Acoustic sensors for monitoring dairy processes

Researchers from TEAGASC are investigating the application of acoustic sensors as potential new process analytical technology tools in food production.

Process analytical technology (PAT) was first defined by the US Food and Drug Administration as a mechanism for manufacturing via design, analysis and control of processes. PAT systems can provide more information about a process in real time compared to traditional process laboratory methodologies (**Figure 1**). Current testing protocols can be time consuming and include taking a sample from the process, analysing the sample in a laboratory using instrumental/chemical analysis, and recording the results in an information management system. Low-cost sensors designed as PAT tools can contribute to an optimised and consistent process. Novel sensors (i.e., optical sensors and acoustic sensors) with robust measuring capabilities for monitoring critical control parameters in a process are now available. Advantages of using such PAT sensors in dairy processes include rapid, non-destructive and non-invasive measurements taken of the process media, which can highlight if corrective action is required during production.

Potential applications in dairy processes

Researchers from Teagasc are now investigating the application of acoustic sensors as potential new PAT tools for monitoring major dairy processes, i.e., gel formation stage during cheese and yoghurt manufacture. Our current studies focus on using acoustic sensors to provide in-line process monitoring, especially for intermediate products. Such products include acid-induced milk gels, fermented milk, and heat-induced whey protein gels.

During processing, these products undergo a physical change from a liquid state to a semi-solid/solid state. Researchers are investigating if these changes can be detected using acoustic sensors. In particular, physicochemical parameters, i.e., density, viscosity and acoustic velocity, are measured using an inline acoustic sensor and correlated with traditional offline reference methods (e.g., rheometry and particle size distribution).

FIGURE 1: Dairy processing environment.

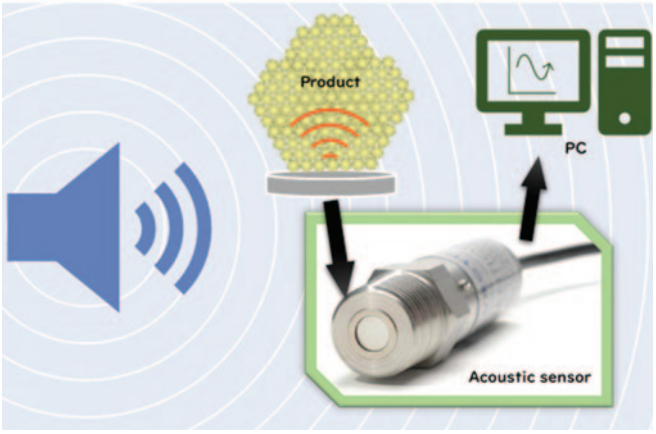

FIGURE 2: Bulk acoustic wave (BAW) sensor.

How does an acoustic sensor operate?

Acoustic sensors have been used for more than 80 years, especially in the telecommunications industry. These sensors measure the properties of a substrate via changes in an acoustic wave generated by a piezoelectric disk. When these waves propagate through the substrate being measured, they are influenced by the physiochemical properties (i.e., density, viscosity) of the substrate (e.g., milk), and are then converted back into an electrical signal to complete the measurement. The physicochemical properties of the substrate affect the travelling path of the acoustic waves, which causes changes in wave velocity and amplitude. These acoustic parameters can be used to measure and monitor the desired attributes of a product (i.e., rheological properties). Examples of acoustic sensors include bulk acoustic wave (BAW) and surface acoustic wave (SAW) sensors.

The BAW sensor used in the current study (**Figure 2**) was originally designed for measuring the viscosity of lubricating oil. This is one of the first food applications where this sensor has been utilised, and our work demonstrates that the BAW sensor has potential for monitoring acid-induced (glucono-delta-lactone) milk coagulation and yoghurt fermentation processes. In particular, it is more sensitive for detecting the onset of gelation compared to traditional gelation rheological methodologies. During the fermentation process, the BAW sensor successfully detected differences in viscosity of yoghurt made from low viscosity- and high viscosity-producing cultures. The sensor was capable of determining the viscosity and gelation time of samples measured using reference rheometry. The sensor has potential to be included as part of a suite of analysis, i.e., pH, texture, colour and syneresis for characterising yoghurt formation and final product quality.

A major benefit of using this sensor is for obtaining additional information on the gelation process.

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