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Non-destructive techniques in dairy industry

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Abstract
Earlier, for food testing, the sample was first digested and then subjected to analysis. These analytical methods are expensive, slow and often required the use of chemical reagents which are ultimately drained. To overcome these drawbacks, many emerging technologies of non-destructive techniques are applicable for analyzing the food products. The potential use of these technologies for measuring and monitoring the quality of dairy products has been evaluated by researchers. The techniques like near infrared radiations, medium infrared radiations, electronic tongue, electronic nose, ultrasound and magnetic resonance may be used to envisage not only the chemical composition but also the quality of milk and the dairy foods. Some of these techniques can be used for on line monitoring and also for determining the structure. These techniques along with their applications in dairy industry have been presented in this paper.

Keywords: Food analysis, Non-destructive, techniques, milk, dairy

Introduction
During the past year, much progress has been made in developing non-destructive techniques for the assessment or inspection of quality parameters of dairy food including internal disorders but also taste, sugar content, and so forth. The traditional methods for analyzing the composition and quality of the food products are tedious and expensive, with a significant burning up of chemicals which not only pollute the environment but also destroy the sample. To overcome these drawbacks, many emerging technologies which lie in the package of non-destructive techniques are applicable for analyzing the food products. The potential use of these technologies for measuring and monitoring the quality of food products including dairy products have been evaluated by a number of researchers.
The non-destructive system set up a contemporary trend in the field of dairy foods which comprises of many different techniques and approaches. In spite of old methods, an emerging technology has set up a way for developing non-destructing system to use as an auspicious application for testing food. Over the past few decades there have been incredible advances in non-destructive testing helping researchers and engineers to embark upon problems of scientific, industrial and environmental field (Nelson *et al.,* 2006) [27]. The development of processing control and automation in the food industry improves production efficiency and quality and provides for more uniform manufacturing of food products. Destructive methods not only cause the environmental pollution but also were costly and time consuming. To overcome the draw backs of these traditional methods, non-destructive techniques have been used for rapid analysis of components of food stuffs. These non-destructive testing and evaluation (NDTE) comprises of many different techniques and approaches. These have been used for quality analyzing in the field of dairy technology and are described further in successive paragraphs.

Near Infrared Spectroscopic Techniques (NIR)
NIR spectroscopy has been the first to be used for the non- destructive quality analysis in milk and milk products. The wavelengths used for analysis ranges from 0.78 to 2.5 µ m. The analytical procedures do not require any sample preparation, thus it has been applied for online testing in dairy industry. Furthermore, NIR technique allows several constituents to be measured simultaneously online in the dairy products (Huang *et al.,* 2008) [14].

Principle: This works on the principle of the interaction between electromagnetic resonance (EMR) and physico-chemical constituents of foods. The energy absorbed is in NIR region which generates the spectrum of particular wavelength; for which either absorption or reflectance of this spectrum is measured and further examined (Alander *et al.,* 2013) [1].

Electronic Nose

Electronic Nose is a machine designed to detect complex odors using sensor arrays. They detect the smell more effectively than the human sense of smell. The sensor array contains broadly tuned sensors, which are usually non-specific. They are standardized with a variety of odors and are sensitive to biological or chemical materials. It comprises of an intelligent sensing device that uses an array of gas sensors which are overlapping selectively along with a pattern reorganization component. The instrument is equipped with appropriate system of pattern recognition capable of identification of simple and complex odors (Labreche *et al.,* 2005) [23].

Principle: The electronic nose mimics human olfaction whose functions are to perceive non separate mechanism, i.e. the smell or flavor. The molecules which are responsible for odor are drawn into the e-nose using sampling techniques such as head space sampling, diffusion methods, bubblers or pre-concentrators (Pearce *et al.,* 2003) [28]. As the sample enters the sensor array, it induces a reversible physical and/or chemical change in the sensing material, which causes an associated change in electrical properties, such as conductivity (Harsanyi, 2000) [13]. Each "cell" in the array can behave like a receptor by responding to different odors to varying degrees (Shurmer and Gardner, 1992) [32]. The electronic nose consists of three major parts which are detecting system, computing system and sample delivery system.

Electronic Tongue

The taste assessment is one of the most important quality control parameter for evaluating a formulation. Any new molecular entity in a formulation can be assessed for evaluating the taste. The taste sensor is multichannel i.e the electronic tongue, determines taste similar to taste perception in humans. Furthermore, such taste sensors have a wide range of selectivity that has the capability to classify an enormous range of chemicals into several groups on the basis of their properties such as taste intensities and qualities (Jain *et al*., 2010) [16].

Two types of electronic tongue systems which are commercially available (Anand *et al*., 2007) [4] are:

- The taste sensing system SA402B (equipped with lipid membrane sensors)
- The ASTREE e-tongue (chemical field effect transistor)

Both measure the changes in electronic potential while investigating liquid samples but the underlying sensor technologies are different.

Principle: The electronic tongue is an instrumental technique which comprises of electrochemical cell, sensor array and appropriate pattern recognition system, capable of detecting and identifying simple or complex soluble nonvolatile molecules which form the distinguished taste of a sample. The sensor array consists of broadly tuned (non-specific) potentiometric metal based electrodes (Ivarsson *et al.,* 2005) [15].

Ultrasonic Technology

Ultrasonic is a rapidly growing technology in the field of research, both for the analysis and modification of food products. Ultrasound is a form of energy generated by sound waves (which exerts pressure) of frequencies that are too high to be detected by human ear, i.e. (Jayasooriya *et al*., 2004) [17]. The ultrasound applications can be classified on the basis of the energy generated by sound field, characterized by sound power (W), sound intensity ($W \cdot m^{-2}$) or sound energy density ($Ws \cdot m^{-3}$) (Knorr *et al* 2004). The sound ranges in use are divided into Low energy and High energy ultrasonic techniques.

Low energy (low power, low-intensity) ultrasound involve the use of frequencies higher than 100 kHz (Jayasooriya *et al*., 2004) [17] whereas high energy (high power, high-intensity) ultrasound involves the frequencies between 18 and 100 kHz. (McClements, 1995) [26]. Ultrasound technology can be performed on line.

Principle: Ultrasonic/ the sound wave (frequency above 16 kHz) produced by the electronic pulse generator, further passes via the test material using the transducers; it either reflects off the extreme side to come back to its point of origin, i.e. pulse or echo, or is received by another transducer at that point. The signal which is received is amplified and assessed (Jayasooriya *et al* 2004) [17].

Applications in dairy industry

The non-destructive methods have triggered much interest for measuring the quality of milk and its products. Some examples of applications of these techniques have been presented in the following table.

Conclusion

The non-destructive methods of food analysis are highly applicable to food industry for quality measurement of raw materials and manufactured products. These are rapid, versatile and accurate for online evaluation of milk and milk products in the industry. It has tremendous potential for deliberation as a guarantee of the quality and safety of dairy foods. Nowadays, the on-line evaluation of composition and other quality attributes have successfully been applied in the cheese, butter and milk powder industry. As sensors often only measure a single constituent or quality property, combined techniques will have to be optimized to measure overall quality. The non-ending work is going on to make the on-line evaluation suitable for small and on-farm scale of production and processing of milk. Commercial application of these techniques will be beneficial for the consumer as well as the grower and trade. As already emphasized in the research needs section, the ideal method covering all requirements of today's and future applications in production, storage, and retail has not yet emerged and probably will not be found in the foreseeable future.

Near Infrared Spectroscopy		
Milk Product	**Application/ measured attributes**	**References**
Milk	Detection of foreign fat adulteration	Sato *et al* (1990)
Raw milk	Fat, protein, lactose and SNF	Tsenkova *et al* (1995)
Milk	Quality during milking	Kawasaki *et al* (2005)
Cow's milk	Fat, protein, and casein	Laporte and Paquin (1999)
Raw milk	Quantization of fat, protein and lactose	Sasic and Ozaki (2001)
Skim milk	Quality loss of pasteurized milk	Al-Qadiri *et al* (2008)
Milk	On line quality monitoring	Kawamura *et al* (2007)
Milk powder	Moisture content and vegetable protein adulteration	Reh *et al* (2004)
Butter and butter oil	Moisture and composition	Kliman and Pallansch (1965)
Cheese	Fat, protein, lactose and moisture	Hall *et al* (1994)
Cheese	Monitoring milk coagulation	Lyndgaard *et al* (2012)
Electronic Tongue		
Milk	Quality due to microbial growth	Winquist *et al* (1998)
Milk	Monitor the cleaning process after pasteurization	Winquist *et al* (2005)
Goat Milk	Adulteration with bovine milk	Dias *et al* (2009)
Electronic Nose		
Milk	Rancidity of milk	Capone *et al* (2001)
Milk	Bacterial growth in milk and shelf-life	Labreche *et al*(2005)
Whole milk powder	Seasonal changes in whole milk powder aromas	Biolatto *et al* (2007)
Danish Blue Cheese	Flavor and aroma	Trihaas *et al* (2005)
Gorgonzola and Cottage cheese	Characterized their flavor and aroma	Ampuero and Bossel (2005)
Ultrasonic Techniques		
Milk	Coagulation process	Gan *et al* (2006)
skim milk	Colloidal properties	Gülseren *et al* (2010)
Packed milk	Quality evaluation	Elvira *et al* (2006)
Milk, cheese and yoghurt	Foreign materials	Chandrapala *et al* (2012)
Cheese manufacturing	Monitoring quality	Koc and Ozer (2008)

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