Feasibility Study of Detection of Pest Infestation using X-ray Computer Tomography and Magnetic Resonance Imaging for Naturally Occurring Pest-infested Apple

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1. Introduction

X-ray computed tomography (CT) is one of the widely used non-destructive testing (NDT) technologies for the inspection of agricultural products [1, 2]. In particular, during the quarantine process, NDT technology can effectively block the introduction of pests that cause irreversible damage to agricultural environments. Among the various NDT technologies, X-ray CT is the most effective method for internal inspection.

In our previous study, we inspected artificially pest-infested agricultural fruits using X-ray CT and magnetic resonance imaging (MRI) and confirmed the feasibility of pest inspection [3]. However, if actual pests infest and grow inside agricultural fruits, further research is needed to determine whether there is a significant difference in composition from the surrounding sound flesh region.

In this study, we investigated the feasibility of internal pest inspection by inspecting naturally occurring pest-infested apples by X-ray CT and MRI. In the CT and MRI images, the pest region inside the apple was analyzed quantitatively, focusing on whether there was a significant difference from the surrounding sound flesh region.

2. Materials and Methods

2.1 Pest-infested apple

Apples presumably infested with pests were harvested on June 23 in 2021. Apples were stored at 15°C for about a month before X-ray CT and MRI inspection. About 10 apples were harvested, and two of them were inspected using X-ray CT and MRI.

2.2 X-ray CT and MRI scans

An X-ray CT scan was performed by the Xradia 620 Versa imaging system (Zeiss, USA) in the Korea Basic Science Institute (KBSI) Gwangju center. The pest-infested apple was fixed on the sample bed using an adhesive tape. The Zeiss Xradia 620 Versa software was used for CT image reconstruction, and the built-in filter was used to reduce noise and increase contrast. CT images were reconstructed into 966 slices with a voxel size of 67 μm.

MRI scan was performed by the Bruker BioSpec 4.7 T animal MRI imaging system (Bruker, USA) in the KBSI Ochang center. As with X-ray CT, pest-infested apple was fixed using an adhesive tape. MRI scan parameter setting and image reconstruction were performed using the Bruker BioSpec software. MRI images were reconstructed into 47 slices with a voxel size of 0.22 mm. The CT number and MRI intensity (arbitrary units) were quantitatively analyzed through 3D Slicer software.

3. Results and Discussion

3.1 X-ray CT inspection

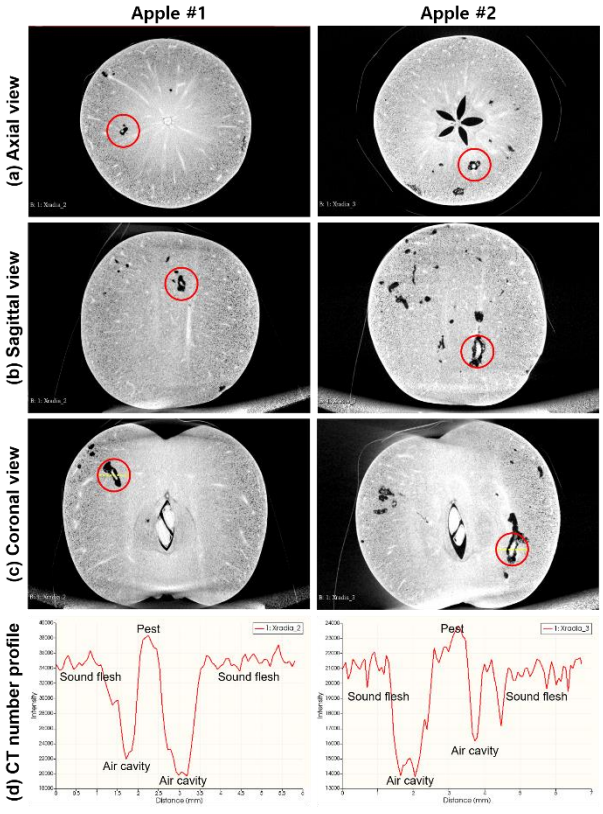

Fig. 1. Apple #1 and #2 X-ray CT images of three different views and CT number profile: (a) Axial view. (b) Sagittal view. (c) Coronal view. (d) CT number profile (horizontal yellow dotted line in (c)). The red circles in (a), (b), and (c) represent the pest-infested region.

Fig. 1 shows the apple CT images of three different views and the CT number profile. The internal pest was clearly identified in three views of the CT images of both apples. Also, the difference in CT number was confirmed in the sound flesh region and the pest region. The mean and standard deviation of CT number of apple #1 and apple #2 in the sound flesh region were 35,214 ± 322 and 20,421 ± 612, and pest region were 22,532 ± 553 and 35,214 ± 812, respectively. The fluctuation in CT number was due to the different exposure times of the detector when scanning apples #1 and #2. And unlike the 12-bit CT number range of general medical CT images, the 16-bit CT number range was used to identify various artifacts effectively.

3.2 MRI inspection

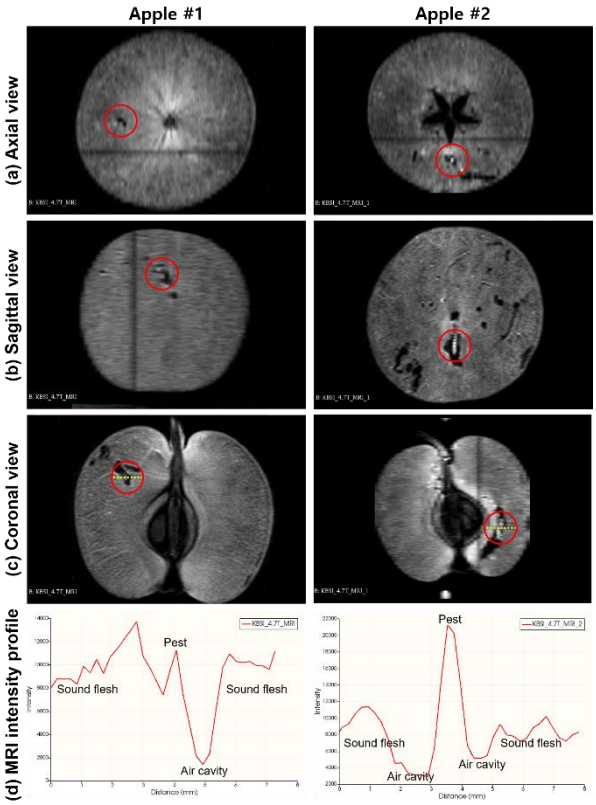

Fig. 3. Apple #1 and #2 MRI images of three different views and MRI intensity profile: (a) Axial view. (b) Sagittal view. (c) Coronal view. (d) MRI intensity profile (horizontal yellow dotted line in (b)). The red circles in (a), (b), and (c) represent the pest-infested region.

Fig. 3 shows the apple MRI images of three different views and the MRI intensity profile. Unlike the apple #1 CT image, the internal pest was not identified in the apple #1 MRI image. Further, it was difficult to distinguish between the pest region and the sound flesh region in the MRI intensity profile. However, the apple #2 MRI images distinguished the internal pest around the sound flesh region. The MRI intensity profile also showed a clear difference from the sound flesh region. The mean and standard deviation of MRI intensity of apple #1 and apple #2 in the sound flesh region were 9,755 ± 461 and 9,844 ± 616, respectively. And pest region were 9,934 ± 1,023 and 16,792 ± 4,902, respectively.

4. Conclusions

This study investigated the feasibility of internal pest inspection by inspecting naturally occurring pest-infested apples by X-ray CT and MRI. Unlike our previous studies, MRI images showed limitations in inspecting internal pests. This is presumed to be because the agricultural fruits inspected to the NDT inspection in this study used naturally occurring rather than artificially created pest infestation conditions, and the resolution of the MRI image was inferior to that of the CT image. In the future, we will identify the species of pest identified inside the apple and conduct further research on the possibility of identifying the age of the pest using CT images. In addition, we will conduct a feasibility study on whether it is possible to automatically distinguish between normal agricultural fruits and pest-infested agricultural fruits using CT numbers.

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