Early detection of freeze damage in navel orange fruit using nondestructive low intensity ultrasound coupled with machine learning

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Abstract

Freeze damage in the orange fruit is a serious problem, especially when the environmental temperature reaches the critical freezing point. Separating the damaged fruit from the healthy ones after harvesting and before storing is an important and fundamental process. Therefore, the aim of this research was to develop a nondestructive system for detecting freeze damage in the orange fruit just after freezing occurrence. For this purpose, a nondestructive system based on ultrasound technology was developed. The support vector machine (SVM) method was applied to develop the models for classifying the healthy and damaged orange fruit. In the SVM modeling, C, γ, and the kernel function strongly affected output of the models. The system provided the excellent results with classification accuracy of 100% for detecting freeze damage. Out-of-sample validation approved a perfect ability of the ultrasonic sensing system to nondestructively detect occurrence of the freeze damage. The reason for the excellent performance of the proposed system is that the freezing phenomenon causes mechanical damage to the fruit, and ultrasound is also a mechanical wave which is strongly influenced by the propagation environment.