Review n. 37 – *Italus Hortus* 26 (1), 2019: 41-49 doi: 10.26353/j.itahort/2019.1.xxxx

Fruit quality: updated definition and modern methods of assessment

Guglielmo Costa
Università di Bologna

Qualità delle ciliegie: definizione aggiornata e nuovi metodi di determinazione

Riassunto. L'aspetto, la dimensione ed alcuni caratteri organolettici della frutta hanno una forte influenza sull'accettazione del prodotto da parte del consumatore. I parametri qualitativi più apprezzati sono sicuramente la dimensione, la dolcezza ed il colore della buccia dei frutti. Altri parametri possono essere più o meno importanti a seconda del tipo di trasformazione a cui la frutta è soggetta. Alcuni di questi parametri, come le dimensioni dei frutti ed il colore della buccia, possono essere migliorati attraverso la tecnica colturale, per la quale riportiamo alcuni esempi (es. l'applicazione di regolatori di crescita e la realizzazione di coperture fisiche degli impianti). Infine, sono elencati i principali metodi standard e ed innovativi per la valutazione dei principali parametri qualitativi.

Parole chiave: caratteristiche qualitative della frutta, metodi per migliorare la qualità della frutta e l'omogeneità di maturazione, frutteto protetto, Fitoregolatori.

Introduction

The term quality implies the degree of excellence of a product or its suitability for a particular use. Quality is a human construct comprising many properties and characteristics that the fruits must have to satisfy the requirements and the needs of the productive chain. However, fruit quality definition is complicate since the productive chain is formed by: grower, packer, distributor, wholesaler, shopper and the ultimate consumer who eats the fruits, who have different expectations from the fruit and, as a consequence, the definition of fruit quality can not be unique.

What determines a "good quality cherry" is still an open topic, but surely the size, the flesh firmness and the sweetness of the fruit have always been fundamental characters. Does the fruit quality of the variety nowadays cultivated fits marketing and consumer expectations? Cherry breeding has been always active both at national as well as at international levels (Sansavini and Lugli, 2008; Kappel et al., 2012; Bujdosó and Hrotkó□, 2017; Dondini et al., 2018) although some of the breeding objectives still up to date are described in details since quite a long time (Bargioni, 1964). However, the most important goals have been oriented in the past and, nowadays as well, according to specific needs, recently mainly towards "Tree and fruiting structure ", "Flower characteristics ", "Tolerance to abiotic and biotic stresses ", "Extension of harvest period " to cover a larger marketing time, "Suitability for mechanical harvesting " (Quero-Garcia et al., 2017). Other objectives concerning more the fruit quality traits have been taken into consideration, such as fruit size, fruit firmness, skin and flesh colour, sugar content and flavour. It has to be underlined that significant achievements have been obtained on fruit size and firmness, and fruit cracking resistance but the increase of fruit organoleptic characters, although considered to some extent, became a primary objective only recently.

Main fruit quality parameters

The main quality parameters studied concern "fruit size", "flesh firmness", "colour of the fruit skin and of the flesh", "soluble solids content" and "aroma", although other morphological and physiological characters are important. Taking into consideration the "quality parameters" that do characterize the "ideal cherry fruit" and that are able to influence the consumers demand the following considerations can be made.

Fruit size: growth and development
Cherry belongs to Rosacee family and the fruit growth follows a double sigmoid curve as in other Prunus spp., (Coombe, 1976). Fruit growth consists of three stages. Stage I is characterized by a rapid growth due mainly to the cell division, in stage II, fruit growth diminish consistently since all the resources are diverted toward the embryo development and

* guglielmo.costa@unibo.it

the endocarp hardening (pit hardening phase). In stage III, growth becomes exponential again ending with fruit maturation and harvest (Olmstead et al., 2007). Since fruit size has a clear economic impact on crop value, several researches have been carried out to investigate the influence of some cultural management techniques and of the environmental factors on fruit size and quality (Whiting and Lang, 2004; Lenahan et al., 2006). However, breeding is certainly determinant in achieving fruits of bigger size and it is appropriate to make light on a recent breeding program carried out at Bologna University, named “30 cum laude” that aims to increase the size of the fruits up to 30-32 mm (tab. 1).

Flesh firmness (FF)

Flesh firmness and crispness are important attributes for consumer acceptability. Firmness values have been found ranging from 2.52 to 4.75 N (Hampson et al., 2014). Flesh firmness does not only influence eating quality, but it also affects fruit storage and shelf life. In fact, firmness correlates with susceptibility to mechanical damage that can occur in the field and in packing-house during fruit movement and sizing, to cope with the high speed packing lines, avoiding the later appearance of pitting on the fruits exposed in the market. Fruit firmness has been associated with several factors linked to texture, cell wall strength, cell-to-cell adhesion, and is influenced by cell wall- and pectin-related enzymes, cell turgor, and environmental conditions during maturation.

Soluble solid content (SSC)

The soluble solids are an important factor in determining consumer’s acceptability. The SSC values of the cherry fruits can reach up to 24.5g/100 g fresh weight (Crisosto et al., 2003; Valero and Serrano, 2010) as related to microclimatic conditions, rootstock selection and planting system, and the time of harvest (González-Gómez et al., 2010; Goulas et al., 2015). It is also interesting to note that the soluble solids content of the cherry grown in the recent past does not differ significantly from that of the variety grown nowadays. There are exceptions that must be underlined, i.e. the series of the “Sweet” variety of the Bologna University, whose values reach higher SSC levels than that of the variety still present on the market, although the SSC values are conjugated to high size (tab. 1) (Lugli, pers. comm).

This challenging breeding program is justified by the fact that it has also been reported that SSC must be above the threshold of 14.0–16.0 g/100 g FW to be fully accepted by the market (Crisosto et al., 2003). In the sweet cherry fruits, sweetness is determined by glucose and fructose content and the sum of the main sugars (glucose, fructose, sucrose and sorbitol) range between 125 up to 265 g/kg of fresh weight.

Titratable acidity (TA)

Titratable acidity is another important attribute in cherry, since it is directly related to the consumer’s acceptability. Titratable acidity is highly cultivar-dependent and is mainly determined by malic acid that is the main organic acid in cherry, representing the 98% of the total acidity (Valero and Serrano, 2010), although other acids (citric, succinic, shikimic, fumaric and oxalic acids) are also present (Usenik et al., 2008) and the total amount range from 3.67 up to 8.66 g/kg FW. Sweet cherries fruits reach a pH values between 3.7 and 4.2, while sour cherries range from pH 3.1 to 3.6 (Ballistreri et al., 2013; Serradilla et al., 2016).

Tab. 1- Caratteristiche qualitative dei frutti di ciliegio della serie “Sweet”, ottenuti nell’ambito del programma di miglioramento genetico dell’Università di Bologna a confronto con le cv. “Burlat” e “Lapins” assunte come riferimento. (Lugli com. pers. Data from 2016-2018).

Tab. 1 - Quality traits of the “Sweet” cherry series belonging to the breeding program of Bologna University compared with Burlat and Lapins as reference cultivars.(Lugli com. pers. Data from 2016-2018).

Cultivar	Size	Weight	IAD	Durofel	Flesh firmness	SSC (Brix°)	Acidity	L	Chroma
Burlat	25.3	9.4	0.83	57	0.28	14.8	7.6	28.9	20
Sweet Lorenz	28.8	10.7	1.73	58	0.67	19.7	7.7	26.8	15.1
Sweet Aryana	28.6	11.0	1.30	58	0.6	18.1	7.3	27.6	18
Marysa	29.2	11.9	1.4	52	0.3	14.7	9.6	28.5	23.7
Sweet Valina	30.7	14.0	1.40	61	0.29	17.5	8.7	28.6	20.4
Sweet Gabriel	30.4	13.3	2.41	64	0.42	19.2	11.2	28.1	13.6
Grace Star	32	15.9	1.51	63	0.43	19.2	9.5	28.8	18.9
Lapins	26.6	9.8	0.82	58	0.51	17.3	10.8	32.7	31.3
Sweet Saretta	31.2	14.5	2.48	57	0.42	20.8	12.3	28.9	13
Sweet Stephany	29.4	12.4	1.89	59	0.44	21	14	29.7	18.7

SSC/TA ratio

The consumers choice does not only consider the sweetness of the fruit but also the titratable acidity, and it is therefore appropriate to consider these two parameters together. Some Authors (Guyer et al., 1993; Dever et al., 1996) have found that the SSC/TA ratio is fundamental and have proposed quality standards for some cultivars capable of achieving acceptability from part of consumers. The studies evaluating the relationship between soluble solids content and acidity with soluble solids/acidity ratio pointed out that when the soluble solids values reach only the 16%, a reduction in consumer preference is determined (Crisosto et al., 2003).

Volatile compounds

The flavanoids or bioflavonoids are a class of plant secondary metabolites that include anthoxanthins (flavones and flavonols), flavanones, flavanonols, flavans and anthocyanidins. They protect against UV radiation, enzyme inhibitors, and precursors of toxic substances, flavour components and antioxidants, and they also provide pathogens resistance (Piccolella et al., 2008). The anthocyanidins are natural pigments, responsible for the attractive colour of cherries (Valero and Serrano, 2010). Their functionality in human health has been proved in numerous studies suggesting protective effects against cardiovascular diseases, cancers and other age-related diseases. These aspects have recently attracted a great deal of attention from the media and are often touted, sometimes even excessively, as "panacea" or potential control agents of some diseases. This could also be used by the agricultural world as a tool for targeted marketing campaigns.

Phenolic compounds

Phenolic compounds are doing important function contributing to several aspects of fruit quality. The composition and the concentration of these compounds are affected by several factors such as harvest time, variety, climatic conditions and growing season. Cherry polyphenols include phenolic acids (hydroxycinnamic and hydroxybenzoic acids) and flavonoids (anthocyanins, flavonols and flavan-3-ols). Those secondary metabolites are known to be involved in anti-oxidative defense against biotic and abiotic stresses such as high and low temperatures, drought, alkalinity, salinity, UV stress and pathogen attack (Viljevac et al., 2012). The skin of the cherry fruits contains the highest levels of total polyphenolic compounds. Beside positively affecting fruit aspect, colour and taste, they have a great ability to prevent degenerative diseases caused by oxidative stress, such as cardiovascular and cancer (Tomás-Barberán et al., 2013).

Flavonoids

The flavanoids or bioflavonoids are a class of plant secondary metabolites that include anthoxanthins (flavones and flavonols), flavanones, flavanonols, flavans and anthocyanidins. They protect against UV radiation, enzyme inhibitors, and precursors of toxic substances, flavour components and antioxidants, and they also provide pathogens resistance (Piccolella et al., 2008). The anthocyanidins are natural pigments, responsible for the attractive colour of cherries (Valero and Serrano, 2010). Their functionality in human health has been proved in numerous studies suggesting protective effects against cardiovascular diseases, cancers and other age-related diseases. These aspects have recently attracted a great deal of attention from the media and are often touted, sometimes even excessively, as "panacea" or potential control agents of some diseases. This could also be used by the agricultural world as a tool for targeted marketing campaigns..

Methods of fruit quality assessment

The criteria for determining fruit quality are distinguished by a degree of complexity and are represented by "visual" methods that allow evaluating the size, shape and color of the fruit. For greater precision and characterization, analytical methods are normally used to determine soluble solids content, flesh firmness and titratable acidity. These methods are practical, require "easy to use" instruments that are largely used, and can give information in real time. The quality can be determined even more precisely by defining the composition and the content of the individual sugars or acids, of the volatile substances and their identification. However, these analyzes require equipped laboratories and trained personnel and have the limit of not providing real time information. Furthermore, most analytical analyzes, regardless of their degree of precision, require the destruction of the examined fruit sample. To avoid this problem, instruments have been recently developed that do not require the destruction of the fruit sample and that can also be used throughout the production chain, in the field, in the packing-house up to the point of sale.

Fruit size

The size of the fruits is usually determined with caliper, simply represented by "a stick" (usually with a series of 8 diameters from 18 to 32 mm), or manual and digital caliper that can be also connected via bluetooth to mobile phones or computers allowing an automatic transfer of the data collected in the field on excel sheets and perform statistical analysis (fig. 1). Particular mention should be made on the development of the sorting machines from some calibrators manufacturers, who have studied and created automatic sizing machines for cherries, equipped with a system called "Cherry vision", able to detect internal and external quality of cherries (size, color, internal defects), softness, absence or less of stem, Brix degree (fig. 1).

Flesh firmness

The instruments used are penetrometers equipped with a 6 mm probe that measures the hardness of the pulp through the resistance opposite to penetration, expressing the value in kg/cm^2. There are different tools for the determination of the firmness distributed by different American and European companies.

Non-destructive devices

- Durofel measures the elasticity of the fruit epidermis, expressing it in an arbitrary unit of Durofel index values. The piston of the instrument is placed on the fruit and a pressure is exerted pressing until it disappears.
- Durometer TR is a non-destructive tool that allows evaluating the degree of ripening achieved by the fruits. The instrument is easy to use: the plunger is placed against the fruit and a progressive force is applied until the fruit is completely against the grey basement of the plunger. The value is expressed in Shore degrees, range of reference for the hardness of a material (fig. 2).
- Fruit firmer TR, developed in New Zealand that allows to quickly quantify the fruit firmness by measuring the deceleration of a small hammer that hits the surface of a fruit through a small, non-penetrating tip. An integrated processor records the collision, analyzes the waveform and displays the data collected on a digital display that can be connected to a program to record, download and analyze the data (fig. 2).

Fruit colour

- Colorimetric charts developed by CTIFL, following the progression of the epidermis color

Fig. 1 Macchine per la calibrazione delle ciliegie equipaggiate con una tecnologia (Cherry Vision 3.0) per la rilevazione automatica di dimensioni, colore e difetti interni ed esterni, ammaccature e contenuto in solidi solubili (°Brix).

Fig. 1 - Sorting, machines for cherries grading, equipped with a Technology (named Cherry Vision 3.0) for the detection of the size, color, internal and external defects, softness and soluble solids content (Brix°).

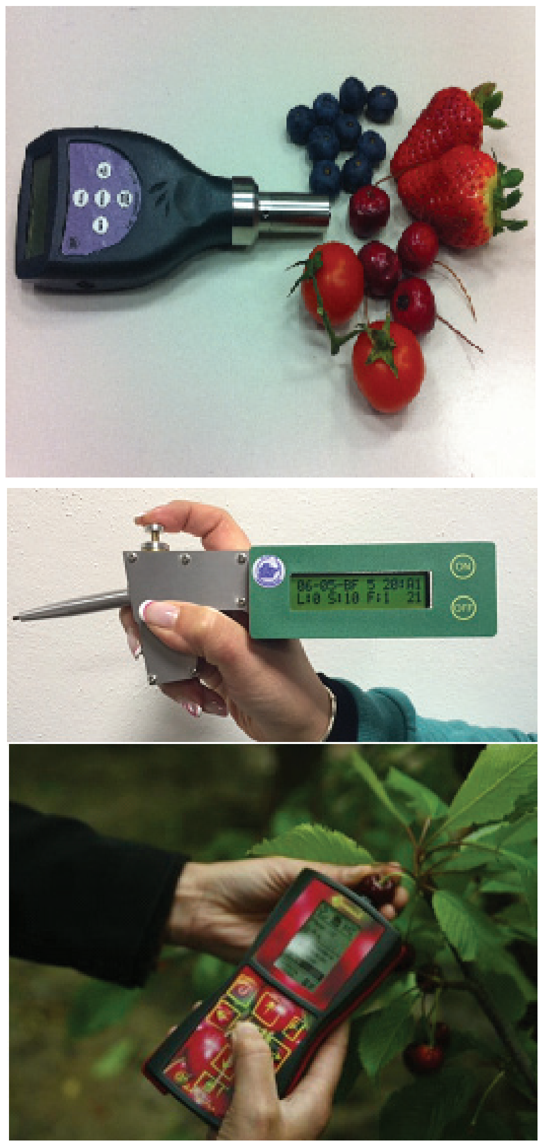


Fig. 2 - Durofel TR e Durometer TR per la misura dell'elasticità del frutto e Cherry-meter per la deterinazione del grado di maturazione (come indice IAD).

Fig. 2 - Durofel TR and Durometer TR for measuring fruit elasticity and Cherry-meter for measuring ripening (as IAD Index)

from pink (1) to red (7), allowto establish the moment of collection. Colorimeter instruments measure the color of the epidermis through three colorimetric indices, L (brightness), a* and b* allowing to calculate the C (Chroma), h° (hue) and the parameters a* and b*. The values of L* and h° decrease with increasing maturation; L*, measures the intensity of the measured surface from 0 (black) to 100 (white) while a* and b* represent the chromatic coordinates that vary from -60 to +60 respectively, describing color variations from green (-60) red (+60) and blue (-60) to yellow (+60) (Crisosto et al., 2003).
- The Cherry meter is a non-destructive instrument that can be used in field conditions on the fruits still on the plant up to storage and processing by measuring the radiation of the NIR band, more precisely the absorbance in the first layers of the fruit flesh (Fig. 2). It provides an Index, called Absorbance Difference Index (IAD), which is obtained by reading the amount of light emitted by the instrument, by three light sources reflected by the fruit at certain wavelengths: 800 nm as reference, 560 nm and 640 nm are the other two considered wavelengths. The values of IAD correlate perfectly with the main quality parameters, such as soluble solids, pulp hardness and fruit epidermis coloring (Nagpala et al., 2017a). The Cherry-meter device, besides assessing the fruit maturity, also allows to determine the fruit homogeneity and represents a potential Decision Support System to evaluate the efficacy of different cultural management techniques. .

Soluble solids content and titratable acidity

Soluble solids content is determined with portable refractometers that can also be digital. These instruments are determining the critical angle of refraction through a sample expressing the value as Brix° representing the sugar content of an aqueous solution.

Titratable acidity is determined with Titrator devices that chemically neutralize organic acids with a NaOH solution. Some of these instruments are semi-automatic allowing to perform the reading on several samples. There are also portable instruments that do allow to read Brix and acidity contemporarily.

Methods to influence fruit quality

Several researches have shown that the choices made at the moment of the orchard realization as well as some cultural management techniques are able to affect fruit aspect and quality. Below are reported some effects that can be obtained with pre-harvest application of plant bioregulators and with net or plastic films covers used to protect the orchard.

Pre-harvest treatment with Plant growth regulators

- GA: GAs are used during the transition between the pit-hardening and cell expansion phases of fruit growth and this application has become a standard practice in different production areas to positively influence the size of the fruit, while when applied later in the season, like at the beginning of stage III, it might increase the flesh firmness and the fruit size (Kappel and MacDonald, 2007; Lenahan et al., 2006). It must be underlined that, as most of the PBRs, GAs application has some collateral effects such as a possible maturation delay that might cause a reduction in soluble solids and an increase in acidity (Cline and Trought, 2007; Zhang and Whiting, 2011) and affect flower differentiation. This last collateral effect, clearly undesirable, might become interesting since reducing fruit load might consequently increase fruit size, an aspect that is recently more and more appreciated by the market. The attempts to achieve a fruit load reduction in order to increase fruit size with blossom thinners did not led to enough reliable results to be translated into practice.
- Ethephon: this ethylene releaser compound has been used on cherry for different purposes. In the 1980/1990 Ethephon was used to increase the performance of mechanical harvesting, although the effect on fruit and on tree (gummosis in some cases) (Olien and Bukovac, 1982) raised concern on its use. Ethephon might cause significantly lower soluble solids concentration and anthocyanin content, reducing the flesh firmness of the treated fruits as compared to untreated control. Ethephon is also used in combination with growth retardants to control the new vegetation and positively affect flower bud differentiation.
- Growth retardants: Paclobutrazol (commercial name Cultar) has been widely experimented in the 1980/1990 and released only in few European countries. Cultar use was interesting when no efficient dwarfing rootstocks were available, the planting density was low and the excess of vegetation was a problem. Cultar was able to effectively control the new growth and to determine some interesting effects on some reproductive aspects (flower differentiation and yield increase) either when used alone or in combination with Ethephon (Cline et al., 2005).

- Prohexadione-Ca (P-Ca, Regalis® in Europe and Apogee® in USA) is another growth retardant, acting as gibberellin biosynthesis inhibitor. This formulate was used alone or in combination with Ethehon to control the excess of vegetative vigour and to increase fruit weight and some quality traits. The results, although promising were dependent upon cultivar, plant growth regulator application rate, time and number of applications (Elfving et al., 2003, 2005; Guak et al., 2005, Cline 2017).

More recently, other PBRs such as abscisic acid and 1-aminocyclopropane-1-carboxylic acid (ACC) have also been experimentally tested in our cherry growing areas. Although preliminary research has shown that the formulations induced an increase in fruit size and in anthocyanins content speeding up ripening (Nagpala et al., 2017b) (tab. 2 and 3) and confirming previous results obtained in different circumstances by other researchers (Tijero et al., 2018), the results can still be considered preliminary and need to be further studied.

Another interesting effect induced by these two new PBRs is the possibility to affect the ripening homogeneity in plants. In figure 3 some effects induced by ABA application and determined with the use of the Cherry-meter are reported.

Also, some biostimulants have been capable to affect fruit ripening and homogeneity. For instance, trials carried out on cvs. Georgia and Ferrovia with a biostimolant containing plant extracts, methionine, phenylalanine and monosaccharides (Sunred) allowed to increase fruit yield and quality and to induce a better fruit homogeneity as compared to control. (tab. 4 and fig. 4).

It must be underlined that the results obtained with the PBRs and the biostimulants are preliminary and need to be further studied to be confirmed, although the obtained effect on the advanced fruit ripening and homogeneity were interesting.

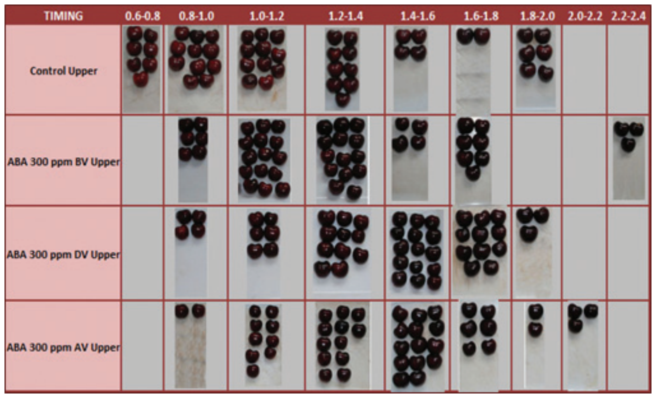


Fig. 3 - Classi di maturazione dei frutti (espresse in I_{AD}) influenzate dall'applicazione di acido abscissico.
Fig. 3- Fruit ripening classes (expressed as IAD) as affected by ABA application.

Tab. 2 - Caratteristiche qualitative dei frutti della cv Lala Star trattati con 300 ppm di ABA (acido abscissico), somministrato in diversi momenti della stagione vegetativa. Per ogni parametro, i valori seguiti dalla stessa lettera non variano significativamente (p=0.05, DMRT).
Tab. 2- Cherry fruits treated with 300 ppm ABA at different application times with their corresponding quality parameters. Means for the same quality parameter followed by the same letter do not vary significantly (p=0.05, DMRT).

Parametri qualitativi		Parte superiore dell'albero				Parte basale dell'albero			
		Controllo	Pre-invaiatura	Invaiatura	Post-invaiatura	Controllo	Pre-invaiatura	Invaiatura	Post-invaiatura
I_{AD} (A_{640}-A_{750})		1.27c	1.29c	1.50b	1.63a	1.28b	1.36b	1.66a	1.57a
Grado Zuccherino (°Brix)		117.2ab	17.12ab	17.36a	17.18b	15.82c	16.02bc	18.04a	16.59b
Croma		20.42a	18.81a	15.71b	15.82b	20.05a	18.66a	14.01c	16.75b
Contenuto in antocianine (mg/100g PF)	Polpa	40.35c	44.08c	66.90b	61.31a	43.04b	48.05b	57.31a	67.82a
	Epicarpo	68.16c	72-02c	81.50b	86.42a	71.36b	74.81b	88.52a	84.55a

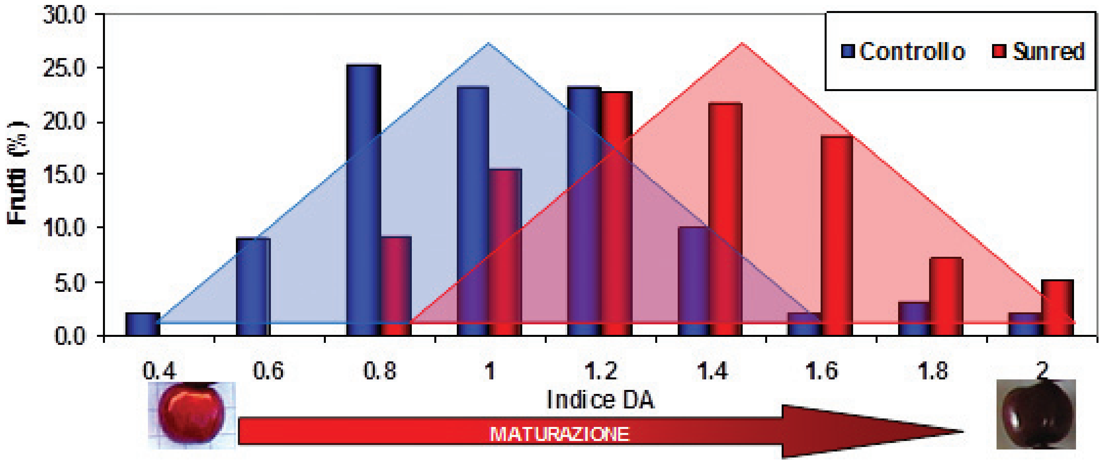
Tab. 3 - Caratteristiche qualitative di frutti di ciliegio dela cv Lala Star sottoposti a diversi dosaggi di ACC (400 and 500 ppm). Per ogni parametro qualitativo, i valori seguiti dalla stessa lettera non variano significativamente (p=0.05, DMRT).
Tab. 3- Cherry fruits as influenced by different dosages of ACC (400 and 500 ppm). Means for the same quality parameter followed by the same letter do not vary significantly (p=0.05, DMRT).

Parametri qualitativi		Controllo	200ppm	400ppm	500ppm	200ppm (applicati due volte)
I_{AD} (A_{640}-A_{750})		0.98°	1.09c	1.23b	1.26B	1.25b
Grado Zuccherino (°Brix)		14.29c	14.83bc	15.20b	15.38b	16.42a
Chroma		23.49°	22.08ab	20.26b	21.12b	20.21b
Contenuto in Antocianine (mg/100g PF)	Polpa	29.07b	31.26b	39.04a	41.24a	40.63a
	Epicarpo	55.94c	60.65b	69.60a	70.91a	70.33a

Tab. 4 – Produttività e caratteristiche qualitative di frutti trattati con il formulato Sunred. Per ogni parametro qualitativo, i valori seguiti dalla stessa lettera non variano significativamente (p=0.05, DMRT).
Tab. 4 - Yield and fruit quality traits as affected by Sunred application. Means for the same quality parameter followed by the same letter do not vary significantly (p=0.05, DMRT).

Cultivar	Produttività (kg/albero)	Peso del frutto (g)	Durezza (kg/cm^2)	Grado Zuccherino (°Brix)	Acidità (g/l acido malico)	L*	Chroma
Giorgia							
Control	51.2	6.60b	0.50b	13.93b	6.39	34.21b	29.08
Sunred	45.9	7.58a	0.54a	14.47a	7.06	35.01a	26.91
Ferrovia							
Control	19.1	10.12a	0.48b	18.88°	7.21	29.02b	20.15b
Sunred	24.6	9.11b	0.53a	15.53b	7.46	32.87a	29.51a

Fig. 4 - Distribuzione delle classi di maturazione dei frutti (espresse in I_{AD}) influenzate dall'applicazione di "Sunred" nella cv. Giorgia.
Fig. 4 - Fruit ripening classes' distribution (expressed as IAD) as affected by "Sunred" application in the cv. Giorgia



Protected cultivation

Nowadays the climatic change requires a physical protection of the orchards. A big evolution in this technique did occur in the last years since the nets, which originally were mainly designed to protect the orchards from the hail, are now multi-purposes net, thanks to plastic films of new generation that allow only to specific wavelengths to pass through, or are heat-protective, allowing not just a hail or rain protection, but also to delay or speed up the ripening or to reduce the fruit ripening variability on the tree, to increase the fruit quality and in some cases to counteract some diseases. Here, some results obtained in the Northern Italy are reported. These plastic films allow the control of fruit cracking caused by the rain and the hail and also allow increasing SSC, and inducing early ripening (in particular Oroplus plastic film alone or in combination with the reflecting mulch) that was clearly evident early in the season (tab. 5 and figs. 5 and 6).

The plastic film covers also positively affect the fruit ripening reducing the differences among the fruit carried out in the upper and the lower part of the tree (tab. 2).

Tab. 5 - Effetto della copertura con film plastici o reti sul contenuto in solidi solubili e sul grado di maturazione (espresso in IAD) (Costa *et al.*, 2015) di frutti di ciliegio. Per ogni parametro qualitativo i valori seguiti dalla stessa lettera non variano significativamente (p=0.05, DMRT).
Tab. 5 - Influence of the plastic film and net protection on fruit soluble solid content and ripening (expressed as IDA) (Costa et al., 2015). Means for the same quality parameter followed by the same letter do not vary significantly (p=0.05, DMRT)

Trattamento	Grado Zuccherino (Brix°)		I_{AD}	
	Parte superiore della chioma	Parte inferiore della chioma	Parte superiore della chioma	Parte inferiore della chioma
Reti anti-grandine	16.96 cA	15.64 bB	0.53 cA	0.41 bB
Oroplus	18.53 bA	16.36 bB	0.71 abA	0.53 bB
Oroplus + telo riflettente	19.84 aA	17.44 aB	0.81 aA	0.80 aA
Controllo non coperto	18.22 bA	15.79 bB	0.63 bcA	0.43 bB

Fig. 5 - "Film plastici diffusi Oroplus" per la protezione del frutteto, associati a pacciamatura riflettente per riflettere la luce nelle parti basali della chioma (Fonte: Costa *et al.*, 2015).
Fig. 5 - "Oroplus diffused plastic film" to protect the orchard and below "reflecting mulch" to reflect the light in the lower part of the canopy (Source: Costa et al.*, 2015).*

Acknowledgements

Thanks to Stefano Lugli for the text critical reading and for research result provided and to the "INNOCER Project- Regione Veneto: Innovazioni di prodotto e di processo per una cerasicoltura di qualità".

Abstract

The fruit appearance, the size and some organoleptic quality parameters have a strong influence on consumer acceptance. The most appreciated parameters are certainly the size, the sweetness and the color of the fruit skin. Other parameters are important as related to the processing destination of the fruit. Some of these parameters as the size and the skin color can be improved with the cultural management and are here reported some examples (i.e. PGRs application and protected cultivation). Finally the main standard and innovative devices for characterizing the main quality parameters are listed.

Keywords: fruit quality traits, methods to enhance fruit quality and ripening homogeneity, innovative methods of determination, protected orchard, PBRs.

References

Ballistreri, G., Continella, A., Gentile, A., Amenta, M., Fabroni, S. Rapisarda, P. 2013. *Fruit quality and bioactive compounds relevant to human health of sweet cherry (*Prunus avium *L.) cultivars grown in Italy.* Food Chemistry 140, 630–638.

Bargioni G., 1964. *Stato attuale, prospettive e problemi della cerasicoltura italiana.* Atti del 1° convegno nazionale "La coltura del ciliegio", Verona, 13 giugno 2014: 21-48

Bujdosó, G. and Hrotkó K.. 2017. *Cherry production* in Cherry, Botany, Production and uses Edited by Quero Garcia J., Iezzoni A., Pulawska, J, and Lang G. CAB International 2017 pp1-14.

Cline, J.A. Trought, M. 2007. *Effect of gibberellic acid on fruit cracking and quality of Bing and Sam sweet cherries.* Canadian Journal of Plant Science 87, 545–550.

Coombe, B.G. 1976. *The development of fleshy fruits.* Annual Review of Plant Physiology 27, 507–528.

Crisosto, C.H., Crisosto, G.M. Metheney, P. 2003. *Consumer acceptance of 'Brooks' and 'Bing' cherries is mainly dependent on fruit SSC and visual skin color.* Postharvest Biology and Technology 28, 159–167

Dever, M.C., MacDonald, R.A., Cliff, M.A. Lane, W.D. 1996. *Sensory evaluation of sweet cherry cultivars.* HortScience 31, 150–153.

Dondini,L., Lugli, S. and Sansavini, S. 2018. *Cherry Breeding: Sweet Cherry (*Prunus avium *L.) and Sour Cherry (*Prunus cerasus *L.).* In Advances in Plant Breeding Strategies: Fruits

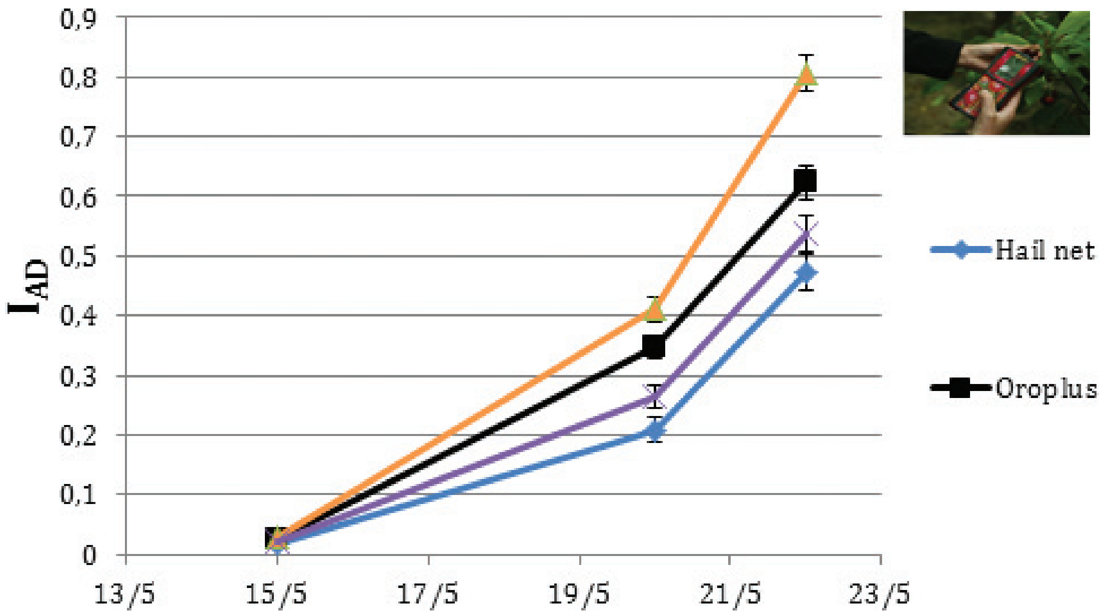


Fig. 6 - Evoluzione del grado di maturazione dei frutti durante la stagione vegetativa in funzione della copertura con film plastici e reti antigrandine (Costa *et al.*, 2015).
Fig. 6 - Fruit ripening evolution during the season as affected by plastic film and hail net protection (Costa et al.*, 2015).*

Editors: Jameel M. Al-KhayriShri Mohan JainDennis V. Johnson, 2018. Pages 31-88

Elfving DC, Lang GA, Visser DB. 2003. *Prohexadione-Ca and ethephon reduce shoot growth and increase flowering in young, vigorous sweet cherry trees.* HortScience 38: 293-298

Elfving DC, Visser DB, Lang GA. 2005. *Effects of prohexadione-calcium and ethephon on growth and flowering of 'Bing' sweet cherry.* Acta Hortic. 667: 439-446

González-Gómez, D., Lozano, M., Fernández-León, M.F., Bernalte, M.J., Ayuso, M.C. and Rodríguez, A.B. 2010. *Sweet cherry phytochemicals: identification and characterization by HPLC-DAD/ESI-MS in six sweet-cherry cultivars grown in Valle del Jerte (Spain).* Journal of Food Composition Analysis 23, 533–539.

Goulas, V., Minas, I.S., Kourdoulas, P.M., Lazaridou, A., Molassiotis, A.N., Gerothanasis, I. and Manganaris, G.A. 2015. *1H NMR metabolic fingerprinting to probe temporal postharvest changes on qualitative attributes and phytochemical profile of sweet cherry fruit.* Frontiers in Plant Science 6, 959.

Guak S, Beulah M, Looney NE. 2005. *Controlling growth of sweet cherry trees with prohexadione-calcium: Its effect on cropping and fruit quality.* Acta Hortic. 667: 433-438

Guyer, D.E., Sinha, N.K., Chang, T.S. Cash, J.N. 1993. *Physiochemical and sensory characteristics of selected Michigan sweet cherry (*Prunus avium *L.) cultivars.* Journal of Food Quality 16, 355–370.

Hampson, C.R., Stanich, K., McKenzie, D.L., Herbert, L., Lu, R., Li, J. and Cliff, M.A. 2014. *Determining the optimum firmness for sweet cherries using Just-About-Right sensory methodology*. Postharvest Biology and Technology 91, 104–111.

Herrero, M., Rodrigo, J. and Wünsch, A. 2017. *Flowering, Fruit Set and Development in Cherry Botany, Production and uses.* Edited By Quero-Garcia J., Iezzoni A., Pulawska A. and Lang G. CAB International 2017,pp 14-35.

Kappel, F. MacDonald, R.A. 2007. *Early gibberellic acid sprays increase firmness and fruit size of 'Sweet- heart' sweet cherry.* Journal of the American Pomological Society 61, 38–43.

Kappel, F., Granger, A., Hrotkó, K. Schuster, M. 2012. *Cherry*. In: Badenes, M.L. and Byrne, D.H. (eds) Fruit Breeding, Handbook of Plant and Breeding 8. Springer Science + Business Media, New York, pp. 459–504.

Lenahan, O.M., Whiting, M.D., Elfving, D.C. 2006. *Gibberellic acid inhibits floral bud induction and improves 'Bing' sweet cherry fruit quality.* HortScience 41, 654–659.

Nagpala, E.G.L., Noferini, M., Farneti, B., Piccinini, L. and Costa, G. 2017a. *Cherry-Meter: an innovative non-destructive (vis/NIR) device for cherry fruit ripening and quality assessment.* Acta Hortic. 1161, 491-496

Nagpala, E.G.L., Noferini, M., Piccinini, L., Fiori, G., Vidoni, S., Bonora, E. and Costa, G. 2017 b. *Exogenous application of plant growth regulators enhances color and anthocyanin content of cherry fruits.* Acta Hortic. 1161, 621-626

Olien WC, Bukovac MJ. 1982. *Ethephon-induced gummosis in sour cherry (*Prunus cerasus *L.). I. Effect on xylem function and shoot water status.* Plant Physiol. 70: 547-555

Olmstead, J.W., Iezzoni, A.F. and Whiting, M.D. 2007. *Genotypic differences in sweet cherry fruit size are primarily a function of cell number.* Journal of the American Society for Horticultural Science 132, 697–703.

Piccolella, S., Fiorentino, A., Pacifico, S., D'Abrosca, B., Uzzo, P. and Monaco, P. 2008. *Antioxidant properties of sour cherries (*Prunus cerasus *L): role of colorless phytochemicals from the methanolic extract of ripe fruits.* Journal of Agricultural and Food Chemistry 56, 1928–1935.

Poll, L., Petersen, M.B. Nielsen, G.S. 2003. *Influence of harvest year and harvest time on soluble solids, titratable acid, anthocyanin content and aroma components in sour cherry (*Prunus cerasus *L. cv. 'Stevns- baer').* European Food Research and Technology 216, 212–216.

Quero-García, J., M. Schuster, G. López-Ortega G. Charlot, 2017. *Sweet Cherry Varieties and Improvement in Cherry Botany, Production and uses.* Edited By Quero-Garcia J., Iezzoni A., Pulawska A. and Lang G. CAB International 2017,pp 60-95.

Sansavini, S. Lugli, S. 2008. *Sweet cherry breeding programmes in Europe and Asia.* Acta Horticulturae 795, 41–58.

Serradilla, M.J., Fotirić Akšić, M., Manganaris, G.A. Ercisli, S., González-Gómez, D. Valero, D., 2017. *Fruit Chemistry, Nutritional Benefits and Social Aspects of Cherries in Cherry, Botany, Production and uses* Edited by Quero Garcia J., Iezzoni A., Pulawska, J, and Lang G. CAB International 2017 pp pp:420-441

Serradilla, M.J., Hernández, A., López-Corrales, M., Ruiz-Moyano, S., Córdoba, M.G. and Martín, A. 2016. *Composition of the cherry (*Prunus avium *L. and* Prunus cerasus *L.; Rosaceae).* In: Simmonds, M.S.J. and Preedy, V.R. (eds) Nutritional Composition of Fruit Cultivars. Academic Press, London, pp. 127–147.

Serradilla, M.J., Martín, A., Ruiz-Moyano, S., Hernández, A., López-Corrales, M. Córdoba, M.G. 2012. *Physicochemical and sensorial characterisation of four sweet cherry cultivars grown in Jerte Valley (Spain)*. Food Chemistry 133, 1551–1559.

Tijero, V., Teribia, N., Muñoz, P., Munné-Bosch, S. 2016. *Implication of Abscisic Acid on Ripening and Quality in Sweet Cherries: Differential Effects during Pre- and Postharvest.* Frontiers in plant science, 7, 602.

Tomás-Barberán, F.A., Ruiz, D., Valero, D., Rivera, D., Obón, C., Sánchez-Roca, C. Gil, M. 2013. *Health benefits from pomegranates and stone fruit, including plums, peaches, apricots and cherries.* In: Skinner, M. and Hunter, D. (eds) *Bioactives in Fruit: Health Benefits and Functional Foods*. Wiley, Hoboken, New Jersey, pp. 125–167.

Turner, J., Seavert, C., Colonna, A. Long, L.E. 2008. *Consumer sensory evaluation of sweet cherry cultivars in Oregon, USA*. Acta Horticulturae 795, 781–786.

Usenik, V., Fabčič, J. Štampar, F. 2008. *Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry (*Prunus avium *L.).* Food Chemistry 107, 185–192.

Valero, D., Serrano, M. 2010. Postharvest Biology and Technology for Preserving Fruit Quality. CRC Press, Boca Raton, Florida.

Viljevac, M., Dugalic, K., Jurkovic, V., Mihaljevic, I., Tomaš, V., Puškar, B., Lepeduš, H., Sudar, R. Jurkovic, Z. 2012. *Relation between polyphenols content and skin colour in sour cherry fruits.* Journal of Agricul- tural Science 57, 57–67.

Wen, Y.-Q., He, F., Zhu, B.-Q., Lan, Y.-B., Pan, Q.-H., Li, C.-Y., Reeves, M.J. Wang, J. 2014. *Free and glycosidically bound aroma compounds in cherry (Prunus avium L.)*. Food Chemistry 152, 29–36.

Whiting, M.D. Lang, G.A. 2004. *'Bing' sweet cherry on the dwarfing rootstock 'Gisela 5': crop load affects fruit quality and vegetative growth but not net CO_2 exchange.* Journal of the American Society for Horti- cultural Science 129, 407–415.

Zhang, C. Whiting, M.D. 2011. *Improving 'Bing' sweet cherry fruit quality with plant growth regulators*. Scientia Horticulturae 127, 341–346.

Zoffoli, J.P., Toivonen P., Wang Y. 2017. *Postharvest Biology and Handling for Fresh Markets in Cherry, Botany, Production and uses* Edited by Quero Garcia J., Iezzoni A., Pulawska, J, Lang G. CAB International 2017 pp:460-484.