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Title:

STORABILITY OF MELON FOR DIFFERENT RIPENESS STAGES AT HARVEST. SELECTION OF INSTRUMENTAL PROCEDURES FOR QUALITY ASSESSMENT.

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Summary:

The consumption of melon (*Cucumis melo* L.) has been, until several years ago, regional, seasonal and without commercial interest. Recent commercial changes and world wide transportation have changed this situation.
Melons from 3 different ripeness stages at harvest and 7 cold storage periods have been analysed by destructive and non destructive tests. Chemical, physical, mechanical (non destructive impact, compression, skin puncture and Magness-Taylor) and sensory tests were carried out in order to select the best test to assess quality and to determine the optimal ripeness stage at harvest. Analysis of variance and Principal Component Analysis were performed to study the data. The mechanical properties based on non-destructive Impact and Compression can be used to monitor cold storage evolution. They can also be used at harvest to segregate the highest ripeness stage (41days after anthesis DAA) in relation to less ripe stages (34 and 28 DAA).Only 34 and 41 DAA reach a sensory evaluation above 50 in a scale from 0-100.

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INTRODUCTION

The consumption of melon (*Cucumis melo* L.) has been, until several years ago, regional, seasonal and without commercial interest. Recent commercial changes and world wide transportation have changed this situation and countries from meridional Europe have discovered that they can easily provide these fruits whenever they are able to guaranty quality.

First references on the post-harvest quality of melon come from the 80's (André, 1982; CEMAGREF, 1982; Dull, 1989). In these studies recommendations are given about standard destructive tests for quality assessments as Solid Soluble Content (SSC) and Magness-Taylor (MT) Firmness. There are specific performance of MT for melons and reference values for several commercial quality such as excellent (refractometric index $\geq$ 12, Magness-Taylor firmness between 0,5 and 1,5 Kg/0,5 cm^2) and good (refractometric index ≥ 9, Magness-Taylor firmness between 0,5 and 1,5 Kg/0,5 cm^2). New indications on destructive tests performed on melon come from Mizrach *et al* (1989), and Cardenas-Weber *et al* (1991), where the elasticity modulus on fruit probes are performed. Mizrach *et al* (1989) demonstrated that there is a strong variation of the elasticity modulus depending on the depth at which the fruit probe is extracted obtaining typical strain-stress curves for outer, middle and inner flesh of the melon. The relationship between the elasticity modulus and attenuation coefficient ($r= 0,787$) of ultrasonic excitation suggest that this measurements could be used for non-destructive internal quality assessment of the melon. The work of Cardenas-Weber *et al* (1991), on the elasticity modulus was oriented to the applicability of a gripping robot, in order to know the maximum force which could be applied to the melon without danger of bruising.

Besides the work of Mizrach *et al* (1991) on the non-destructive internal quality assessment of melons, new techniques as impact and acoustic impact response have been carried out on melon. Non-destructive impact have been used by our research group Agulheiro Santos (1991), Agulheiro Santos and Ruiz Altisent (1993), with good perspectives for melon ripeness assessment, based on a previous development (Chen *et al*, 1985 and Garcia, 1988b) already tested for other fruits types: apple and pear,

peaches, apricots, avocado (Jarén *et al,* 1992, Correa *et al,* 1993, Barreiro e Ruiz-Altisent, 1993).
Acoustic impact response has been widely studied by Sugiyama *et al* (1994) showing a high correlation between the transmission velocity of the acoustic impact and the fruit firmness measured as penetration resistance (N) with 3 mm rod (r=0,832). Finally, in 1998 a portable prototype based on the acoustic impact response has been presented by Sugiyama *et al* (1998) in order to perform field measurement of the ripeness stage of melons.

OBJECTIVES

The main objectives of this work are:

- To study the main sources of variation in the mechanical, physical and chemical properties of melons during cold storage;
- To select the best tests to assess quality/ripeness
- To determine optimal ripeness stage at harvest in relation to sensory evaluation

MATERIAL AND METHODS

Fruits belonged to *Cucumis melo* L. cv. Gustal. A factorial design concerning ripeness stage at harvest (3 modalities) and cold storage period (7 modalities) has been used.
Ripeness stages consisted of 1) a complete ripe group of fruits (41 days after anthesis DAA), 2) an unripe but very near from the ripe stage (34 DAA) and 3) an absolutely unripe (28 DAA) sample.
The fruits were stored at 6°C of temperature and 90% of R.H.. At predetermined days (3, 8, 15, 21, 27 and 31) samples were removed from cold storage and analysed. Each sample covered 4 fruits, so a total amount of 84 melons were used.
The tests carried out can be summarised as follows:
1 – Physical: Observation of external and physical characteristics such us: **diameter**, **length**, **weight** and **weight loss** (weightl), **volume**, and **flesh width** (fleshw).
2 – Mechanical
Non destructive Impacts, a spherical mass with 47,292 g of weight indent the fruit at the height of 12 cm. The maximum force (IMF), maximum deformation (IMD), permanent deformation, absorbed energy (IME) and impact duration (ITT) are extracted from the deceleration data registered by an accelerometer.
Compression, using a 30mm diameter sphere until 3mm of deformation are reached . Force at 3mm is measured (CF3).
Skin Puncture, using a cylindrical rod, 0.5 mm diameter. Test is performed until a maximum of 8 mm of penetration is reached. The maximum puncture force (PMF), the puncture deformation (PD) and the remaining force after skin rupture, named as stable puncture force (PFS), are measured.
Magness-Taylor Test, using a 8mm diameter rod, the test is performed in the mesocarp of halved fruits at 1.5 cm depth from the skin. A maximum penetration of 8 mm is used as endpoint. The maximum force (MTFIR), the deformation at the maximum force (MTD) and the force at 3mm (MT3) and 8 mm (MT8) are measured.

3 – Chemical: **Solid Soluble Content,** in fruit juice using a refractometer at Magness-Taylor site (Brixpar) and average fruit measurement (Brixtot).
4 – Sensory: **Sensorial Evaluation** with a pool of 8 people maximum trained for this commodity (Global Hedonic evaluation).

RESULTS AND DISCUSSION

Sources of variation affecting mechanical, physical and chemical parameters

Several mechanical tests are more related to the changes that occur during cold storage than to the ripeness stage at harvest (F value in ANOVA analysis higher for "storage duration" than for "days of anthesis"). That is the case for :

- Non destructive impact : Maximum force (Fstorage=42.05), Impact duration (Fstorage=35.31)
- Non Destructive Compression : Force at 3mm (Fstorage=54.22)
- Magness-Taylor firmness : Force at 3mm (Fstorage=55.28)

The loose of weight is also the physical parameter showing the highest relationship with changes occurred under cold storage (Fstorage=106.67).
The ripeness stage at harvest is mainly related to the chemical test such as Soluble Solid Content (F value for "days of anthesis" = 32.82 when compared to 3.78 for "storage duration"). Some mechanical parameters also relate mainly to the ripeness stage at harvest as the Maximum Force (MFP, Fanthesis=50.80) and the Stable Force (StFP, Fanthesis=46.10) both belonging to the skin puncture test. This is also the case for most of the physical parameters : diameter (Fanthesis=16.12), lenght (Fanthesis= 11.86), volume (Fanthesis=16.44).
The highly significant effect obtained in the interaction between "days after anthesis" and "cold storage duration" for several mechanical parameters: impact maximum force (F interaction=6.46, see first row in Figure 1), impact duration (F interaction=8.19), Magness-Taylor firmness (F interaction=9.83) and force at 8mm (F interaction=9.41), and force at 3mm deformation (F interaction=8.74) under non destructive compression, indicates a differential behaviour of melons under storage due to differential harvest conditions.
A Principal Component Analysis has been carried out using a pool of 14 physical, mechanical and chemical parameters. The first Principal Component, explaining a 43 % of the total variance,, is composed by mechanical tests such as Maximum Impact Force (IMF), Maximum Impact Deformation (IMD), Impact duration (ITT), maximum deformation at Skin Puncture (PMF), Force at 3mm under Compression (CF3), and a physical parameter as Loose of Weight (weightl, see Figure 2). All of them showing a very high correlation one-another. The representation of individuals under this Principal Component shows that this Factor mainly relates with the changes occurred under cold storage as shown through the ANOVA. The three different ripeness stages at harvest exhibit distinct behaviors during cold storage; the less ripe fruits were those having a wider change (See figure 3). In all three ripeness stages at harvest (28, 34 and 41 DAA) there is a sigmoid behavior during cold storage, however the inflexion point and range of variation of the sigmoids differs in all three cases. This is also confirmed by a significant effect in the ANOVA of the interaction "Storage Period" – "Days After Anthesis" in the variables associated with the first PC.

The Solid Soluble Content (SSC) is related to the Second Principal Component (24% of total explained variance) also highly independent from the parameters forming the First Principal Component as the SSC increases for higher number of days after anthesis at harvest and remains fairly constant (see second row in Figure 1).
The use of the Principal Components (PC) instead of the individual parameters allows to obtain a more smooth information of the changes occurred in the melons along the cold storage period. (compare first row in Figure 1 and Figure 3).

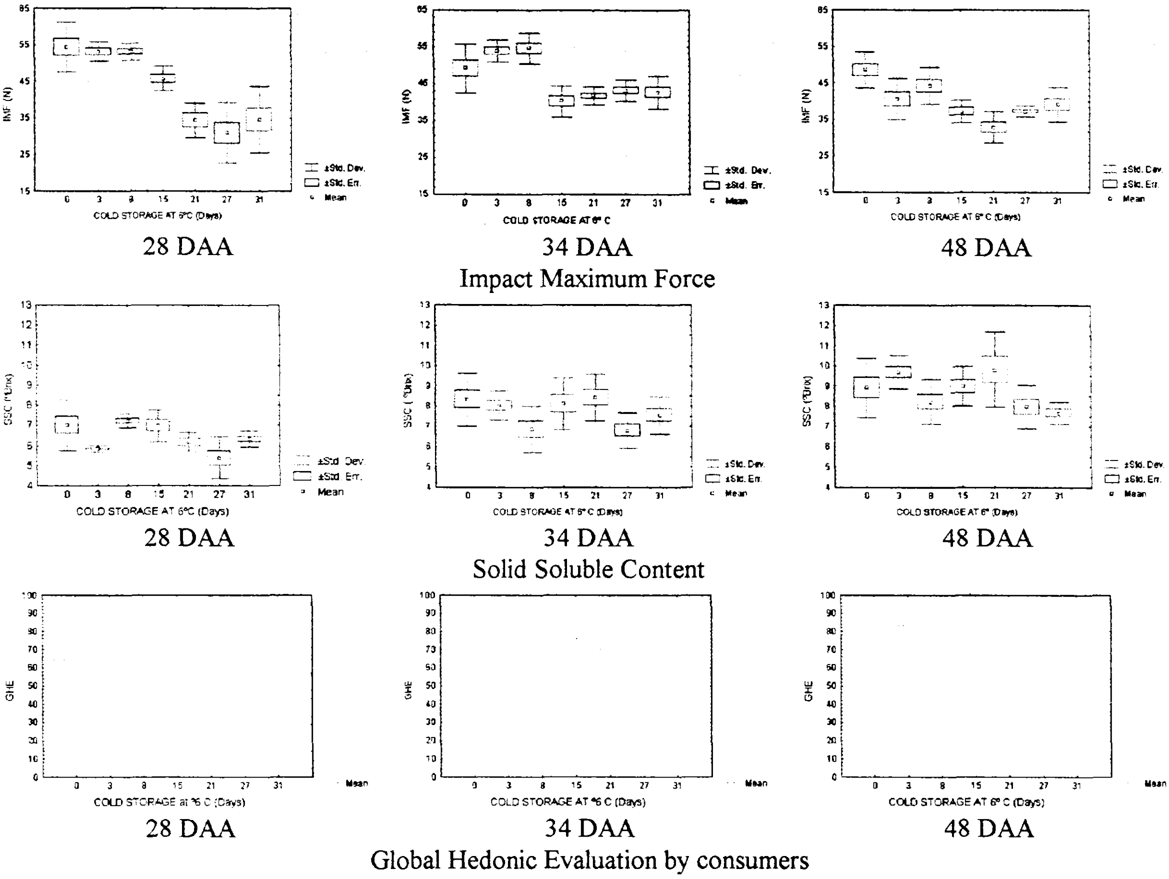


Figure 1. Evolution of selected mechanical, chemical and sensory parameters during cold storage for 3 different ripeness stages at harvest

Selection of tests for quality assessment

The chemical test along with the skin punction are the tests enabling to establish the ripeness stage at harvest. However other mechanical test as non destructive impact and compression allow to segregate at harvest the most ripe melons (41 DAA) when compared with the others ripeness stages (34 and 28 DAA) and simultaneously to follow changes during storage.

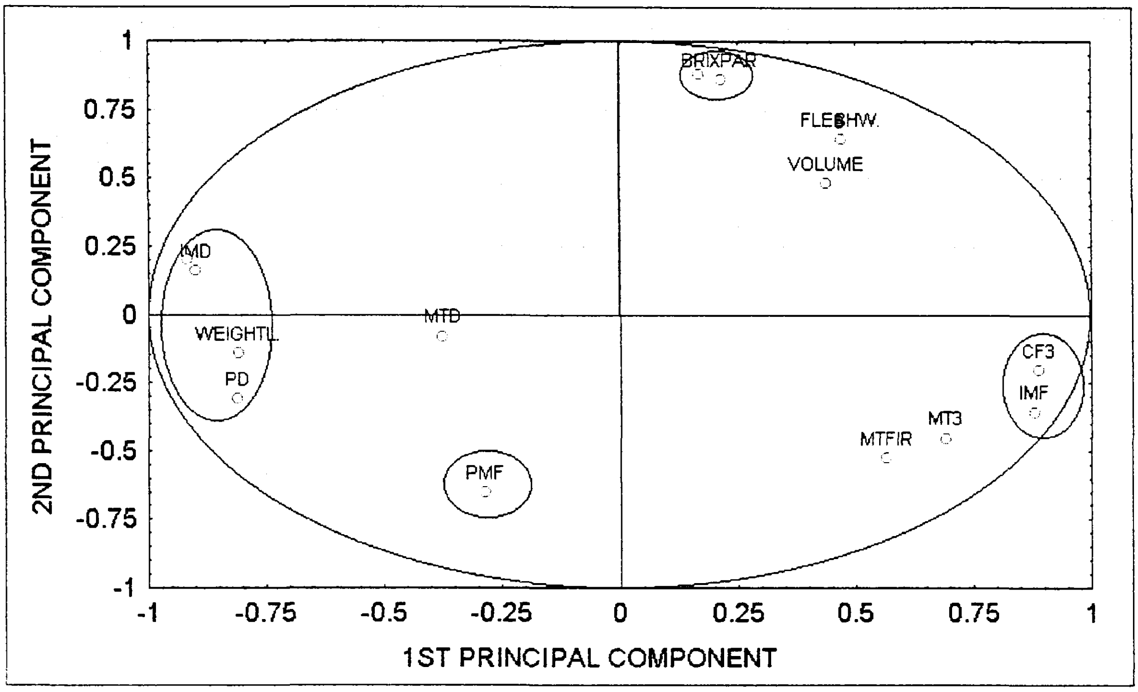
Optimal ripeness stage at harvest in relation to sensory quality

When comparing SSC and mechanical properties against the sensory evaluation (see third row in Figure 1) it is clear that the Global Hedonic Evaluation is based on the values of SSC while the mechanical properties are only important to decide about quality when the values of SSC are very low. The 28 DAA never reach a Global

Hedonic Evaluation above 50 in a scale 0-100 in spite of 34 and 41 DAA samples which reach 75 and 84 respectively.
The ripeness stages referred in this work as 34 and 41 DAA are therefore the most adequate to in relation to sensory quality.

Variable	**MS Effect** *F* P-level				Degrees of freedom	Number of Observations	Cv %
	1 Days after anthesis	2 Days of cold storage	1x2 Interaction	MS Error			
IMF	**596.425** *25.00407* 0.00	**1003.047** 42.05097 0.00	**154.207** 6.46486 0.00	23.85311	145	166	10.91
IME	**0.000056** 8.11722 0.00	**0.000198** 28.77386 0.00	**0.000024** 3.53834 0.00	0.000007	145	166	5.36
ITT	**4.35817** 14.16550 0.00	**10.86455** 35.31340 0.00	**2.51841** 8.18568 0.00	0.307661	145	166	9.38
MTFIR	**240.3767** 35.04213 0.00	**216.0179** 31.49110 0.00	**67.4349** 9.83067 0.00	6.859649	145	166	36.34
MT8	**160.9494** 33.39626 0.00	**172.4208** 35.77653 0.00	**45.3266** 9.40507 0.00	4.819383	145	166	36.99
PMF	**45.64687** 52.79955 0.00	**8.67996** 10.04007 0.00	**1.24907** 1.44479 0.15	0.864532	145	166	18.84
PFS	**2.434983** 46.10055 0.00	**0.715790** 13.55176 0.00	**0.138229** 2.61704 0.00	0.052819	145	166	32.22
CF3	**5.92908** 16.55113 0.00	**19.42381** 54.22192 0.00	**3.12981** 8.73691 0.00	0.358228	145	166	20.31
Brixtot	**37.80316** 30.60918 0.00	**3.44391** 2.78853 0.02	**1.44802** 1.17246 0.32	1.235027	62	83	12.17
weightl	**1193.393** 14.3277 0.00	**8885.087** 106.6730 0.00	**207.339** 2.4893 0.00	83.29277	62	83	17.07
Diameter	**9.490342** 16.11985 0.00	**1.997981** 3.39368 0.01	**0.652174** 1.10775 0.37	0.588737	62	83	4.83
Volume	**810004.4** 16.44193 0.00	**250654.6** 5.08793 0.00	**37983.5** 0.77101 0.68	49264.57	62	83	13.99

Table 1. ANOVA Analysis (MS effect, F value and p-level) for the chemical, mechanical and physical parameters in relation to ripeness stage and cold storage period.



Factor Loadings
Extraction: Principal components
(Marked loadings are > .700000)

	Factor 1	Factor 2	Factor 3
IMF	0.84190846	-0.4769169	0.1126708
IMD	-0.89152765	0.29260828	-0.06556573
ITT	-0.89966397	0.32256285	-0.10132693
MTFIR	0.45812293	-0.51765256	-0.24315165
MTD	-0.37945568	-0.04494544	0.55178512
PMF	-0.34508127	-0.64150632	0.34021494
PD	-0.8430376	-0.21135044	0.12758529
CF3	0.86510441	-0.31660942	0.13408784
WEIGHTL	-0.81086637	-0.06488877	0.35023255
FLESHW.	0.55374117	0.56097525	0.39696493
BRIXPAR	0.30059567	0.8495196	-0.07992433
BRIXTOT	0.25945111	0.87011139	-0.08454277
VOLUM	0.50613127	0.40042608	0.58363439
Expl.Var	5.62306408	3.2015635	1.1752625
Prp.Totl	0.43254339	0.24627412	0.09040481

Figure 2. Principal Component Analysis based on physical, mechanical and chemical parameters.

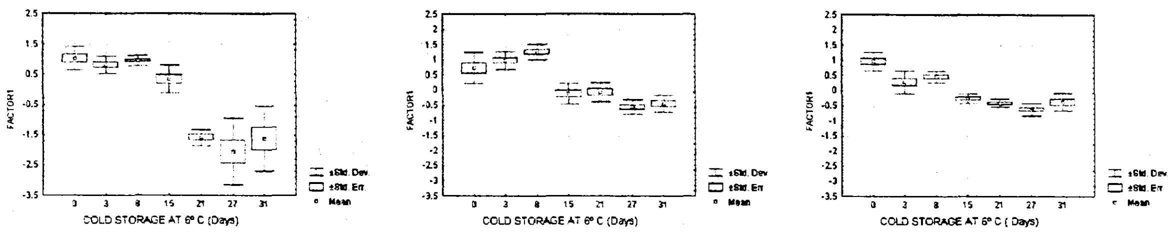


Figure 3. Evolution of the 1st Principal Component for different days of anthesis and cold storage periods.

CONCLUSIONS

- The ripeness stage at harvest relates to the chemical properties, which also remain fairly constant even they are 31 days of cold storage.
- The mechanical properties based on non-destructive Impact and Compression can be used to monitor cold storage evolution. They can also be used at harvest to segregate the highest ripeness stage (41DAA) in relation to less ripe stages (34 and 28 DAA).
- Texture evolution along cold storage exhibit a sigmoid behavior for the three ripeness stages at harvest. The ripeness stage of 28 DAA shows the worst evolution when compared to 34 and 41 DAA.
- Only 34 and 41 DAA reach a Global Hedonic Evaluation above 50 (75 and 84 respectively) in a scale from 0-100.

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