm) in the two seasons, respectively. The period between July 27 until September 5 was characterized by slow increase in fruit weight. After this rapid stage, slower increase was noticed (from Sep. 13 to Oct. 30), it could be a result of the decrease in auxin level in the fruit or the competition on the auxin between embryo and fruit flesh tissue. As a result of this competition the enlargement of the flesh is slow. After this time a sharp expand in the fleshy part was occurred (from 1.19 to 2.10 gm) and (from 1.2 to 2.07 gm) from Sep. 9 to Sep 20 and from Sep. 18 to Oct. 3, in the two season, respectively. This marked increase in fruit fresh weight could be a result of the increase in moisture content in the fruit. Consequently, the exogenous factors such as non available moisture, high temperature or sever evaporation conditions may decrease the growth rate of the fruits. Concerning the Arbequina cultivar somewhat similar fruit growth pattern. Fruit weight at the end of early stage (stage one) was (0.71 and 0.78 gm) at July 13 and 22 in the two seasons, respectively. At the beginning of third stage, fresh fruit weight increased from 1.19 to2.23 gm and from 1.20 to 2.18 gm in the two seasons, respectively. This rapid increase in fruit weight was coincided with the change in fruit color. The increment in flesh weight seems to be connected with the fruit moisture content, the higher the fresh fruit weight the higher the fruit content. As for the Arbequina cultivar results obtained were similar to those of the Bouteillan and Koroneiki cultivars. Fruit size increase in the third stage comes mainly from increased moisture content of the fruit, if the tree lacks soil moisture during his period, or if strong desiccating winds occur, the expected increase in fruit size can not take place. The Arbequina cultivar fruit exhibited similar cyclic growth curve as did the other two cultivars. These findings are in line with those reported by Hartmann and Opitiz [1].

Moisture Content: Data concerning the changes in fruit moisture content and its rate of change are presented in Tables 1 - 6. For the Arbequina in the first season, it could be seen that fruit moisture content markedly increased in the early stage of fruit development from May 11 to July 13, 2004, moisture content value raised from 0.19 to 0.39 gm (about 105% increase). Fruit moisture content turned to very slow rate for about 25 days from July 27 to August 24, 2004 (only about 5% increase), after which the rate of moisture sharply increased for about 15 days from 0.70 gm/fruit at Sep. 5 to 1.33 gm/fruit at Sep. 20, 2004 (about 40% increase). Fruit moisture content tended to fluctuate towards the end of the season. Data of the second season show that fruit moisture content increased markedly during the early fruit development stage, followed by a very slow increase from July 13 till Sept. 5,

Table 1: Fruit weight, moisture, oil and dry matter contents of Arbequina olive during 2004 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
5-11	0.25k	0.00	0.17g	0.00	0.08g	0.00	0.00f	0.00
26-5	0.39j	56.00	0.24f	26.10	0.13f	116.66	0.02f	0.00
6-Oct	0.50i	28.20	0.29f	20.83	0.18e	38.46	0.03ef	50.00
26-6	0.62h	24.00	0.35e	20.68	0.22e	22.22	0.05e	66.66
13-7	0.71g	14.52	0.39e	11.42	0.25d	13.63	0.07ed	40.00
27-7	0.75g	5.63	0.41e	5.12	0.26d	4.00	0.08d	14.28
8-11	0.80f	6.67	0.42e	2.43	0.29d	11.53	0.09d	12.50
24-8	0.82f	2.50	0.43e	2.38	0.29d	0.00	0.10d	11.11
9-5	1.19e	45.12	0.70d	62.79	0.35c	20.68	0.14c	40.00
13-9	1.74d	46.22	1.10c	57.14	0.42b	20.00	0.22b	57.14
20-9	2.10c	20.69	1.33b	20.19	0.50a	19.04	0.27b	22.72
25-9	2.23b	6.20	1.37a	3.01	0.52a	4.00	0.34a	25.92
10-3	2.29a	2.70	1.38a	0.73	0.55a	5.76	0.36a	5.88
13-10	2.30a	0.44	1.36a	-1.45	0.56a	1.81	0.38a	5.88
30-10	2.25ab	-2.17	1.31b	-3.67	0.56a	0.00	0.38a	0.00

Means having the same letters within a column are not significantly different at 5% level

Table 2: Fruit weight, moisture, oil and dry matter contents of Arbequina olive during 2006 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
24-5	0.14m	0.00	0.09g	0.00	0.05e	0.00	0.00ef	0.00
6-8	0.37l	270.00	0.28f	366.17	0.09e	125.00	0.00ef	0.00
20-6	0.53k	43.24	0.32f	14.28	0.18d	100.00	0.03e	0.00
7-5	0.72j	33.96	0.42e	31.25	0.25c	38.89	0.05e	33.33
22-7	0.78i	9.85	0.46de	9.52	0.27c	8.00	0.05e	25.00
8-10	0.86h	10.25	0.50d	8.69	0.30c	11.11	0.06de	20.00
25-8	0.93g	8.14	0.52d	4.00	0.31c	3.33	0.10d	66.67
9-10	1.03f	10.75	0.54d	3.84	0.37c	19.35	0.12d	20.00
18-9	1.20e	16.50	0.66c	22.22	0.41b	10.81	0.13d	8.33
26-9	1.68d	40.00	1.04b	57.57	0.44b	7.32	0.20c	53.84
10-3	2.07c	23.21	1.30a	25.00	0.50a	13.63	0.27b	35.00
10-11	2.18b	5.31	1.35a	3.84	0.52a	4.00	0.31ab	14.81
20-10	2.25a	3.21	1.36a	0.74	0.54a	3.84	0.35a	12.90
11-1	2.27a	0.89	1.37a	0.73	0.55a	1.85	0.35a	0.00
11-7	2.27a	0.00	1.35a	-1.45	0.56a	1.81	0.36a	2.86

Means having the same letters within a column are not significantly different at 5% level

Table 3: Fruit weight, moisture, oil and dry matter contents of Bouteillan olive during 2004 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
5-11	0.20j	0.00	0.11f	0.00	0.09d	0.00	0.00ef	0.00
26-5	0.41i	105.00	0.24e	118.18	0.17d	88.89	0.00ef	0.00
6-10	0.53h	29.27	0.34d	41.67	0.19cd	11.76	0.00ef	0.00
26-6	0.61g	15.10	0.36cd	5.88	0.24c	26.31	0.01e	0.00
13-7	0.68f	11.47	0.39c	8.33	0.26bc	8.33	0.03e	200.00
27-7	0.73f	7.35	0.40c	2.56	0.28b	7.69	0.05de	66.67
8-11	0.76ef	4.11	0.41c	2.50	0.29b	3.57	0.06d	20.00
24-8	0.79e	3.95	0.42c	2.43	0.30b	3.45	0.07cd	16.67
9-5	0.93d	17.72	0.52b	23.81	0.31ab	3.33	0.10c	42.86
13-9	1.09c	17.20	0.63a	21.15	0.32a	3.23	0.14b	40.00
20-9	1.16b	6.42	0.65a	3.17	0.33a	3.12	0.18ab	28.57
25-9	1.19ab	2.59	0.67a	3.08	0.33a	0.00	0.19a	5.56
10-3	1.21a	1.68	0.67a	0.00	0.34a	3.03	0.20a	5.25
13-10	1.23a	1.65	0.66a	-1.49	0.36a	5.88	0.21a	5.00
30-10	1.24a	0.81	0.66a	0.00	0.37a	2.78	0.21a	0.00

Means having the same letters within a column are not significantly different at 5% level

Table 4: Fruit weight, moisture, oil and dry matter contents of Bouteillan olive during 2006 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
24-5	0.13k	0.00	0.07h	0.00	0.06e	0.00	0.00e	0.00
6-8	0.27j	107.69	0.15g	114.28	0.12d	100.00	0.00e	0.00
20-6	0.47i	74.07	0.30f	100.00	0.17cd	41.67	0.00e	0.00
7-5	0.57h	21.27	0.35ef	16.67	0.21c	23.53	0.01de	0.00
22-7	0.65g	14.03	0.41e	17.14	0.22bc	4.76	0.02d	100.00
8-10	0.68fg	4.61	0.42d	2.44	0.23bc	4.54	0.03d	50.00
25-8	0.71f	4.41	0.43d	2.38	0.24b	4.35	0.04d	33.33
9-10	0.73ef	2.82	0.43d	0.00	0.25b	4.17	0.05cd	25.00
18-9	0.78e	6.85	0.46cd	6.98	0.26ab	4.00	0.06c	20.00
26-9	0.88d	12.82	0.51c	10.87	0.27a	3.85	0.10bc	66.67
10-3	1.01c	14.77	0.59b	15.68	0.28a	3.70	0.14b	40.00
10-11	1.11b	9.90	0.68a	15.25	0.28a	0.00	0.15ab	7.14
20-10	0.16ab	4.50	0.68a	0.00	0.29a	3.57	0.19a	26.67
11-1	1.19a	2.59	0.69a	1.47	0.30a	3.45	0.20a	5.26
11-7	1.20a	0.84	0.70a	1.45	0.30a	0.00	0.20a	0.00

Means having the same letters within a column are not significantly different at 5% level

Table 5: Fruit weight, moisture, oil and dry matter contents of Koroneiki olive during 2004 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
5-11	0.27j	0.00	0.20d	0.00	0.07d	0.00	0.00d	0.00
26-5	0.45i	50.00	0.33cd	37.50	0.12d	100.00	0.00d	0.00
6-10	0.52h	15.56	0.37c	12.12	0.15d	25.00	0.00d	0.00
26-6	0.63g	21.15	0.41c	10.81	0.20c	33.33	0.02cd	0.00
13-7	0.73f	15.87	0.47b	14.63	0.22c	10.00	0.04c	100
27-7	0.80e	9.59	0.50b	6.38	0.24bc	9.09	0.06c	50.00
8-11	0.82de	2.50	0.50b	0.00	0.25b	4.17	0.07bc	16.67
24-8	0.84d	2.44	0.51b	2.00	0.25b	0.00	0.08bc	14.28
9-5	0.87d	3.57	0.52b	1.96	0.26b	4.00	0.09b	12.50
13-9	1.04c	19.54	0.67a	28.8	0.27b	3.85	0.10b	11.11
20-9	1.13b	8.65	0.69a	2.98	0.30ab	11.11	0.14ab	40.00
25-9	1.17ab	3.54	0.71a	2.89	0.31a	3.33	0.15a	7.14
10-3	1.18a	0.85	0.70a	-1.40	0.32a	3.22	0.16a	6.67
13-10	1.19a	0.84	0.69a	-1.42	0.33a	3.12	0.17a	6.25
30-10	1.21a	1.67	0.69a	0.00	0.34a	3.03	0.18a	5.88

Means having the same letters within a column are not significantly different at 5% level

Table 6: Fruit weight, moisture, oil and dry matter contents of Koroneiki olive during 2006 season

Day	Fruit weight (gm)	Increase (%)	Moisture content (gm)	Increase (%)	Dry matter content (gm)	Increase (%)	Oil content (gm)	Increase (%)
24-5	0.14k	0.00	0.08g	0.00	0.06d	0.00	0.00de	0.00
6-8	0.29j	123.08	0.19f	137.5	0.10c	100.00	0.00de	0.00
20-6	0.46i	58.62	0.33ef	73.68	0.13c	30.00	0.00de	0.00
7-5	0.54h	17.39	0.36e	9.09	0.17bc	30.77	0.01d	0.00
22-7	0.59g	9.26	0.39de	8.33	0.19b	11.76	0.01d	0.00
8-10	0.62fg	5.08	0.40d	2.56	0.20b	5.26	0.02d	100.00
25-8	0.65f	4.84	0.41d	2.50	0.21b	5.00	0.03d	50.00
9-10	0.66ef	1.54	0.41d	0.00	0.21b	0.00	0.04cd	33.33
18-9	0.70e	6.06	0.42d	2.44	0.22b	4.76	0.06c	50.00
26-9	0.84d	20.00	0.50c	19.05	0.25ab	13.63	0.09bc	50.00
10-3	0.95c	13.09	0.58b	16.00	0.26a	4.00	0.11b	22.00
10-11	1.00bc	9.26	0.62ab	6.89	0.26a	0.00	0.12ab	9.09
20-10	1.04b	4.00	0.63a	7.61	0.27a	3.85	0.14a	16.67
11-1	1.10a	5.77	0.67a	6.35	0.28a	3.70	0.15a	7.14
11-7	1.11a	0.91	0.66a	-1.49	0.29a	3.57	0.16a	6.67

Means having the same letters within a column are not significantly different at 5% level

then a sharp increase was occurred between July 5 till September 20 (about 47% increase). Fruit moisture content showed a steady increase value towards the ripening stage. Data of the other two cultivars showed somewhat similar growth pattern in which the early one showed a sizeable increase in fruit moisture content, followed by a period of decreasing develop rate, while the last phase was characterized by a rapid rate of moisture increase. Generally, it can be mentioned that the timing of each phase and its duration differed according to the cultivar and season. It is interesting to note that the change in fruit moisture content is greatly connected with the fruit growth development in fresh weight. These findings are in harmony with those obtained by Hassan [5], Fouad *et al*., [8,] and Kaynas *et al*., [9] who mentioned that moisture content showed wide variation according to cultivars and seasons. Similar results were obtained by Ezzat and El-Azzouni [2].

Dry Matter Content: Data concerning the changes in dry matter other than oil during fruit development are presented in Tables 1 - 6. According to the obtained data in the first season, it could be seen that, the early phase was characterized by a rapid rate of increase. The rate of increment in fruit dry matter content was 100.0, 50.0, 22.2 and 13.6% for the four sampling data, respectively. Thereafter the increment in dry matter turned to the slow rate till the fruit attained the harvesting stage. The rate of increase was 5.8, 1.8 and 0% in the latest three sampling dates respectively. Data of the second season, whereas the rate of increase reached its highest value during the early fruit development stage after which the rate of increase was characterized by a slow rate of increase. Regarding the Bouteillan and Koroneiki cultivars, the same pattern was found whereas timing of each phase and its duration differed according to cultivar and season. The highest rate of increase in the dry matter other than the oil probably due to carbohydrate accumulation during the early development stage. Therefore, a sizable amount of metabolic compounds goes into fatty acids and oil.

Oil Content: According to Tables 1 - 6 for the Arbequina in the first season, it could be seen that the period from May 5 till August 24, the fruit oil content was rather low. It never exceeded 0.10 gm/fruit. Oil begins to accumulate in the fruit in late August and early September and a sizable increase in fruit oil content was observed in the second half of September. Fruit oil content increased from 0.14 to 0.34 gm/fruit from September 5th till September 25th. This marked increase in fruit oil content occurred during fruit coloration and reached its maximum at the end of October, as fruits become completely colored. Data of the second season and the two other olive cultivars showed similar pattern where the rate of oil accumulation was rather slight that no significant increment in fruit oil content was observed till about the second half of September. The coloration phase which occurred at the second half of September till the end of October yielded the significant increase in fruit oil content. Rate of oil accumulation differed according to tested cultivar and season of study. Results obtained in this work are in conformity with those obtained by Hartmann and Opitiz [1] who reported that the amount of oil increases gradually through fall and winter and reaches its maximum in late December and January, as fruits becomes completely black. Similar observations were recorded by Tous *et al*., [10] who found that Arbequina cultivar fruits between (165 and 195 days after fruit set) seems to be an optimum harvesting period, where oil content is high enough. Also, the obtained results are in line with the findings of Ezzat and El-Azzouni [2] and Hegazi [4]. So, it is important for olive growers to supply adequate water for several weeks just before harvest (about 22 to 26 weeks) after fruit set to obtain high fruit and oil quality.

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