Dielectric microwave spectroscopy for non-destructive food analysis

Identification

Key words: dielectric properties, permittivity, salt, fat, °Brix, water, water activity, time domain reflectometry, guided microwave spectroscopy, non-destructive analysis

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How does it work?

Primary objective: Non-destructive on-line tool to predict water content, water activity, salt and fat content, and monitor quality in food products.
Working principle

The permittivity of a food product can be determined and used to have access to its composition. The electrical permittivity of a material is given by the relative complex permittivity $\varepsilon = \varepsilon_r - j \varepsilon''$, where $\varepsilon_r$ is the relative real permittivity or dielectric constant and $\varepsilon''$, the relative loss factor and $j = \sqrt{-1}$. The dielectric constant is often related with the ability of the material to store energy while the loss factor represents the ability of the material to convert the electromagnetic energy into thermal energy. The main idea of the dielectric microwave spectroscopy is to send electromagnetic waves in the ranges from 20 MHz to 20 GHz on a sample and to evaluate the response of the reflected or transmitted signals. At laboratory scale, the main systems available are based on an open-ended coaxial probe connected to a vector analyser. Like in UV/Vis spectroscopy, the system sends a frequency and records the reflected signal that results in a dielectric spectrum. The posterior analysis of the reflected dielectric spectrum gives the appropriate information. For fast non-destructive analysis, two basic systems are available on the market, the Time Domain Reflectometry (TDR) for solid and liquids products and the Guided Microwave Spectroscopy (GMS) for pumpable products.

- In the TDR system, the device continuously generates a step signal with less than 100 ps rise time and a repetition frequency of 5 MHz, corresponding to a frequency range from 20 MHz to 5 GHz. The open end coaxial sensor acquires the reflected signal with a time resolution of 10 ps. The shape and intensity of the signal will depend on the variable dielectric parameters and, with appropriate calibration, will give the chemical composition or the food quality. (Sketch 1)

- In the GMS system, when the electromagnetic wave is sent through a section of waveguide over a spectrum of frequencies, there is a frequency below which transmission does not occur, thus giving the Cut-off frequency ($f_c$). The transmitted signal presents three main regions: the pass band regions, the cut-off regions and the intermediate regions with the cut-off slope. The analysis of the transmitted signal, especially of the cut-off frequency and cut-off slope is directly connected to the electrical permittivity of the food product. Thus, with the appropriate wave guides and calibrations, GMS can give the chemical composition of the food product. (Sketch 2)

For both systems a simple PCA (Principal Component Analysis) can give the desired information concerning: water, salt and fat content, maturity of fruits, quality of fish products and °Brix in juices, among others.

**Images**

**Additional effects**

**Important process parameters**

- Equipment parameters: frequency range, geometry of the wave guide for GMS system, intensity of the electromagnetic wave, calibration, contact level with the product (in TDR system, the sensor must be as close as possible to the product).
Important product parameters

• Product parameters: electrical permittivity, temperature, chemical composition, viscosity.

What can it be used for?

Products

Most products with water content from 30 to 100% can be analysed.

Operations

Quality control, process monitoring

Solutions for short comings

Real-time process monitoring using smart sensors.

What can it NOT be used for?

Products

• Products with very low electrical permittivity such as fat or air bubbles
• Frozen products
• Packaged products cannot be analyse by TDR system

Operations

- Other limitations

Since dielectric microwave spectroscopy is a temperature-dependent system, monitoring of products with variable temperature can result in deviations.

Risks or hazards

- Implementation

Maturity

Some equipment based on the TDR and GMS systems is already in use for on-line measurements, mainly for the meat and fish sector.

Modularity

Equipments are mostly small enough to be easily installed in a production line.

Consumer aspects

- Legal aspects

No current regulation for this technology

Environmental aspects

- Facilities that might be interesting for you

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<tr>
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<td>ONIRIS-GEPEA</td>
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Further Information

Institutes
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Companies
Sequid GmbH, Thermo Scientific, Agilent Technologies

References

Source: