The time is ripe! An innovative contactless method for the timely harvest of soft fruits

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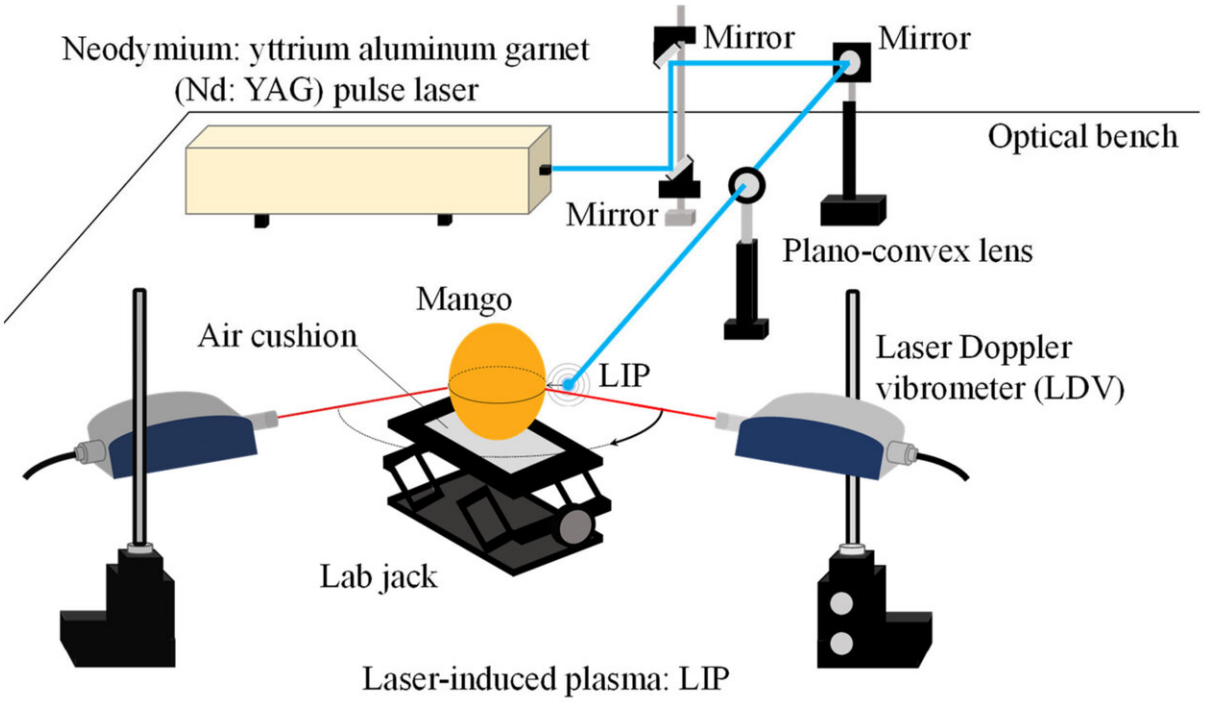

A pulsed laser is focused by a lens onto a point close to the surface of the fruit. The laser-induced plasma creates a shockwave that excites Rayleigh waves on the surface of the mango, which are then measured using laser Doppler vibrometers. Credit: Shibaura Institute of Technology

In agriculture, there are many mechanical methods to indirectly measure a fruit's ripeness through its firmness. However, most fall short for soft

fruits, which do not exhibit the same types of measurable vibration as harder ones. Now, scientists from Shibaura Institute of Technology, Japan, have developed an innovative method to measure fruit firmness using laser-induced plasma shockwaves. Their contactless, non-destructive approach works on mangoes and should be useful for other soft fruits as well.

Those who work in agriculture are tasked with ensuring a timely harvest so that ripeness is at an optimal point when the fruit is sold, both to minimize the amount of fruit that goes to waste and maximize the quality of the final product. To this end, a number of techniques to assess fruit ripeness have been developed, each with their respective advantages and disadvantages depending on the type of produce.

Although biochemical and optical methods exist, mechanical techniques are the most widely used. They indirectly assess ripeness based on the fruit's firmness. In turn, firmness is quantified by observing the vibrations that occur on the fruit when mechanical energy is accurately delivered through devices such as hammers, pendulums, or speakers. Unfortunately, these approaches fall short for softer fruits, which are more readily damaged by the contact devices used.

In a recent study published in *Foods*, a team of scientists from Shibaura Institute of Technology (SIT), Japan, addressed this issue through an innovative method for measuring the firmness of soft fruits using laser-induced plasma (LIP). This work is a sort of follow-up of a previous study in which LIP was used to quantify the firmness of harder fruits.

But what is LIP and how is it used? Plasma is a state of matter similar to the gaseous state but in which most particles have an electric charge. This energetic state can be produced in normal air by focusing a high-intensity laser beam onto a small volume. Because the generated plasma "bubble" is unstable, it immediately expands, sending out shockwaves at

ultrasonic speeds. Professor Naoki Hosoya and colleagues at SIT had successfully used LIP shockwaves generated close to the surface of apples to excite a type of vibration called $_0S_2$ mode, colloquially referred to as "football mode vibration" because of how the resulting deformation looks on spherical bodies. They then verified that the frequency of the $_0S_2$ mode vibrations was correlated with the firmness of the fruit.

However, soft fruits do not exhibit $_0S_2$ mode vibrations, so the team had to analyze an alternative type of oscillation: Rayleigh waves. These are waves that occur exclusively on the surface of bodies without penetrating far into the interior. Using Kent mangoes, a setup for generating LIP, and commercially available laser-based vibrometers, the scientists verified that the velocity at which Rayleigh waves propagate is directly related to the firmness of the mangoes. Because the propagation velocity markedly decreases with storage time, it provides a reliable way to indirectly assess ripeness.

The team went further and looked for the best position on the mangoes' surface to determine the velocity of Rayleigh waves. Mangoes, as well as other soft fruits, have large seeds inside, which can alter the propagation of surface waves in ways that are detrimental to measurements. "The results of our experiments indicate that Rayleigh waves along the 'equator' of the mango are better for firmness assessment compared to those along the 'prime meridian,'" explains Hosoya. The experiments also revealed that cavities within the fruit's flesh or decay can greatly affect the results of the measurements. Thus, as Hosoya adds, they will keep investigating which is the best area to measure firmness in mangoes using their novel approach.

In short, the team at SIT has engineered an innovative strategy to assess the ripeness of soft fruits from outside. "Our system," remarks Hosoya, "is suitable for non-contact and non-destructive firmness assessment in mangoes and potentially other soft fruits that do not exhibit the usual $_0S_2$

mode vibrations." Further refinement of such firmness assessment methods will hopefully make them more reliable and accessible for the agricultural industry. With any luck, their widespread adoption will ensure that fruits reach your plate only when the time is ripe.

More information: Nayuta Arai et al, Soft Mango Firmness Assessment Based on Rayleigh Waves Generated by a Laser-Induced Plasma Shock Wave Technique, *Foods* (2021). DOI: 10.3390/foods10020323

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