Doctoral (PhD) thesis

HEALTHCARE AND USAGE VALUE OF HUNGARIAN BRED APPLE AND SOUR CHERRY VARIETIES ON THE BASIS ON FRUIT ANALYSIS

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1. INTRODUCTION

So-called civilian diseases mean more serious problems on the basis of speeded up lifestyle of today and unhealthy nutrition. The medical sciences show a keen interest in phytho-nutriens because this science prefers disease prevention instead of therapy. International research's results confirm beneficial effects of fruit species on human health.

Fruits of apple and sour cherry can be eaten in unlimited quantity for people who suffer from different illness (for instance obesity, diabetes, intestinal problems). Both fruit species have curative effects which can be utilized in the common therapy. Beside of fresh consumption both fruit species are suitable for producing products having functional effects.

Ecological conditions of Carpathian basin are excellent for growing apple and sour cherry which is confirmed by growing traditions, great number of landscape selected varieties and plenty of varieties' different shapes. Both fruit species can be grown safety and apples and sour cherries, were grown among Hungarian climate conditions, have special aroma and excellent fruit quality. Thanks to these reasons apple is grown in the largest volume of Hungary which is followed by plum and sour cherry. Volume of sour cherry is total production of plum nearly.

Fresh consumption of fruit species having significant biological activity as well as breeding for industrial purposes becomes ones of the most important aims in the future. There are some breeding workshops for creating novel apple and sour cherry varieties in Hungary. Creation of new Hungarian apple assortment's means breeding of novel resistant and tolerant apple varieties coming out from breeding workshop of Department of Fruit Sciences of Corvinus University of Budapest. Hungarian sour cherry varieties usage is supported by long-term cross breeding carried out at Research Institute for Fruitgrowing and Ornamentals Budapest-Érd as well as landscape selection made by Research Institute for Fruitgrowing in Újfehértó.

On one hand, I would like to add more information to purposeful breeding work on the basis of my research's results. On the other hand, I would like to popular health-conscious diet with some basic information. My null hypothesis is to decide whether apple or sour cherry varieties could be the important keystones in health-conscious diet of Hungarian society.

2. RESEARCH AIMS

My PhD research focuses on apple and sour cherry. Both fruit species play an important role in Hungarian fruit production on the basis of economical and human physiological reasons. On the one hand, aim of my research is to compare Hungarian bred multi-resistant **apple** varieties, candidates, and commercial standard varieties by their healthcare compounds as well as their eating quality and their food industrial value. On the other hand, I dealt with complex evaluation of **sour cherry** varieties to give useable results for science and practice using the following examinations:

- Detection and comparative mathematical evaluation of physical parameters (size and weight parameters, flesh firmness, color) of novel bred multi-resistant apple varieties (‘Artemisz’, ‘Cordelia’, ‘Hesztia’, ‘Rosmerta’) and candidates (MT-01, MT-11, MT-12, B-403) as well as commercial varieties (’Gala’, ’Watson Jonathan’, ’Idared’), furthermore, some important Hungarian sour cherry varieties (’Érdi jubileum’, ’Érdi bőtermő’, ’Maliga emléke’, ’Kántorjánosi 3’) and IV-3/48 candidate having effects on market value of the fruits.
- Examination and mathematical evaluation of inner content value having effects on utilization and taste value (refraction, titratable acid content, sugar/acid ratio, carbohydrate and acid fractions). In the case of apple samples were taken at the optimal ripening time, in the case of sour cherry samples were collected during the picking period.
- Changing of antioxidants and other biological active compounds (polyphenol and anthocyanin content, water soluble antioxidant capacity as well as pectin and mineral content) in the obtained years. In the case of apple samples were taken at the optimal ripening time (between 2007 and 2011), in the case of sour cherry samples were collected during the picking period (between 2007 and 2010) and during the whole ripening period (2008).
- Examination of storage’s effects on changing of novel multi-resistant apple varieties’ fruit quality having a comparative evaluation were carried out to susceptible and resistant control varieties.
- Detection and mathematical modeling of examined sour cherry varieties’ anthocyanidin profile
- Clarification of sour cherries’ role in the mouth hygiene.
- Optimization of sour cherry picking time by physical parameters and inner content value.
- Creation of color scale for apple and sour cherry to determine their optimal picking time.

3. MATERIAL AND METHOD

3.1. Origin of research material

Research material was from two fruit sites. Apple samples were collected from Research and Experimental Farm of Department of Fruit Sciences of Corvinus University of Budapest's Factulty of Horticultural Sciences (hereafter orchard in Soroksár). Sour cherry samples were taken from Experimantal Fields (in Érd-Elvira major) of Research Institute for Fruitgrowing and Ornamentals Budapest-Érd.

3.2. Examined varieties

Fruits of Hungarian bred multi-resistant apple candidates and hybrids (MT-01, MT-11, MT-12, B-403) as well as novel Hungarian bred multi-resistant ('Artemisz', 'Cordelia', 'Hesztia', 'Rosmerta') and commercial varieties ('Gala', 'Watson Jonathan', 'Idared', respectively in storage trials 'Prima') were examined in our trials. Furthermore, self-fertile sour cherry varieties' fruits ('Érdi jubileum', 'Érdi bőtermő', 'Maliga emléke', 'Kántorjánosi 3') and IV-3/48 candidate's fruits also were involved in our experimentation.

Sour cherry orchard in Érd-Elvira major was in the 10^{th} to 14^{th} leaves during our study (between 2007 and 2010).

Apple fruit samples were picked by hand at the optimal ripening time from 4 trees of each variety. Sour cherry samples were collected from 8 to 15 trees of each variety by hands, from all four points of compass (between 2007 and 2011).

3.3. Methods of fruit analysis

Physical parameters (weight, size parameters, refraction, flesh firmness, color) and inner content value (FRAP value, polyphenol, pectin, mineral and total acid content, sugar and acid compounds) of involved apple varieties were determined at the optimal picking time (between 2007 and 2011). Furthermore, changing of new resistant varieties' color parameters as well as refraction and total acid content were tracked during the fruit ripening period. Storage ability of resistant as well as resistant ('Prima') and susceptible ('Watson Jonathan') control varieties' fruit was also examined. During the examination fruits were stored in controlled atmosphere cold chambers (on 2 to 3 ˚C, 85 to 90 % air humility content) for four month (in 2010).

Main physical (fruit weight and fruit size parameters, refraction, color of fruits) parameters and inner content value (FRAP value, polyphenol, anthocyanin, mineral and total acid content) of sour cherry varieties' fruit were determined during the harvest time between 2007 and 2010.

Samples were taken in three times during the whole picking period. Changing of fruits' anthocyanidin content and sugar and acid compounds were trucked during the whole ripening period from beginning of ripening (when color of fruits changed from green to yellow) till overripe status in nine picking times.

Effects of sour cherry on human's saliva bacteria flora were also studied using agar diffusion method. Furthermore, MIC and MBD values as well as time-related effect of bactericides were also determined. Effect spectrum of sour cherry juice was tested on well-know opportunistic and pathogen strains and two other beneficial strains.

3.4. Statistical evaluation methods

Statistical analyses of data were full fielded by PASW Statistic 18 program. During the statistical analysis some statistical models were used, the chosen models depended on sample size, equality of deviations as well as distribution analysis.

ANOVA – analysis of variance was used to evaluate size and weight parameters of sour cherry varieties because sample number was big and data had normal distribution.

Non-parametric models were chosen to analyze water soluble antioxidant capacity, polyphenol, anthocyanin, water soluble dry matter and titratable acid content of sour cherry varieties because sample size was small. Among non-parametric models Kruskal-Wallis and Mann-Whitney tests was used during statistical analysis.

Using multivariate regression analysis changing of anthocyanidin, sugar and acid compounds were characterized during whole ripening period. Determination of model having best goodness-of-fit was decided by ordinary least squares so difference of sum of squared real and estimated values was minimal.

To compare apple varieties hierarchic cluster analysis was used on the basis of examined years' data. Results were illustrated on dendrograms.

Color coordinates (L*, a*, b*) of apple and sour cherry varieties, measured during the ripening period, were grouped by their Euclidean distance using K-mean method. Goodness of grouping was confirmed by discriminate analysis.

4. RESULTS AND CONCLUSIONS

4.1. Characteristics, which determine consumer preference and processing possibilities

4.1.1. Valuable characteristics of apple varieties

Today there are some foreign bred resistant apple varieties, which are available for growers however these varieties don't have big ratio in practice apart from some exceptions (e.g. 'Florina', 'Prima'). On one hand, reason of this can be explained by lack of marketing. On the other hand, reason also can be that early ripening resistant varieties introduced first in the production had poor fruit quality. Hungarian apple growing having varieties with excellent fruit quality should be competitive on home and international markets both fresh consumption and food industrial purposes. Comparison of novel bred resistant varieties as well as selected hybrids and well-known, wide-spread varieties in the Hungarian apple production was reasonable because of above mentioned fact.

We can state that fruit weight (139 to 269 g) of examined apple varieties vary on a very large scale, from the small size (MT-01, MT-11) to the very large size ('Cordelia') all size categories can be found. Except apple chips production processing industry doesn't have any demand on fruit size but fruits belong to different size categories are suitable for different consumer sections' demand.

There are basically different demands on varieties are suitable for fresh consumption and industrial processing. Apple's consumer preference is determined by harmonious taste depend on sugar/acid ratio principally (Harker et al 2002). On the industrial processing's (concentrate, juice, puree, dried fruits) point of view other factors (susceptible to breakdown, acid, pectin and polyphenol content) play an important role (Nótin et al 2011.). Resistant varieties (13.38 to 14,12 Brix%) and selected hybrids (13,15 to 14,62 Brix%) have higher refraction value compared to 'Idared's and 'Gala's as well as 'Rosmerta' nears 'Watson Jonathan's refraction value. Acid content of examined varieties varied on a large scale (0,31 to 0,94%). Acid content of MT-01 and 'Gala' was similar to each other, both had low acid content but resistant 'Hesztia' and 'Rosmerta' neared, 'Artemisz' and 'Cordelia' exceeded acid content of 'Watson Jonathan', which is suitable for juice making.

For instance, there is a close correlation between ripening processes between chlorophyll degradation and biosynthesis of color pigments and development of fruit color. Our results confirmed that there is a lineal regression between changing of sugar and acid content as well as

sugar/acid ratio and changing of color parameters (L*, a*, b*) during ripening period. So, optimal ripening status, which is marked by a color card on the basis on optimal sugar/acid ratio, can be determined.

Apple's flesh firmness has an important role because of food industrial point of view so varieties with firmer fruit flesh can be mostly pressed better. Demands on industry are firm tissue (Stégerné 2007) but flesh texture has effects on consumption characteristic value and storage life as well. There were big differences in flesh firmness of examined apple varieties, all had enough firmness. 'Artemisz' (7,9 kg/cm^2) and 'Cordelia' (8,28 kg/cm^2) had extreme high flesh firmness but low flesh firmness of 'Rosmerta's fruits give possibility to produce different food industrial products (e.g. concentrate, puree).

Conclusions cannot say about changing of texture during the storage because we have just one year data. But it can be stated that all resistant varieties' flesh firmness had similar or better parameters compared to control varieties both at optimal ripening time and during the whole storage.

4.1.2. Valuable characteristics of sour cherry varieties

Examined sour cherry varieties' fruit weight increased intensively in the first half of ripening which slowed down as well as stopped in the second half of mature. There was a huge variability in examined sour cherry varieties' fruit weight. IV-3/48 (4,28 g) had the smallest fruit weight, which is followed by 'Érdi jubileum' (5 g), 'Kántorjánosi 3' (5,3 g) and 'Érdi bőtermő' (6,2g) in increasing order. 'Maliga emléke' (7,3 g) had the largest fruit weight in our trial. Consumer's preference is determined by fruit size significantly but IV-3/48's early ripening time offsets to its small fruit size. This hybrid is suitable for some special processing possibilities (e.g. sour cherry in cognac covered by chocolate) because of its small fruit size.

Refraction value of 'Schattenmorelle', 'Gerema', 'Újfehértói fürtös', 'Cigány 7' and 'Stevnsbaer Brigitte' sour cherry varieties were determined by German researchers (Bonerz et al,. 2007). Their results (13,84 to 17,18 Brix%) were similar to our results (10 to 20 Brix%) but German scientists' results showed smaller range because samples were collected just at optimal ripening time for processing industry, German researchers didn't track changing of Brix values during the whole ripening period. On the basis of our results refraction increased continuously during the whole picking time, this phenomenon was similar to marasca-type (*Cerasus marasca rect*) sour cherries (Pedisić et al., 2007). However, refraction of Hungarian bred sour cherry

varieties was much lower (10 to 20 Brix%) compared to marasca-type sour cherries (17 to 26,5 Brix%) because of their different genetic background.

According to our results titratable acid content of included sour cherry varieties decreased during the ripening time. There were significant differences in total acid content, which was similar to water-soluble dry matter content, was modified in different degree by year. High sugar content of 'Érdi jubileum' coupled to high acid content but sweet taste of IV-3/48 was thanked to high sugar content and low acid content. Fruit of 'Kántorjánosi 3' were acidic because this variety had high acid content (1,3 to 1,6 %) beside of low sugar content (14 to 15 Brix%). This acidic taste is better than acidic taste of 'Schattenmorelle' because the German variety had low sugar (13,8 Brix%) and high acid (1,8 %) (Bonerz et al., 2007).

We stated that increasing of fruit weight wasn't significant in the second half of ripening. In this stage of ripening sugar/acid ratio, which is typical for the variety, becomes stabil, refraction values are quite similar to each other and intensity of acid content's decreasing is slowing down. Increase of sugar compounds of examined sour cherry varieties showed a Brody model during the ripening. The highest glucose, fructose and saccharose content was in fruits of 'Érdi jubiluem', 'Maliga emléke' and 'Kántorjánosi 3' had the lowest sugar content. The most important acid compound of sour cherry is malic acid but there is a lot of difference in its quantity. Concentration of other acid compounds also showed huge variability. Graphics, which describe changing of sugar and acid compounds, confirm that sugar content doesn't increase and acid content doesn't decrease significantly after 80 % of ripening. This phonological stage is ideal for processing industry. On the basis of these results optimal sour cherry picking time is between second and third picking. This is confirmed by fruit removal force measurements made by Mrs. dr. Kállay at the Research Institute for Fruitgrowing and Ornamentals Budapest-Érd. Furthermore, it is fact that during late shaking when the fruits are ripen than 80 % ratio of damaged fruits decrease notably, which permit of shipping with bigger juice loss (Kállayné et al., 2010).

4.2. Characteristics of fruit species having determined role in healthcare

4.2.1. Healthcare value of apple varieties

Pectin content of apple varieties influences not only on fruit flesh consistency and storage life but this compound means its most important healthcare value (Nara et al., 2001, Billy et al., 2008). 'Gala', 'Watson Jonathan', MT-01 and MT-11 had low pectin content. Fruits of 'Artemisz', 'Hesztia' and 'Rosmerta' contained similar pectin content like 'Idared' (0,76 %).

‘Cordelia’ fruits (0,86 %) had an outstanding pectin content, which was similar high like its flesh firmness. However resistant apple varieties had similar pectin content like ‘Idared’ but their values were higher compared to pectin content of ‘Watson Jonathan’ and ‘Gala’. ‘Cordelia’, B-403 and MT-11 can have an important role in healthcare nutrition because of their outstanding pectin content.

Beside of high pectin content apple has a beneficial effect on human body thanks to its polyphenol content. Our polyphenol results (194 to 479 mg GS/l) were nearly similar to results (99 to 451 mg GS/l) of hybrids and commercial varieties derived from Canadian breeding program (Khanizadeh at al., 2008). Sanoner and his research group (1999) measured higher and extraordinary unbalanced values in cider hybrids’ and varieties’ fruits (110 to 600 mg GS/l), which were from France breeding program. Furthermore, Petkovsek and his colleagues (2007) also had similar results (215 to 652 mg GS/l) to Sanoner and his research group’s results, they examined pectin content of scab resistant and sensitive varieties’ fruits. On the basis of our results the lowest value was 107 mg GS/L (on ‘Gala’) while the highest value was 392 mg GS/l (on ‘Hesztia’) in average of three years. Difference was 3,6 times.

FRAP value showed similar differences compared to polyphenol value. The lowest FRAP value was produced by ‘Gala’ (0,47 mmol AS/l), MT-01 had the highest one (1,44 mmol AS/l). Antioxidant capacity of both varieties showed more than treble differences. All examined samples derived from Research and Experimental Farm of Soroksár so fruit site conditions were same therefore it can be considered that genetical background of variety determines its antioxidant characteristics basically. There are some research on studying relationship between resistance determined by genes and quantity of antioxidant compounds (Treutter, 2005, Petkovsek et al., 2007). According to Usenik and her research group’s results (2004) polyphenol concentration of apple fruits determines degree of its resistance/sensitivity to *Venturia inaequalis*. Total flavanols content of scab resistant apple varieties was three times higher than sensitive varieties’ by Treutter and Feucht’s results (1990).

It can be stated that resistant varieties have higher polyphenol content compared to commercial varieties and their FRAP values near as well as in the case of some resistant varieties exceed significantly the sensitive varieties. ‘Hesztia’ and MT-01 can play an important role in healthcare nutrition in the future due to their antioxidants. Among the resistant varieties ‘Artemisz’ had the lowest polyphenol content and FRAP value, both were similar to commercial cultivars. Because of low polyphenol content and FRAP value ‘Artemisz’ is suitable for dried fruit production due to having less taste for breakdown.

Petkovsek and his research group (2007) measured malic (5,02 to 12,82 mg/ml) and citric acid content (0,049 to 0,209 mg/ml) as well as glucose (9,41 to 38,03 mg/ml), fructose (51,94 to 89,79 mg/ml) and sorbitol content (2,66 to 10,9 mg/ml) of resistant and sensitive apple varieties. These compounds were examined by our research group too. All examined apple varieties have favorable fructose/glucose ratio therefore these varieties have an important part in dietary. MT-01, 'Cordelia' and 'Hesztia' resistant varieties can play an important role in dietary of diabetes due to their sugar compounds.

To have much more complex picture about healthcare value of fruits mineral content of apple varieties and hybrids, which fill a part in ion-exchange of human body and antioxidants' protection mechanisms, were examined only in 2011. Examined fruits have an alkaline effect on of human body as well as maintenance of Na/K ratio because of their extreme high K content (96 to 178 mg/100g). MT-11 had the highest K content (178,71 mg/100g), which was almost double than in the fruits of 'Gala' (98,98 mg/100g) and 'Prima' (96,44 mg/100g) varieties. Samples consisted of iron, zinc, copper and manganese in small quantity, these elements are necessary for production antioxidant enzymes. We can consider that mineral content of examined resistant apple varieties and hybrids nears and in some cases exceeds mineral content of commercial varieties.

4.2.2. Healthcare value of sour cherry varieties

It is important to determine optimal picking time of fruits, which are used as raw material for producing food industrial products having functional effects, from aspects of nutritional biology and human physiology. This determination can be fulfilled by measuring of biological active compounds e.g. measuring of antioxidants compounds' quantity.

Sour cherry's total antioxidant status can be well characterized by total polyphenol, total anthocyanin and water soluble antioxidant capacity (FRAP). Value of sour cherry's polyphenol content stays within the large range of 160 to 527 mg GS/100g and it increases in notable degree during the ripening period. Fruits of 'Érdi jubileum' and IV-3/48 had outstanding polyphenol content. Pedisić and his research group's results (2007) measured big differences in antioxidants' quantity derived from different fruit sites. Furthermore, this research group confirmed increasing of antioxidants during the ripening period. These results prove that formation of antioxidant compounds depend on cultivar, fruit site conditions, maturity status and effects of examined years significantly.

There are a lot of methods to determine antioxidant capacity of fruit species in the literature (e.g. FRAP, TEAC, ORAC, CUPRAC) but results of different methods can't be compared to each other. Papp and her co-authors (2008) used FRAP method, which was chosen by ourselves too, and they got similar results in 'Érdi bőtermő's fruits like us.

Hungarian bred sour cherry varieties have higher anthocyanin content compared to Western-European and American sour cherry varieties (Kirakosyan et al., 2009) but this compound shows a big variation on a large scale as well as fruit site has an important effects on the antioxidant capacity (Papp et al., 2008). Wang and his research group (1997) confirmed that total anthocyanin content of 'Újfehértói fürtös' (its brand name in the USA is 'Balaton') was six times higher compared to American 'Montmorency' variety. Examined sour cherry varieties had high polyphenol and anthocyanin as well as FRAP content, which showed in intensive increasing except 'Kántorjánosi 3' during the ripening period. There are big differences among varieties and crop years, which have different effects on varieties. 'Érdi jubilem' showed stabile results year by year but inner content value of 'Érdi bőtermő' was influenced in high degree by effect of examined years on quality.

Fruits of IV-3/48 and 'Érdi jubileum' had outstanding antioxidant content in point of view of polyphenol and anthocyanin content but candidate's results was influenced in high degree by crop years. Antioxidant parameters of 'Érdi bőtermő' neared this value as long as fruits of 'Maliga emléke' and 'Kántorjánosi 3' contained much lower antioxidant content.

Beside of antioxidant compounds' examinations another aim of our research was to track changing of sour cherry fruit color during the whole ripening period because fruit skin color, which shows a close correlation with anthocyanin content, is one of the most important indicators of ripening status. There was a negative logarithmic correlation (R^2= 0,945) between anthocyanin content and fruit color's changing during the ripening period. Furthermore, we confirmed that changing of fruit color is continuously but it is more intensive at the beginning of picking period. Growing season has a remarkable effect on fruit color, which can realize in modification of picking date and intensity of fruit color changing. However growing season influences fruit color in second half of ripening period in small degree.

Some anthocyanin compounds of 'Schattenmorelle', 'Gerema', 'Újfehértói fürtös', 'Cigány 7', and 'Stevnsbaer Brigitte' varieties were determined in previously studies made in Europe (Bonerz et al., 2007) as well as 'Montmorency', 'English Morello' and 'Balaton' varieties' anthocyanin compounds were defined in American studies (Chandra et al., 1992; Wang et al., 1997). However, these research works focused mainly on determination of cyaniding-3-0-glucoside at optimal picking time. Broad-spectrum analysis of Hungarian bred sour cherry

varieties having outstanding anthocyanin content haven't happened yet. Furthermore, wide analysis of promising novel Hungarian bred sour cherry candidates hasn't fulfilled yet. This was the reason why we studied changing of some anthocyanin compounds' real quantity in important sour cherry varieties' fruits during the whole ripening period.

Notable part (80 %) of European bred sour cherry varieties' total anthocyanin compounds (569 to 858 mg/l) examined by Bonerz and his research team (2007) was consisted of cyanidin. Kirakosyan and his research team (2009) stated that about 93 % of 'Montmorency's total anthocyanidin content was total cyanidin content. In the case of 'Balaton' sour cherry variety this ratio was about 93,5 %. An outstanding cyanidin-3,5-di-O-glucoside content was measured in IV-3/48 fruits but same compound content of 'Érdi jubileum' fruits was evanescent. 'Kántorjánosi 3', 'Érdi bőtermő' and 'Maliga emléke' also had little cyaniding-3,5-O-glucoside content. In contrast to previous results (Bonerz et al., 2007; Kirakosyan et al., 2009) changing of Hungarian sour cherry varieties' cyaniding-3,5-O-glucoside content depended on variety.

Beside of cyaniding and glucosides, malvidin and pelargonidin play an important role in formation of fruits' colors. An extreme high pelargonodin-3,5-O-glucoside was measured in fruits of 'Érdi jubileum'. 'Kántorjánosi 3' contained also high but a bit less pelargonidin-3,5-O-glucose concentration than 'Érdi jubiluem'. IV-3/48 and 'Érdi jubiluem' had outstanding malvidin-3-galactozide content, the smallest concentration of this compounds was in 'Érdi bőtermő' and 'Maliga emléke'. It can be assumed that non-Morello cherries derived from another genetic centre having non-stainy juice (for instance 'Montmorency') differ from Morello cherries with stainy juice, which are from Carpathian basin (Brown et al., 1996; Tóth, 2001).

Food industrial research put an important stress on mineral content of foods during the last couple of years in special consideration of elements (Mg, Zn, Cu) having a seeded role in antioxidant protection system. Changing of minerals in sour cherry fruits hasn't examined during the ripening time yet. Our results, which were collected at the optimal ripening time, are similar to literature data (Bonerz et al., 2007, Papp et al., 2008). It was stated that there are big differences in most examined elements among the varieties and picking times. 'Érdi jubileum' and IV-3/48 had extreme high mineral content. Thanks to macro- and micro element content sour cherry varieties are suitable for supplement of human body with necessary minerals from natural source.

4.3. Antibacterial effect of sour cherry varieties

Antibacterial effect of different plant species was combined with their biological active compounds by previous scientific results (Falleh et al., 2008). Sour cherry can be a promising species by HPLC and spetrophotometric results. Our research work is the first one with aim to examine beneficial effect of sour cherry fruits on human saliva's flora. Our results disagreed with other research groups' results working on antibacterial effect of other fruit species. Nzeako and Al Hasmi (2006) reported that black currant, raspberry, mango, pineapple, guava and mixture of different fruit species' juice have no effect on *Pseudomonas aeruginosa.* Furthermore, Lee and his colleagues (2003) discovered that juice of vegetables and fruits weren't an obstructive effect on *Klebsiella pneumoniae* ssp. *pneumonia* bacterium.

Results of our research work confirmed that juices of tested Hungarian bred sour cherry varieties can kill off antibiotic sensitive *P. aeruginosa* and *K. p. pneumoniae* bacteria species, which have a very harmful effect on human body. We proved that bacteria-killing effect of sour cherry juice wasn't influenced by extreme physical conditions since these juices were effective after scalding and deep freezing. We underlined that there is a close correlation between ripening status, concentration of biological active compound in the fruits and antibacterial effect.

Our results demonstrate antibacterial effect of sour cherry fruits and differences between the varieties. Tested sour cherry varieties can play an important role in mouth hygiene thanks to their important antibacterial effect. Biological active compounds of sour cherry varieties are effective against some opportunist bacterial strains since they don't have any effects on beneficial *Lactobacillus* species therefore these compounds can be used in diary product production (for instance yoghurt production). Bacterium-killing compounds of sour cherry are also effective after scalding and deep freezing. This effect doesn't correlate to natural acid content of sour cherry therefore bacterium-killing compounds can be effective after different food industrial processes too.

4.4. New scientific results

I summarize new scientific results of my PhD study hereinafter:

1. Analysis of novel Hungarian bred resistant apple varieties and the most important sour cherry varieties having own data on their market value determined by physical characteristics
2. Evaluation and comparison of examined fruit species' value-added processing and taste value by inner content value influenced foremost in the point of view of demands of fresh consumption and processing industry
3. Confirmation of suitability for production high quality products having real fruit content and healthcare value from 'Artemisz', 'Cordelia', 'Hesztia' and 'Rosmerta' apple varieties, as well as 'Érdi jubileum' and IV-3/48 sour cherry varieties raw material.
4. Complement of Hungarian apple assortment with novel Hungarian bred resistant varieties as well as redemption of 'Jonathan' varieties by their physical and inner content value's demonstration.
5. Verification of Hungarian bred sour cherry varieties' anthocyanidin profile, which is different from foreign bred sour cherry varieties' profile and mathematical modeling of changing of some anthocyanidin compounds during the ripening period.
6. Clarification of sour cherry's beneficial role in the mouth hygiene using microbial test, confirmation of its antibacterial effect against a lot of opportunist bacterial strains, verification of saving beneficial *Lactobacillus spp*.
7. Development of color scale with 10 degrees for three novel Hungarian bred apple and five Hungarian sour cherry varieties to determine their optimal picking time. This color scale can be used in practice.

4.4. SUMMARY AND CONCLUCIONS

Scientific research has focused on free radicals' reactions and oxidative stress processes happened in human body for a long time. Composition of a suitable diet is the simplest and most effective method to support elimination system and increase its affect.

Biological active compounds and valuable characteristics of some apples and sour cherry varieties and candidates were measured in our trials. Both fruit species are grown in the largest quantity.

We declare that all multi-resistant apple varieties' inner content value near or exceed to commercial varieties' Importance of apples in healthcare can be thanked to its high pectin and polyphenol content. Pectin and polyphenol content of resistant varieties' fruits near or have higher than commercial varieties'. Therefore fresh consumption of these varieties can play an important role in healthcare nutrition.

Beside of apple consumption as fresh fruit this fruit species is important for the processing industry since it can be processed and sold in different ways by qualitative parameters.

According to expectations of food processing industry high refraction value of resistant varieties combined with high acid content. Furthermore, thanks to their favorable sugar/acid ratio these varieties have similar harmonic taste like 'Idared' and 'Watson Jonathan' commercial varieties having big importance in fresh consumption and food industrial processing. Storage of novel bred resistant varieties is similar to standard commercial varieties. Therefore fruits of 'Rosmerta', 'Hesztia', 'Cordelia' and 'Artemisz' are recommended to enrich European and Hungarian assortments for fresh consumption and choice of tastes. Based on examined parameters it can be assumed that novel Hungarian resistant varieties are suitable for juice and fruit concentrate production, due to high pectin content of their remaining pomace these varieties can be raw material of pectin production as well as they are also suitable for jam production mixed with other fruit species. Furthermore, functional food industrial product having high quality can be produced by using novel resistant varieties because of their high pectin and polyphenol content.

Beside of their high market value their suitability for growing among orchard conditions is confirmed by lower costs of production because of less plant protection treatments. 'Rosmerta' resistant variety is good for changing 'Jonathan' varieties which have a determined role in Hungarian apple production during previous decades and grown for concentrate production today. Appearance and taste of 'Rosmerta' are very similar to 'Jonathan' however this variety

has a great future in the Hungarian apple production due to its inner content value and its low costs to produce. ’Rosmerta’ can be the determined variety of the concentrate industry. New bred apple varieties having different valuable characteristics (flesh firmness, polyphenol content) can be suitable for special food industrial purposes (puree, dried fruits) however it is necessary to test their adaptability.

Color scale about determination of optimal picking time of ’Rosmerta’, ’Hesztia’, and ’Cordelia’ was worked out for practical purposes.

During previous decades we can refer to the results of fruit qualitative examinations, which the Department of Fruit Sciences’ breeding work have achieved state approved, multi-resistant new apple varieties having good adaptability to Hungarian climate conditions, are suitable for creating novel assortment. This assortment fits to 21st century’s qualitative and food safety requirements.

On the basis of our research weight accession of examined sour cherry varieties stopped at the second picking time, typical sugar acid content worked out, refraction value didn’t increased in significant degree, decreasing of acid content wasn’t important. Fruits’ biological active compounds (mineral, anthocyanin, polyphenol content, and water-soluble antioxidant capacity) were high however qualitative accessions of these compounds have not finished yet. These results complemented with results of fruit removal force examinations as well as shaking trials fulfilled at the Research Institute for Fruitgrowing and Ornamentals Budapest-Érd are confirmed that second picking time was the optimal picking time for sour cherry varieties because juice loss was notable during late picking. Fruits harvested at the optimal harvest time are suitable for fresh consumption as well as food industrial purposes and play an important role in healthcare nutrition because of their beneficial inner content value. ’Érdi jubileum’ and IV-3/48 varieties can be suggested for production of functional food.

Fruits of examined sour cherry varieties are suitable for different growing, consuming and food industrial demands. We take IV-3/48 into growers’ consideration both fresh consumption and industrial purposes because of its very early ripening time (last decade of May), its significant antioxidant content, its optimal sugar compounds and sugar acid content. Its very early ripening time assures not only high market price but also better utilization of processing machines in the food industrial factories.

All examined sour cherry varieties play an important role in healthcare and health preventive nutrition due to their high biological active compounds. Examined sour cherry varieties can be suitable for different food industrial purposes because these varieties save their

active compounds after deep freezing and boiling. Sour cherry varieties involved in our trial are suitable for food industrial production having higher quality.

It can be stated that Hungarian sour cherry varieties have outstanding anthocyanin content compared to European and American varieties. In contract of Western-European and American varieties color of Hungarian sour cherry varieties is caused by different anthocyanidin compounds appeared together at the same time. Furthermore, sour cherry varieties have unique, very varied anthocyanidin profile. It was confirmed that quantity of anthocyanidin compounds increased continuously during the whole ripening period and it reached a relative stabile value, when the ripening status was close to optimal ripening time. Fruits of 'Érdi jubileum' and IV-3/48 contained highest concentration of anthocyanidin compounds having positive effect on human body.

'Érdi jubileum' and IV-3/48 varieties can be suggested for production of functional food and natural coloring material due to their significant biological active compound content but checking of anthocyanidin compound is necessary during the whole processing process.

Sour cherry could have a more important role in mouth hygiene because of its antibacterial effect as well as consumption of this fruit species could be part of special diet after chemotherapy.

IV-3/48 candidate sour cherry variety can be put into special diet of diabetics due to its low sugar content and optimal sugar compounds. IV-3/48 also can be used as parent in breeding programs because of its very early ripening time and significant high antioxidant content.

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