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Variety specific integrated fruit production development in order to optimize inner content values

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Summary: In this paper we introduce our results of three years (2007–2009) investigations carried out in the framework of "Research and development in foodstaff chain" – project of Regional University Knowledge Center by the members of Corvinus University of Budapest – Department of Pomology and, Research Institute for Fruit growing and Ornamentals, Budapest-Érd. The main objectives of the project were the followings: submission of sour cherry candidate suitable for industrial process for state approval; determination of physical parameter and inner content value changes of sour cherry varieties during ripening; evaluation of health care attributes of sour cherry fruit; ripening process description by the colour and the force required to pick fruits of sour cherry. We stated that the optimal beginning and period of the harvest can be determined with the fruit removal force. In this period the fruit growth stops, juiciness ratio does not change, refractions are approximately equal, acidic content turns to decreasing trend. However the proportion of anthocyanin and polyphenol can still increase. Fruits harvested in this period fulfil a wide range of industrial process opportunities. 'Érdi jubileum' and candidate IV-3/48 according to their inner content values are suitable for high quality products (containing real fruit material in high proportion).

Key words: anthocyanin, colour parameters, FRAP polyphenol, removal force, sour cherry

Introduction

Sour cherry (*Prunus cerasus* L.) production of the world exceeds 1 million tons and we have to count with further increasing in the following years. Sour cherry is grown mainly in Eastern Europe and the production of Hungary is dominant. Furthermore we consider sour cherry production as a leading branch according to its production values and the proportion of the export (*Kállay, 2003*). As approximately the half of our 13 000 hectare sour cherry orchards are not older than 10 years; our production may exceed 60–70 thousand tons.

Professional representatives of the European sour cherry growers agreed on that the volume of production can not be increased further. European sour cherry production fluctuates between 300–400 thousand tons in the recent years (*Kállay T-né & Szenci, 2009*).

Prices of processed fruit products appearing on the shelves of supermarkets are too low, so it is very hard to realize the costs of production even in the case of machinery harvested fruits. As a result of this growers are forced to choose the most optimal machinery harvest solution which preserves the fruit quality. All these enhance the modernization of machinery harvest technology and the determination of the optimal harvest time. Processing industry demands and the exploitation opportunities of biologically active compounds of the fruits should be taken into consideration.

Unique features of the Hungarian sour cherry varieties are that on one hand they are suitable for industrial processing and on the other hand they are suitable for fresh consumption according to their favourable sugar/acid ratio. Demands of the processing industry are: uniform and intensive fruit colour, large fruit size, small stone, thin skin, firm texture and suitable sugar/acid ratio.

Favourable physiological effects of sour schery are based on high polyphenolic, anthocyanin (*Kállay* et al., *2008*), vitamin and mineral content (*Ficzek et al, 2008*). Previus examinations proved there are significant differences in inner content values (e.g. soluble solids, sugar, acid or Vitamin C) according to the ripening stage (*Sang, 2003.; Stégerné* et al., *2003*).

Materials and methods

Ripening process of sour cherry varieties was followed in the Research Institute for Fruitgrowing and Ornamentals Budapest – Érd (henceforward: Érd Ltd.). Ripening stages (from the beginning of ripening to overmaturity) were determined by the force required to pick the fruits from the

stem. 80–100 measurement per each ripening stage was carried out in the orchard on labelled trees.

Parallel with the orcard measurements inner content values were determined in each ripening stage at Corvinus University of Budapest (henceforward: CUB), Department of Pomology. Weight, size parameters, stone/flesh ratio, juiciness, pH, water soluble solid (Brix%) and titratable acid content of the investigated sour cherry varieties were determined under laboratory conditions. Antioxidant parameters, water soluble antioxidant capacity, total anthocyanin- and polyphenol content were measured in the case of sour cherry varieties as well. Water soluble antioxidant capacity (FRAP) was determined on λ=593 nm according to the method of Benzie and Strain (*1996*). Total anthocyanin content was measured on λ=530 nm with the method of Füleki and Francis (*1968*) by Hydrochloride-ethanol colour extraction. U-2800A spectrophotometer was used for this purpose. Polyphenol content was measured on λ=765 nm in the presence of Folin-Ciocaltens reagent. For this measurement gallic acid calibration curve was used according to the method of *Singleton & Rossi (1965)*.

Sugar and acid fraction of sour cherry varieties were measured with HPLC during the ripening process.

In order to determine sour cherry ripeness we used the colour changes of the skin. Colour of the varieties was guesstimated from the beginning of ripening to the time of harvest. Colour scale Ctifl – elaborated for sweet cherries – was used for this purpose. Konica-Minolta Cromameter CR 400 was used in order to refine the guesstimated values.

Harvesting experiments were carried out in Érd Ltd. 'Érdi bőtermő' and 'Kántorjánosi 3' were harvested in commercial orhard planted in 1996–97. 'Érdi jubileum' and candidate IV-3/48 were harvested in test plots. The latter two has outstanding inner content values. According to our 2007 harvesting experiment 'Maliga emléke' proved to be unsuitable for machinery harvest. That is why we skipped this variety in the further shaking experiments.

Variety suitability for machinery harvest was determined by damage-examination on the fruits harvested with harvester on frequency 720 min^{-1}.

Our base orchard was in Érd Ltd, and the examinations were extended to the fruit orchards of Agárd Fruct JSC. (2007–2008), and sour cherry orchard of Vitamór Ltd. (2009).

Results

Sour cherry candidate submission for state approval

Self compatible sour cherry hybrid IV-3/48 was submitted for state approval. Its fruits are small (4g), skin and flesh dark red, dyeing fruit juice. Important antioxidant values: anthocyanin content: 400 mg/100g; polyphenol content: 500 mg/100g (outstanding high). Great value of the genotype is its early ripening (end of May). Its suitability for industrial process is under estimation in Vitamór Ltd. under semi-industrial conditions. There is a great interest for the variety right away; as according to its early ripening, the season in sour cherry processing industry may begin 3 weeks earlier.

Determination of the optimal machinery harvest time for sour cherry varieties with consideration of the force required to pick fruits and some important inner content parameters

Antioxidant compound changes of the involved sour cherry varieties during ripening process were determined by the total anthocyanin- and polyphenol content and water soluble antioxidant capacity (FRAP) *(Figure 1, Tables 1–3)*. Investigated sour cherry varieties contain antioxidant compounds in high concentration. Anthocyanin content and water soluble antioxidant capacity of 'Érdi jubileum', 'Érdi bőtermő' and IV-3/48 inreased significant during ripening. On the other hand no significant changes in water soluble antioxidant capacity of 'Maliga emléke' was measured. A decreasing trend was measured in the case of 'Kántorjánosi 3' in consideration of polyphenol, anthocyanin and water soluble antioxidant capacity during ripening. 'Érdi jubileum' and IV-3/48 had outstanding polyphenol and anthocyanin content.

For testing fruit removal force we developed SZ-T05 digital dynamometer. The instrument was tested on 3 varieties in 2007. Fruit removal force changes during ripening were measured in 2008–2009.

Instrument parts: manual dynamometer unit, commutable hook, battery charger

Technical data: measurement range 10.0 N; scale 0.01 N; accuracy 0.5%

Fruit removal force, fruit weight and some important inner content value are shown in *tables 1–3*. (separate table for each variety).

In the case of IV-3/48 fruit removal force did not decrease under 1 N as the fruits fall down with stalks together. On the other hand Brix%, anthocyanin and polyphenol content increased. The most important antioxidant compound reached outstanding high values at harvest time (harvesting date labelled with asterisk) compared to the other sour cherry varieties *(table 1)*.

Table 1. Fruit removal force and inner content changes in candidate IV-3/48 during ripening.

Date of measurement	Fruit removal N	Fruit forceweight g	Anthocyanin mg/l	Polyphenol mg/l	Brix %	acid %
2008.05.29	-	4,43	250,0	305,2	12,9	1,01
2008.06.03*	1,62	4,83	417,5	475,4	15,2	1,03
2009.05.19	1,54	3,17	150,0	244,1	10,0	1,23
2009.05.25	1,53	3,89	307,5	449,2	12,5	1,04
2009.05.27*	1,29	3,84	482,0	527,2	12,0	1,01

Table 2. Fruit removal force and inner content changes in 'Érdi jubileum' during ripening

Date of measurement	Fruit removal N	Fruit forceweight g	Anthocyanin mg/l	Polyphenol mg/l	Brix %	acid %
2008.06.03	2,05	4,81	220,0	258,4	15,2	1,73
2008.06.06	1,55	5,61	225,0	253,2	16,2	1,61
2008.06.09	1,36	6,11	232,5	282,7	15,3	1,56
2008.06.13*	1,10	5,97	228,7	338,8	15,3	1,41
2009.05.28	2,47	3,82	150,0	213,8	16,5	2,28
2009.06.02	1,99	4,88	200,0	274,4	17,0	2,13
2009.06.05	1,51	5,00	272,5	319,4	19,5	1,97
2009.06.08*	0,99	5,42	325,0	340,9	19,0	1,97

Table 3. Fruit removal force and inner content changes in 'Érdi bőtermő' during ripening

Date of measurement	Fruit removal N	Fruit forceweight g	Anthocyanin mg/l	Polyphenol mg/l	Brix %	acid %
2008.06.12	1,64	6,05	89,0	173,6	12,5	2,78
2008.06.16	1,23	6,33	161,0	215,2	13,6	2,41
2008.06.19	0,59	6,35	175,0	223,4	13,6	2,47
2008.06.23*	0,74	6,92	192,0	286,3	15,3	2,11
2008.06.26	0,62	7,19	195,0	310,9	15,4	1,78
2009.06.05	1,52	5,03	115,0	203,9	16,5	1,81
2009.06.08	1,20	5,86	174,0	247,5	18,0	1,65
2009.06.11	1,00	5,88	198,7	296,9	17,5	1,65
2009.06.15*	0,90	6,32	214,3	322,1	19,0	1,42
2009.06.22	0,79	6,39	211,1	422,3	19,5	1,26

Ripening time of 'Érdi jubileum' in 2009 began earlier than in other years. Fruit removal force approximated 2.5 N on 28th May, than decreased gradually under 1 N till the time of machinery harvest; 8th June *(table 2)*. Inner content values were the most favourable in 2009; antioxidant content increased constantly, and refraction reached favourable values as well.

Fruit removal force decreased under 1N till the time of harvest in the case of 'Érdi bőtermő' *(Table 3)*.

By that time anthocyanin content reached the maximum value. According to our experiments the optimal machinery harvest time is between the last two sampling date in both two years *(Table 3)*. This is the only commercial variety that can be shaked well without any chemical treatment.

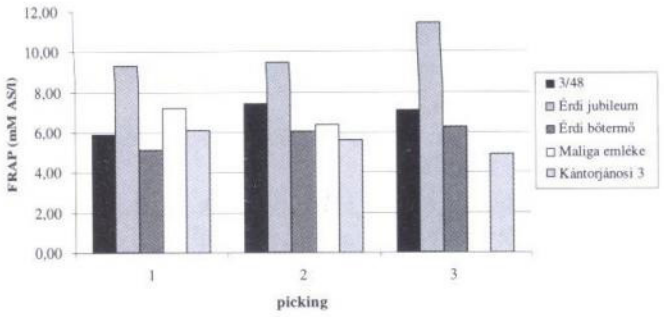

Fig. 1. Water soluble antioxidant capacity (FRAP) changes of sour cherry varieties during ripening

Ripening process of 'Kántorjánosi 3' can be illustrated well by the fruit removal force decrease *(Figure 2)*. This is the only variety in which anthocyanin and polyphenol values decreased at the end of the ripening season.

It can be stated that the machinery harvest should be started between 0.5–1.0 N, and should be finished within 4–5 days; According to the fruit removal force tests and inner content measurements carried out on 'Érdi jubileum', 'Érdi bőtermő', 'Kántorjánosi 3' varieties. During this period fruit removal force decreses further, losses by fruit drop can not be leaved out of consideration. Although anthocyanin and polyphenol content may increase; acidic content (%) shows decreasing trend which indicates the unfavourable changes in the fruit taste. Fruit weight did not change significantly between the last two sampling date.

Products with ethylene agent are widely used in connection with machinery harvest (Ethrel, active agent: 40% etefon). Effect of ethrel treatment on fruit removal force was investigated in 2009 for all varieties. *Fig. 2.* shows the results of the treatment on 'Kántorjánosi 3'. It can be stated 5–7 days after the treatment the fruit removal force decreased significantly (under 0.6 N). In the case of candidate IV-3/48 fruit removal force did not decreased under 0.8 N even after the treatment. As a result of ethrel treatment, high ratio of the fruits (79%) falls from the trees without stalk. According to the two yeard of investigation the proper time of the treatment is at 2–2.5 N fruit removal force. Thus fruit removal force measurement can be used well for determining the proper time of chemical treatment.

Colour changes of sour cherry varieties during ripening

Hundreds of colorimetric measurements were carried out in the case of each sour cherry variety and picking time. Discriminance-analysis were used to decide wether the Ctifl

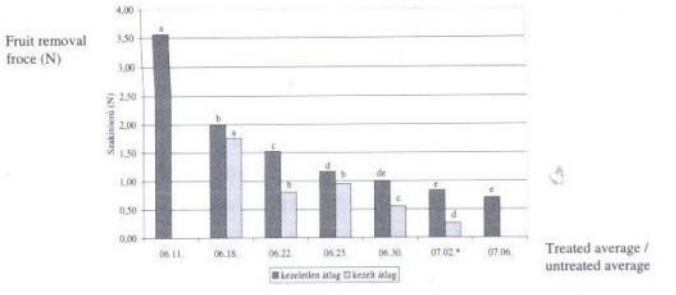

Fig 2. Fruit removal force changes between the fruit and tha stalk; during ripening in the case of Ethrel treated and untreated 'Kántorjánosi 3' trees. (*: the day of shaking)

colourcard-system elaborated for sweet cherries is equivalent with the colorimetric measurements. It turned out that a specific colourcard is needed for sour cherries. For this reason we divided the measured lightness values (L=20.29-44.28) into 7 equal ranges, as lightness is the most-significant colour feature. Than fruits colour values were averaged in each range. According to this we attained 7 reference colours *(Table 4)*, which were printed digital tehnology.

Table 4. Reference colours for sour cherry colour scale

category	Average L*	Average a*	Average b*
1	22.714	11.872	2.667
2	25.711	12.412	2.882
3	28.347	17.345	4.764
4	32.038	27.527	10.531
5	35.574	34.685	15.943
6	38.348	36.605	19.440
7	43.016	43.750	25.445

Sugar and acid fraction changes in sour cherry varieties during ripening

Carbohydrate fractions (glucose, fructose, and D-ribose) of sour cherry varieties were determined with HPLC method. Carbohydrate fractions increasment during ripening is sutifiable in the case of all investigated sour cherry varieties. Fruits contained glucose in the highest concentration while D-ribose in the lowest among the detected fractions. 'Érdi jubileum' contained the detected sugar fractions in the highest concentration. Acid fractions (malic acid, succinic acid, tartaric acid and fumaric acid) were determined also with HPLC method. Acid fraction concentration of the fruits decrease during ripening in the case of each acid type. Sour cherry fruits contain malic acid in the highest concentration.

Our results of sugar and acid fractions are reported in other international journal.

Evaluation of agro-physical attributes and suitability for machinery harvest of sour cherry varieties

When investigating agro-physical attributes we stated that the differecce between cracking and yield point is multiple in the case of 'Érdi jubileum' and 'Érdi bőtermő' (1.93 N and 1.49 N respectively), than in the case of 'Kántorjánosi 3' and 'Maliga emléke'. Varieties with higher values can tolerate more mechanical stress without cracking and juice flow; which is an advantageous feature at machinery harvest. Machinery harvested fruits were softer than the fruits hand picked in case of both firmness feature. Machinery harvested fruits are exposed at least 4–6 force stesses (on the tree, on the trash, on the conveyer etc.) till they get into the boxes; which nac result in deformation and softening. These experiences are confirmed with fruit damage investigations: samples taken from the boxes contained 20% more damaged fruits than on the trash. It was important to divide the fruits with small damage (skin tear less than 2 mm around the stalk). These fruits are still suitable for industrial process, although it turns our attention to the importance of the possible shortest processing time.

Conclusion

New scientific results

- We determined the changes of inner content values – important in human health care – during ripening in the case of 4 important sour cherry varieties ('Érdi jubileum', 'Érdi bőtermő', 'Maliga emléke', 'Kántorjánosi 3') and a candidate submitted for state approval (iV-3/48). These inner content values are water soluble antioxidant capacity, anthocyanin-, polyphenol-, vitamin C, sugar and acid content.
- We determined the most important features for the industrial process (refraction, pH and acidic content and sugar fractions).
- We stated that 'Érdi jubileum' and candidate IV-3/48 according to their inner content values are suitable for high quality products (containing real fruit material in high proportion).
- We proved first the antibacterial effect if sour cherry fruit.
- Submission of sour cherry candidate (IV-3/48) for state approval.
- Optimal harvest beginning and period can be determined with the fruit removal force. In this period the fruit growth stops, juiciness ratio does not change, refractions are approximately equal, acidic content turns to decreasing trend. However the proportion of anthocyanin and polyphenol can still increase. Fruits harvested in this period fulfil a wide range of industrial process opportunities.
- A 7 degree colour scale was elaborated for the Hungarian sour cherry varieties.

Results utilizable immediately in practice

- Machinery harvest technology elaborated for sour cherry varieties for industrial process.
- Prototype of a digital dynamometer, three years testing on sour cherry varieties

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