SENSING PHYSICAL STAGE OF FRUITS BY THEIR RESPONSE TO NON-DESTRUCTIVE IMPACTS

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ABSTRACT

Fruits of two varieties of both apples and pears were tested in the laboratory to measure their response to a small energy impact applied by an impact tester. Samples of fruits of increasing maturity were tested during several weeks. Non-destructive impacts and other destructive and non-destructive measurements of post-harvest ripeness were applied. A new software was created to control the impact test, calculate the eleven parameters, and sort out the fruit. This software needs a data base and may create new ones. The implementation of an on-line impact device for automatic detection of texture is being designed (patent pending).

INTRODUCTION

Fresh fruit plays an important role in man's nutrition. Our society demands higher quality products and producers try to increase their market value. Qualitative evaluation of agricultural products has been a matter of interest to researchers for many years. However, there is no clear definition of fruit quality. Nevertheless, what we call organoleptic quality could be summarized as "eating pleasure". Many quality factors such as size, shape, colour, flavour, firmness, and taste are related to maturity. Since many quality-ripeness factors of agricultural products are related to their physical properties, it is necessary to develop non-destructive techniques to evaluate post-harvest ripeness based on physical properties.

Some impact parameters (maximum force, maximum deformation, duration of impact ...) are closely related to ripeness. A combination of some of these parameters as a quality index could facilitate the detection of very small ripeness differences (García et al., 1988). Under certain conditions, the impact test could be a non-destructive technique.

One of the most practical and successful techniques for non-destructive quality evaluation and sorting of agricultural products is the electro-optical technique, based on the optical properties of the product. By studying the reflectance curve and its first derivative at various wavelength regions it is possible to select a set of wavelengths at which the optical readings appear to correlate with maturity (García et al., 1992).

OBJECTIVES

The objectives of this study were:

1.-To determine which impact parameters are most closely related to ripeness.

2.-To create a software to control the impact test, calculate the parameters, and sort the fruits.

3.-To create a data base for sorting different fruits.

EXPERIMENTAL PROCEDURE

Two varieties of both pears ("Blanquilla" and "Decana de Comice") and apples ("Golden Delicious" and "Starking") were tested. Fruits came from Lérida (Spain) and were transported to the Physical Properties Laboratory of the Agricultural Engineering Department in Madrid. All the fruits were stored in a 20±2ºC room. Fruits were classified by weight, size, and freedom from mechanical injuries and decay.

A first group of ten fruits was tested in a non-destructive way several times throughout their ripening till senescence. A second group, similar to the first one, was tested on the same days in a non-destructive way first, and then in a destructive way, therefore it had to be replaced by a new one on the next test (Fig. 1). Pears were tested every two days and apples every three days. The following tests and measurements were made on each fruit:

<u>Non-destructive</u>

-An impact test was performed using the impact test system developed by Chen et al. (1985). A 50 g instrumented steel rod with a spherical tip and a radius curvature of 0.94 cm was dropped from a 4 cm height onto each pear; 3 cm in the case of apples (Fig. 2). Two impact tests were conducted on each fruit. The acceleration of the rod during impact was measured from the data given by an accelerometer connected to the end of the indentor. The other impact parameters were calculated and recorded on a computer disk file.

-Measurements included mass, radius of curvature, and perimeter.

<u>Destructive</u>

-Bruise evaluation. During each impact test, the spherical tip was first smeared with ink. When the tip came in contact with the fruit, it left an ink mark showing the area of contact. Each contact point was labelled, and the bruises in the fruit were allowed to develop for about 2 h. The degree of bruise was evaluated by cutting through the center of the bruised region (perpendicular to the fruit surface) and measuring the maximum width and depth of the bruise with a stereo-microscope, (Nikon model SMZ-2T, x10-63), wich was equipped with a caliper and a camera (Rodríguez et al 1991).

-Penetration test (Magness-Taylor). This test was performed using an Instron universal testing machine model 1122. A standard 7.9 mm diameter rod was used at 10 mm/min until the rod went 6 mm into the fruit. Two penetration tests were performed at two different locations along the equator on each fruit without skin (Fig. 3).

-Cylindrical specimen cut. This test was done using the same Instron machine used in the former test. Cylindrical fruit samples were 6 mm diameter. These were placed into an instrument specially designed for this test. A force was applied at 20 mm/min until the cylindrical specimen was completely cut off. Lateral compression was applied (Ruiz-Altisent et al. 1989) (Fig. 4).

-Skin colour. The reflectance spectrae and that of the first derivative of the skin of five fruits of each variety were measured using a Perkin-Elmer 555 spectrophotometer. The visible spectro (340 nm-800 nm) was studied at 20 nm intervals (Fig. 5).

-Taste quality. Five cylindrical specimen of each fruit were tasted by five different untrained assessors. Their opinions were registered according to a hedonic scale in a form (Piggott, 1988) (Fig. 6).

-Measurements included the percent soluble solids and pH of the fruit juice, measured with a refractometer and a pHmeter respectively.

STATISTICAL ANALYSIS

Impact data from the first group were analysed using a stepwise discriminant analysis (Judez, 1990; program Discrim). The program performs a discriminant analysis between two or more groups. The variables used in computing the linear classification functions are chosen in a stepwise way, both forward and backward. At each step, the variable that adds most to the separation of the groups is entered into (forward) or the variable that adds least is removed from (backward) the discrimination. The analysis was performed taking the succesion of days as different stages in the ripening process. Impact data from the second group were analysed as anonymous.

The impact parameters chosen were (Fig. 7):

1.-Total duration . . . . TD
2.-Final duration at speed = 0 . . . . FD
3.-Time to maximum force . . . . TM
4.-Increment TD-FD . . . . IT
5.-Slope force/deformation . . . . F/D
6.-Slope force/time . . . . F/T
7.-Maximum force . . . . MF
8.-Maximum deformation . . . . MD
9.-(F/T)/FD C
10.-Elasticity modulus . . . . EM
11.-Maximum shear stress . . . . SS

Elasticity modulus and maximum shear stress proved to be so low in discriminating groups and so difficult to determine that they were substituted by

10.- MD^3/2
11.- MF/(MD^3/2)

RESULTS AND DISCUSSION

"Blanquilla" pears were tested five times, "Decana de Comice" pears eight times, and apples ten times. The analysis was first made with all groups (all days), that is to say ripeness stages. Because of the small observed difference between consecutive groups, a selection was made in order to increase the differences among them. The first, the last and the middle day were chosen.

The results show the percentage of well-classified fruits:

Variety	% (all groups-days)	% (selected groups-days)
Blanquilla	76 (5 groups)	97 (3 groups)
Decana	60 (8 groups)	97 (3 groups)
Golden	59 (10 groups)	97 (3 groups)
Starking	54 (10 groups)	100 (3 groups)

The discriminating analysis selected the most appropriate variables in each case. The most discriminant variables were MF, IT, and C.

The stepwise way for sorting each variety was:

Blanquilla	C
Decana	MF-IT-FD-C
Golden D.	SS-MF-IT
Starking	MF-F/T-MD-FD

A high correlation was found between the classification of the anonymous samples made by the discriminating analysis and the results obtained from the destructive tests.

The evaluation of the bruise damage showed that impacts do not cause any damage during the first ripening stages. Under these conditions, the impact test proved to be a non-destructive technique.

Given the good results obtained with Discrim, a new software has been created to control the impact test, calculate the eleven parameters, and sort the fruit in a direct way and a very short time. This software needs a data base that is created by pre-classified specimens and may create new ones. The system is therefore self-instructing. The implementation of an on-line impact device is being designed.

The results of the stepwise discriminant analysis of the reflectance curves (R) and their first derivative (R') gave a 100 per cent of well-classified fruits for all the varieties when the three selected groups were taken. The wavelengths (nm) selected for the analysis were:

VARIETIES	CURVES	WAVELENGTHS
Blanquilla	R	690,680,710,600,400,630,460
	R'	460,690,450,620,510
Decana de Comice	R	670,630
	R'	630
Golden Delicious	R	340,760,570
	R'	670,500,560,730
Starking	R	340,530
	R'	670,660,550,630,720

CONCLUSIONS

Using this analytical procedure, it is not necessary to choose any variables since the discriminating analysis can work with the eleven and selects the most appropriate ones in each case. The software created proved to be valid as a fruit maturity sorting system based on non-destructive impact parameters.

A selection of the results functions as a data base. The program allows creating new data base for different varieties and species.

Classification of fruits into ripeness classes is more accurate using this impact response and discriminant analysis than using conventional destructive tests.

The same analytical procedure was very effective for classification of fruits based on reflectance spectrophotometry.

ACKNOWLEDGEMENT

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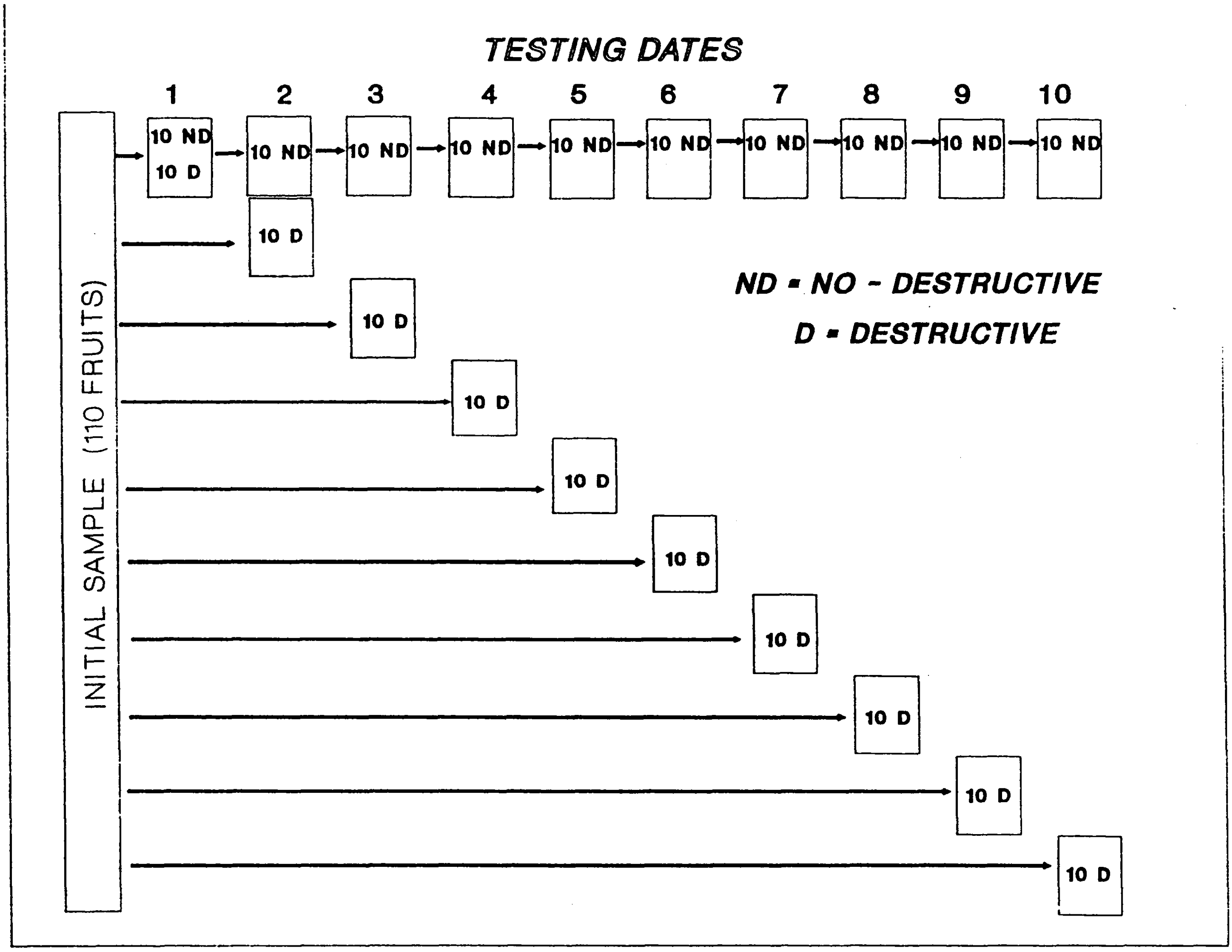

Fig.1 Schematic diagram of the experiment design.

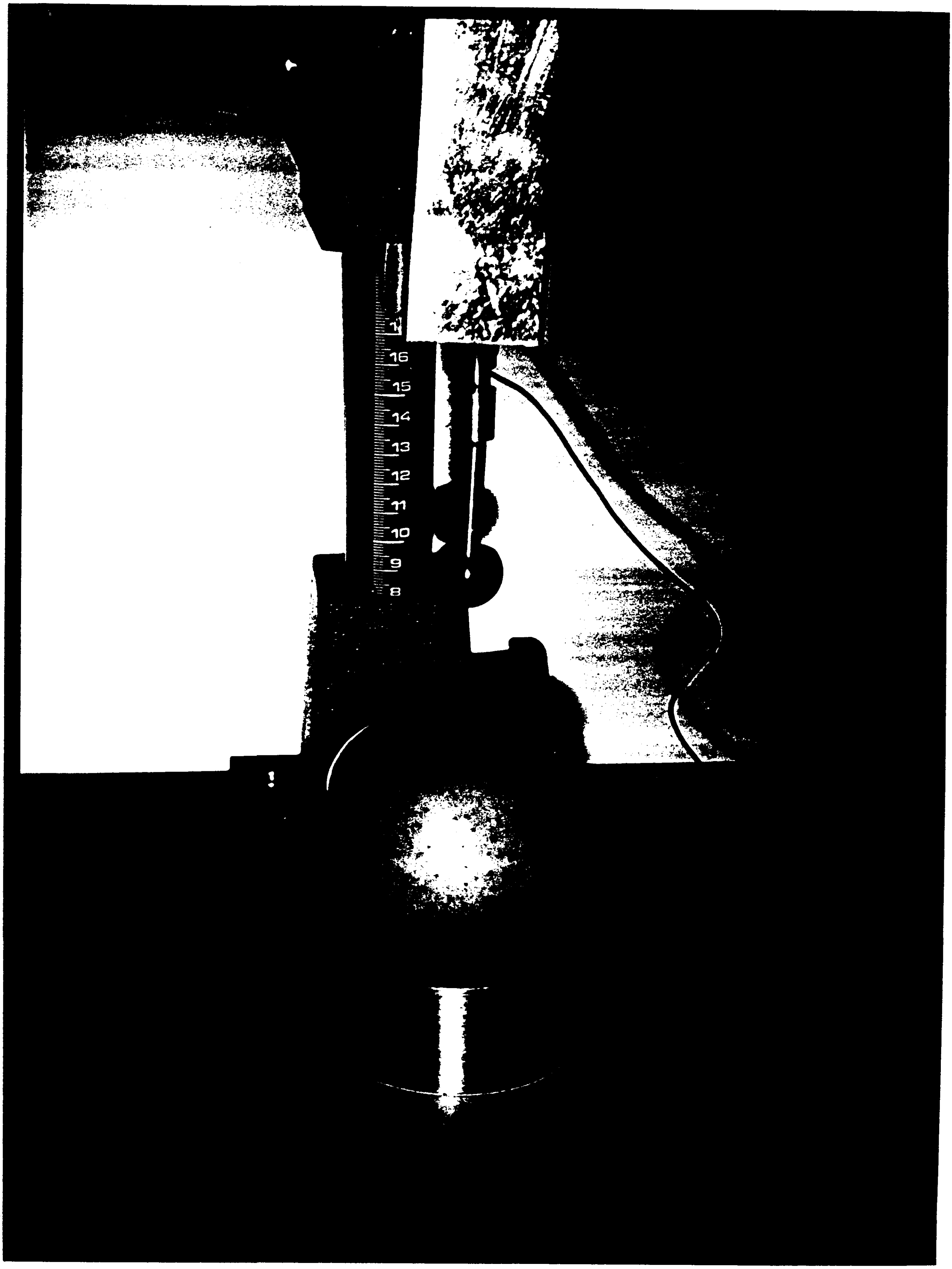

Fig.2 Impact test system.

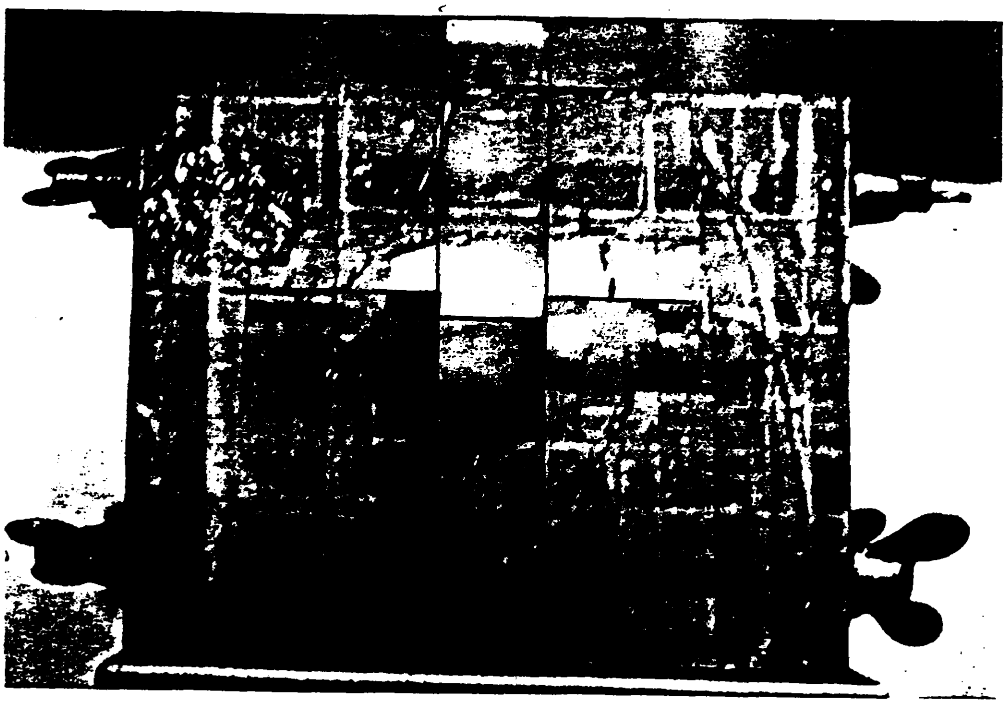

Fig.4 Cilyndrical fruit samples into an instrument specially designed for the cylindrical specimen cut test.

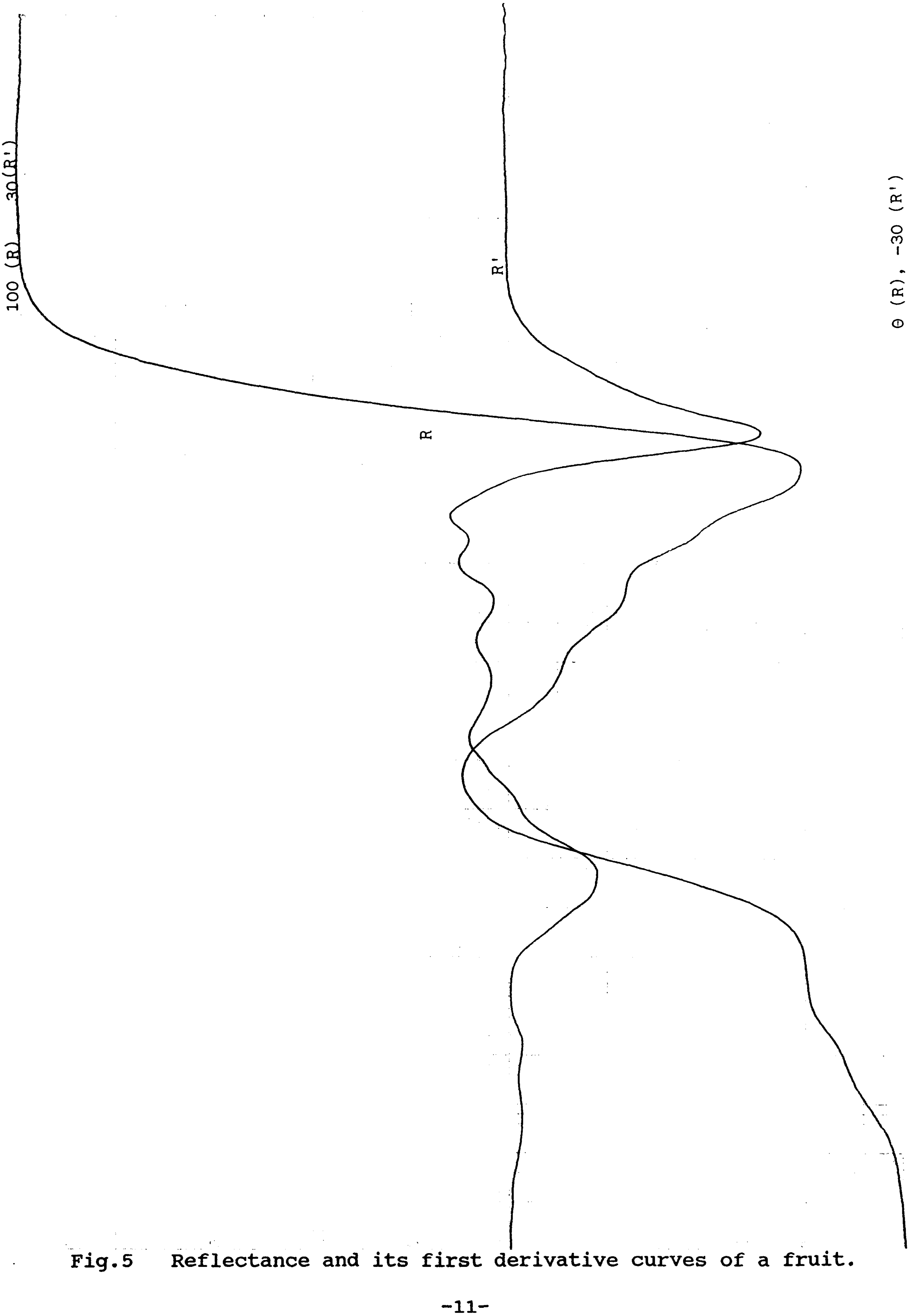

Fig.5 Reflectance and its first derivative curves of a fruit.

NAME: DATE:

	1	2	3	4	5	6	7	8	9	10
I WOULD EAT THIS EVERY OPPORTUNITY I HAD										
I WOULD EAT THIS VERY OFTEN										
I WOULD FREQUENTLY EAT THIS										
I LKE THIS AND WOULD EAT IT NOW AND THEN										
I WOULD EAT THIS IF AVAILABLE BUT WOULD NOT GO OUT OF MY WAY										
I DON'T LIKE IT BUT WOULD EAT IT ON AN OCCASION										
I WOULD HARDLY EVER EAT THIS										
I WOULD EAT THIS ONLY IF THERE WERE NO OTHER FOOD CHOICES										
I WOULD EAT THIS IF I WERE FORCED TO										

COMMENTS:

Fig.6 Hedonic scale form.