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POST HARVEST MATURITY OF AVOCADOS EVALUATED BY NON - DESTRUCTIVE TESTS

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ABSTRACT

Flesh firmness in fruit depends on the maturity degree and it can be determined, in a destructive way, by measuring the required force to penetrate the fruit. However, important researches have been carried out in order to determine the maturity degree in fruits by non-destructive procedures. The objective of this work was to accomplish a comparative study between the mechanical parameters, resulting from controlled impacts and flesh firmness, and a traditional index, used in the evaluation of maturity in "Hass" avocados (*Persea americana* Mill.). Two batches of fruits were selected. One of them was not in contact with ethylene absorber, while the second one had a sepiolite absorber sachet which was smeared with $KMnO_4$, in a dose of 9,5 g kg^{-1} per fruit. A computer assisted impact-testing device with a 49,29 g stem and a 0,04 m height was used. Impacts proved to be non-destructive under these conditions and therefore they could be used to determine the ripening stage in "Hass" avocado. The results were similar to both groups, although the one treated with the ethylene absorber presented a delay, making clear its effect on retarding the process of full ripeness in fruits.

Keywords: mechanical properties, firmness, impact.

ESTÁGIO DE MATURAÇÃO NA PÓS-COLHEITA DE ABACATES AVALIADO POR PROCESSOS NÃO DESTRUTIVOS

RESUMO

A firmeza dos frutos depende do grau de maturidade e pode ser determinada por métodos destrutivos, medindo-se a força requerida para perfurar o fruto. No entanto, pesquisas importantes têm sido desenvolvidas para determinar o grau de maturidade em frutos por meio de procedimentos não-destrutivos. O objetivo do presente trabalho foi realizar um estudo comparativo entre os parâmetros resultantes do impacto mecânico controlado e os do tradicional método destrutivo por penetração, para avaliação da firmeza como índice de maturação em abacates “Hass” (*Persea americana* Mill.). Neste estudo foram selecionados dois lotes de frutas, os quais foram submetidos a diferentes tratamentos. No primeiro lote não se utilizou absorvedor de etileno, enquanto que no segundo os abacates receberam sachês de sepiolita contendo $KMnO_4$, na dose de 9,5 g kg^{-1} por fruta. O equipamento utilizado nos testes apresenta uma haste de 49,29 g e 0,04 m de comprimento, a qual promove o impacto nos frutos mediante comando computadorizado. Sob estas condições, os impactos provaram ser não destrutivos, de tal maneira a propiciar a avaliação do grau de maturação em abacates “Hass”. Os resultados obtidos foram similares para ambos os lotes estudados, havendo, entretanto, o retardamento do processo natural de maturação no lote em contato com absorvedor de etileno.

Palavras-chave: propriedades mecânicas, firmeza, impacto

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INTRODUCTION

Flesh firmness in fruits is related as being their resistance to shearing and deformation, being connected to the characteristics of the cell walls and to the resistance of intercell joints. To some extent, it depends on the maturity degree of the fruit. Flesh firmness is determined, in a destructive way, by measuring the required force to a penetrometer, equipped with a cylinder that goes into the fruit, penetrate the fruit, which is usually without skin. It is not possible to use a normal penetrometer in avocados. For this reason, De La Plaza et al. (1975) suggest a modified version with a double plate. By using this system, flesh firmness can be measured in avocados (De La Plaza et al., 1983), custard (*Annona cherimoya*) and apples (De La Plaza, 1980; De La Plaza et al., 1989).

In the last few years, important researches have been carried out in order to determine the maturity degree in fruits by non-destructive procedures. For that purpose, different methods and techniques have been designed and tested, such as: mechanical vibrations, sonic pulses frequency, reflection in the near infrared and nuclear magnetic resonance, with limited success (García Ramos et al., 2003). The use of these techniques in real processes in order to obtain data automatically is mainly limited by the need of modifications in the handling of the fruits and the difficulty in installing sensitive surfaces.

The evaluation of the maturity degree in fruits by studying the existence of relationships between the mechanical parameters (which characterize the response to non-destructive mechanical impacts) and flesh firmness, shows several advantages over other techniques. Impact force analysis is attractive as an on-line system because the measurements are quick (impacts spends only milliseconds), the fruit handling aspects, such as accurate placement of the fruit on a sensor, are not complicated and the sensors are inexpensive (McGlone et al., 1997). Nahir (1986) and Delwiche (1987, 1987a) designed systems based on their free-falling on rigid surfaces equipped with force sensors to evaluate flesh firmness in fruits. The variability of fruit mass and the impossibility of controlling the points of contact with the sensitive surface resulted in inaccurate results.

Some progress in the design and application of a mechanism to determine the response of fruits to impacts has been made by Rodriguez & Ruiz (1988), Garcia (1988), Ruiz et al**.** (1989, 1990, 1990a) and Jarén & García-Pardo (2002). Some researchers have used a computer assisted impact-testing device to study the impact resistance in order to evaluate the susceptibility to possible damages. Results of those previous studies have shown that the evaluation of flesh firmness in fruits made by impact techniques can be successfully used (Jarén & García-Pardo, 2002). From these works, an obvious relationship between the resulting impact parameters and the maturity level can be established. They also demonstrated that a small impact, which does not damage the fruit, can offer valuable data and useful information in order to classify fruits according to their ripeness stage.

The objective of this work was to accomplish a comparative study of the mechanical parameters resulting from controlled impacts and flesh firmness, a traditional index used in the evaluation of maturity in "Hass" avocados (*Persea americana* Mill.).

MATERIAL AND METHODS

The fruit

The study was done with "Hass" avocados (*Persea americana* Mill.) from Malaga in Spain, which were daily analyzed. After a rigorous selection, they were classified according to their size, ripeness stage and sanitary condition.

The condition

The fruits were placed in plastic boxes that were wrapped, sealed with low polyethylene bags density (0,025 mm of thickness) and kept at 20 ºC for eleven days. They were divided into two batches. The first one was not in contact with ethylene absorber, while the second one received a dose of 9,5 g kg^{-1} per "Green Keeper" fruit. Both lots were tested on intervals of 1, 5, 7, 9, and 11 days. Each box, containing ten fruits, was considered a sample unit.

Analytical Techniques

a) Mechanical Impacts

A computer controlled impact test device with a 49,29 g impacted and a 0,04 m drop height was used. It consists, basically, of a steel impacting rod with a spherical tip, which allows different height settings for dropping over the fruits. The whole mechanism is controlled by a computer, equipped with a software to record, process, and display the mechanical resulting parameters from impacts (Figure 1).

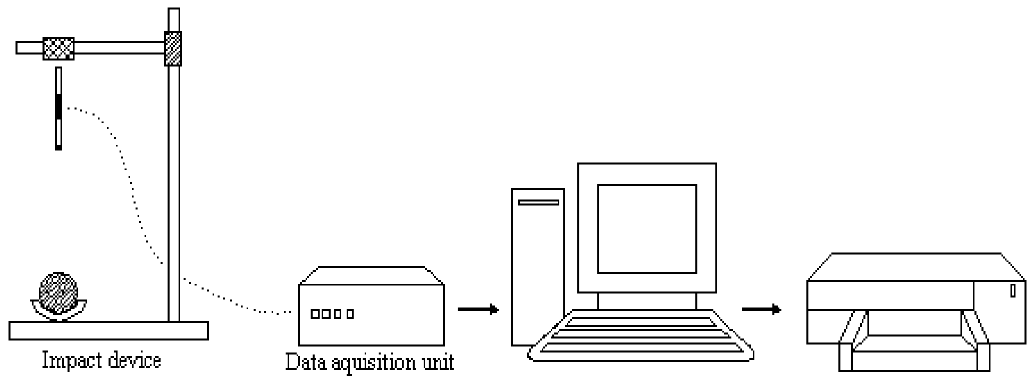

Figure 1- Impact testing device.

b) Firmness

It was used an universal testing machine (Instron 1140), fitted with a double plate, to measure flesh firmness.

c) Skin Resistance

Skin resistance to puncture was measured, as a complementary test, with an universal testing machine (Instron 1122) fitted with a 0,5 mm diameter flat base probe. All tests were carried out at three different points that are equidistant from the equatorial zone of the fruits. Five avocados were chosen randomly from each sample unit.

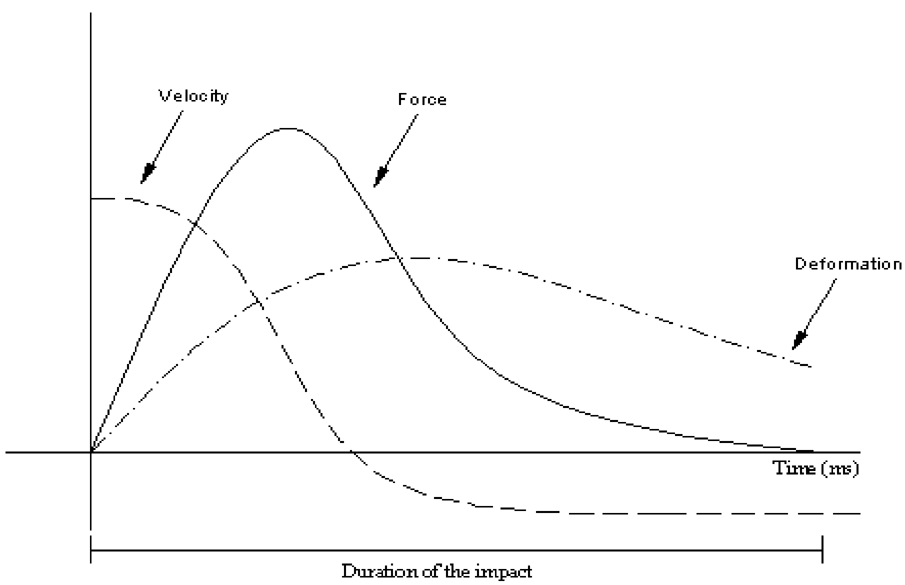

Figure 2- Impact response

Statistical Analysis

For each treatment (with and without ethyleno absorber), the regression equations ($R^2 \geq 0,90$) were adjusted to the experimental data for non destructive mechanical parameters in function of the maximum penetration force.

RESULTS AND DISCUSSION

The results allowed to select the impact parameters with higher degree of correlation with flesh firmness (Table 1). The results that corresponds to the average of fifteen measures are presented In Table 2. The effect of the application of the ethylene absorber is seen in all studied parameters. The use of the absorber reduces the ethylene concentration in the air inside the sample units (boxes).It, together with the modified and steam saturated atmosphere generated within the polyethylene bags, retards the ripeness process. The generated atmosphere inside the polyethylene wrapped boxes, with high concentrations of CO_2 and low concentrations of oxygen, reduces the fruits sensitivity or the response to ethylene so that it retards the ripeness process. By adding the absorber, this effect is increased and the concentration of ethylene is kept low during the storage.

Table 1 - Selected parameters included in the analysis

Variables	Units	Symbol	
		Control	With absorber
Duration of impact	ms	DUT	DUG
Slope Force/Time	KN s^{-1}	FIT	FTG
Slope Force/Deformation	N mm^{-1}	FDT	FDG
Modulus of elasticity	mN m^{-2}	MET	MEG
Maximum deformation	Mm	DMT	DMG
Maximum penetration force	N	FMT	FMG
Maximum puncture force	N	PUT	PUG
Time	Days	-	-

Table 2 - Maximum penetration and puncture forces and impact parameters (15 measurements average data)

Days	FMG (N)	FMT (N)	PUG (N)	PUT (N)	DUG (ms)	DUT (ms)	FTG (kN s^{-1})
0	76,46	76,46	4,2	4,20	2,75	2,75	66,72
5	74,68	75,73	3,94	3,57	2,84	2,79	65,39
7	68,01	67,76	4,02	3,31	2,90	2,90	54,50
9	60,82	40,02	3,87	2,83	3,13	3,72	50,31
11	22,27	3,14	2,84	2,07	3,87	4,92	36,92

Continuation:

Days	FIT (kN s^{-1})	FDG (N mm^{-1})	FDT (N mm^{-1})	MEG (Mm m^{-2})	MET (Mn m^{-2})	DMG (mm)	DMT (Mm)
0	66,72	93,03	93,03	31,17	31,17	0,85	0,85
5	67,21	90,55	89,41	30,02	30,40	0,88	0,84
7	52,47	73,65	70,60	23,72	22,31	0,89	0,90
9	35,87	68,46	47,20	21,72	13,85	0,91	0,99
10	26,72	47,08	33,14	15,00	10,06	1,07	1,27

Firmness Evolution

Table 2 and Figure 2 clearly show how fruits become less hard, an evident sign of maturation. In both sets, the decrease started on the 6th day. The effect of the absorber was plainly observed by the end of the experiment.

The fruits submitted to ethylene absorber presented approximately 20 N of strength, while those without the treatment presented approximately 3 N, what made them non-suitable for fresh market.

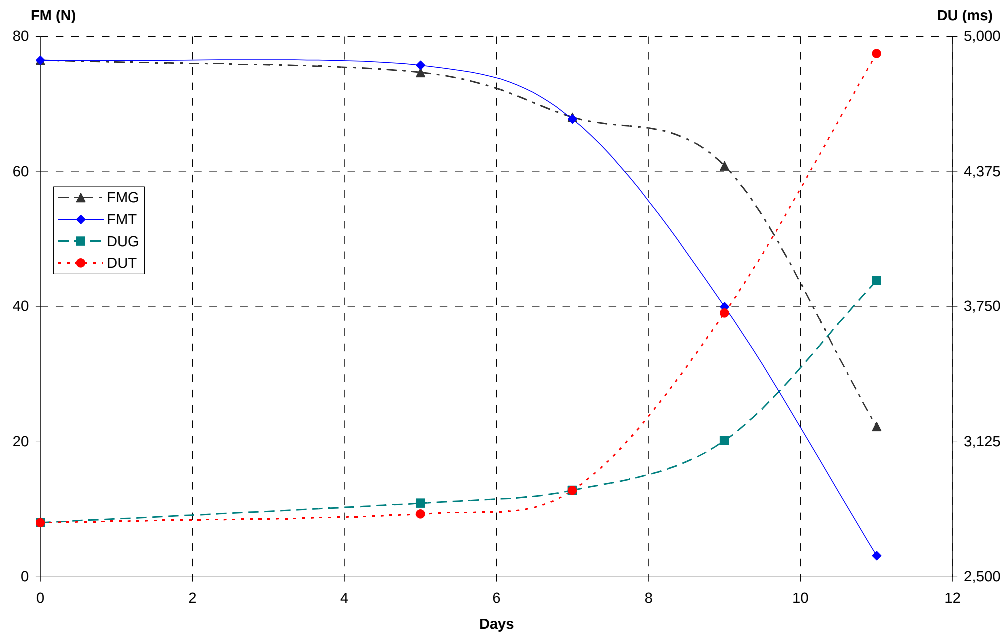

Figure 3 - Evolution of maximum penetration force (firmness) and the duration of the impact

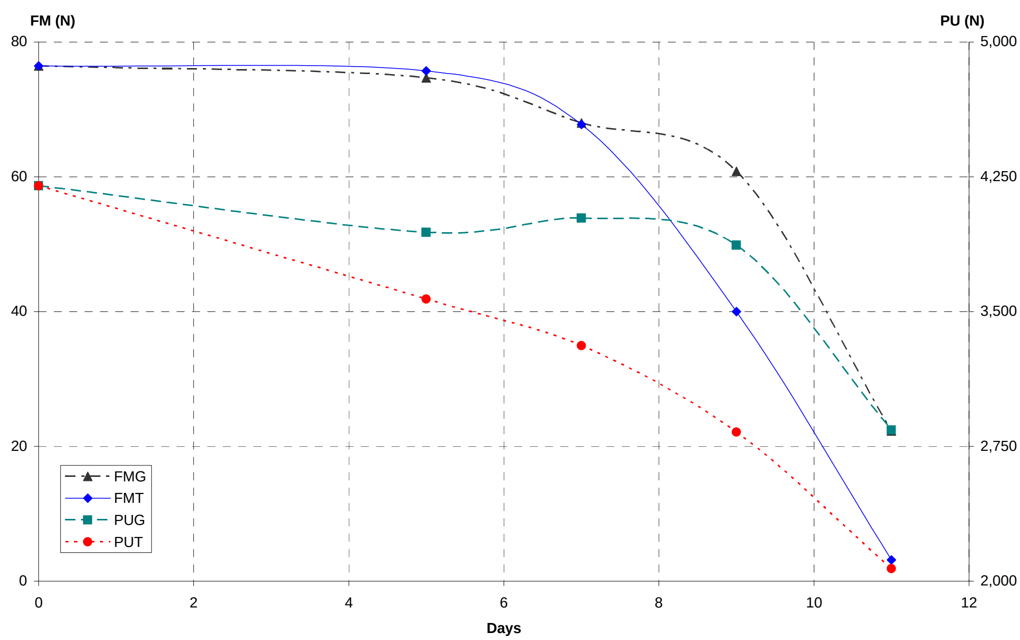

Figure 4 - Evolution of the maximum penetration force (firmness) and maximum puncture force

Skin Resistance Evolution

Skin resistance decreases in a similar way to flesh firmness when ripeness becomes complete. The effect of the ethylene absorber is clearly seen in fruits with a higher skin resistance. The results for the batch in which the "Green-keeper" was used were practically constant until the 9th day. From the analysis of the data, an exponential correlation with the maximum penetration force was established (Table 3). It suggests the possibility of taking skin resistance as an index of the ripeness stage of the fruit.

Impact Mechanical Parameters

Taking flesh firmness as an index of maturity, the mechanical parameters which result showed a higher correlation were: duration of impact slopes of the force/time and force/deformation, maximum deformation and modulus of elasticity. There is a direct correlation between the slopes and the modulus of elasticity, and an inverse correlation between the duration of impact and the maximum deformation (Figure 2). The study of these results suggests that the response to non-destructive impacts used to analyze maturity in avocados might be as valid as the traditional methods used to determine flesh firmness. It may be noticed that both batches presented similar results, although the application of the ethylene absorber causes some retardation.

Regression analyses of the obtained data were made in order to find the more accurate mathematical model to express the relationship between each parameter and the maximum penetration force (Table 3).

Table 3 - Adjusted equations of the puncture force and the impact variables with the maximum penetration force. (Correlation coefficients ≥ 0,90).

VARIABLES	EQUATIONS
Maximum puncture force	PUG= 2,463.exp(0,007.FMG)
	PUT= 2,007.exp(0,008.FMT)
Duration of impact	DUG= 4,324 – 0,020.FMG
	DUT= 4,971 – 0,030.FMT
Slope force/deformation	FDG= 35,031.exp(0,012.FMG)
	FDT= 29,938.exp(0,01.FMT)
Slope force/time	FTG= 28,462.exp(0,010.FMG)
	FIT= 24,137.exp(0,013.FMT)
Modulus of elasticity	MEG= 10,888.exp(0,013.FMG)
	MET= 8,763.exp(0,015.FMT)
Maximum penetration force	DMG= 1,165.exp(-0,004.FMG)
	DMT= 1,273.exp(-0,005.FMT)

CONCLUSIONS

It may be concluded through the results obtained from data analysis that the mechanical parameters, resulting from non-destructive impact test: duration of impact, slopes of the force/time and force/deformation, maximum deformation and modulus of elasticity are indicators of the ripeness stage in post-harvest avocados. The application of ethylene absorber is a low cost technology and allows to retard full ripening of the fruits. Puncture test, used to measure skin resistance, can also be considered as an indicator of maturity degree in "Hass" avocados.

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