QUANTITATIVE MAGNETIC RESONANCE IMAGING OF TOMATO FRUIT

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INTRODUCTION

MRI is an appropriate technique for non-destructive studying of internal structures and micro dynamics of water in plant tissues. Moreover, information about various internal quality factors, such as stage maturity or tissue damage can be obtained by choosing imaging sequences and their parameters [1,2]. The first aim of this study was to access to structural and physiological aspects of tomato fruit by means of quantifications of T_1 and T_2 relaxation times and of evaluation of tissues porosity. Furthermore, CDD camera images were acquired in order to correlate results if MRI experiments with cellular structure.

MATERIALS AND METODS

Fourteen Tradiro red and firm tomato fruits at the same stage of ripening were used in this study. All measurements were performed on a 0.2 T electromagnet scanner in open configuration (Magnetom Open, Siemens, Erlangen, Germany). For all images geometrical parameters were: matrix size =128²; FOV=128² mm² and slice thickness=5 mm. Relaxometry measurements consisted of the following: *1)* T_2 relaxation acquired using multi spin echo sequence (MSE) with: TE=30 ms; N_{TE}=32; TR=10 s; 2 averages and *2)* T_1 relaxation data acquired using TOMROP sequence with: TI=210 ms; N_{TI}=32; angle=10°; TR=10 s; 3 averages. Mono-exponential fits on a pixel-by-pixel bases were used to extract relaxation times from corresponding image series. In order to evaluate tissues porosity, two additional spoiled gradient echo (GE) images were acquired with: angle=40°, TR=1 s; 2 averages; TE_1=9 ms and TE_2=40 ms for the first and the second image, respectively. Furthermore, one tomato fruit was used to acquire T_2 maps with variable echo spacing (30, 50 et 90 ms).

At the same time, tissue structure of four tomatoes was observed by macro-vision using a CCD camera (Sony XC 8500 CE) fitted with a 50 mm lens and a 20 mm extension tube. 10.7 mm x 14.4 mm images were digitized in pixels of 18.6² µm².

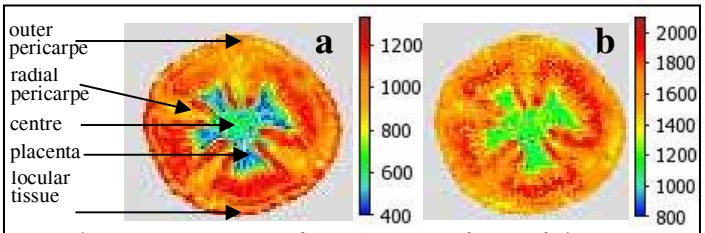

Figure 1: T_2 (a) and T_1 (b) false colour maps of tomato fruit

RESULTS AND DISCUSSION

An example of T_2 and T_1 maps with tissues annotations is shown on Fig. 1 Mean T_2 (Fig. 2.) and T_1 values of different tissues were extracted from the maps for all tomatoes studied. T_2 and T_1 parameters allowed to discriminate between tissues and revealed many structural details of tomato fruits. Changes in water relaxation can be related to changes in local water content, susceptibility effects or/and cell size and geometry [3]. The effect of the cell size was confirmed by macro-vision (Fig. 3) showing that cells of the outer pericarpe are significantly larger then cells of the centre and placenta which can be correlated with T_2 values of these tissues (see Fig. 2).

In MSE experiment with various echo spacing, T_2 decreased for long echo spacing for all tissues except the locular one. The relative T_2 loss when echo spacing was increased from 30 ms to 90 ms was: 32% for the centre, 28 % for the placenta, 20% for the radial pericarpe, 12 % for the outer pericarpe and -6% for the locular tissue. The dependence of T_2 on pulse spacing is explained by diffusion of water molecules trough internal magnetic field gradients generated in sample where there is a variation in magnetic susceptibility [4]. This effect becomes predominant for long pulse spacing. GE images with TE_1=40 divided by corresponding images with TE_2=9 were also used to monitor the presence of air in tissues as the signal of these ratio images is sensitive to T_2*. Porosity of columela and placental tissues are found to be more important than porosity of pericarpe and locular tissues. MRI results concerning tissue porosity were confirmed by macro-vision, which showed important presence of air bubbles in the placenta and centre, but not in the pericarpe.

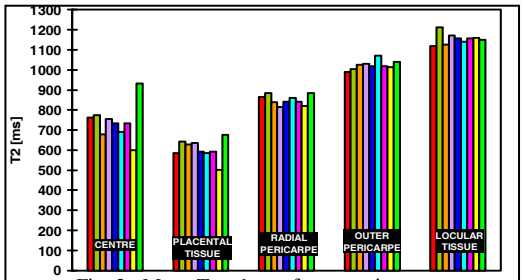

Fig. 2 : Mean T_2 values of tomato tissues. Colours correspond to different tomatoes.

CONCLUSION

We demonstrated in this study that quantitative evaluation of MRI parameters reflects the differences in physiological properties among tomato tissues and permits to distinguish between them. Parallel MRI and camera experiments permit a better understanding of relaxation processes and contribute to the interpretation of the contrast origins in MRI of plant tissues. Cell size was found to contribute in T_2 relaxation mechanism. The study demonstrated significant porosity variations among tomato tissues that also play a role in T_2 results, especially for long echo times. The method can be used to study tomato evolution during ripening or storage and to estimate internal fruit quality.

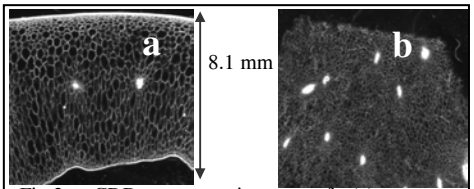

Fig.3 : CDD camera images of (a) outer pericarpe and (b) placental tissues

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