MEALINESS ASSESSMENT IN FRUITS USING MRI TECHNIQUES

[1] Pilar Barreiro Elorza ; [1]Margarita Ruiz-Altisent; [2] Encarnación Fdez. Valle. [2]Jesus Ruiz-Cabello;
[1] Departamento de Ingeniería Rural. ETSIA. Email:labpropfis@iru.etsia.upm.es
[2] Unidad de RMN. Instituto Pluridisciplinar. UCM

ABSTRACT

Mealiness is a sensory attribute that cannot be defined by a single parameter but through a combination of variables (multidimensional structure). Previous studies propose the definition of mealiness as the lack of crispiness, of hardness and of juiciness. Current aims are focused on establishing non destructive tests for mealiness assessment. MultiSliceMultiEcho Magnetic resonance images (MRI, 64*64pixels) have been taken corresponding to a 8ms of Echo time. Small samples of Top Red apples stored 6 months at controlled atmosphere (expected to be non mealy) and 2ºC (expected to be mealy) have been used for MRI imaging. Three out of four apples corresponding to the sample maintained at controlled atmosphere did not develop mealiness while three out of four fruits corresponding to the sample stored at 2ºC became mealy after 6 month of storage. The minimum T2 values/image obtained for the mealy apples shows to be significantly lower when compared with non mealy apples pointing that a more dis-aggregated structure leads to a quicker loss of signal. Also, there is a significant linear correlation (r=-0.76) between the number of pixels with a T2 value below 35ms within a fruit image and the deformation parameter registered during the Magness-Taylor firmness test. Finally, all the T2 images of the mealy apples show a regional variation of contrast which is not shown for non mealy apples. This variation of contrast is similar to the MRI images of water-cored apples indicating that in these cases there is a differential water movement that may precede the internal browning.

INTRODUCTION

Mealiness is a negative attribute of sensory texture that combines the sensation of a dis-aggregated tissue with the sensation of lack of juiciness. Since January 1996, a wide EC Project entitled : "Mealiness in fruits. Consumers perception and means for detection" is being carried out. Within it, three sensory panels have been trained at : the Institute of Food Research (IFR, United Kingdom), the Instituto de Agroquimica y Tecnología de los Alimentos (IATA, Spain) and the Institut voor Agrotechnologisch Onderzoek (ATO-DLO, Netherlands) to assess mealiness in apples. In all three cases, mealiness has been described as a multidimensional sensory descriptor gathering the loss of consistency and of juiciness (Individual Annual and 18 months Reports). Also a Repertory Grid has been carried out on 4 countries (Belgium, Denmark, Spain and UK) and 5 languages (Danish, English, French, Flemish a Spanish) on 120 consumers per country. The result can be summarised by saying that the consumers perceive mealiness in apples as the loss of crispiness, of hardness and of juiciness (FAIR Project Report). Also within the EC Project several instrumental procedures have been tested for mealiness assessment. In this sense the Physical Properties Laboratory (LPF-UPM) has focused its aims in a first stage on performing instrumental

tests for assessing some textural descriptors as crispiness, hardness and juiciness. The results obtained within these tests have been shown to correlate well with the sensory measurements (Barreiro et al, 1997) in apples, but also have succeeded when trying to generate several texture degradation levels on peaches from which mealiness appears to be the last stage (Ortiz et al, 1997). At the current stage a reference instrumental procedure for destructive mealiness assessment has been developed. Also, it has been confirmed that mealiness does not appear for all fruits at the same time (Ortiz et al, 1997) and therefore it is essential to assess mealiness on individual fruits. Thus, the development of non destructive techniques for a precise assessment of mealiness onset is essential.

The MRI together with X-Ray imaging techniques are the most extended techniques capable of evaluating global internal quality in a non-destructive way (Chen & Sun, 1991). Magnetic Resonance Imaging (MRI) makes use of the magnetic properties that some atomic nuclei have, especially hydrogen nuclei from water moleçules. When placed in a magnetic field (such as in an MR instrument), the natural magnetic fields of the hydrogen nuclei re-orient themselves along the strong magnetic field of the scanner. This orientation may be perturbed by exciting those nuclei with a burst of elctromagnetic energy (rf pulse). As these excited nuclei realign themselves with the scanner's magnetic field, they emit a radiofrequency signal that can be detected by a receiver coil. The nuclei emit different signals depending on their surroundings. The contrast between various structures would be poor since tissues do not differ substantially in water content. However, there are numerous properties of the tissue water which can be exploited to provide contrast and these can be used to obtain further useful information.

In the field of internal quality evaluation, the MRI technique has been proposed to identify mechanical damages (bruises) in onions, apples, peaches and pears (Chen et al, 1989). Also, the MRI technique has been used to assess internal injury due to conservation treatments as : chilling injury in Persimmons (Clark & Forbes, 1994), watercore in apples (Wang et al, 1988) and internal breakdown in melons (Zion, 1994). These three studies are deeply related to the work that will be presented here as mealiness also appears associated with cold storage and it has also been described as a chilling injury (physiological disorder that appears when plant tissues are exposed to low or non freezing temperatures).

In the case of persimmons, chilling injury is described as a initial tissue breakdown and lack of cohesion between cells followed by formation of a firm gel and by a lack of juiciness without changes in the total amount of water content. Also a browning of the flesh is indicated (Clark & Forbes, 1994). This definition fits into the previous description of mealiness. Also in this study an indication on the differential pattern on mealiness onset is given, as mealiness appears to affect only to some fruits and not to the whole of them. This fact also agrees with the mealiness onset pattern given for peaches by Ortiz et al. in 1997. The study of Clark and Forbes in 1994 also indicates that for some bagged replicates it appeared a very bright area by the core which indicated the presence of water in a distinct motional way. Fruits showing this bright contrast area also showed through destructive test for gelling, juiciness and firmness assessments the presence of the mentioned chilling injury which was undetectable else non-destructive way. In control samples, this bright contrast areas in the core of the persimmons tended to evolve into internal browning. This showed that the internal browning and the above defined chilling injury could be related.

Finally, the study of Clark and Forbes in 1994 indicates that the only quantitative difference in the MRI images of persimmons before and after a six weeks of cold storage period is a slight decrease in the T2 values which the authors of this study assume as an effect of the loss of fresh weight (water) during storage.

The studies on watercore in apples (Wang et al, 1988) and internal breakdown in melons (Zion, 1994) show both disorders to be very similar. The main feature agrees with the characteristic shown for chilled persimmons, that is, the appearance of very bright/dark areas by the core of the fruit. The study of Shiow et al (1988) also indicates that the watercore in apples remains in a determined area ($\pm$ 20% from the centre of the fruit). Watercore also appeared for more mature fruits (higher number of days from full bloom) and lower firmness. Also a differential pattern for the watercore in apples is shown as this physiological disorder does not affect all the fruits at the same time. These features agree with the clues given for mealiness appearance in apples by Harker and Hallet in 1992.

As a previous work on the MRI technique, the LPF-UPM has developed a T2 calibration protocol which leads to an accuracy in the T2 values assessment of $\pm$2.4% (FAIR Project Report). The work that will be presented in this paper must be considered as the previous test for extracting MRI features for mealiness assessment in apples.

OBJECTIVES

- To check the reliability on the decrease of the T2 values for apples during storage.
- To search for MRI features for mealiness assessment in apples.

MATERIAL AND METHODS

Eight apple fruits corresponding to the variety "Top-Red" have been tested under mechanical and MRI imaging techniques. These fruits correspond to selected samples of a wide experiment for mealiness assessment on 420 fruits (referred above) . Four apples correspond to a small sample of fruits stored in Controlled Atmosphere conditions in commercial storage chambers for a 6 months period, while the rest of 4 apples correspond to a small sample of fruits stored at 2°C also in commercial chambers for the same period.

After the set of MRI images was performed on the mentioned apples, there was a need of searching for water-cored apples within the wide experiment in order to confirm the MRI features extracted for the fruits originally tested. In this sense four new apples were chosen within a group of the wide experiment where a 60% of water-cored apples had been previously detected. For this group only 1 apple had developed a water-core disorder.

The MRI procedure was taken from the protocol developed in a previous MRI experiment MRI experiments were performed on a Bruker Biospec 47/40 (Ettlingen, Germany) spectrometer complete with actively-shielded imaging gradients capable of reaching 100 mT/m along all axes. The bore size of the magnet is 40 cm, buth with gradient stack in place, the bore is reduced to 26 cm. A home-built high pass birdcage coil (N=8) with an inner diameter of 10.4 cm and a length of 14.0 cm was constructed to adapt the coil to the maximum size of our apples.

Apples were imaged as 64x64 matrices using the standard two dimensional spin echo sequence. 1 slice and 20 echoes were collected with different echo time, TE, of 8 and 9.5 ms, and

a fixed repetition time of 3000 ms. Other acquisition parameters were a 5 mm slice thickness and a 10 cm field of view (FOV). Pulse gains, attenuator and shimming settings were previously adjusted for a 8 cm sphere filled with dopped water (cupper sulfate, 1% w/w) and were held constant along the total experiment, in which several apples were imaged under these conditions. Field homogeneity was tested as the lack of change in the images of the spherical phantom before and after the apples recording. For comparison, all images were reconstructed with identical scale factor. The magnitude of these multiecho images was fitted on a pixel by pixel basis using a two parameter (T2 and the signal intensity at equilibrium) monoexponential function without baseline, using the standard Bruker imaging Fit Package, which uses the Levenberg-Marquart criterion for chi-square minimization operating on a Silicon Graphics Indigo computer. The software package allows to choose a threshold to remove those pixels with low signal to noise ratio, in such a way that T2 maps of all samples were obtained discarding pixels (previous to the fitting) under the 15% of the maximum signal intensity (this value was found correct to get rid of background pixels). Histograms were attained by intersection of two selected regions of interest, one from the entire apple and other from the ripe middle area.

The mechanical tests carried out on the samples can be summarised as:

- Magness-Taylor penetration test : Carried out with a Texture Analyser XT2 on entire. Magness-Taylor flesh penetration test was performed for a 8mm diameter rod. A maximum penetration of 8mm was applied at 20 mm/min speed rate. The maximum penetration force (N) and deformation (mm) were registered ; force values will be used as Magness-Taylor firmness.
- Confined compression test : It was carried out with the same Texture machine on cylindrical probes of 1.7 cm height and 1.7 cm of diameter. Probes were confined in a disc of 1.7 cm height, with a hole of the same diameter as the probe. A maximum deformation of 2.5 mm was applied at 20 mm/min speed rate. The rod used in this test had a 15..3 mm diameter in order to avoid rod/disc contacts during compression. Deformation was immediately removed at the same speed rate; three repetitions were made per fruit. The following parameters were registered through this tests: Force/deformation ratio within the elastic behaviour (N/mm, this magnitude will be used as compression hardness), and the Juice area (mm^2, JUICE) of the spot accumulated in a filter paper placed underneath the probe during the test (this magnitude will be used as compression juiciness).

The solid soluble content was measured using a digital refractometer PR-101 ATAGO

Statistica 4.5 for Windows has been used for data analysis.

RESULTS AND DISCUSSION

General Overview of the Samples

All fruits submitted to Controlled atmosphere showed higher soluble solids content, around 13°BRIX, when compared to the fruit stored at 2°C (lower than 12°BRIX).

The Magness-Taylor firmness test shows than 3 out of the 4 fruits corresponding to the Controlled Atmosphere sample had a firmness above 16N, while all the fruits stored at 2°C hadFirmness values bellow 16N

Identification of Mealy Fruits by Mechanical Means

The confined compression test proposed by the LPF-UPM for the identification of mealy fruits by destructive instrumental means (FAIR Pproject Report) indicates that only 1 out of the 4 fruits tested submitted to Controlled Atmosphere conditions had developed mealiness, while 3 out of the 4 fruits tested stored at 2°C had already developed mealiness at that stage (see Fig. 1) ; 24 dots are displayed in Figure 1 as three repetitions of the confined compression test were carried out per fruit.

The classification of the fruits into : Hard (Magness-Taylor Firmness above 16N) and Soft (Magness-Taylor Firmness bellow 16N) or into non mealy (hard or soft combined with juiciness above 400mm2) and mealy (soft combined with juiciness bellow 400mm2) has been used to extract features from the MRI images.

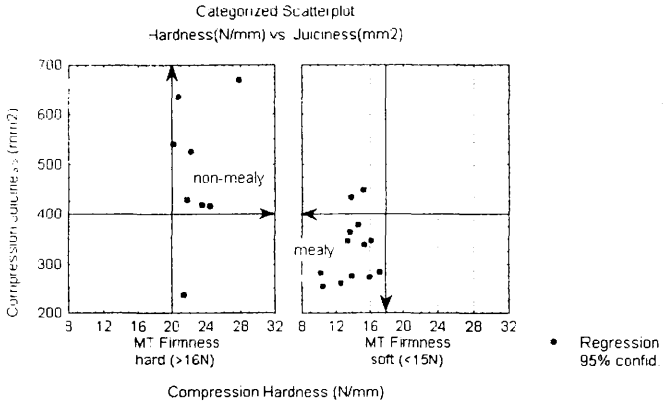


Figure 1. Identification of mealy fruits through the destructive reference test proposed by the LPF-UPM.

Extraction of Features within the MRI images for Mealiness Assessment

From each MRI image corresponding to the 8 fruits tested, several characteristic parameters as the minimun T2 value/image, the average T2 value/ image, and the maximum T2 value/image were extracted (see Table 1) and studied in relation to the classification of the fruits into Hard/Soft and Non-Mealy/Mealy. There is no significant effect of Hard/Soft Magness-Taylor Firmness on the characteristic T2 parameters, but there is a significant effect (1% significant level, F=13.21) value for the Mealy textured fruits of the minimum T2 value/image with lower minimum T2. In order to check the consistency of the minimum T2 value in relation to the whole image, a study on the number of pixels with a T2 value bellow 30ms or 35ms (intermediate values between the minimum and the average T2 values) was carried out ; the number of pixels bellow 30ms represented less than 1% of the fruit (in all cases around 2000 pixels), while the number of pixels bellow 35ms represented around a 2% of the fruit. The

effect of the Non-Mealy/Mealy characteristic of the fruit remains significant for the number of pixels bellow 30ms (5% significant level, F=4.65) while it turns to non significant for the number of pixels bellow 35ms, as it is also non significant for the average T2 value/image or fo the maximum T2 value/image.

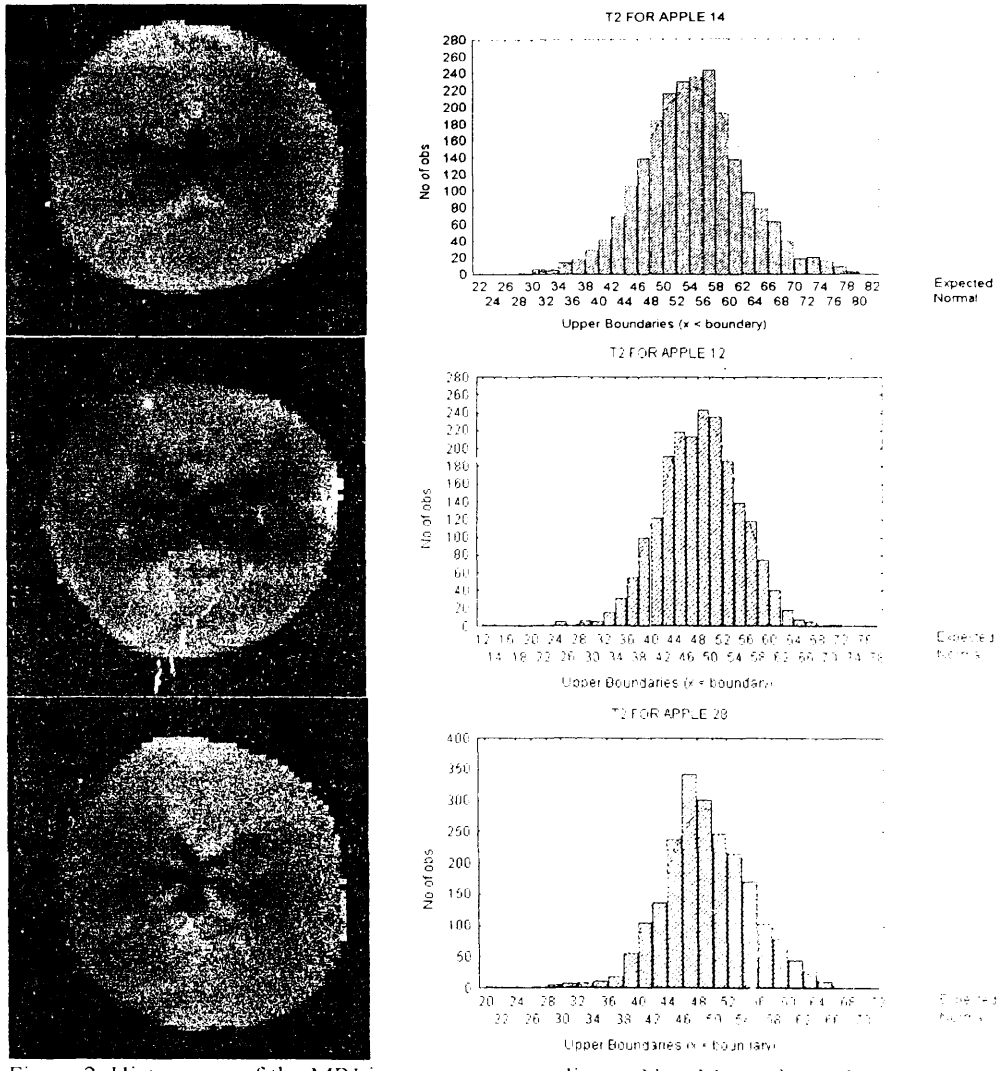
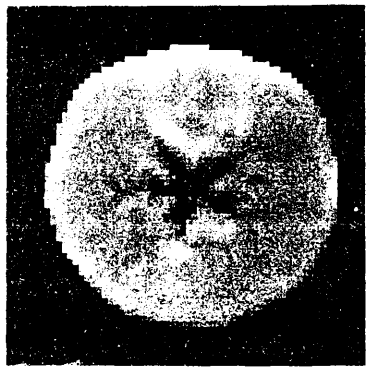


Figure 2. Histograms of the MRI images corresponding to Non-Mealy fruits (1)



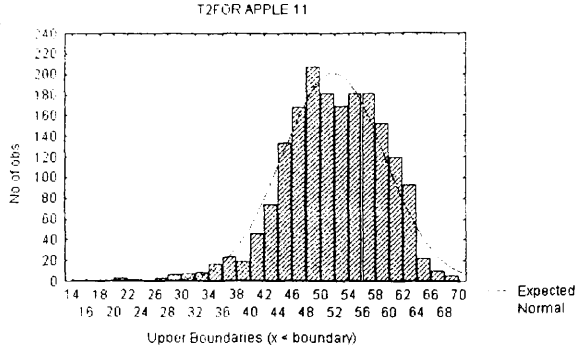
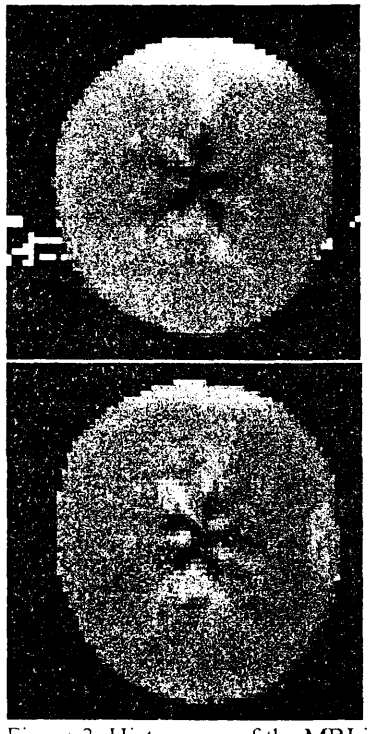


Figure 2. Histograms of the MRI images corresponding to Non-Mealy fruits (II).



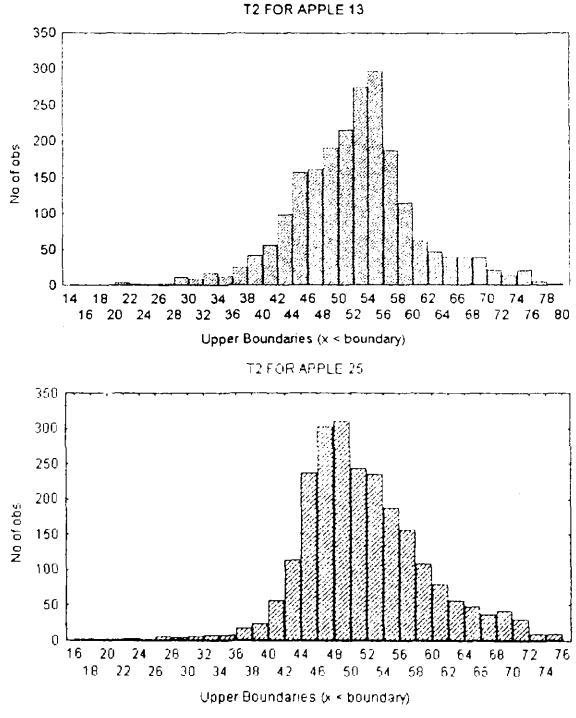


Figure 3. Histograms of the MRI images corresponding to Mealy fruits (I).

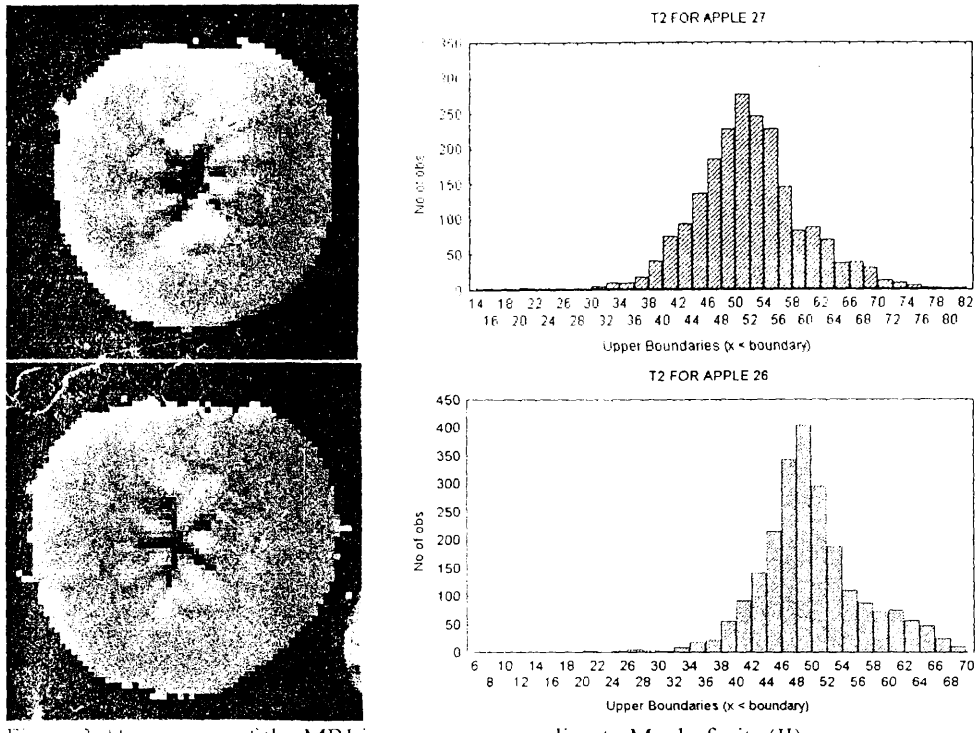


Figure 3. Histograms of the MRI images corresponding to Mealy fruits (II).

A study on the correlation coefficients has been made between the mechanical and the MRI parameters. The results show that only the deformation parameter measured during the Magness-Taylor Firmness test shows a significant correlation with some of the MRI parameters : the number of pixels bellow 30ms (r=-0.71) and the number of pixels bellow 35ms (r=-0.76).

Apart from the study on several characteristic T2 parameters, further work has been carried out on the whole histograms of the fruits as a visual study of the images indicated the presence of high/low T2 contrast areas by the core of mealy apples similar to the ones obtained for water-cored apples. The study carried out on the histograms (see Fig. 2 & 3) revealed that normal distributions of the T2 values are found for all the Non-Mealy apples, while all the Mealy apples show a tail in the histogram by the high T2 extreme similar to the tail observed in an histogram of a water-cored apple (see Fig. 4). The high/low T2 contrast areas found for the Mealy fruits indicates, as proposed by Clark and Forbes for persimmon (1994), the presence of water in a motional way that may lead to this water-core disorder. The proportion of pixels involved in the tails of the histograms for the Mealy apples (around 14%) is similar to the proportion of pixels involved in the tail of a water-cored apple (16%). The observation of a tailed

involved in the tail of a water-cored apple (16%). The observation of a tailed histogram allows to segment the image for the assessment of the tissue area were the water appears in a motional way.

type of texture	n	min. T2 ± STD	averag T2 ± STD	max. T2 ± STD	n° of p T2<30 ms ± STD	n°of p T2<35 ms ± STD
Non-Mealy	4	22.98 ±3.57	50.98 ±2.50	74.66 ±4.68	11 ±6.48	37.50 ±12.88
Mealy	4	16.28 ±5.29	51.44 ±1.05	76.35 ±4.52	16.75 ±6.58	38.25 ±11.01
ANOVA Analysis		**	ns	ns	*	ns
F value		13.21			4.65	
water-core	1	21.869	63.35	139.76	4	8

Table 1. Characteristic parameters of the T2 MRI images. The fruits are listed for decreasing Magness-Taylor Firmness values.

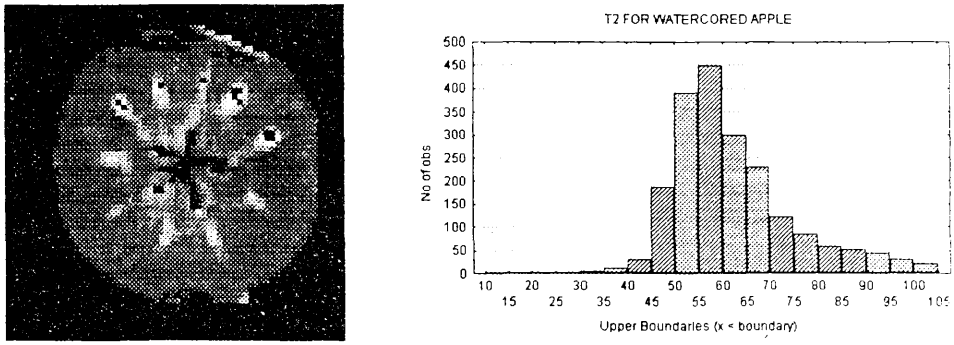


Figure 4. Histograms of the MRI images corresponding to a water-cored apple.

CONCLUSIONS

The conclusions obtained for the previous test on the extraction of MRI image features for mealiness assessment in apples can be summarised as :

- the minimum T2 value/image is the only T2 parameter that shows a significant effect of the Non-Mealy/Mealy texture stage of the fruit
- the number of pixels in a T2 image below 35ms (an intermediate value between the minimum and the average T2 values) shows a significant correlation coefficient (r=-0.76) with the deformation parameter registered within the Magness-Taylor firmness test. though this MRI parameter only represents a 2% of the cross-section of the fruit.

- The most important MRI image feature is the presence of a "tail" in all the histograms of mealy fruits, which is located in the maximum T2 extreme of the histograms. However the maximum T2 value/image is not itself significant.
- the shape of the "tailed" histograms of mealy fruits is similar to the histogram of a water-cored apple. Also the amount of pixels involved in the tails of the histograms is similar for mealy (around 15%) and the water-cored apple (16%).

ACKNOWLEDGEMENTS

To the EC Project FAIR CT960302 : Mealiness in fruits, consumer perception and means for detection within which this study has been carried out, under which financial aid has been carried this study

REFERENCES

Barreiro P.; M. Ruiz-Altisent ; C. Ortiz ; V. De Smedt ; S.Schotte ; Z. Bhanji ; I. Wakeling. 1997. Comparison between sensorial and instrumental measurements for mealiness assessment in apples. A collaborative test. Submitted to the Journal of Texture Studies

Chen P., and Sun z. 1991. A review of Non-Destructive Methods for Quality Evaluation abd Sorting of Agricultural Products. Journal of Agricultural Engineering Research 49 :85-98

Clark C..J. and Forbes S.K. 1994. Nuclear Magnetic Resonance Imaging of the development of chilling injury in 'Fuyu' persimmon (Diospyrus Kaki). New Zealand Journal of Crop and Horticultural Science Vol 22 :209-215

Harker F.R.; Hallett I.C. 1992. Physiological changes associated with development of mealiness of apple fruit during cold storage. Hortscience 27(12):1291-1294.

Ortiz, C ; Barreiro, P ; Ruiz-Altisent, M., Riquelme , F. Assessment of textural disorders in peaches (Cv. *Maycrest)* during cold storage by instrumental means. Instrumental assessment of mealiness (II). Submitted to the Journal of Texture Studies

Various authors.1996. Mealiness in fruits, consumer perception and means for detection : Individual Annual Report & 18th Month Report. EC Project FAIR CT960302

Wang S.Y., Wang P. C. And Faust M. 1989. Non-Destructive Detection of Water-core in apple with Nuclear Magnetic Resonance Imaging. Scientia Horticulturae 35 :224-234

Zion B. 1994. Detection of Internal Tissue Breakdown in Galia Melons by Magnetic Resonance Methods. Annual Report of the Institute of Agricultural Engineering. The Volcani Centre