Journal of Nutrition & Food Sciences
ISSN: 2155-9600
Satyam et al., J Nutr Food Sci 2014, 4:3
DOI: 10.4172/2155-9600.1000273
Research Article Open Access

Non-Contact Ultrasonic Based Stiffness Evaluation System for Tomatoes during Shelf-Life Storage

Satyam Srivastava[1]*, Saikrishna Vaddadi[2] and Shashikant Sadistap[3]

[1]*AES, Academy of Scientific & Innovative Research (ACSIR), CSIR-CEERI, India*
[2]*Scientist, AEG, Council of Scientific and Indrustrial Research (CSIR- CEERI), India*
[3]*Senior Principle Scientist, AEG, Council of Scientific and Indrustrial Research (CSIR- CEERI), India*

Abstract

This paper addresses a use of the non-contact ultrasonic based stiffness or firmness measurement technique for tomatoes quality judgment. Here, both the change in received acoustic signal attenuation and its propagation delay due to variation in stiffness of tomatoes are recorded over a time period from fresh to full ripen cycle of tomato. The experimental setup consist of ultrasonic transducer (400EP14D) have center frequency 40 KHz with 1350 typical beam angle, interface circuit to connect with ARM9 processor using the Linux OS with qtopia based GUI for data acquisition and further analysis purpose. The data obtained by the developed system is also transferred to PC using Zigbee wireless network for further processing and training using various pattern recognitions techniques under the developed system software package. A second order nonlinear relationship between the attenuation, propagation delay was observed until the end of shelf life of tomatoes under test. The ARM9 based developed system helps both in linearization and auto calibration of the measured data well as has advantage of multiple sensor connectivity for different analysis like temperature and humidity compensation. The results obtained are also validated using standard Alpha-Mos system consists of 12 gas sensors using odor sensing technique. Thus the developed non-contact ultrasonic based system is cost effective, low power and compact system to differentiate between quality (mature and immature) of tomatoes as well as prediction of different factors like chilling injury, TSWV (tomato spotted wilt virus), sunscald and it can be further applied to other types of fruits where stiffness change is major factor for quality of the fruit.

Keywords: Stiffness; Shelf-life; Ultrasonic; *Lycopersion esculentum*; Maturity; Non-contact

Introduction

There is growing pressure within the food industry to improve the measurement of food quality, particularly fruits like tomato, mango, guava etc due to their large consumption as well as limited supply [1]. This inspection may include looking for time-dependent physical changes, non-uniformity of the product, or contamination. The need for reliable inspection is becoming increasingly critical due to more number of shopping malls, food shops etc [2]. Product quality management of prime importance to promote fresh fruits and vegetables consumption and to deliver high quality food products [3]. Tomato is second most consuming fruit in India after potato [2]. The major problem with this fruit is that stiffness of tomato decreases very rapidly over the time period and it moves towards different diseases attacks [4]. Stiffness or firmness of tomato is the major deciding factor which can easily relate with quality of the tomato sample. Ripening of tomato can be easily figure out by analyze the flesh softening in any kind of the tomato sample [5]. Stiffness of the tomato depends upon its various layers like endocarp, mesocrap, exocrap and seeds [6]. Stiffness or firmness of tomato sample decreases as liquids (peroxides family acids, water etc.) found between endocarp and seeds decreases over the time period [7]. Developed non-contact ultrasonic based system detects tomato maturity level based on measured stiffness of the tomato sample. Tomatoes basically have five major stages from breaker (first stage in which most of the part consists of green color) to deep red stage. Stiffness of the tomato flesh also decreases from breaker stage to deep red stage [8].

There has been recent interest in using ultrasound to investigate factors such as change in texture, stiffness or firmness in food products [9]. One of the major reason for this is that ultrasound properties are very sensitive towards stiffness of the different kind of fruits like tomato, apple etc [10]. Acoustic technique has ability to differentiate between different medias based on its propagation velocity and attenuation. Propagation delay between transmit ultrasound signal and received ultrasound echo signal. Thus using usual contact or non-contact techniques, ultrasound can be used to measure the moisture content in any fruit sample and based on past observations [11]. It is very easy to figure that moisture content of any fruit sample decreases over the time period due to different environmental conditions. Ultrasonic measurements on food products have been performed primarily using contact ultrasonic echo observation technique in the past [12-15]. This technique can characterize the fruit sample based on its different maturity levels for food as well as well beverage samples [12-15].

Sample Preparation

This section addresses the detailed information about sample preparation for experiments performed over the time period. Tomato selected as a preliminary food sample for analysis because its easy availability as well as it is the most consuming food sample in India after potato. Experiments were conducted on the fifteen tomatoes divided in three batches have different maturity levels collected from local market. Collected samples have been preserved in different environment

***Corresponding author:** Satyam Srivastava, AES, Academy of Scientific & Innovative Research (ACSIR), CSIR-CEERI, India, Tel: 91-1596-243489; E-mail: satyamsrivastava2442@gmail.com

Received January 28, 2014; **Accepted** April 26, 2014; **Published** April 30, 2014

Citation: Satyam S, Saikrishna V, Shashikant S (2014) Non-Contact Ultrasonic Based Stiffness Evaluation System for Tomatoes during Shelf-Life Storage. J Nutr Food Sci 4: 273. doi: 10.4172/2155-9600.1000273

condition like first batch stored in the sampling chamber with constant temperature and humidity conditions because there is an essential need to study the effect of environment conditions on different parameters like ripening rate, stiffness, sweetness etc. Constant 200°C temperature and 90% humidity have been applied in sampling chamber for maintaining the controlled environment. Second and third batch have been preserved in open and chilling environment (40°C) respectively.

Data acquisition process has been performed after every 24 hours with a sampling time of 2 minutes. System records the transmitted ultrasound signal with received ultrasound signal reflected from tomato flesh. Received ultrasound signal has been further converted in to pulse form for reduction of complexity (Figure 1).

Experimental Setup

A nondestructive ultrasound based method has been performed for monitor the stiffness as well as firmness of tomato food sample. Developed experimental setup consists of a transmitter, receiver pair of 40 KHz frequency with required transmitter and receiver circuitry. Transmitter circuit consists of 555 timer IC for pulse generation in monostable or one shot mode. 555 timer have two states but low logic is more stable comparison to higher one, so by default timer always prefers to be in low logic state but whenever micro controller unit triggers timer unit, it moves in higher logic state and generates a square wave pulse. Generated pulse triggers ultrasonic transducer for transmit the ultrasound signal. Transmit signal incident on tomato sample and reflects back with some loss of energy because some amount of energy has been absorbed by tomato flesh. So, transmit signal gets attenuated with some attenuation depending upon the stiffness of the tomato flesh. This attenuation depends on the maturity level of the tomato and varies over the inspection time period. Echo signal has been received by ultrasonic transducer as shown in preliminary block diagram of experimental set up. It further passes through a low pass filter for noise reduction. After this stage system detects the peak of the received ultrasound signal for calculation of attenuation. Peak detection and pulse conversion block has been employed with the system for attenuation calculation and data collection in digital form respectively. A threshold unit also has been employed with overall circuitry for detection of peak threshold of the received signal (Figure 2).

All required circuitry with transmitter as well as receiver node has been integrated inside an aluminum sampling chamber as shown in Figure 3. It also avoids the external interference with transmitted as well as received ultrasound signal (Figure 3).

DSO was not an appropriate solution to detect the minor change in propagation delay between transmitted as well as received ultrasound signals. A microcontroller unit can also detect only the change in propagation delay up to micro seconds but in some time period propagation delay between transmitted and received signal went up between two signals up to nano seconds. So, a time to digital conversion (TDC-GP21) integrated circuit is also interfaced with controller unit using SPI protocol for calculation of propagation delay between the transmitted as well as received signal. After required improvements have been performed, improved system with ARM-9 processor unit, touch screen based GUI can detects the change in tomato stiffness and also predict ripening period with require temperature and humidity parameters for ripening control process.

Firmware Development

Firmware development consists of algorithm development for detection of propagation delay between transmitted and received signal and attenuation in received signal due to tomato flesh. Firmware

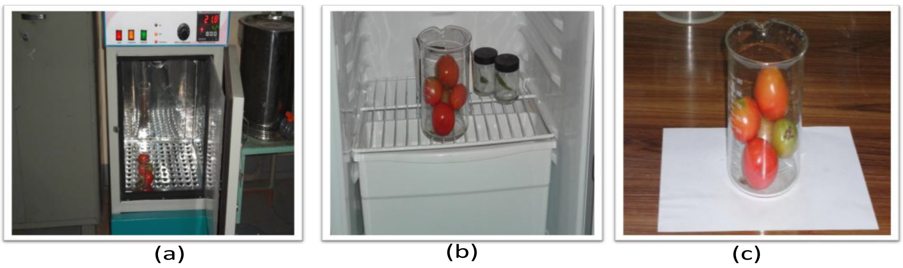


Figure 1: (a) Tomato samples (Batch-1) preserved in sampling chamber b) Tomato samples (Batch-2) preserved in refrigerator c) Tomato samples (Batch-3) preserved in open environment.

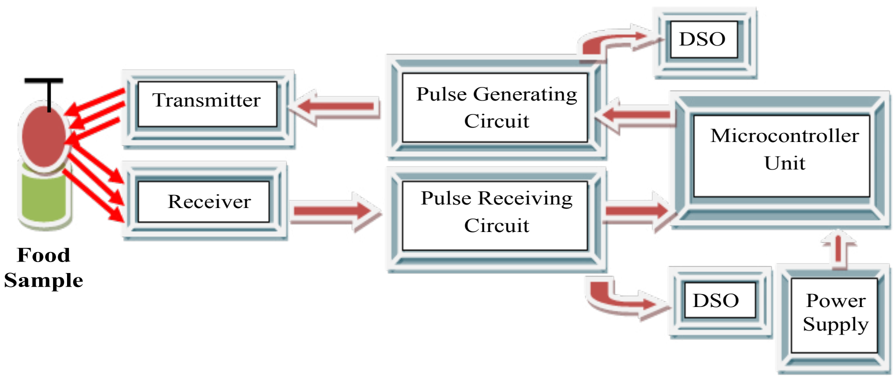


Figure 2: Block Diagram of preliminary experimental set up.

Citation: Satyam S, Saikrishna V, Shashikant S (2014) Non-Contact Ultrasonic Based Stiffness Evaluation System for Tomatoes during Shelf-Life Storage. J Nutr Food Sci 4: 273. doi: 10.4172/2155-9600.1000273

consists of ARM-9 processor unit interface with ultrasonic transducers for sensing the tomato flesh stiffness as well as maturity level. System also has ability to transfer data from host system to PC for further analysis. Firmware also consist of touch screen with qtopia based GUI for quick suggestion for the tomato samples. It also provides internet as well as Ethernet connectivity for data transfer (Figure 4).

System monitors the major lobe of the received ultrasonic signal and labeled stop tag after receiving the major lobe of the ultrasonic echo signal. System further converts received ultrasonic signal to pulse form and passes it through high pass filter have cut off frequency 50 KHz for noise removal process. Attenuation as well as propagation delay further calculated by the received signal in pulse form as shown in Figure 5. After completion of data acquisition, system calculates propagation delay as well as attenuation in transmitted signal from using following approach.

Tpd=Tstart-Tstop---(1)

Attenuation=Atransmitted-Arecieved------------------(2)

Attenuation(d.b.)=20 log Attenuation----------------------(3)

Results and Validation

Attenuation as well as propagation delay of the transmitted ultrasonic signal passes through the flesh of the tomato have been recorded during the course of storage time for batches B1-B3 (T1- T15). It has been observed that ripening rate of sampling chamber batch is slow comparison to open environment. Open environment batch moves very fast toward ripen stage and also infected with some disease like TSWV, sunscalds and common fungus. Ripening rate of the chilling environment batch (B3) is much less compared to other two batches. All samples belongs to this batch have been stuck in their stage and finally faced chilling injury. Developed system is able to discriminate between mature, immature or ripen and rotten tomatoes. System is also able to predict the approximate days remaining for any tomato sample to move towards rotten stage based on the calculated attenuation as well as propagation delay related to transmitted ultrasonic signal (Table 1). Discrimination between a immature (green) tomato, ripen (Red and yellowish) tomato and rotten tomato can be discriminate by received sensor response as shown in Figure 6.

There is a need to observe ripening rate in different environment conditions for system development. So, ultrasonic sensor response has

S.N.	Maturity Index	Attenuation (d.b.)	Propagation Delay (micro second)
1	Immature Sample	6.2	420
2	Ripen Sample	7.6	480
3	Rotten Sample	8.3	560

Table 1: Parameter variation with different stages of the food sample.

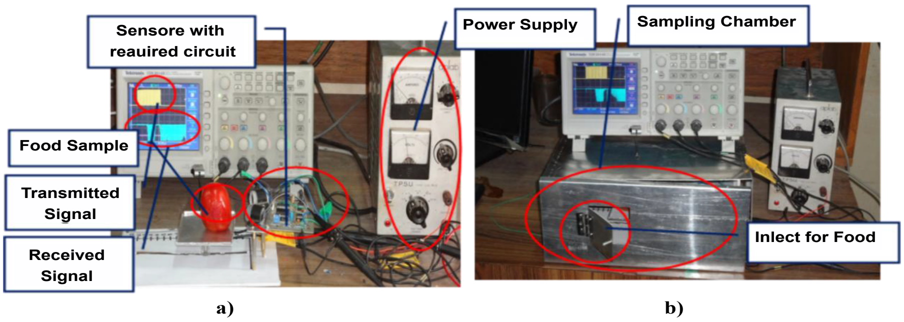


Figure 3: a) Preliminary Experimental Setup for Data Acquisition b) Improved Preliminary Experimental Setup for Data Acquisition.

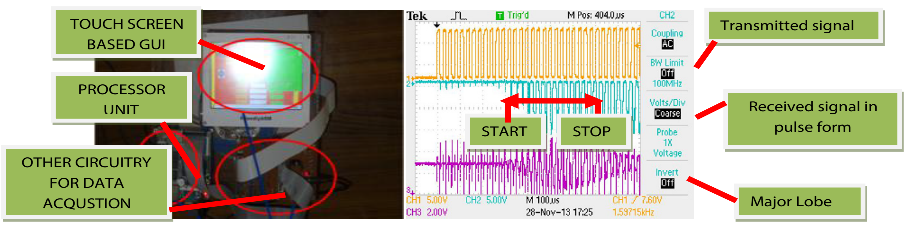


Figure 4: a) Host system for Data Acquisition b) Preliminary data acquisition.

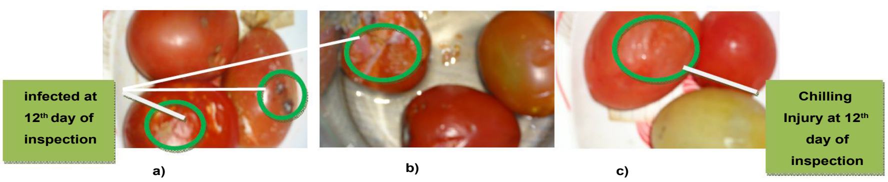


Figure 5: a) Controlled environment b) Open environment c) Chilling environment.

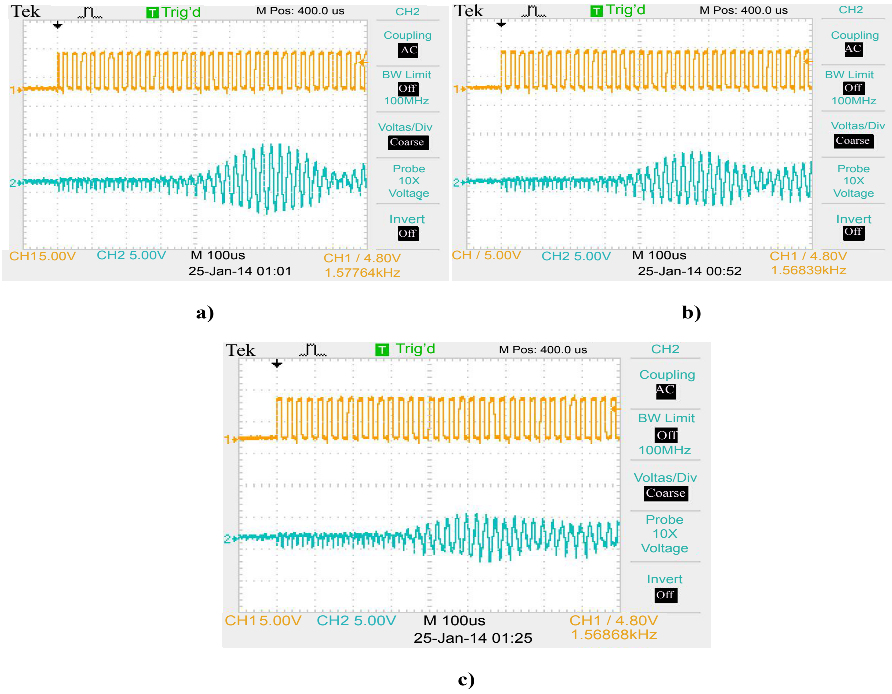


Figure 6: a) Sensor response for immature tomato sample b) Sensor response for mature tomato sample c) Sensor response for rotten tomato sample.

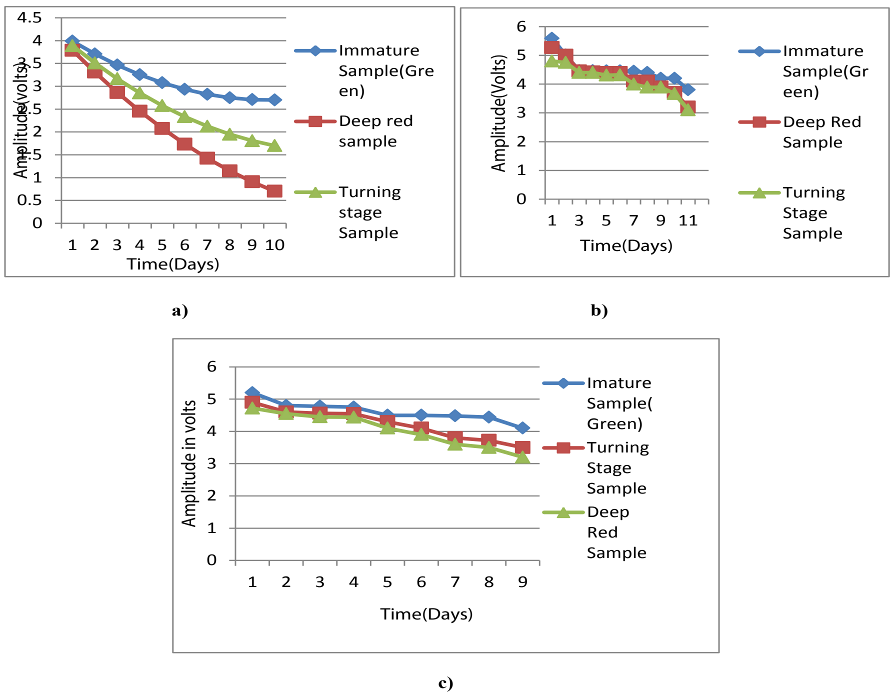
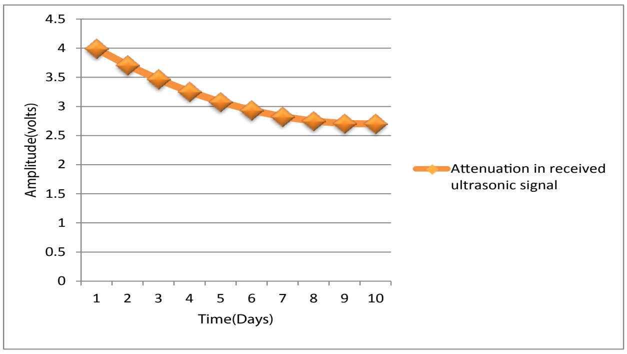


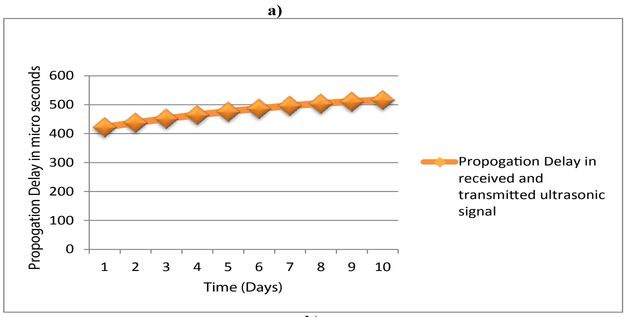
Figure 7: a) Open environment sensor response b) Chilling environment sensor response c) Sampling chamber sensor response.

been recorded for all three batches over the time period. It has been observed that ripening rate in controlled environment have 200°C and 80% humidity is proper for ripening of tomatoes. This environment takes around 5-6 days for proper ripening while as on other hand chilling environment batch have very less ripening rate compare to other two environment conditions. In this environment conditions sample get stuck in their stages and after 5 to 6 days sample faces chilling injury and exocrap as well as mesocrap of the tomato samples has been damage as shown in Figure 7.

A nonlinear relation has been figure out between the firmness and attenuation of the received ultrasonic signal. Propagation delay



a)



b)

Figure 8: a) Stiffness change with attenuation b) Propagation Delay variation with time.

S.N.	Time in Days	Ammonia (ADC Value)	Ethylene (ADC Value)	CO_2 (ADC Value)
1	Day 1	5	200	280
2	Day 2	12	250	250
3	Day 3	14	280	220
4	Day 4	20	320	-
5	Day 5	22	-	180
6	Day 6	-	320	150
7	Day 7	28	350	80
8	Day 8	35	400	50

Table 2: Validation using aroma sensing technique [33].

between transmitted and received signal also has been related nonlinearly. Ripening parameter or maturity index can be predicted using propagation delay as well as attenuation in transmitted acoustic signal (Figure 8).

Attenuation (d.b.)= -.01667×Time (Days)+.32619×Time (Days)+6.7071

Propogation Delay(Tpd)= -0.6×Time(Days)+17+Time(Days)+4.1×102

Where Tpd is in micro seconds and time is in days.

All results also validated with standard alpha-mos aroma sensing system results and it has been observed that results of developed stiffness sensing system and standard alpha mos aroma sensing system have been matched with more than 90% accuracy. Aroma sensing technique also has been employed on the same set of tomato batches using E-NOSE as well as commercial Alpha MOS system. It has been observed that ethylene concentration as well as ammonia concentration increases over the time period as tomato sample moves towards rotten stage. As raw of ammonia, ethylene and carbon die oxide gas sensor has been presented in Table 2 for same batches of tomatoes. It has been observed that as stiffness of tomato flesh has been decreases, it moves towards rotten stage. All three aroma sensors also indicate the same pattern over the time period of experiment. Ethylene and ammonia increases over the time period because of the emission of both gases from the tomato sample while as CO_2 concentration decreases.

Conclusion

This study examined the potential use of a nondestructive as well as non-contact ultrasonic based system for monitor the ripening of tomatoes over the time period of inspection. An ultrasonic based non-contact stiffness monitoring system has been developed successfully. The measured attenuation as well as propagation delay was found to be nonlinearly related to firmness of the tomatoes stored for 15 days. Tomato samples divided in three batches for observing the environment parameters influence on ripening rate performed successfully. However in some of the data samples scattered too much in attenuation as well as lack of very much clear trend in relationship between attenuation and firmness of tomato sample during the course of shelf life was found. The reason might be the irregular flesh structure of tomato is a relevant factor.

Acknowledgements

Author is grateful to CSIR-CEERI, Director Dr. Chandra Shekhar for giving chance to develop such kind of project in CSIR-CEERI as well as allowing us to publish this work. Thanks are due to AEG team members who helped us in successful completion of and installation of ultrasonic based food quality detection system.

References

1. Marc Valente, Alexia Prades, Didier Laux (2013) Potential use of physical measurements including ultrasound for a better m0061ngo fruit quality characterisation. J Food Eng 116: 57-64.
2. Gan TH, Pallav P, Hutchins DA (2006) "Non-contact Ultrasonic Quality Measurements of Food Products", J Food Eng 77: 239-247.
3. Sigfusson H, Ziegler GR, Coupland JN (2004) Ultrasonic Monitoring of Food Freezing. J Food Eng 62: 263-269.
4. Gülseren I, Coupland JN (2007) "Ultrasonic Velocity Measurements in Frozen Model Food Solutions", J Food Eng 79: 1071-1078.
5. Taifi N, Moudden A, Faiz B, Maze G, Décultot D, et al. (2006) Contrôle Ultrasonore de laCongélation/Décongélation de Poissons, 12ème Col. Nat. de la recherche en IUT, Brest 1-2 juin.
6. Bashford AG, Schindel DW, Hutchins DA, Wright WMD (1997) Field characterization of an air-coupled micromachined ultrasonic transducer. Journal of Acoustic Society of America 101: 315-322.
7. Castillo M, Payne FA, Hicks CL, Lopez MB (2000) Predicting cutting time of coagulation goats milk using diffuse reflectance: effect of pH, temperature and enzyme concentration. International Dairy Journal 10: 551-562.
8. Javanaud C (1998) Applications of ultrasound to food systems. Ultrasonics 26: 117-123.
9. Gan TH, Hutchins DA, Billson DR, Schindel DW (2001) The use of broadband acoustic transducers and pulse-compression techniques for air-coupled ultrasonic imaging. Ultrasonics 39: 181-194.
10. Cook CE (1960) Pulse compression - Key to more efficient radar transmission. Radar System 3: 310-315.
11. Gan TH, Hutchins DA, Billson DR (2002) Preliminary studies of a novel air-coupled ultrasonic inspection system for food containers. J Food Eng 53: 315-323.
12. Herbert S, Riaublanc B, Bouchet B, Gallant DJ, Dufour E (1999) Fluorescence spectroscopy investigation of acid or rennetinduced coagulation of milk. Journal of Dairy Science 82: 2056-2062.
13. Hull JB, Muumbo AM, Whalley R (1995) Controlling waste in food processing using ultrasound level monitoring technology. Strategies for Monitoring, Control and Management Waste 35-48.

14. Hutchins DA, Schindel DW, Bashford AG, Wright WMD (1998) Advances in ultrasonic electrostatic transduction. Ultrasonics 36: 1-6.

15. Kumbhar A, Gharpure DC, Botre BA, Sadistap SS (2012) Embedded e-nose for food inspection. In Physics and Technology of Sensors (ISPTS), 2012 1st International Symposium.