Abstract
This article reviews the most recent researches about the use of nondestructive air-coupled ultrasound in food industries. In the field of food quality assessment, in several researches detection of foreign bodies, and measurement certain parameters of interest, such as the amount of a certain additives are investigated. Also in other research a rapid, non-contact and non-destructive air-coupled ultrasound technique has shown itself to be a feasible method for investigating the quality of milk-based beverages, and possibly other food products. Air-coupled ultrasound can be used in on-line situations for measuring food materials such as chocolate and cheese. It is also capable of performing nondestructive measurements on moving sealed metal cans containing food, and is able to detect foreign bodies with the top removed, as encountered before sealing. Air-coupled ultrasound has been used to perform measurements on liquids and starch-based materials, within containers similar to those used in the food industry. Ultrasonic pulse-compression (UPC) is then applied to increase the sensitivity of signals transmitted through the containers. It will be demonstrated that various nondestructive non-contact measurements are possible, including the detection of variations in consistency within starch-based liquids within a microwaveable food container, measuring of beverage level in polymer-based bottles, and the tomographic imaging of likewise containers to detect foreign objects.

Keywords: Air-coupled ultrasound, Nondestructive, Non-contact ultrasound, Food quality.

1- Introduction

Ultrasonography technology has been progressively applied to describe and study of food materials due to its nondestructive, rapid, and automated potential for food quality measurement and process control. To date, customary ultrasound procedure uses a coupling medium between the transducer and the test sample to overcome the high attenuation due to the large acoustic impedance mismatch between air and the material. For a coupling medium, liquids, such as oils, or gels have been used. However, the coupling media might change or destroy liquid-sensitive, porous, and continuously formed food materials by absorption or interaction of liquid couplants. Further, the use of a coupling liquid makes rapid measurement and process control cumbersome. Consequently, non-contact ultrasound could become an exciting alternative if appropriate technology becomes available [11]. Air-coupled ultrasound is a non-contact technique for defect or foreign body detection and measuring properties or amount of certain additive in food products in other uses which is growing for non-destructive testing, as food products should not be contaminated during manufacturing by couplings used in usual ultrasonic testing such as water and oil. The air-coupled ultrasonic method is very effective for the testing of large areas. Ultrasonic waves can cover long distances, and the lack of water columns allows for high scan velocities without any contact of transducers by sample. The technique is simple, non-invasive and inexpensive compared to other technique such as laser, NIR and MRI. With the right tool, it is possible to make sensitive inspections for defects such as voids, cracks and dis-bonds in a wide variety of water-incompatible materials [1,2,3,5].

2- Non-contact evaluation of milk-based products

In a research an air-coupled ultrasonic method has been developed and used for detect physicochemical changes of liquid beverages within a container. A glass container used to feasibility of visual inspection for verifying the ultrasonic measurement results. This work, done by use of two capacitive transducers, and pulse-compression techniques. The non-contact pulse-compression system was used to evaluate agglomeration processes in milk-based products. It is shown that the signal amplitude varied with time after the samples had been treated with lactic acid, thus accelerating sample destabilization. Non-contact imaging by scanning in several directions across the container was also performed to track destabilization of samples. The images obtained via ultrasonic were compared to images captured by digital camera. Coagulation with glucono-delta-lactone of skim milk mixed into this container could be monitored by a precision of a pH of 0.15. This rapid, non-contact and non-destructive technique has shown itself to be a feasible method for checking the quality of milk-based and maybe other food products, as shown in figure 1. Two transducers were carefully located opposite each other with a distance of 50 mm. Both transducers had an active eyelet of 10 mm diameter. One of the transducers transmit a broadband ultrasonic chirp signal into the air as a source. Longitudinal waves spread through the air to the square glass container, passed through it, and were detected on the other side using receiver transducer [4].
3- Nondestructive air-coupled ultrasonic inspection system for food containers

In this application non-contact air-coupled ultrasound has been used to make measurements on starch-based materials, within containers such as those used in the food industries. Ultrasonic signals in this technique generated in the air over a reasonable bandwidth using capacitance transducers with polymer membranes. To increase the sensitivity of signals transmitted through the containers the Ultrasonic pulse-compression (UPC) is then applied. It will be shown that many non-contact measurements are possible, such as detection of variations in consistency within starch-based liquids into a microwaveable food container, measuring of beverage level in polymer-based bottles, and the tomographic imaging of likewise containers to detect foreign objects [6].

The setup provided for level measurement is shown in figure 2, measurements repeated for different liquid volumes [6].

In other experiment set as shown in figure 3, a microwaveable food container between the transducers used. A linear scan across the cross section of the container was performed. The corn flour mixed in hot water to create artificial anomalies. The starch that was not completely dissolved was placed in many locations in the container and scanned. These experiments show that changes in density of the foods in the form of sauce could be detected by air-coupled ultrasonic while they could not be seen by naked eye [6].
Air-coupled ultrasonic technique for real-time process control in food industries

In a research the use of air-coupled ultrasound and Near Infrared (NIR) as complementary techniques for food quality assessment studied. A major study, in assistance with four industrial food companies has been performed, to study the use of air-coupled ultrasound and the NIR to detect foreign bodies, and to measure certain parameters of interest, like the amount of a certain additive. The research has shown that air-coupled ultrasound can be used in on-line situations, measuring food materials such as cheese and chocolate. It is also capable of performing measurements on moving sealed metal cans containing food, and is able to detect foreign substances with the top removed, as encountered just before sealing. NIR has been used as a complementary technique to test food materials where propagation of air-coupled ultrasound was found to be difficult. This could be due to the presence of air pockets within the food, such as bread dough [7].

Figure 4(a) shows the air-coupled system used to investigate cans in a lab-based mock-up of a production line, with the transducers aligned horizontally. Typical output waveforms are shown in Figure 4(b). It can be seen that the signal through the can has arrived sooner, due to the higher velocity in the can than in the air, and such signals can be used to characterize the properties of the food in the can, even if it is moving past the transducers [7].

Figure 5 shows an example of foreign body detection within a block of cheese, illustrating detection of a 2mm glass fragment. Also shown images of chocolate samples, where the presence of purposely-added ingredients has been detected [7].
5- detection of surface defects in food cans
In other research an ultrasonic inspection system used for detection of surface defects in food cans. The performance of the system is demonstrated empirically in detection of the presence of the pull tab on the removable lid of easy-open food cans, in a production line. It is found that three factors limit the efficiency of the classification: the misalignment of the samples, their separation of the ultrasonic transducer, and the vibration of the conveyor belt. When these factors are controlled, classification success rates between 94% and 99% are achieved [10].

6- Conclusions
Air coupled ultrasonic is one of the newest advances in the nondestructive testing and has many applications in science, such as wood products, composites, metal parts, accurate timing measurement, large area scanning and more applications this technique has many advantages like needless of water or oil couplants. By air-coupled ultrasonic transducers we can measure quantity of interest or detect presence of the desired component without contact with sample [9]. Air-coupled ultrasonic inspection can be considered as a non-contact or minimally-invasive method, because the coupling medium (air or other gas) is part of the natural environment and therefore no additional physical contact is required [8].

References