

Assessment of Some Maturity Indicators and Fruit Growth in Three Apple Cultivars

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Abstract

The continual increase of local apple production urges the optimization of all factors that impact fruit quality and quantity, in particular to those destined for long-term cold storage. Among them, the harvest dates of each apple cultivar intended for long-term storage are of great importance to the final freshness and quality of the fruits. In developed countries, those dates are being determined through the frequent assessment of some fruit maturity indicators, of which the most popular include: fruit firmness, total soluble solids and starch conversion. On the other hand, picking up apples when they have reached their maximum fruit weight increases the growers' income. It has been shown that such issues are not sufficiently known by the respective stakeholders in our country. This study was focused on assessing the progress of the abovementioned maturity indicators and fruit weight in 2012 and 2013 of three main Korça region apple cultivars, Golden Delicious, Red Chief and Granny Smith. The measurements were made in five day intervals. The optimum harvest dates for Golden Delicious was 23 September 2012 and 18 September 2013, for Red Chief 20 September 2012 and 14 September 2013, while for Granny Smith 6 October 2012 and 1 October 2013. Fruit growth continued very slightly after those days, to reach their maximum weight. The results of this study were similar to the outcomes of same studies made in other countries.

KEYWORDS: apple, maturity, long-term storage, weight.

INTRODUCTION

The apple fruit production is increasing rapidly in Albania, particularly those 5- 6 recent years. That's due to growing demand for fresh fruit and vegetables of local consumers, as well as the farmers' interest to expand their cultivated areas with apple trees, as such a fruit has generated higher revenues than other crops, especially cereals. On the other hand, the support of Albanian government with grants for new apple orchards and cold storages for them has positively impacted the sector. In the past twenty years, Albania has imported huge amounts of apples, while nowadays the internal market demand is met, and modest quantities are being exported. In the mid - long term, enter in mass production of the new intensive apple orchards will further increase the apple amounts. Under such circumstances, to keep the sector profitable, round year apple availability would be required, which consequently requires their long term cold storage.

Several authors in their works have found that in addition to ensuring the right cold storage parameters (temperature, relative humidity, air elements ratio, etc.), an important role in apple quality after refrigeration plays the harvest date of each cultivar. That is related to fruit maturity stage in the moment they are put in cold storage (Vielma *et al.*, 2008; Kvikliene, 2001; Franelli & Casera, 1996; Streif, 1996).

To get the best quality, each apple cultivar should be harvested just before entering the climacteric period, which means a bit before starting the massive production of ethylene and respiration activity (Little & Holmes, 2000) and the harvest to be completed shortly, within several days (Blanpied & Silsby, 1992). That's the best time for refrigeration. According to the literature, each apple cultivar has its own optimal harvest time, which may change from year to year. If fruits are harvest much in advance related to that optimal time, their growth is not completed, thus they are of a smaller weight, have less flavor and untypical cultivar color. In addition, during refrigeration such fruits are more susceptible to superficial scald, bitter pit, internal disorders, etc (Blanpied & Silsby, 1992) and lose more weight, as their cuticle is not fully formed. On the other hand, if such an optimal harvest time is exceeded, apple fruits cannot stand longer in refrigeration, as they are quickly soften, produce non-characteristic aromas and are more prone to diseases and rotting.

Apple cultivars have a great variability between each other regarding their maturity time. Even more, the maturity date of same cultivar may change each year, sometimes more than 2-3 weeks (Beaudry, 2012). That's depended on the bloom dates and temperatures, especially in the first phase of fruit growth. On the other hand, the fruit growth follows an exponential- linear model (Goudriaan & Monteith, 1990). According to that model, apple fruits increase initially their volume and weight exponentially due to continues cell division, while later on until harvest the growth is linear based on increase of existing cell size only. During the fruit maturation time, the growth rate decreases and it stops when fruits are totally mature (Beaudry *et al.* 1993).

In the developed countries, determination of apple maturity destined for cold storage is an annual process based on maturity indices. In many EU countries, the Streif Index widely is used for that purpose, which comes as a ratio of fruit firmness with production of total soluble solids and starch index (Streif, 1983, 1996).

There have not been such applicative studies in Albania regarding physiological processes of pre and post-harvest of apples and interaction of agro-technical and environmental factors on apple quality, shelf-life and weight. The harvest period has been mainly based on empiric methods and organoleptic estimation of apple fruits by producers and cold storage companies. Until recent years, due to limited apple production and storage of relatively small amounts, that have not played any significant impact on growers/storage company's incomes. However, from now on and in the future, when the apple production and their cold storage are expected to grow several fold, the optimization of all abovementioned factors are getting more importance.

In that context, the study was undertaken to determine the optimal harvest time of Korça area main apple cultivars according to contemporary methods, by following in same time their fruit weight progress.

MATERIALS AND METHODS

To monitor the maturity indices and fruit weight, three main apple cultivars of Korça are were selected: Golden Delicious, Red Chief dhe Granny Smith, grafted on MM 106 rootstock at a density of 1250 trees/ha, in an orchard in Drenova Commune, Korça District, Albania, with coordinates: latitude 40° 35' 33" N, longitude 20° 45' 53" E, and altitude 860 m above sea level. Trees were trained to a slender spindle form, hand thinned within 40 – 50 DAFB to have a certain density of fruits/cm² of trunk cross-sectional area for each cultivar (Papamihal^{a-b-c}), drip-irrigated and

fertigated based on water and nutrition requirements, while plant protection in accordance with the Integrated Pest Management principles and no soil tillage practiced against weeds, with herbicide used instead. Four apple fruits were picked up from each tree, one per each cardinal directions (East, South, West, and North), 1- 2 height from soil level. That sample size provides a margin of error statistically accepted of 5% in the confidence level about mean, standard deviation and variation. Apple fruits were picked and their maturity indexes and weight were analyzed in six different dates for Golden Delicious and Red Chief: at 130; 135; 140; 145, 150 Days After Full Bloom and at harvest, 152 DAFB. While for Granny Smith cultivar seven times, and in addition to those five DAFB dates of two others cultivars, one at 155 DAFB and the seventh one at harvest 159 DAFB.

The apple fruit indexes were:

- The Fruit firmness (F) in kg/cm^2 , measured by a hand penetrometer (Wagner FT 30 brand) with an 11 mm probe.
- The Total Soluble Solids (TSS) in Brix degree, measured by a hand refractometer (ATC REF-114 brand).
- Starch Index (SI) through immersion for 30 sec. of half apples cut in their equatorial plan into a solution which contained 10 gr dissolved crystals of Potassium Iodide (KI) and 2.5 Iodine (I) per liter of water. Estimation of starch conversion in simple sugars was made through the comparison of each half fruit with standard tables 1- 10, where 1 shows nil starch conversion, while 10 shows its 100% conversion.
- The Streif Index was calculated based on the abovementioned indexes, according to the following formulae:

$$\text{Streif Index} = \frac{\text{Firmness (F)}}{\text{Total Soluble Solids (TSS)} \times \text{Starch Index (SI)}}$$

- The average apple fruits weight, through weighing each of them to a digital electronic scale 2 kg and precision level of 0.1 gr.
- The growth rate of fruit weight in relation to their maturity indices.

The calibration of penetrometer, refractometer and scale was made each sampling time, prior to make measurements. All data collected were analyzed by using Minitab 16 statistical Program, with a 95% confidence level.

RESULTS AND DISCUSSION

Data collected about the fruit maturity indexes and weight for three apple cultivars under study showed that there were changing values of these indices from one to other picking time. The fruit's firmness was decreasing as their maturity progressed, while in the main time, the total soluble solids and starch index were increasing, along with fruit weight. Based on maturity index figures was calculated the Streif Index for each cultivar. Regarding this index, there are differences between cultivars.

Golden Delicious cultivar

The maturity indices of Golden Delicious cultivar for year 2012 and 2013 are shown in Table 1 and Table 2. Based on those figures, the Streif Index was calculated. This Index had its maximum value of 0.207 at 130 DAFB on 11 September 2012, while on 3 October (152 DAFB) same year, the lowest one 0.061 (Table 1). In year 2013 for the same DAFB timeframe it was respectively 0.234 on 4 September and 0.066 on 26 September (Table 2).

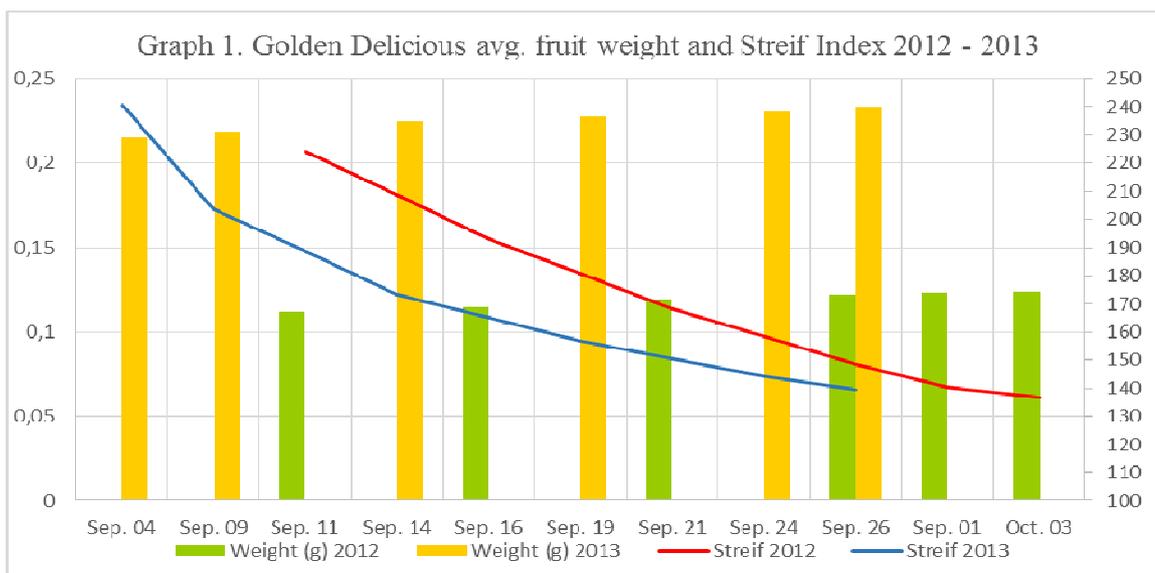
Table 1. Golden Delicious maturity indexes and Streif Index (year 2012)

Sampling dates (year 2012)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg.Starch Index (1-10)	Avg. Streif Index
11 Sept. (130 DAFB)	20	7.7	12.85	2.9	0.207
16 Sept. (135 DAFB)	20	7.5	13.35	3.6	0.155
21 Sept. (140 DAFB)	20	7.2	13.70	4.6	0.114
26 Sept. (145 DAFB)	20	6.9	14.00	6.0	0.082
01 Oct. (150 DAFB)	20	6.5	14.25	6.8	0.067
03 Oct. (152 DAFB)	20	6.4	14.30	7.3	0.061

Table 2. Golden Delicious maturity indexes and Streif Index (year 2013)

Sampling dates (year 2013)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg.Starch Index (1-10)	Avg. Streif Index
04 Sept. (130 DAFB)	20	7.6	12.50	2.6	0.234
09 Sept. (135 DAFB)	20	7.3	12.75	3.3	0.173
14 Sept. (140 DAFB)	20	7.1	13.20	4.4	0.122
19 Sept. (145 DAFB)	20	6.9	13.40	5.4	0.095
24 Sept. (150 DAFB)	20	6.6	13.65	6.5	0.074
26 Sept. (152 DAFB)	20	6.4	13.80	7.0	0.066

According to literature, it is recommended that the optimum harvest date for long term cold storage of Golden Delicious apples is when the Streif Index reaches a 0.1 value. However, as such a value may corresponds to only one day, which makes already impossible to harvest big orchards with that cultivar in such a short term, it was advised to start and complete harvesting as soon as possible, just in a couple of days before and after that optimum date. In regard to Starch Index value, it is advised to be less than 6. Referring to data of Table 1 and Table 2, resulted that the optimal date for harvesting Golden Delicious was 23 September 2012 and 18 September 2013 (Streif Index value 0.1). On the other hand, based on a study on predicting the Golden Delicious fruit growth on the same orchard with same trees, the weight for each picking date was calculated. (Papamihal, 2014^a). The Streif Index and fruit weight dynamics for both years are shown in Graph 1.



Red Chief cultivar

The maturity indices of Red Chief cultivar for year 2012 and 2013 are shown in Table 3 and Table 4. Based on those figures, the Streif Index was calculated. This Index had its maximum value of 0.255 at 130 DAFB on 10 September 2012, while on 2 October (152 DAFB) same year, the lowest one 0.067 (Table 3). In year 2013 for the same DAFB timeframe it was respectively 0.256 on 4 September and 0.075 on 25 September (Table 4).

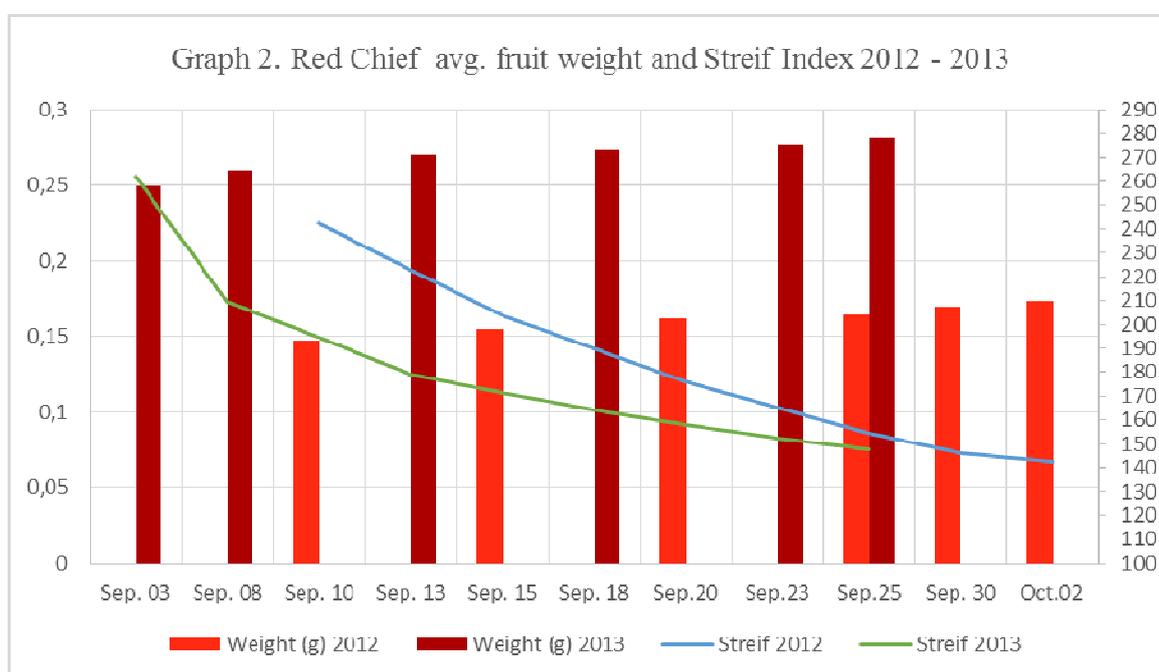
Table 3. Red Chief maturity indexes and Streif Index (year 2012)

Sampling dates (year 2012)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg. Starch Index (1-10)	Avg. Streif Index
10 Sept. (130 DAFB)	20	8.1	10.6	3	0.255
15 Sept. (135 DAFB)	20	7.9	11.2	4.3	0.164
20 Sept. (140 DAFB)	20	7.5	12	5.2	0.120
25 Sept. (145 DAFB)	20	7.3	12.6	6.7	0.086
30 Sept. (150 DAFB)	20	6.9	13.1	7.2	0.073
02 Oct. (152 DAFB)	20	6.8	13.3	7.6	0.067

According to literature, it is recommended that the optimum harvest date for long term cold storage of Red Chief apples is when the Streif Index reaches a 0.12 value, but as abovementioned, as such a value may corresponds to only one day, it was advised to start and complete harvesting as soon as possible, just in a couple of days before and after that optimum date. Referring to data of Table 3 and Table 4, results that the optimal date for harvesting Golden Delicious was 20 September 2012 and 14 September 2013 (Streif Index value 0.12). On the other hand, based on a study on predicting the Red Chief fruit growth on the same orchard with same trees, the weight for each picking date was calculated. (Papamihal, 2014^b). The Streif Index and fruit weight dynamics for both years are shown in Graph 2.

Table 4. Red Chief maturity indexes and Streif Index (year 2013)

Sampling dates (year 2013)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg. Starch Index (1-10)	Avg. Streif Index
03 Sept. (130 DAFB)	20	8.0	10.4	3.0	0.256
08 Sept. (135 DAFB)	20	7.8	11.0	4.1	0.173
13 Sept. (140 DAFB)	20	7.5	11.5	5.2	0.125
18 Sept. (145 DAFB)	20	7.3	12.1	6.0	0.101
23 Sept. (150 DAFB)	20	7.1	12.8	6.7	0.083
25 Sept. (152 DAFB)	20	7.0	13.0	7.2	0.075



Granny Smith cultivar

The maturity indices of Granny Smith cultivar for year 2012 and 2013 are shown in Table 5 and Table 6. Based on those figures, the Streif Index was calculated. This Index had its maximum value of 0.761 at 130 DAFB on 12 September 2012, while on 11 October (159 DAFB) same year, the lowest one 0.125 (Table 5). In year 2013 for the same DAFB timeframe it was respectively 0.816 on 6 September and 0.134 on 4 October (Table 6).

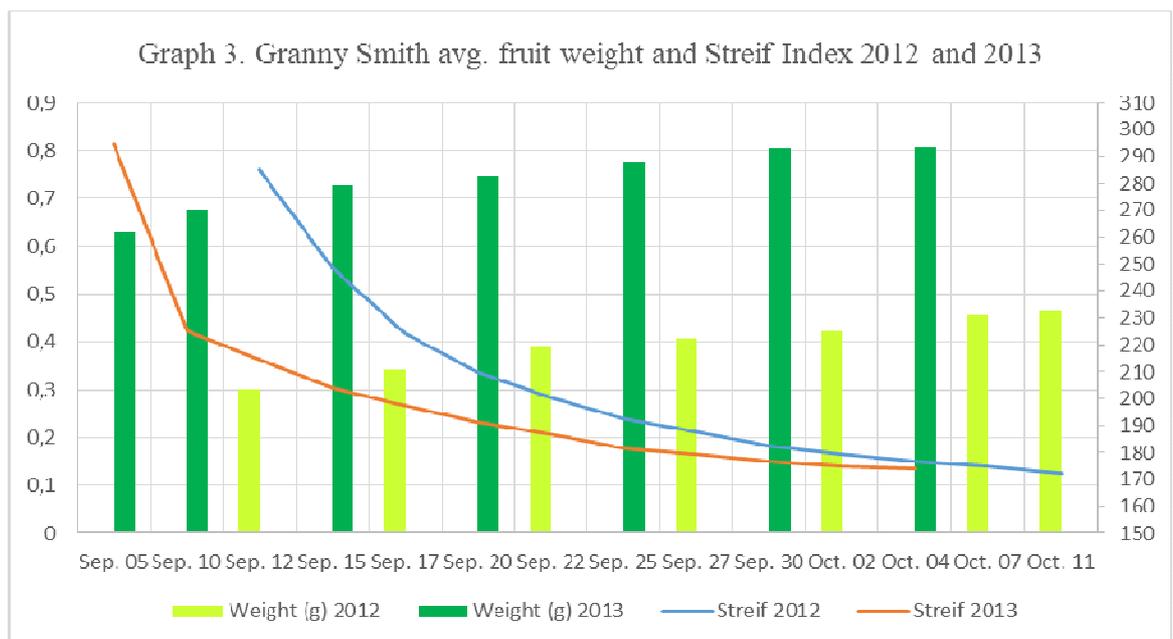
Granny Smith is a late-ripening cultivar with maturity indices that change very slowly, by offering to growers the opportunity for a longer harvesting period than two other cultivars, which may last for even more than two weeks (Kupferman, 1992). It's advises to start harvest for storage when Total Soluble Solids are more than 11.5⁰Brix, while Streif Index is more than 0.15, which corresponds to date 6 October 2012 and 1 October 2013.

Table 5. Granny Smith maturity indexes and Streif Index (year 2012)

Sampling dates (year 2012)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg. Starch Index (1-10)	Avg. Streif Index
12 Sept. (130 DAFB)	20	9.4	9.5	1.3	0.761
17 Sept. (135 DAFB)	20	9.1	9.9	2.2	0.418
22 Sept. (140 DAFB)	20	8.9	10.5	3.0	0.283
27 Sept. (145 DAFB)	20	8.7	11.1	3.7	0.212
02 Oct. (150 DAFB)	20	8.5	11.5	4.5	0.164
07 Oct. (155 DAFB)	20	8.4	11.7	5.1	0.140
11 Oct. (159 DAFB)	20	8.3	11.9	5.6	0.125

Table 6. Granny Smith maturity indexes and Streif Index (year 2013)

Sampling dates (year 2013)	Sample size (fruits)	Avg. Firmness (kg/cm ²)	Avg. Total Sol. Solids (°Briks)	Avg. Starch Index (1-10)	Avg. Streif Index
05 Sept. (130 DAFB)	20	9.2	9.4	1.2	0.816
10 Sept. (135 DAFB)	20	9.0	9.7	2.2	0.422
15 Sept. (140 DAFB)	20	8.8	10.0	2.9	0.303
20 Sept. (145 DAFB)	20	8.7	10.4	3.6	0.232
25 Sept. (150 DAFB)	20	8.6	11.0	4.4	0.178
30 Sept. (155 DAFB)	20	8.5	11.3	5.0	0.150
04 Oct. (159 DAFB)	20	8.3	11.5	5.4	0.134



CONCLUSIONS

Data collected showed that for each of three apple cultivars in this study, the respective fruit maturity indices and Streif Index changed from one to other picking dates.

For Golden Delicious resulted that 23 September 2012 and 18 September 2013 were the optimum harvest dates for long term storage, as Streif Index was 0.01 on those dates.

For Red Chief the optimum harvest dates for long term storage were 20 September 2012 and 14 September 2013. Harvest for both cultivars should be completed within five days.

Granny Smith, as a late ripening cultivar, which undergo slower changes in maturity indices has more flexibility in harvest, and the process can last longer (up to two weeks). In year 2012 harvest could started on 6 October, while in year 2013 on 1 October.

Fruit weight gain for three cultivars during the period from the optimum harvest date for cold storage to commercial harvest was not to a significant level, compare to benefits in quality during storage.

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