QUALITY INDEXES FOR 'GOLDEN SMOOTHEE' APPLES IN RELATION TO CONSUMER EVALUATION

Diana Molina[1,2*], Simo Alegre[3], Tomas Casero[1], Mariona Casals[4], Joan Bonany[4], Joaquim Carbó[4], Jaume Puy[5] and Inmaculada Recasens[1,2]

[1]UdL-IRTA, Postharvest Dpt., CeRTA
[2]Dpto. Hortofruticultura, Botánica y Jardinería, ETSEA, UdL.
[3]IRTA. Experimental Station of Lleida [5]Dpto. Química, ETSEA, UdL
[1, 2, 3, 5]C/ Rovira Roure 191, 25198 Lleida, SPAIN
[4]IRTA. Experimental Station of Mas Badia
[4]Crta. de la Tallada s/n, 17134 La Tallada, Girona, SPAIN

*Corresponding author: diana.molina@irta.es

(Received July 7, 2005/Accepted November 7, 2005)

ABSTRACT

This study, which was carried out in 2002 and 2003, investigated the relationship between quality parameters and consumer scores in order to determine the most accurate harvest indexes and variables for evaluating fruit quality according to consumer expectations for 'Golden Smoothee' apples produced in Catalonia (Spain). Fruits were harvested according to a completely randomised pattern at six different dates in each year. On each date, 20 fruits were selected in order to analyze their quality parameters at harvest. Other fruits were stored in an ultra low oxygen atmosphere (1% O_2 and 1% CO_2) for eight months. After storage, samples of 20 fruits were used to analyze quality parameters. Sensory testing was carried out with consumer panels at two different locations (Girona and Lleida). Tests were conducted with a total of 1,800 consumers after fruit samples were removed from cold storage.

Average consumer ratings were highest for the fifth harvest date in 2002 and the sixth harvest date in 2003. Firmness, and acidity are highly negatively correlated with consumer score. Soluble solid content is strongly positively correlated with consumer score. Acoustic frequency at harvest is the variable best correlated with consumer score and Magness Taylor firmness. Other acoustic measurements such as acoustic firmness (stiffness factor) at harvest and after storage, and acoustic frequency after storage appear uncorrelated not only with consumer score but also with most of

quality variables studied. Consumers appreciated sweetness more than firmness and acidity.

Key words: apple, sensory testing, quality parameters, principal component analysis

INTRODUCTION

The apple is not only the most consumed fruit in Spain, but also throughout the world. Catalonia produces almost fifty percent of the apples grown in Spain, and Lleida accounts for around eighty percent of total apple production in Catalonia, with approximately 300,000 tons of fruit per year. It is therefore very important to evaluate and adjust existing harvest indexes or to suggest new ones in accordance with consumer tastes and preferences.

Quality is usually defined in terms of all of the characteristics of a food that lead a consumer to be satisfied with the product (Harker et al., 2003). The concept of quality can be studied from different perspectives; that of the consumer, or of the producer and the fruit industry. In both cases, efforts mainly focus on establishing a reference system that is valid for measuring fruit quality, and of course for establishing the most appropriate methodologies and parameters for reliably predicting how consumers and the market are likely to react to the product in question. For the fruit industry it of great importance to be able to predict consumer tastes and requirements (Shewfelt, 1999).

Establishing the optimum harvest date is an important factor in obtaining quality fruits. With the use of controlled atmospheres, only apples picked at the optimum stage of maturity can be suitably stored for periods of 6 months or more. The best way to provide customers with good quality apples is therefore to select the most appropriate harvest date to guarantee consumer acceptance (Streif, 1996; Plotto et al., 1995).

Some studies, such as Lopez et al. (1999), Eccher Zerbini et al. (1999) and Plotto et al. (1995, 2000) have documented the fact that low oxygen long-term storage offers benefits in terms of maintaining fruit texture, soluble solids, and acidity but often does not offer the same advantages with respect to aroma formation. The election of storage conditions should therefore be made in accordance with all of the characteristics that affect fruit quality and influence the final decision concerning what consumers decide to purchase.

The methodology chosen to investigate consumer preferences depends on the final objective of the study. Consumer studies are generally aimed at determining the opinions and preferences of consumers with a view to introducing new varieties into the market (Stainer et al., 1996) and evaluating the acceptation of particular aspects related with fruit quality (Durner et al., 1992). However, over the last few years, a new objective has emerged, that of selecting the optimum harvest date by taking into account consumer acceptance (Plotto et al., 1995).

Despite being time consuming and expensive, destructive methodologies have been traditionally used as reference measurements of quality in fruit and vegetables. In the specific case of apples, firmness, soluble solid content and acidity are usually considered the destructive variables that are best correlated with consumer acceptance and therefore serve as good indicators of texture, sweetness and tartness (Hoehn et al., 2003; Harker et al., 2002; Mehinagic et al., 2004).

Nowadays, one of the most important topics in fruit quality research is the establishment of non-destructive systems to evaluate and guarantee the quality of fruits. Along these lines, measures of non-destructive firmness have been carried out using different approaches. Some of the most relevant techniques used include measurements of the optical properties of fruits, recordings of acceleration curves associated with the impact of a small-mass, and acoustic impulse responses.

The acoustic response technique has been used to evaluate the tissue properties of horticultural commodities and also their firmness. This technique offers good prospects for studies on apples, because it has a high correlation with several mechanical attributes (Barreiro et al., 1998) and also facilitates a complete study of all the processes associated with the concept of firmness. In their results with 'Golden Delicious' apples, Duprat et al., (1997) found that acoustic response measurements combined with size measurements gave a good indication of changes in fruit maturity before, during and after harvest. This technique may serve as an important tool for studying the postharvest evolution of fruit and vegetables, in this sense, it is interesting to evaluate its relationship with consumer acceptance and other quality parameters.

The principal aim of this study was to evaluate the relationship between quality parameters and consumer scores in order to know the most accurate harvest indexes and variables for evaluating fruit quality according to consumer expectations for 'Golden Smoothee' apples produced in Catalonia (Spain).

MATERIAL AND METHODS

Quality parameters

The study was carried out in 2002 and 2003 with 'Golden Smoothee' apples harvested from six different orchards and on six different dates. On each date, 20 fruits from each orchard were used to analyze quality parameters at harvest time. Firmness (kg) was measured by applying the Magness Taylor Methodology at two opposite points on the equator of each fruit; this was done with an 11 mm diameter Effegi Penetrometer (+/- 0.01 kg), once a thin slice of skin had been removed from each side. Acoustic

firmness (AWE) and frequency (Hz) were measured at the equator of the fruit in three repetitions using an AWETA Acoustic Firmness Sensor. In this device, an acoustic signal is generated by means of a gentle impact on the equator of the fruit. This signal is detected by a microphone positioned nearby but not in contact with fruit surface. This signal is processed and transformed to obtain a peak of natural frequency, which is used to calculate the Stiffness Factor as $f^2 * m^{2/3}$, where f represents this frequency and m is the fruit mass. The starch index was measured using an Agrotechnologie AM93 machine and visual way (EUROFRU scale, 1-10). Soluble solid content (º Brix) and titratable acidity (g l^{-1}) were determined using freshly prepared juice. Individual fruits were ground in an electric juice extractor. Soluble solid content was measured using a digital temperature compensated refractometer (model PR-101, Atago Co. Tokyo Japan) and titratable acidity (expressed as malic acid) was determined by titrating 10 mL of juice with 1.0 M NaOH to pH 8.2. Superficial skin colour on the two sides: yellow (1) and green (2), was established using a Minolta Colorimeter CR200 (+/- 0.01 resolution). Standard CIE L*, a*, b* colour space coordinates, L, a, and b were obtained and a+b and a/b were calculated for each side to follow the characteristic change of colour from green to yellow o this variety. Weight (g); diameter (cm); pH; sugar/acidity ratio and russeting were also recorded. At harvest time, the following harvest indexes were also calculated: Streif Index (Streif, 1996), De Jager Index (De Jager and Roelofs, 1996) and FARS index (De Long et al., 1999).

Other fruits were stored in a controlled ultra low oxygen (CA–ULO) atmosphere (0.5ºC; 1% O_2; 1% CO_2) for eight months. After storage, fruit quality parameters were also evaluated (Tab. 1) and sensory tasting was carried out.

Sensory tasting

After eight months in cold storage in CA – ULO, sensorial tasting was carried out with consumer panels at two locations (Girona and Lleida) with a total of 1,800 consumers.

The survey format was designed to obtain the following information: the first part of the survey identified the consumers and provided information about general consumer preferences. In the second part, they evaluated fruit samples and scoring them on a scale from –3 to + 3. Each consumer tasted portions of fruit corresponding to six harvest dates from one orchard. These samples were identified by means of an internal code. The average consumer score was used as a criterion for acceptance.

Table 1. Code variables used in PCA and PLS regression, for quality parameters, harvest indexes and average consumer scores determined for 'Golden Smoothee' apples from different orchards at different harvest dates

Quality parameter at harvest time	Code
Weight	Pes
Diameter	Cal
Firmness (Penefel)	Pm
Acoustic firmness (AWETA)	AWI
Frequency	AWF
Russeting	Rus
Visual starch index	IMV
Starch index (Agrotechnologie AM93)	AMI
Soluble solid content	SM
Acidity	Ac
pH	pH
Ctifl color yellow side	Yellow
Ctifl color yellow side	Green
Cie L*a*b* color from yellow side	L1, a1, b1
Cie L*a*b* color from green side	L2, a2, b2
Cie L*a*b* color average both sides	Lm, am, bm
Cie L*a*b* color combinations both sides a+b	amasb
Cie L*a*b* color combinations both sides a/b	adivb
Streif harvest index	Streif
De Jager harvest index	De Jager
FARS harvest index	FARS
Sugar/acidity ratio	SudivAc
Quality parameter after storage	**Code**
Weight	SPes
Firmness (Penefel)	SPm
Acoustic firmness (AWETA)	SAWI
Frequency	SAWF
Soluble solid content: Average	SSM
Yellow side	SS1
Green side	SS2
Acidity	SAc
pH	SpH
Cie L*a*b* color from yellow side	SL1, Sa1, Sb1
Cie L*a*b* color from green side	SL2, Sa2, Sb2
Cie L*a*b* color average both sides	SLm, Sam, Sbm,
Cie L*a*b* color combinations both sides a+b	Samasb
Cie L*a*b* color combinations both sides a/b	Sadivb
Sugar/acidity ratio	SSu/Ac
Average consumer scores	Calif

Multivariate analysis

In this work, principal component analysis (PCA) and partial least square (PLS) were used to study the relationship between consumer acceptance and apple quality parameters. Unscrambler software 6.11 version was used (Camo, 1997). PCA provided an exploratory data analysis based on multivariate projection methods that helped to visualise all the information contained in the data set (Benavides et al., 2001). Samples were codified using a code (eg. 3 G O 5) whose first digit corresponded to the year, whose second and third were the initial letters of the name of the orchard, and whose fourth was the date of harvest. The data set included six category variables to identify the harvest date (1, 2, 3, 4, 5, 6), six category variables for the different orchards (Mo, Go, Al, Fo, Gi, Si) and two category variables to identify the year (2 and 3). Category variables were codified using a discrete variable for each category listed in Table 1.

A Principal Component Analysis (PCA) was constructed, with the resulting data matrix containing 72 samples and 62 variables for both years. These sample values correspond to average orchard data for each parameter. As the variables were measured in different units, there were large differences between them with respect to the mean, variance and standard deviation. Prior to performing PC models, the data obtained were therefore centred and weighted with the inverse of the standard deviation of each variable in order to give all of the variables the same chance of influencing the estimation of the components.

PCA was carried out to analyze the effect of year and harvest date. The data set was separated using different variables for measurements at harvest time and for measurements after cold storage (Tab. 1). Post-storage measurements are identified with an initial “S” in the name of the variable.

To study the correlation between all the variables and the average consumer score, a Partial Least Square (PLS) model was constructed using full cross-validation based on the same data matrix.

RESULTS AND DISCUSSION

The average consumer rating was highest around the fifth harvest date in 2002 and the sixth harvest date in 2003 (Fig. 1). In both cases, the date with the highest score corresponded to the second part of the harvest period. Thus, in this case, ultra low oxygen storage conditions were appropriate for maintaining fruit quality in apples picked in late harvests. For all orchards, the acceptance of the highest scoring date was above 77% in 2002 and above 73% in 2003 (data not shown).

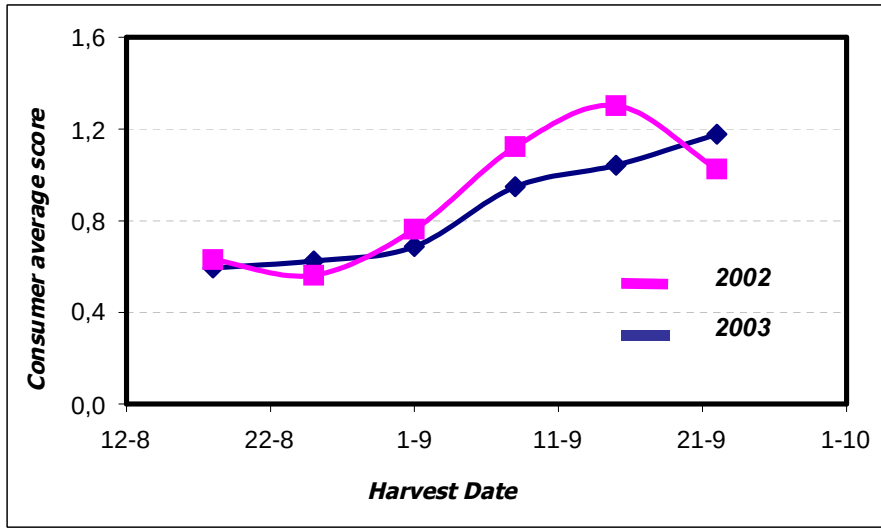

Figure 1. Average sensorial taste score for 'Golden Smoothee' apples harvested on different dates in 2002 and 2003, and stored for 8 months in a CA-ULO

For these two years the data with the best score corresponded to quality parameter values for firmness after storage of between 5.6 kg and 6.0 kg, soluble solid content of between 14.0 and 16.1 º Brix, and titratable acidity values of between 3.5 and 4.3 g/l malic acid (data not shown). For Hoehn et al., 2003, the minimum values of these three parameters, for both years, according to acceptance by Swiss consumers were 5 kg for firmness, 12º Brix for soluble solid content and 3.2 g/l malic acid. In both years Catalan consumers preferred higher values of these parameters than Swiss consumers, indicating their preference for firm and sweet fruits.

A Principal Component Analysis (PCA) model made up with fruits characterized by all the variables listed in Table 1 was used to obtain a global overview of all the samples of both years. In this PCA model, 68% of total data variance in the was explained by the two first PCs. Figures 2a and 2b show the score and loading plots corresponding to PC1 vs PC2 from the PCA model. The score plot described in Figure 2a clearly shows the evolution of samples with the harvest date for all the orchards, thus the sample size seems to be adequate to describe the process of maturation of the fruit. From the score plot it was also possible to observe a clear separation between years (Fig. 2b), with two groups showing a similar distribution of samples over PC space.

Comparing figure 2b with the loading plot in figure 2c shows that the 2002 samples were associated with higher soluble solid content values while 2003 samples were associated with higher pH values (Fig. 2c). Early harvest dates were associated with high values of firmness at harvest and after

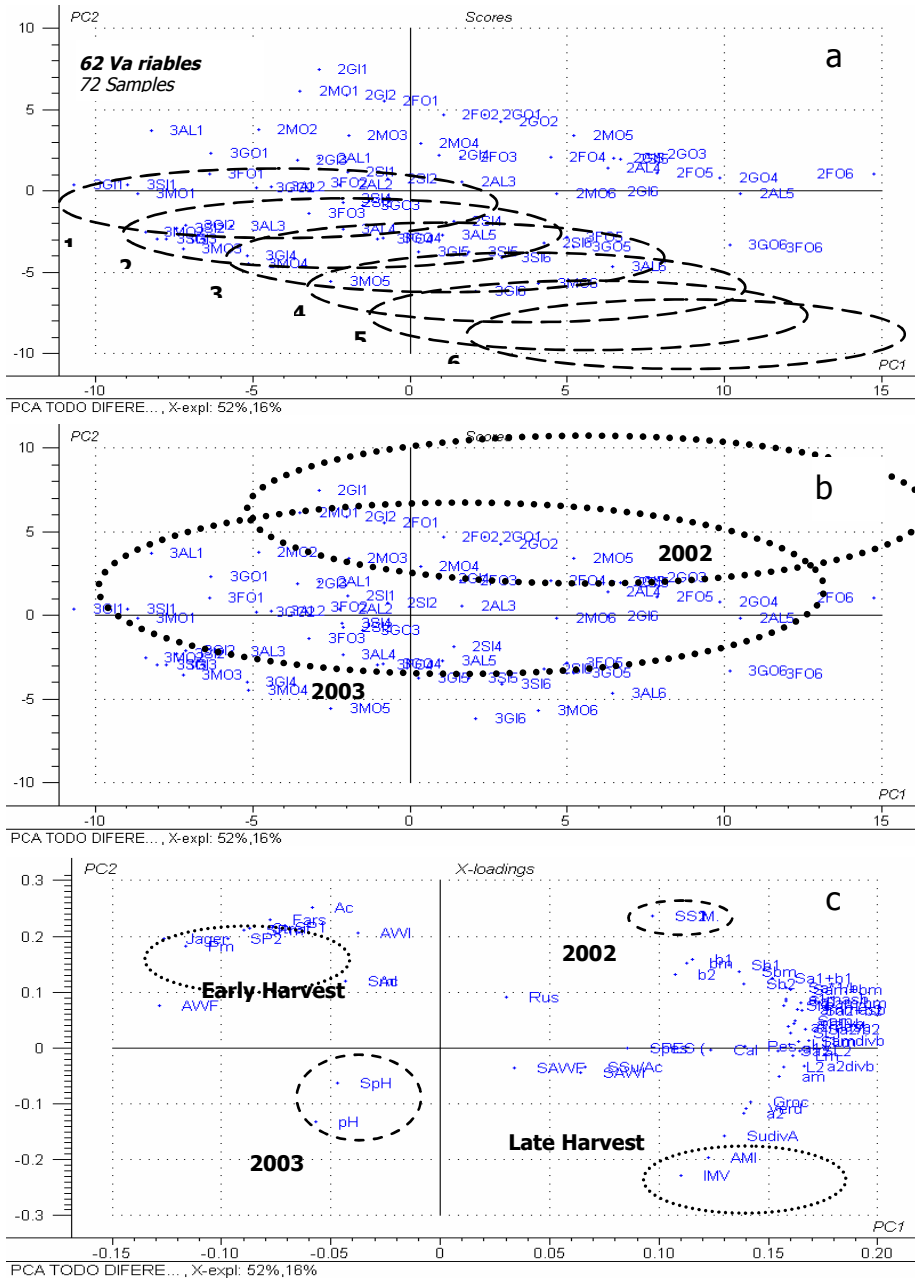

Figure 2. PCA Model using data corresponding to 2002 and 2003, with 62 variables and 72 samples. a) Score plot of PC1 versus PC2 using all data; direction of harvest date. b) Score plot of PC1 versus PC2 using all data; year separation. c) Loading plot of PC1 versus PC2 from PCA model using all data. Variables are labelled as listed in Table 1 and samples are labelled using code defined in text

storage, acidity at harvest and harvest indexes such as De Jager and FARS. These harvest indexes allow then, differentiated the harvest date among the fruits early harvested. Late harvest fruits were associated with high values for the starch index, sugar-acidity ratio and color parameters at harvest (Fig. 2c). These results agree with those reported by Merész et al. (1996) for 'Golden Smoothee' cultivar.

Partial Least Squares (PLS) model of Consumer Acceptance

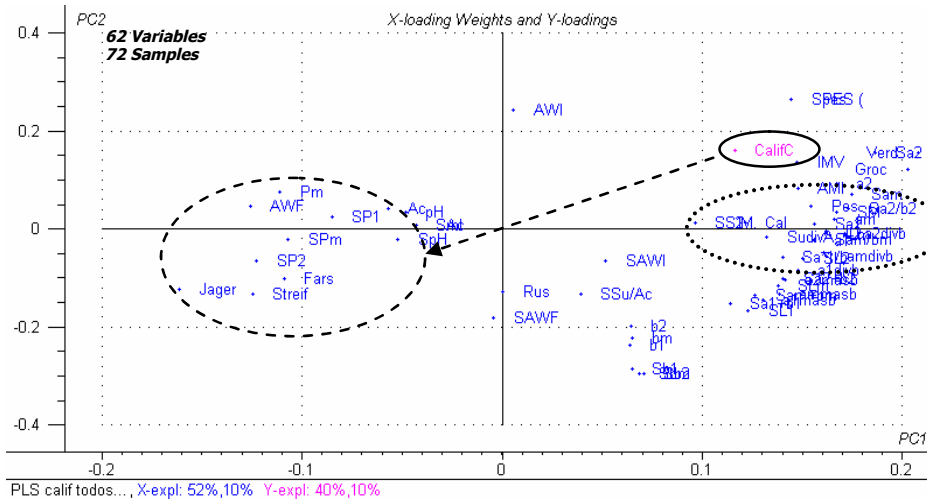

Figure 3. Loading plot of PC1 versus PC2 from PLS model of variable average consumer scores obtained using 62 variables and 72 samples for both years. Variables are labelled as listed in Table 1 and samples are labelled using code defined in text

A PLS regression model for the consumer acceptance using as X variables the rest of parameters reported in Table 1 was conducted. Two factors were relevant in the model as determined from full cross validation. The predicted versus measured average consumer score using this PLS model produced a regression coefficient of 0.61; this indicates that around 40% of the variance in the consumer score can be explained by parameters listed in Table 1. The loading plot of PC1 vs PC2 from this PLS model is shown in Figure 3. As we observe from the position of the variables in the PLS loading plot, consumer acceptance variable – Calif – appears to be clearly anti-correlated with harvest indexes Streif, De Jager and FARS, firmness at harvest and after storage and acidity at harvest. Moreover the consumer score appeared to be positively correlated with starch index, soluble solids content at harvest and after storage and some color parameters at harvest and post storage such as a* value from the green side (a2). This may, at least partly, explain the higher average mark

for the 2002 samples, which was due to higher values for soluble solid content.

Figure 3 also shows that firmness at harvest and after storage, and acidity at harvest are highly negatively correlated with consumer score. Studies such as Hoehn et al. (2003), Harker et al. (2002) have also found similar relationships between these variables and consumer scores.

These three variables should therefore be considered as important instruments for predicting sensory attributes such as texture, sweetness and tartness, which are detected and appreciated by consumers.

In the loading plot of the PLS model (Fig. 3), it is possible to appreciate that the De Jager Index is the most negatively-correlated harvest index of those studied. This also can be seen in the previous PCA model (Fig. 2c).

According to this result, the non-destructive variable Acoustic Frequency at harvest is the only one that was well correlated with PC1 and negatively correlated with consumer scores. Other acoustic variables measured were more correlated with PC2 which explain only a 10% of the total variance of the consumer scores. The relationship between acoustic frequency and firmness measured by Magness Taylor is also good, whereas a poor correlation between the rest of acoustic measurements and firmness measured by Magness Taylor was found. Significant correlations between Acoustic Firmness (Stiffness Factor) and Magness Taylor firmness measurements have been reported by Abbot et al. (1992), Galili and De Baerdemaeker (1996), De Belie et al. (2000). The present results showed that among acoustic firmness measurements, acoustic frequency is the most correlated one with Magness Taylor firmness and consumers scores.

CONCLUSIONS

Catalan consumers appreciated sweet apples from late harvests more than firm and acid apples from early harvests.

Firmness, and acidity were highly negatively correlated with consumer scores, while soluble solid content was strongly positively correlated with consumer scores.

Fruits from early harvest dates were better differentiated by harvest indexes such as De Jager and FARS, while fruits from late harvests were better differentiated by the starch index and by certain other parameters like sugar-acidity ratio and color parameters.

Acoustic Frequency at harvest was the best correlated variable with consumer score and Magness Taylor firmness. Other acoustic measurements such as acoustic firmness (stiffness factor) at harvest and after storage and acoustic frequency after storage appeared to be uncorrelated not only with consumer scores but also with most of quality variables studied.

REFERENCES

Abbott J.A., Affeldt H.A., Liljedahl L.A. 1992. Firmness measurement of stored 'Delicious' apples by sensory methods, Magness-Taylor, and sonic transmission. J. AMER. SOCI. HORT. SCI. 117: 590-595.

Barreiro P., Ortiz C., Ruiz-Altisent M., De Smedt V., Schotte S., Andani Z., Wakeling I., Beyts P.K. 1998. Comparison between sensory and instrumental measurements for mealiness assessment in apples. A collaborative test. J. TEXTURE STUD. 29: 509-525.

Benavides A., Recasens I., Casero T., Puy J. 2001. Chemometric analyses of 'Golden Smoothee' apples treated with two preharvest calcium spray strategies in the growing season. J. SCI FOOD AGRIC 81: 943-952.

Camo 1997. Unscrambler users guide. Windows Version 6.11 b Camo ASA Trondheim.

De Belie N., Shotte S., Lammertyn J., Nicolai B., De Baerdemaeker J. 2000. Firmness changes of pear fruit before and after harvest with the acoustic impulse response technique. J. AGR. ENG. RES. 77(2): 183-191.

De Jager A., Roelofs F. 1996. Prediction of the optimum harvest date of Jonagold. In: A. De Jager, D. Johnson, E. Hohn (ed.), Determination and prediction of optimum harvest date of apples and pears. COST 94. European Commission. Luxembourg, pp. 21-31.

De Long J.M., Prange R.K., Harrison P.A., Shofield R.A., De Ell J.R. 1999. Using the Streif index as a final harvest window for controlled-atmosphere storage of apples. HORTSCIENCE. 34(7): 1251-1257.

Duprat F., Grotte M., Pietri E., Loonis D. 1997. The acoustic impulse response method for measuring the overall firmness of fruit. J. AGR. ENG. RES 66: 251-259.

Durner, E.F.; Polk, D.F.; Goffreda, J.C. 1992. Low-input apple production systems: Consumer acceptance of disease- resistant cultivars. HORTSCIENCE 27(2): 177-179.

Eccher Zerbini P., Pianezzola A., Grassi M. 1999. Post-storage sensory profiles of fruit of five apple cultivars harvested at different maturity stages. J. FOOD QUAL. 22: 1-17.

Galili N., De Baerdemaeker J. 1996. Performance of acoustic test methods for quality evolution of agricultural products, ISMA Conference, September 1996, Leuven, Belgium.

Harker F.R., Marsh K.B., Young H., Murray S.H, Gunson F.A., Walker S.B. 2002. Sensory interpretation of instrumental measurements 2: sweet and acid taste of apple fruit. POSTHARVEST BIOL. TECH. 24: 241-250.

Harker F.R., Gunson F.A., Jaeger S.R. 2003. The case for fruit quality: An interpretative review of consumer attitudes and preferences for apples. POSTHARVEST BIOL. TECH. 28: 333 –347.

Hoehn E., Gasser F., Guggenbühl B., Künsch U. 2003. Efficacy of instrumental measurements for determination of minimum requirements of firmness, soluble solids, and acidity of several apple varieties in comparison to consumer expectations. POSTHARVEST BIOL. TECH 27: 27-37.

Lopez M., Lavilla T., Graell J., Recasens I., Vendrell M. 1999. Effect of different CA conditions on aroma and quality of Golden Delicious apples. J. FOOD QUAL. 22: 583-597.

Merész P., Sass P., Lovasz T. 1996. Evaluation of harvest indexes of apples grown in Hungary. In: A. De Jager, D. Johnson, E. Hohn (ed.), Determination and

prediction of optimum harvest date of apples and pears. COST 94. European Commission. Luxembourg, pp. 53-60.
Mehinagic E., Royer G., Symoneaux R., Bertrand D., Jourjon F. 2004. Prediction of the sensory quality of apples by physical measurements. POSTHARVEST BIOL. TECH 34: 257-269.
Plotto A., Azarenko A.N., Mattheis J.P., McDaniel M.R. 1995. 'Gala', 'Braeburn', and 'Fuji' apples: Maturity indices and quality after storage. FRUIT VAR. J. 49: 133-142.
Plotto A., McDaniel M.R., Mattheis J.P. 2000. Characterization of changes in 'Gala' apple aroma during storage using some analysis, a gas chromatography–olfactometry technique. J. AM. SOC. HORT. SCI. 125: 714 -722.
Streif J. 1996. Optimum harvest date for different apple cultivar in the 'Bodensee' area.. In: A. De Jager, D. Johnson, E. Hohn (ed.), Determination and prediction of optimum harvest date of apples and pears. COST 94. European Commission. Luxembourg, pp. 15-20.
Shewfelt R.L. 1999. What is quality? POSTHARVEST BIOL. TECH. 15. 197-200.
Stainer R., Giuliani G., Youseff J., Toffolutti B. 1996. Qualitative characteristics and consumer assessment of new apple cultivars. RIVISTA DI FRUTTICOLTURA E DI ORTOFLORICOLTURA 58: 11, 43-46.

WSKAŹNIKI JAKOŚCI JABŁEK 'GOLDEN SMOOTHEE' W RELACJI DO OCENY KONSUMENCKIEJ

Diana Molina, Simo Alegre, Tomas Casero, Mariona Casals, Joan Bonany, Joaquim Carbó, Jaume Puy i Inmaculada Recasens

STRESZCZENIE

Badania przeprowadzono w latach 2002 i 2003 w celu uzyskania wskaźników jakości dobrych dla określenia optymalnego terminu zbioru jabłek ('Golden Smoothee') uprawianych w różnych sadach w Katalonii w Hiszpanii. W obu latach owoce zbierano w sześciu różnych terminach, w układzie kompletnie losowym. Z każdego terminu wybrano 20 owoców w celu oznaczenia parametrów jakościowych podczas zbioru. Pozostałe owoce przechowywano w warunkach ultra niskiego stężenia tlenu (1% O_2 i 1% CO_2) przez 8 miesięcy. Po przechowywaniu wykonano oznaczenia parametrów jakościowych na 20 owocach. Po wyjęciu próbek

z przechowywania przeprowadzono także ocenę smakowitości w dwóch grupach konsumentów w dwóch miejscach (Girona i Lleida) z ogólnym udziałem 1 800 osób. Średnia ocena konsumentów była wyższa dla owoców zebranych w piątym terminie w 2002 roku i w szóstym terminie w 2003 roku. Jędrność i kwasowość są wyraźnie negatywnie skorelowane z oceną konsumentów, a zawartość ekstraktu jest silnie pozytywnie skorelowana z oceną konsumentów. Wczesne terminy zbiorów wiążą się z wyższymi wartościami indeksów zbiorczych, takich jak indeks De Jagera i FARS, jędrności i kwasowości, natomiast późniejsze zbiory wiążą się z wyższymi wartościami indeksu skrobiowego i niektórych innych parametrów, takich jak stosunek cukrów do kwasów i parametry koloru. W badaniach zastosowano metodę opartą na pomiarze sygnału akustycznego wysyłanego przez owoc po mechanicznym wymuszeniu. Na podstawie odbieranego sygnału obliczane były dwa parametry określane jako częstotliwość i sztywność. Częstotliwość mierzona w czasie zbioru była parametrem najlepiej skorelowanym z ocenami konsumentów i jędrnością mierzoną metodą Magnessa Taylora. Pomiary akustyczne, takie jak jędrność (współczynnik sztywności) podczas zbioru i po przechowywaniu oraz częstotliwość po przechowywaniu wydają się nie być skorelowane ani z ocenami konsumentów, ani z większością badanych parametrów jakości owoców. Konsumenci wyżej cenili sobie słodki smak jabłek niż ich jędrność i kwasowość.

Słowa kluczowe: jabłka, smakowitość, parametry jakościowe, analiza składowych głównych