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THESES OF DOCTORAL (PH.D.) DISSERTATION

Relations of productiontechnological elements, environmental factors and post harvest quality attributes of apple

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INTRODUCTION

Recently much emphasizes is put on quality in fruit production. However, in the chain of production, commerce and consumption each participant differently composes what does quality mean. So as to be present on the market quality and quantity should be kept prior equally just like all information and knowledge supporting it.

Looking over the diverse expectations composed by consumers, marketers and producers toward fruit varieties, in the background of their well defined stereotypes, fruit quality can be characterized by concrete physical and chemical parameters. In the background of any parameters, just like sugar content, flash firmness and also their ripening stand chemical compounds. Going further, in the mechanism and equilibrium of these, enzymatic and hormonal processes are genetically determined. The chain of these processes is highly affected by technological and environmental factors.

Hungarian apple plantations are characterized by an unreasonable level of heterogeneity. It is evident, that basic difference is to be noted between apple production technologies on sandy soil of Szabolcs and of that executed on loamy soil anywhere else in the country. The diversity of producing areas, and of producing techniques, the broadening of cultivar supply, the producers' society showing diverse level of professional knowledge are all elements that put together this unreasonable heterogeneity.

The mostly critical from its determination factors are technological elements based on human factor, through which people get into direct contact with the trees. In intensive fruit production this has even higher significance, since the smaller the trees are the more they are vulnerable to any intervention. These days we need to put much emphasise on to highlight certain questions of apple production technology, so as to be present in the same rank with the word's honoured fruit producers through exploiting our natural endowments.

My thesis work discusses behaviour of quality and ripening parameters in relation to slenderspindle-canopy structure, to timing and severity of hand thinning, to Ca-spray nutrition, to summer pruning, and to post harvest ULO-storage and shelf life.

PLACE, MATERIALS AND METHODS OF EXPERIMENTS

Place of the experiments

Most experiment was established in the apple orchard of the Kasz-Coop Ltd. In Sáránd, which is about 20km from Debrecen in south-southwest direction (north latitude: 47º23'; east altitude: 21º35'). The approximately 100ha orchard was established on medium-tight loamy soil.

The water and mineral supply of the soil is good. The fertilization is based on regular soil- and leaf-analyses results. Irrigation is backed up with data of precipitation soil water changes, air humidity and linear fruit-growth. Between row space is covered with natural weed-succession, chemical weed-control is applied in the rows. The Ltd. follows IP management.

Harvest date is determined with the joint observation of the calendar date, starch-index, flesh firmness, background colour and fruit weight.

Climatic characteristics of the experimental years

The average annual precipitation in the orchard is 584mm. Between April and September this is about 340mm in average. To suffice the annual 800mm water-requirement of the apple it is due to calculate with an about 50-220mm required yearly water supply in average years. The biggest portion of the precipitation falls in June, the least in January. Soil water is below 2m, thus it does not effect soil-moisture characteristics of the productive soil layer.

An extending high temperature was registered in 2006, while 2005 and 2004 fell below the average in this concern. 2005 could be referred to as an ideal year. It is interesting to note, that in 2004, besides a considerable precipitation supply the relatively hot summer resulted certain fruit-burn, but this was not significant.

Involved varieties in our trials were the following:

- 'Golden Reinders',
- 'Jonagold',
- 'Gala must',
- 'Braeburn'.

Studies of canopy-structure (1st experiment)

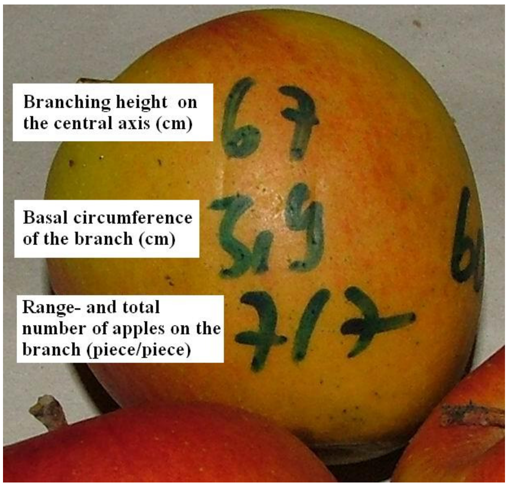
The material of our observations were 5 slender spindle shaped 'Breaburn/M.9' trees in the 4m between row and 0,8m between tree spacing (3100tree/ha), established in 1998.

Along with the random selection of the trees we gave attention to their homogeneity in canopy-structure, bud differentiation and fruiting part numbers.

Our observations were made on un-thinned trees, thus all the fruits set were taken into respect. Sample trees were thus chosen based on their different fruit set level. This difference is represented in Table 1.

Table 1. Fruit set of the trees involved into the experiment(Derecske, 2006)

Fruit load	
absolut	specific
db/fa	db/TCS cm^2
62	4,09
74	6,79
92	8,16
135	7,24
159	10,04
TCS = Trunk Cross Section	



Picture 1. Marking of apples before harvest

The following parameters were written onto all of the apples on the trees with permanent marker one week before the harvest (Picture 1):

(a) branching height of branches and twigs,

(b) basal circumference of the bearing branch,

(c) range- and total number of apples on the branch: 1/7 at the central leader, 7/7 represents the terminal fruit in this example.

Harvest date was determined with the joint observation of the calendar date, starch-index, flesh firmness, background colour and fruit weight. The harvest was performed at a time. The apples were stored under 4-5 ºC in a RA-storey up to their processing.

The fruit thinning and summer pruning experiments (2nd experiment)

Fruit thinning and summer pruning experiments were established in the 0,8m between tree and 4m between row spaced part of the orchard, established in 1997 with slender spindle canopy. Three cultivars were applied to establish treatments as follows (Tables 2-4):

Table 2. Fruit thinning treatments of 'Gala must' (Derecske, 2005)

Treatment (GM)	**Timing**	Specific fruit load (p/TCS cm^2)
Control	**Unthinned**	4,73
1. thinning	**7th June**	3,15
2. thinning	**27th June**	2,27
3. thinning	**18th July**	2,31
4. thinning	**7th August**	1.95

Table 3. Fruit thinning treatments of 'Jonagold' (Derecske, 2005)

Treatment (JG)	**Timing**	Specific fruit load (p/TCS cm^2)
Control	**Unthinned**	8,88
1. thinning	**6th June**	3,14
2. thinning	**18th July**	3,06
3. thinning	**8th August**	3,19
4. thinning	**30th August**	2,47

Table 4. Fruit thinning treatments of 'Golden Reinders' (Derecske, 2005)

Replication	**Treatment (GR)**	Timing	Specific fruit load (p/TCS cm^2)
	Control	Unthinned	7,68
1. thinning	**Sever**	6th June	4,28
1. thinning	Medium	6th June	4,07
1. thinning	Mild	6th June	7,68
2. thinning	**Sever**	7th July	3,99
2. thinning	Medium	7th July	5,82
2. thinning	Mild	7th July	5,96

Where:

Sever: 1db fruit let,

Medium: 2db fruit lets,

Mild: 3db fruit lets from a cluster was left.

Each treatment was established in randomized order in five replications. Analyzed samples of treatment consisted from 10 apples picked by trees, thus 50-50 apples were checked for each treatment.

At the establishment of summer pruning treatments we aimed to eliminate crowding, intending, upward and inward growing one year growth. The removal of 2nd year parts was scarce. Timing of treatments and specific fruit load is shown in Table 5.

Table 5. Summer pruning treatments of 'Gala must' (Derecske, 2005)

Treatments	**Timing**	Specific fruit load (fruit/TCS cm^2)
Control	**Unpruned**	3,73
1st pruning	**7th June**	3,15
2nd pruning	**27th June**	2,27
3rd pruning	**18th July**	2,31
4st pruning	**7th August**	2.95

The harvest was performed at a time. Samples consisting of 5 × 10-10 fruits were stored under 4-5 ºC in a RA-storey up to their processing.

There can be considerable difference between trees of a plantation in respect to their flowering, in the numbers of fruits set and also in their volume (TCS cm^2). Thus it is crucial – just like in the case of pruning- to establish a fruit thinning suited for specific characteristics of the trees.

For examination of that supposed factor, how does primary fruit set, so the fruit load before thinning, and further also their non specific (fruit/TCS cm2) but absolute (fruit/tree) fruit-load affect quality attributes at harvest, their weight and flesh firmness, a further complimentary experiment was established.

Three fruit-load levels were established based on the advice of the chef-gardener and on data of several years, 10t/ha lower and higher than the advised optimum yield in the same orchard with 'Gala must' cultivar.

In the establishment of the 15, 25 and 35t/ha fruit-load levels on 20-20 apple trees besides those listed on the 7th page, total number of fruits set was also counted at each tree. After this numbers of apples due to have been removed (or those, due to have been left on the trees) was defined using LAFFER's curve on the basis of trunk cross sections (fruit/TCS cm^2).

Observation of orchard-microclimatic effects of summer pruning and (3rd experiment)

The applied domestically developed 24channelled meteorological detection-system is equipped with an SM2 data-logger and high sensitivity and accuracy (temperature and humidity) sensors in three atmospheric levels (50cm, 120cm, 250cm).

Direction and velocity of the wind is measured in 250cm height from the ground, over the culture. Radiometers were situated into the canopy, with which we could measure global radiation and radiation-balance at a time. The precipitation-meter belonging to the system was placed under the tree. Thus the radiation decrease in the culture and the interception could also be calculated.

In different aged apple cultures it was studied that culture-age, summer pruning through their effect on tree thickness, density and height, how do effect on temperature, humidity and radiation circumstances inside the orchard.

Efficiency of Ca-containing effective materials (4th experiment)

Our Ca-spray nutrition experiment with ’Braeburn’ variety was established in the about 40ha apple orchard of the Almker Ltd. in Nyírbátor on sandy soil. The orchard was established in 2000 with ‘M.9/Braeburn Hillwel’ grafts, with 4m between row and 0.75m between tree spacing, north-south row direction. Four materials were probed in 2005 and further two besides the four in 2006 (Table 6).

Symptoms of bitter pit were experienced regularly in the orchard at this sensitive cultivar.

Table 6. Materials probed in 2005 and 2006, and their equalized effective material content

	%			mg/kg					
	N	Mg	CaO	Fe	Mn	Mo	B	Zn	Cu
In 2005 and 2006:									
Kemira	15		25						
Fruton			17.5						
Calbit-C			15						
Wuxal	10	1.9	15	400	900	20	400	200	300
Further on in 2006:									
Fitohorm-40 Ca	10		15						
Panda	10	2	15				0,05	0,02	

Treatments with the corresponding forms of Ca-effective materials were made in the same manner and same timing, with the correct dosage given by producers.

For estimating the efficiency of the treatments, mineral analysis was made from apple peel before storage. At sampling for this purpose, no distinction was made between healthy and diseased apples. Ten apples were peeled from each treatment.

About 35 tons of apples of each treatment were picked from adjacent 1-1 hectares in the same orchard. Apples were inspected before and after storage. Symptoms of bitter pit were checked and evaluated separately by trained workers. Diseased (not marketable) apples were discarded, no classification was made.

Along with evaluating our results in 2005 besides the efficiency of the materials we put emphasizes on their prices and costs. In 2006 with a more detailed analysis much attention focused on to characterize Ca-content of different tissue layers (peel, flesh and core). For this purpose Malagrow Ltd. provided analytical data.

Post-harvest behaviour of quality and ripening parameters (5th experiment)

Samples of 25 apples were taken regularly on three weeks bases from ULO-storage.

From this item 5 apples were inspected directly after sampling, and further 5-5 apples were processed on weekly bases through three weeks. Apples were kept under 25°C and 30% of humidity resembling shelf-life.

Through our examinations we measured the following attributes of the apples

- weight (g)
- starch index (1-10)
- colouration (1-100 cower % × 1-5 colour deepness point) subjectively determined,
- flesh firmness measured with FT 327 Effegi-type penetrometer (lb/cm^2)
- total sugar content derived from soluble solid concentration with the Y = 2,1486 X + 82,591 formula suggested by The International Sugar Committee, where Y: sugar content (g/l), X: Brix %.
- total titrate-able acid content (g/l)
- trunk cross-section (cm^2) and to analyse canopy structure:
- basal cross-section of the branches (cm^2)
- numbers and length of shoots (peace, cm).

From the data on sugar and acid content THIAULT's (1970) quality index (Pomona value) was determined (MI = total sugar g/l + 10 × total acid g/l). In the case of post harvest analyses Streif-index was calculated from the data on starch content, flesh firmness and total soluble solid content.

Mineral element content of the plant samples were measured with ICP-OES in the Institute of Food Processing, Quality Control and Microbiology.

Data was processed and visualized with EXCEL software. Differences of the treatments establishes in split-plot pattern were calculated with one way analysis of variance with the $SzDp5\% = tp5\% * \sqrt{2 * (MQb \div n)}$ formula.

RESULTS

Quality of 'Braeburn' apples depending from the fruit load of the trees and specific fruit load of the branches

Diagram 1 shows average quality indices (THIAOULT, 1970) of the examined trees of different fruit load.

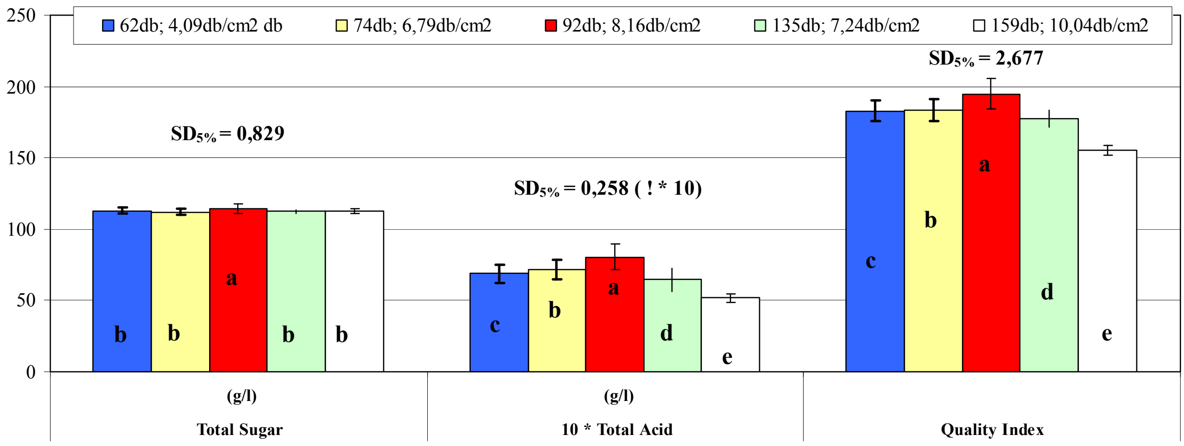


Diagram 1. Quality parameters of apples on differently loaded 'Braeburn' trees (Derecske, 2006)

In respect to the different fruit loads it is visual, that its medium level resulted the best values. It worth attention to recognize, that acid content reacts more sensitively to the changes of fruit load, than does sugar content.

Diagram 2 visualizes different specific fruit loads of the branches.

It could be a question, weather an ideal number of apples for a given branch cross-section could be defined, so as to promote evolution of quality fruits, or there is no such correlation.

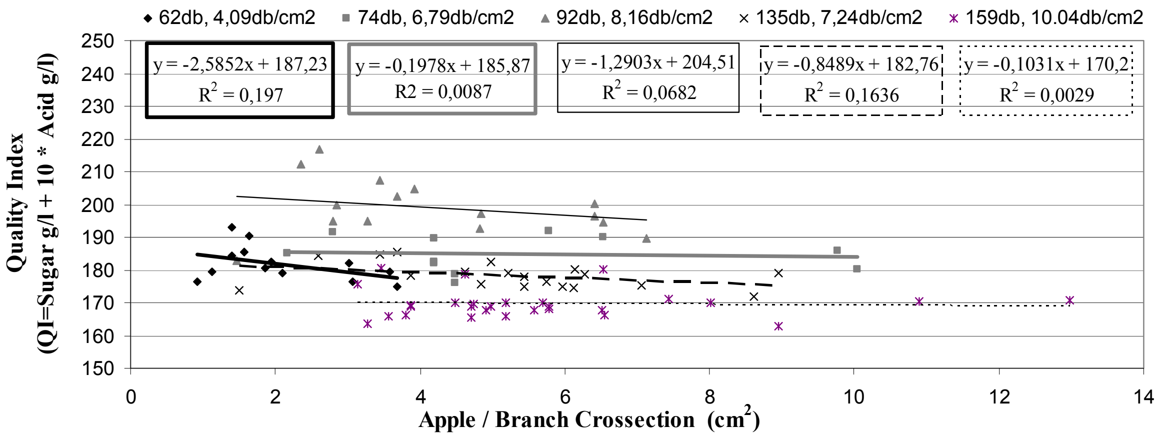


Diagram 2. Quality Indices of apples in relation to specific fruit load of the branches of five differently loaded 'Braeburn' apple trees (Derecske, 2006)

On the 2nd diagram it is visual, that along with increase of the specific fruit load of the branches within a tree, there is a slight decrease in the quality index of the apples. It is evident, that with decreasing fruit load of the trees the specific fruit load of the branches also decreases. Observing the quality index also from the point of the total fruit load of the trees a good optimal approximate value could be a 3-5p/cm^2 TCS interval.

The distance of the fruits from the central leader

Diagram 3 exhibits change in concentration of apple sup and acid/sugar ratio in relation to the distance from the central axis.

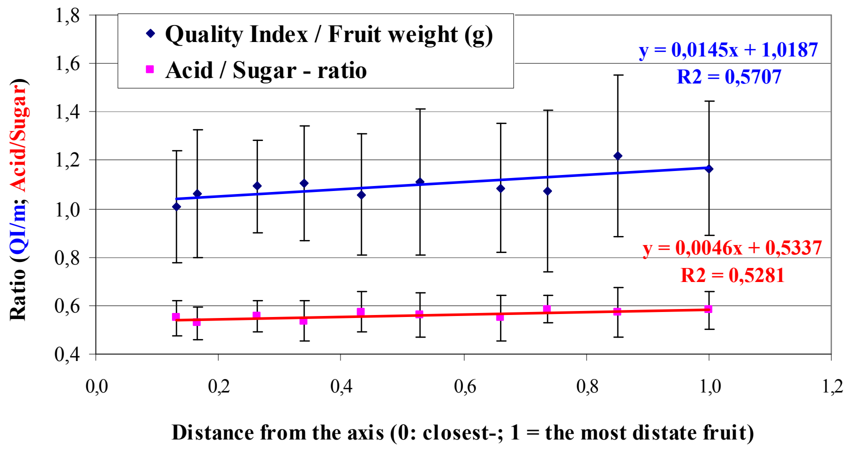


Diagram 3. Quality concentration of the apple sup in relation to the distance from the central axis on the average of all branches of 5 'Braeburn' apple trees (Derecske, 2006)

The diagram derived from average of all branches of the 5 trees clearly shows, that the quality index divided with the fruit weight (quality concentration) increases with the distance from the central leader with a considerable (r^2= 0,57) correlation.

From the point of physiological processes and storability of the apples a further interesting effect could be, that the apples' acid/sugar ratio also increases with the distance from the axis (r^2=0,53).

Colouration of the fruits did not show any consequent dynamics in this concern when we analysed single branches. However, the 4th diagram shows the change of colouration on the basis of the average of all branches of the 5 trees.

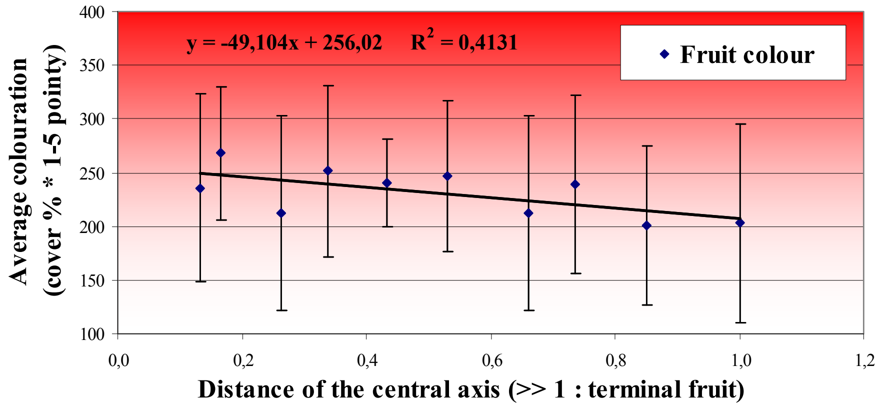


Diagram 4. Colouration of apples in relation to the distance from the central axis on the average of all branches of 5 'Braeburn' apple trees (Derecske, 2006)

Diagram 4 exhibits a controversial, but clear tendency. The colouration of the apples decreases with their distance from the central leader. The high level of the standard deviation represents the great variation observed in the case of single branches. It must be respected, that there was a 20-50% relative standard deviation.

Despite of the spectacular tendency, there is no significant difference between apples bred in the inner and outer parts of the canopy.

Effect of the timing of hand thinning on the fruit quality of 'Jonagold' apples

Diagram 5 shows in the case of **'Jonagold'** cultivar, that the finish fruit weight decreases with later thinning.

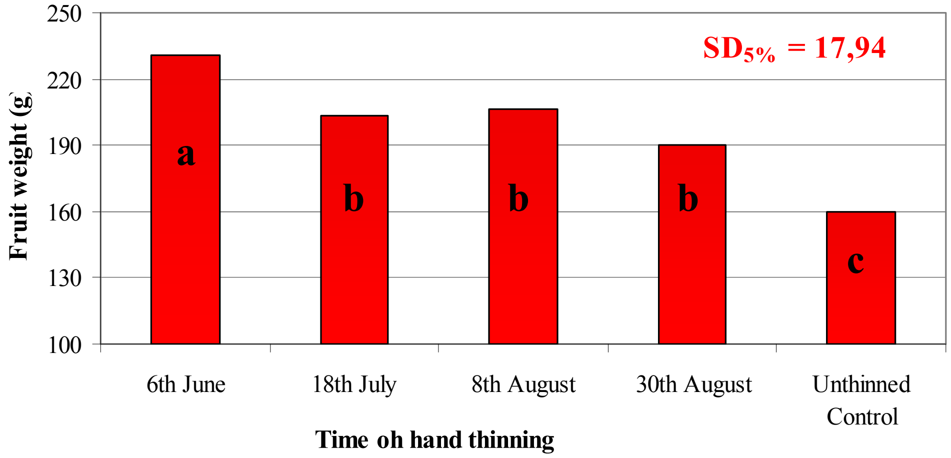


Diagram 5. Fruit weight of 'Jonagold' apples in relation to the timing of hand thinning (Derecske, 2005)

It is also visual, that there was no significant difference in fruit weight in case of timings between 18th July and 30th August.

Average fruit weight of unthinned control (end of September) stood below each fruit thinning treatments.

Diagram 6 represents flesh firmness of 'Jonagold' apples at harvest time in relation to the timing of fruit thinning.

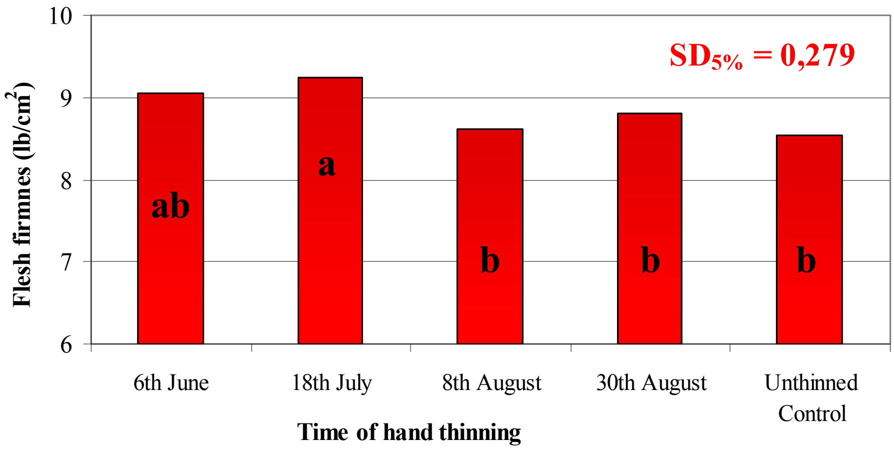


Diagram 6. Flesh firmness of 'Jonagold' apples in relation to the timing of hand thinning (Derecske, 2005)

It is clear to see, that timing of hand thinning can alter flesh firmness with about 1lb/cm^2. According to the diagram a slight decrease in flesh consistency is expectable with a later timing of the measure. However, this difference can hardly be deemed serious.

Diagram 7 shows total soluble solid-content of 'Jonagold' apples at harvest time in relation to the timing of fruit thinning.

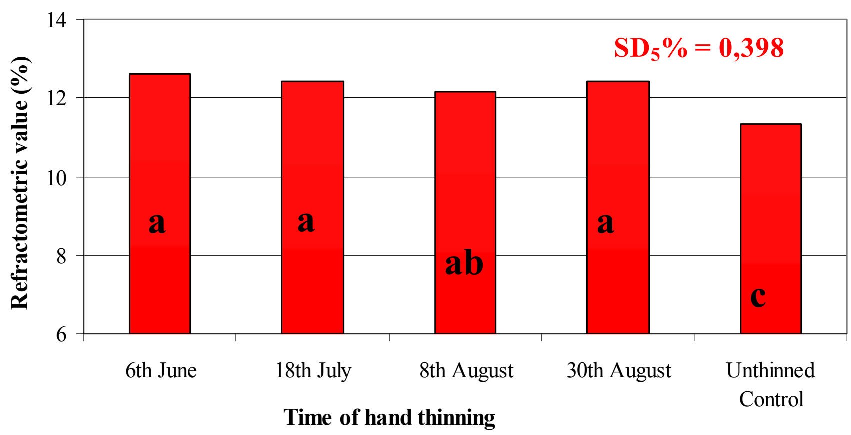


Diagram 7. Refractometric value of 'Jonagold' apple-juice in relation to the timing of hand thinning (Derecske, 2005)

The treatment of 30th August was established after termination of the shoot growth, and it was very close to harvest time.

From diagrams 5-7th it could be seen, that fruit thinning of the 'Jonagold' cultivar after the end of shoot growth, negatively affects average fruit weight, but can have certain positive effect on flesh firmness and total soluble solid content (Brix%).

7th table summarizes results of our thinning-time experiments wit 'Gala must' and 'Jonagold' cultivars.

Table 7. Summary table of results concerning to timing of fruit thinning (Derecske, 2005)

Parameters of foliar analyses and fruit quality		Along with later hand-thinning	
		'Gala must'	'Jonagold'
Foliar	K-content	Increases	-
	Ca-content	Decreases	-
	Cu-content	Control x 4	normal
Fruit weight (g/fruit)		Decreases	decreases
Fruit	Dry matter	decreases	decreases
	Flesh firmness	stagnates / decreases	decreases
	Total sugar	decreases	decreases
	Total acid	increases	increases
	Vitamin C	increases	stagnates

Fruits of trees thinned later, could be characterized with a higher foliar K/Ca ratio (provisionally lower storability), softer fruit flesh consistency, lower dry matter and sugar content, but a higher total acid content.

Effects of thinning severity on fruit quality of 'Golden Reinders' apple

Thinning severity treatments in this trial was not established on the basis of trunk cross section but with a range of within flower-cluster thinning severity (4. page). Thus 1, 2 or 3 fruit lets were left per flower cluster.

Diagram 8. shows average fruit weight (harvest time) of 'Golden Reinders' apples in relation to the thinning severity.

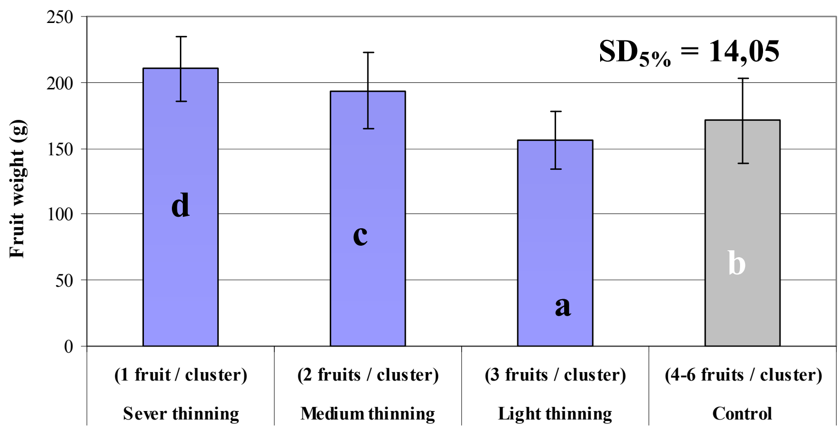


Diagram 8. Fruit weight of 'Golden Reinders' apples in relation to thinning severity (Derecske, 2005)

From the diagram it is clear to see, that along with increasing fruit load the finish fruit weight decreases.

Diagram 9 shows average flesh firmness of 'Golden Reinders' apples in relation to the thinning severity.

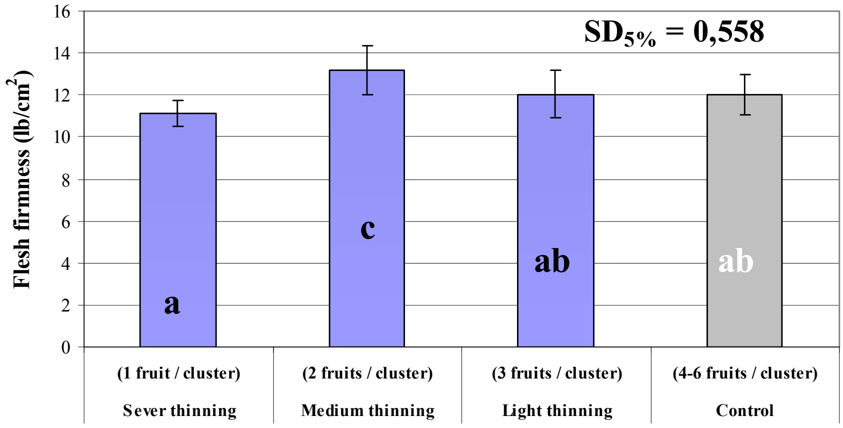


Diagram 9. Flesh firmness of 'Golden Reinders' apples in relation to thinning severity (Derecske, 2005)

With lowering the fruit load of the trees, flesh firmness at harvest time decreases, thus according to the diagram ripening process of fruits of weakly loaded trees is faster compared to the unthinned control and those of optimal fruit load. It is also visual, that the best flesh firmness could be recorded at intermediate fruit load.

Diagram 10 shows the total soluble solid content (sugar) of 'Golden Reinders' apples in relation to the thinning severity.

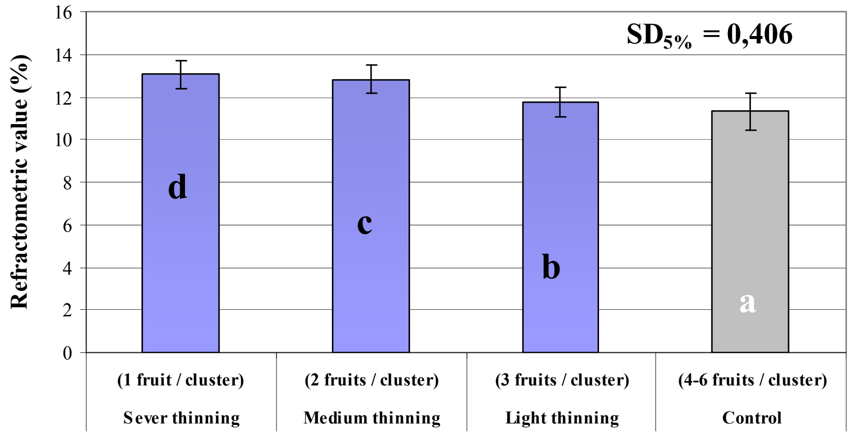


Diagram 10. Refractometric value of 'Golden Reinders' apples in relation to thinning severity (Derecske, 2005)

Diagram 10 shows that with increasing fruit load the sugar content of the fruits decreases.

Through results of thinning severity treatments of 'Golden Reinders' it can be stated, that a more sever thinning results bigger, sweeter but softer apples, although the best flesh firmness data could be measured at optimal fruit load.

Effects of fruit set and –thinning on quality parameters

Diagram 11 shows relation of different absolute fruit load of the trees (fruit/tree) and average fruit weight on three specific fruit load level (fruit/TCS(cm^2).

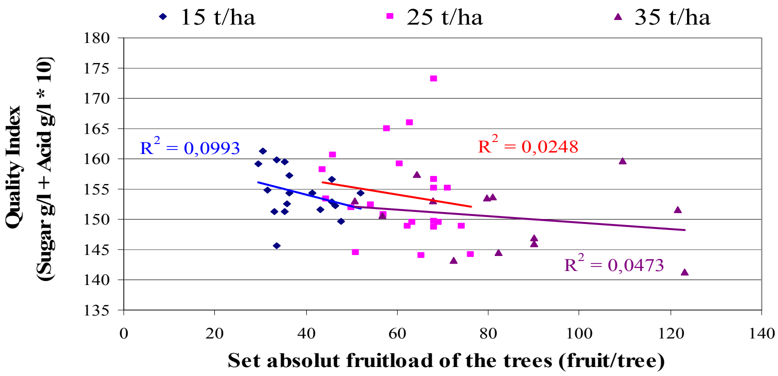


Diagram 11. Average fruit weight of 'Gala must' apples in relation to the set absolute fruit load of the trees (fruit/tree) (Derecske, 2006)

It is evidently visual from the 12th diagram, that average fruit weight decreases with the established higher fruit load (fruit/TCScm^2). Furthermore it can also be observed, that within the established specific fruit load levels (fruit/TCScm^2) average fruit weight shows further considerable decrease with increasing absolute fruit load (fruit/tree).

It shall be respected, that according to correlation quotients this relation is highly affected by other factors.

Diagram 12 clearly shows, that primary fruit load (before thinning) had no effect on harvest time fruit weight.

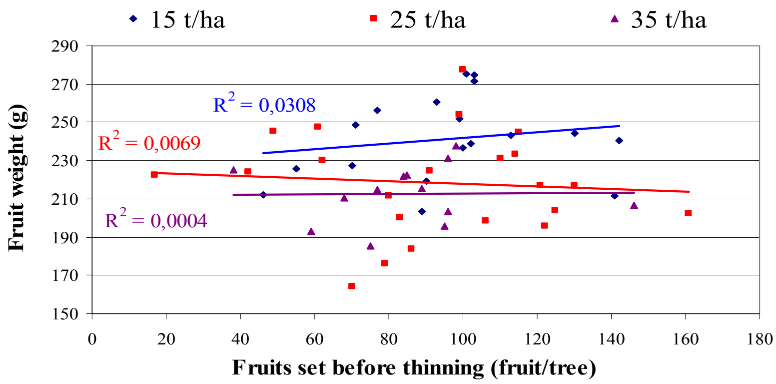


Diagram 12. Average fruit weight of 'Gala must' apples in relation to the original fruit set (before thinning) of the trees (Derecske, 2006)

Diagram 12 simply shows the significant difference in average fruit weights between the three established fruit load levels.

Diagram 13 visualizes quality index of the fruits in relation to the primary fruit load (fruit set before thinning) of the trees.

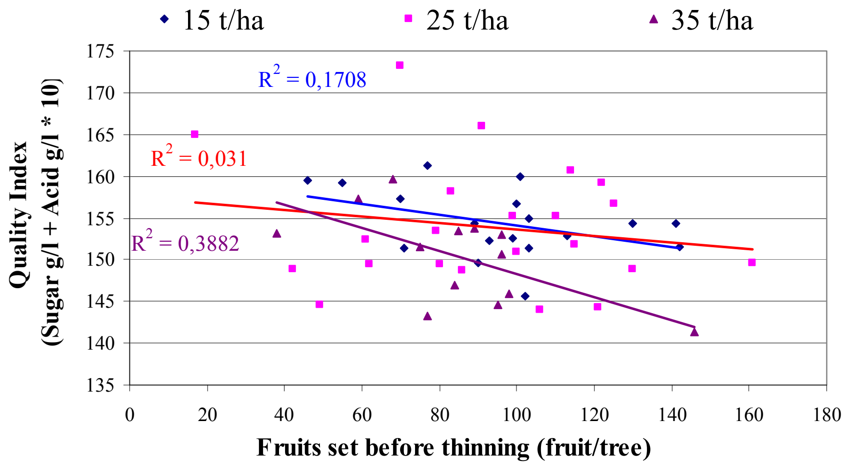


Diagram 13. Average Quality Index of 'Gala must' apples in relation to the original fruit set (before thinning) of the trees (Derecske, 2006)

The correlation quotient in the case of 15 and 35t/ha specific fruit could be considered noteworthy. Higher level of primary fruit load (fruit set) before thinning, has considerable negative effect on quality index of the fruits irrespective to specific fruit load levels (15, 25 and 35t/ha calculated on the basis of $TCScm^2$). This result underlines importance of chemical thinning which can be executed earlier.

Fruits of trees showing higher levels of primary fruit load (fruit set before thinning) can be considered to be the same in fruit weight and flesh consistency, but lower in their quality index to those grown on tress from which fewer apples were due to be removed to set the optimum fruit load level.

Table 8 summarizes results of our thinning-severity experiments with 'Gala must' and 'Golden Reinders' cultivars.

Table 8. Summary table of results concerning thinning severity (Derecske, 2005, 2006)

Parameters of foliar analyses and fruit quality		Along with more sever fruit thinning	
		'Gala must'	'Golden Reinders'
Foliar	K-content	increase	increase
	Ca-content	stagnate	stagnate
	Cu-content	normal	Control x 2,5
Fruit weight (g/fruit)		increase	increase
Fruit	Dry matter	-	stagnate
	Flesh firmness	**maximum at optimum**	**maximum at optimum**
	Total sugar	increase	increase
	Total acid	**maximum at optimum**	increase
	Vitamin C	-	? decrease

Tendencies exhibited in 8th table could generally stand for fruit load of apple trees.

Apples of threes of more sever fruit thinning could be characterizes with higher fruit weight and sugar content, besides increasing foliar K/Ca-ratio (stable Ca, increasing K), which means provisional lower storability.

From the point of flesh consistency and total acid content the intermediate fruit load shows the best results. Similar result are reported in 5.1. paragraph of the thesis work on canopy structure (also 1st diagram of this booklet).

Foliar Cu-content in the case of unthinned control 'Golden Reinders' was more than two times that of other treatments. In the case of 'Gala must' this effect did not evolve.

Effects of summer pruning and plantation age on radiation balance and diurnal temperature fluctuation of the orchard

Diagram 14 shows the average daily regime of the global radiation in the orchard before and after summer pruning.

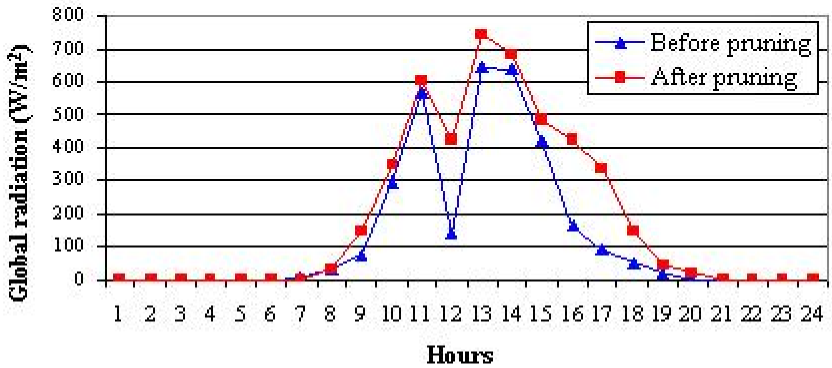


Diagram 14. Dynamics of the global radiation in the canopy before and after summer pruning (Derecske, 2005)

Evaluating the daily regime of the global radiation measured with a radiation-sensor situated inside the canopy the diagram suggests, that there is a considerable fall-back in midday hours thanks to the self-shading of the canopy. The degree of this decrease is about 70-75% before but only 20-25% after summer pruning.

Examination of the global radiation balance regime of the orchard on the basis of the out of orchard space can also be interesting. This parameter could be referred to as relative radiation balance.

Diagram 15 shows percentage of global radiation in the canopy on the basis of that measured out of the orchard before and after summer pruning.

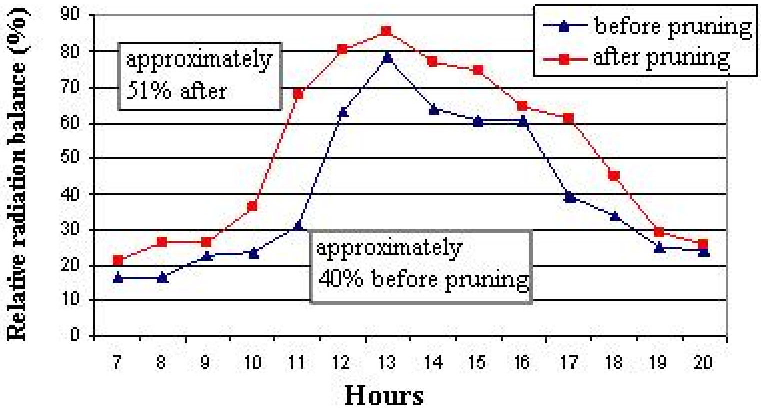


Diagram 15. Proportion of global radiation measured in the canopy to that of the out of orchard space (Derecske, 2004; well resembling 2005)

Results show, that the relative radiation balance of the canopy increased with 11% after summer pruning. In a replication trial in the subsequent year established in another part of the orchard of different canopy density a 13% increase vas detected thanks to the summer pruning.

The biggest differences between before and after summer pruning radiation balance can be observed in the hours before and after midday, hence increasing colouration of the apple. In the morning, at noon and in the late afternoon hours this difference is negligible.

Diagram 16 exhibits diurnal temperature change of a 7 year old orchard before and after summer pruning (highlighted with red colour), and also that in the case of different aged 5 and 9 year old orchards without pruning and out of orchard control space (grey columns).

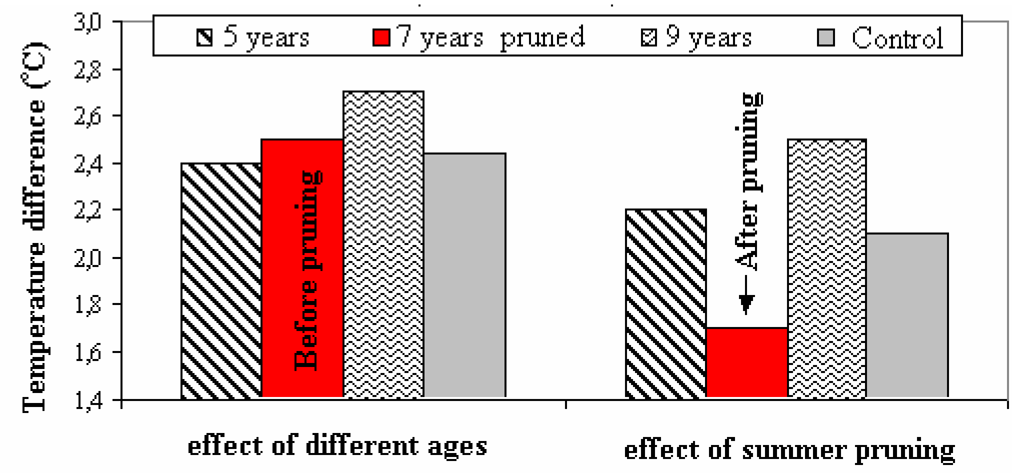


Diagram 16. Difference of the average diurnal temperature change in different aged cultures and also before and after summer pruning (Derecske, 2005)

It is clear to see, that fluctuation of the diurnal temperature change greatly weakens after summer pruning. It is also interesting to notice, that this fall back of the temperature change goes even below that experienced in the out of orchard space.

The experienced results make clear, that along with the orchard density the diurnal temperature change also increases. This can be due to plantation density, orchard age and vegetative growth characteristics. It can also be stated, that summer pruning greatly weakens diurnal temperature change in the orchard microclimatic space.

Efficiency of different Ca-containing sprinkle materials

Table 10 shows mineral composition of the apple skin at different treatments at harvest. Values of calcium, potassium and boron are prior to be respected.

Table 10. Results of 'Braeburn' apple peel analysis of storage year 2005-2006 (Nyírbátor, 2006)

	Control I.	II.	III.	IV.	V.	SD 5%
Ca	**286 a**	**272 a**	**409 a**	**496 b**	**715 c**	**151**
Cu	1.38	0.641	0.813	1.36	**2.58***	0.87
Fe	19.7	**10.6***	**9.75***	14.5	***14.1**	5.3
K	5983	6367	5176	5559	5790	1124
Mg	411	364	383	445	503	127
Mn	4.12	3.01	4.16	3.44	**6.47***	1.57
Mo	0.0734	**0.318***	0.158	**0.179***	**0.289***	0.096
P	451	580	358	436	473	134
Zn	5.24	**2.92***	**3.05***	**2.26***	4.2	1.68
B	0.01	**2.26***	0.865	**3.5***	**4.46***	1.34
K/Ca	20,92	23,41	12,66	11,21	8,10	
K+Mg/Ca	22,36	24,75	13,59	12,10	8,80	

For calcium, it is possible to reach a threefold increase of this nutrient in the apple peel. Treatments with the third (III) and fourth (IV) substances showed a 40% and 70% increase compared to the control. Increase of the apple peel calcium content in the case of the fifth (V) treatment shall be considered extremely high with its 150% level.

Table 11 shows losses from bitter pit before and after storage in case of 'Braeburn' items treated with different Ca effective materials.

Table 11. Distribution of bitter pit incidence of cv. 'Braeburn' apple in treatments with different Ca-spray materials (Nyírbátor, 2006)

From 35 tons	Loss before storage		Stored in	Loss after storage		Total loss	
	t	%	t	t	%	t	%
Control	13.7	**39.14**	21.3	1.26	**3.60**	14.96	**42.74**
II.	5.75	**16.43***	29.25	1.33	**3.80**	7.08	**20.23***
III.	4.63	**13.23***	30.37	1.011	**2.89**	5.641	**16.12***
IV.	4.05	**11.57***	30.95	1.131	**3.23**	5.181	**14.80***
V.	5.55	**15.86***	29.45	1.523	**4.35**	7.073	**20.21***
LSD 5%	3.45	**13.4**	14.9	0.56	**1.17**	3.87	**17.9**

It is possible to lower the incidence of bitter pit with about 20-40% with the application any of the Ca-spray materials. Cost calculation showed that if we speared about 7 tons of apples for quality market at a low 100 HUF/kg apple price, it is about 700.000 HUF saving at 20% quality retention, since we can calculate that 1% quality retention equals 35.000 HUF/ha (Table 12), that is about 140EUR/ha.

Table 12. Cost efficiency of Ca-spray materials (Nyírbátor, 2006 spring)

Nyírbátor (2005)	Costs of Ca-treatments				Total loss		Quality retention compared to the control		Saving = A - B
	HUF/kg	kg	replications	HUF (B)	t	%	%	HUF (A)	HUF/ha
Control	107	7	7	5243	14.96	42.74	0	0	-5243
II.	775	7	7	37975	7.08	20.23*	22,51	787850	749875
III.	1075	4	7	30100	5.641	16.12*	26,62	931700	901600
IV.	520	5	7	18200	5.181	14.80*	27,94	977900	959700
V.	970	3	7	20370	7.073	20.21*	22,53	788550	768180

According to the calculation presented in Table 12, it is visual that using any kind of Ca-spray it is possible to spare a considerable amount of money between ¾ to 1 million HUF (about 4000EUR). A difference of 200.000HUF depends on the decision, which material to use.

In 2006 involving two further materials the mineral analysis of the apples was carried out again, which -based on our experience in 2005- was extended to deeper tissue layers. Results concerning to the Ca-content are presented in the 17th diagram.

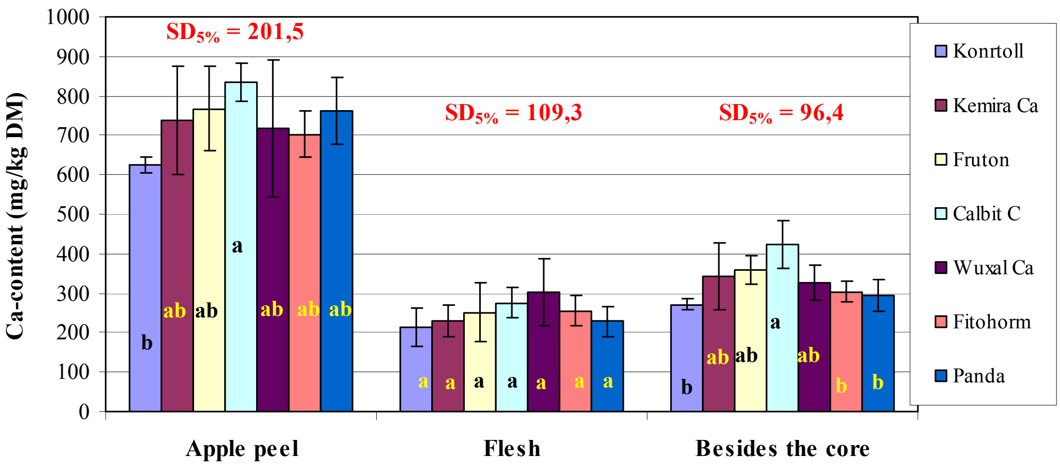


Diagram 17. Efficiency of Ca-spray materials in three tissue layers of 'Braeburn' apples (Nyírbátor, 2007 spring)

In our trials with Ca-effective materials with the sensitive 'Braeburn' cultivar on sandy soil in 20006 we recognised, that with a serial treatment with any of the studied materials a significant 10-30% Ca-content increase in apple skin, a 20-50% Ca-content increase in apple core, and a 20-40% decrease could be achieved.

There was no significant difference between Ca-content of apple cortex of the different treatments.

Behaviour of quality parameters under ULO-storage

Diagram 18 shows regime of flesh firmness and total soluble solid content of 'Golden Reinders' apples under ULO-storage.

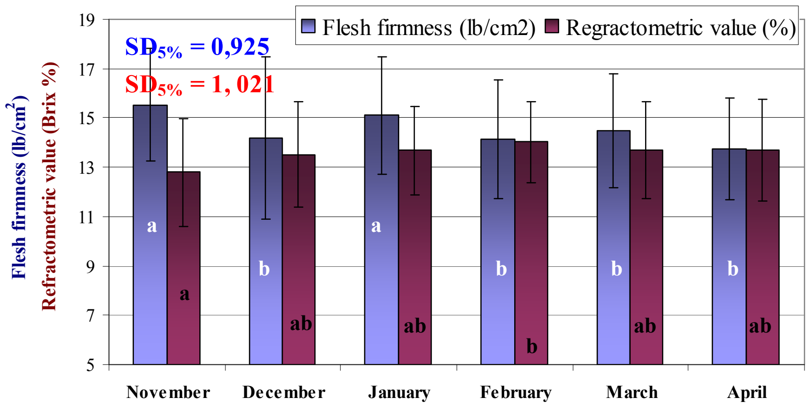


Diagram 18. Dynamics of the flesh firmness and refractometric value of 'Golden Reinders' under ULO-storage on the average of three consecutive years (Derecske, 2004-2006)

The diagram shows, that flesh firmness of the 'Golden Reinders' apples dynamically decreases, however the total soluble solid content is extending between January and February. This increase of the sugar content can be mathematically proved.

Under ULO-storage flesh firmness regularly showed decreasing tendency, the refractometric value showed regular emerging around 3^{rd} 4^{th} month after stored in.

Diagram 19 shows regime the quality index of 'Golden Reinders' apples under ULO-storage.

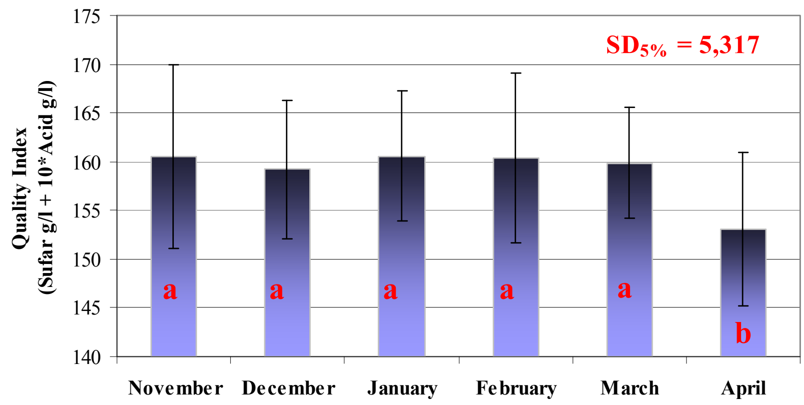


Diagram 19. Dynamics of the Quality Index of 'Golden Reinders' under ULO-storage (Derecske, 2004-2006)

It is visual, that the quality index in the case of the 'Golden Reinders' in the studied years did not change considerably. However, a serious decrease of the parameter could regularly observed in the April-May interval, which besides the constant refractometric values highlight the dramatic decrease of acid content.

Behaviour of quality parameters under shelf life

Diagram 20 shows change of flesh firmness of 'Golden Reinders' under three weeks shelf-life in three years.

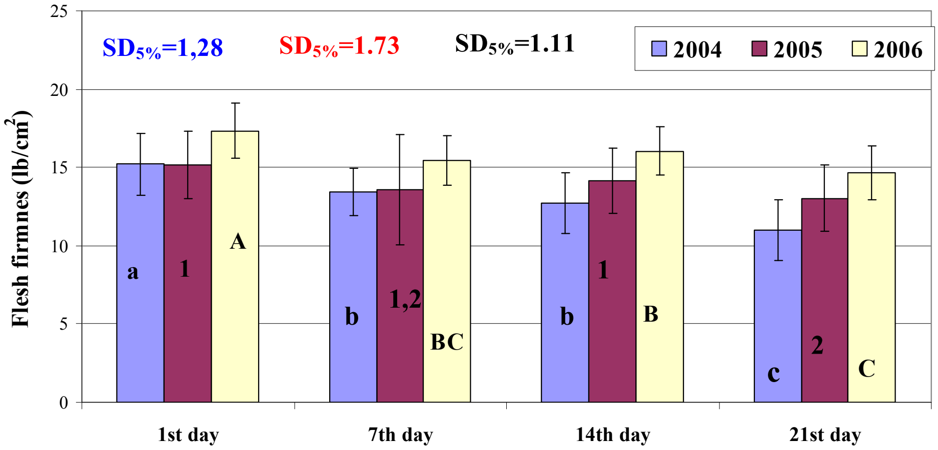


Diagram 20. Change of the flesh firmness of 'Golden Reinders' under shelf-life (Derecske, 2004-2006)

Analysing the flesh firmness it can be seen, that the expected dynamic decrease in flesh consistency only in 2004 was experienced. In 2005 and 2006 the parameter showed extending values after 14 days shelf-life.

Diagram 21 shows change of the refractometric value of 'Golden Reinders' under three weeks shelf-life in three years.

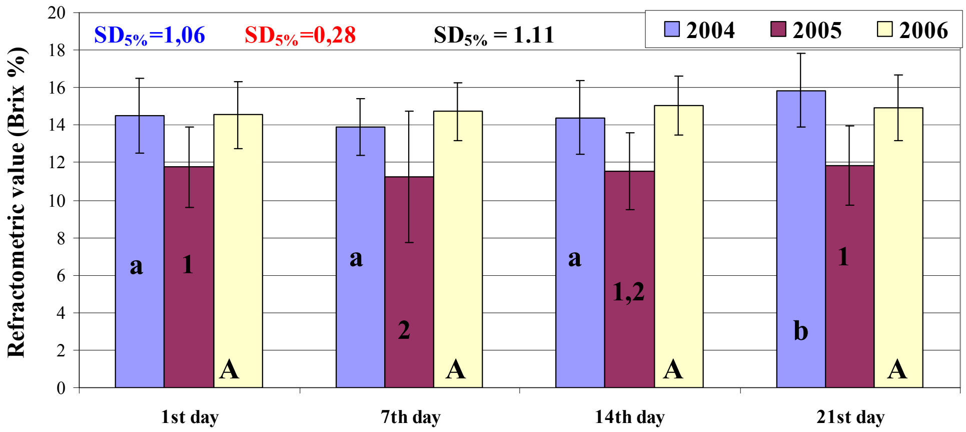


Diagram 21. Stability of the refractometric value of 'Golden Reinders' under shelf-life (Derecske, 2004-2006)

In contrast with that experienced under UL-storage, the refractometric value increases (2004, 2006) or remain unchanged (2005) under shelf-life.

Diagram 22 shows change of the quality index of 'Golden Reinders' under three weeks shelf-life in three years.

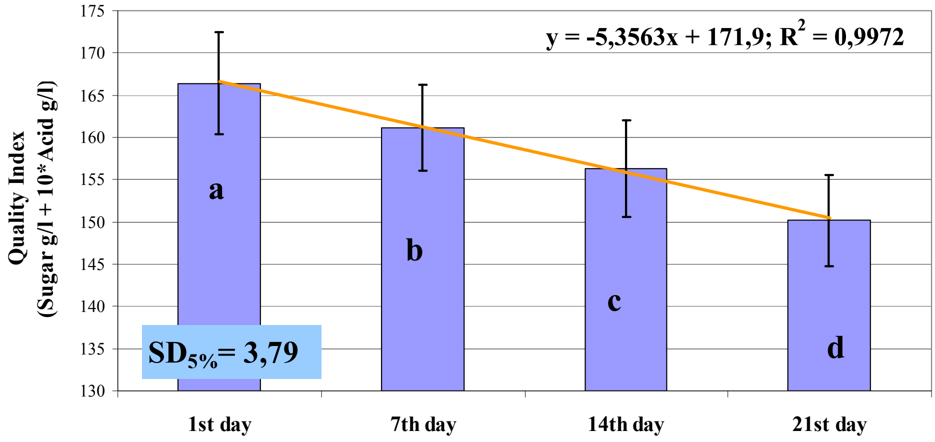


Diagram 22. Dynamics of the Quality Index of 'Golden Reinders' under shelf-life (Derecske, 2004-2006)

From the diagram dynamic decrease of the quality index is clearly visible. Besides the constant sugar content it is clearly understandable that the quality change is due to the decrease of acid content.

Break down of the acid content entails increase of the tissue pH, although this decrease in quality index of the apples indicate their senescent physiological stage.

New and novel scientific results

- Based on our experiments on side-branches of slender spindle canopies a 3-5 fruits/cm^2 branch cross-section theoretical interval could be comprehended as an ideal fruit load.
- On 'Braeburn/M.9' trees irrespective of their fruit load, quality index of the fruits increases (5-10 points) but fruit weight decreases with their distance from the central leader.
- Higher level of fruit load before thinning negatively affects quality index of the apples irrespective of the specific fruit load level (fruit/cm^2 TCS). This result underlines importance of the earliest chemical thinning.
- As a result of our Ca-spray trial with 'Braeburn' cultivar in 2006 on sandy soil, in apple flesh a generally lower Ca-value was measured irrespective of the treatments. Despite this, a considerable 20-50% increase could be detected in apple core compared to the control.

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