Product Quality and Safety

Intelligent technologies for assessment of quality and safety of food agricultural products

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Abstract. *This paper presents the INTECHN project concept which is focused on the development of intelligent technologies and tools for quality and safety assessment of widespread food agricultural products, such as cereals, fruits, vegetables, milk, dairy products, meat and meat products. An analysis of recent solutions in the subject domain is made. The INTECHN platform model is presented.*

Key words: food quality, safety assessment, intelligence technologies, computer vision, spectroscopy.

Introduction

Food safety and quality is one of the priorities in EU. It takes place in many national and international standards and normative documents, European programs, directives and decisions. They include the entire process related to food quality assurance, from production of raw materials to food quality assessment and food preservation.

Food quality control is an important element of these programs. The higher EU requirements concerning food quality and safety improvement demand development of new, advanced, effective automated technologies for food quality assessment.

The main INTECHN (Intelligent Technologies for Assessment of Quality and Safety of Food Agricultural Products) project objective is to develop intelligence technologies and tools for assessment of quality and safety of widespread food agricultural products, like cereals, fruits, vegetables, milk, dairy products, meat and meat products. The technologies, which are used for this purpose, are rather primitive in many respects and didn't change for many years. The expert is the key figure in the assessment of great part of the quality properties of agricultural products. They depend on his knowledge, experience and capability to interpret results. This defines to a certain extent the nature of assessments - subjective, slow and insufficiently precise. That is why the development of new advanced automated technologies for assessment of the quality of agricultural products and safety is a priority in various EU research programs.

Particularly the INTECHN project is focused on the development of new technologies and tools for:

1. Automated assessment of main quality properties of cereals such as purity, authenticity, infections, etc., which use intelligent tools based on computer vision systems, systems for spectral analyses, Wavelet transformations, pattern recognition, neural networks, fuzzy logic, etc.
2. Automated assessment of the main quality properties of fruits and vegetables, such as external and internal defects, content of dry substances, sugar substances, etc. Assessment and classification of investigated products are based on the analysis of spectral permeability and/or reflection in visible and near infrared spectrum. New sensor modules will be developed in the frame of the project. These modules will have intelligent control algorithms, which will be based on advanced information technologies such as artificial neural networks, genetic algorithms, fuzzy logic, wavelet transformation etc.
3. Automated assessment of the main quality properties and safety of milk, dairy products, meat and meat products, which will include determination of composition and technological properties of products, as well as identification of different adulteration and contamination with pathogen microorganisms. Two different approaches will be used for this purpose. The first approach will be based on spectral analysis in visible and near infrared region, combined with different chemometric methods for quantitative analysis and classification. The second approach will use product images and image processing techniques for assessment of quality properties of products.

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Material and methods

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Recent investigations in the subject domain include two kinds of methods - destructive and non-destructive. The destructive methods are based on analytical chemical methods (wet chemistry) and some instrumental methods like gas–chromatography and liquid-chromatography (Yoshizawa, 2001; Young and Games, 2003**),** emission spectral analysis, surface plasmon resonance (Mullett et al., 1998), etc. The non-destructive methods use computer vision systems (Aitkenhead et al., 2003; Brosnan and Sun, 2003), systems for analysis of transmitted and diffuse reflected radiation **(**Paizier et al., 2001**),** X- radiation (Carvalho, 2001), near-infrared (Dowell and Maghirang, 2002; Woodcock et al., 2008), and UV-VIS spectroscopy (Dowell et al., 2002), etc.

Methods for assessment of fruit and vegitable quality can be divided into two groups - subjective (manual) and objective (machine) methods. The objective methods are the following: mechanical (measurement of object shape, dimensions, bulk, mass, density, etc.); physical (measurement of heat conductivity, acoustics, electrical conductivity, permeability, etc.); chemical (photocolorimetry, thermochemistry, electrochemistry, flotation, filtration, etc.); electromagnetic (electrical and magnetic fields, X-ray, UV, VIS, IR, laser radiations, etc.).

Methods, which are based on measurement of electromagnetic radiation, correspond in the utmost degree to modern requirements for remote and non-destructive evaluation of quality of fruits and vegetables. The features of radio-wave, microwave (Irudayaraj and Reh, 2007**)**, optical (UV, VIS, IR) (Ozaki et al., 2007; Workman and Weyer, 2007) and X-ray (Irudayaraj and Reh, 2007) methods are investigated and analyzed. The optical methods are characterized by high accuracy of measurement and correspond to modern technologies, conditions and requirements.

Products with outside defects can relatively easily be classified through known sorting technologies (Ruben et al., 2006). Inside defects are invisible and they require new decisions and technique, which provide information about the internal properties of products. Besides inside defects caused by different diseases and irregular structure, the internal properties of products related to the degree of maturity, inner colour, amount of solids, sugars, protein, vitamins, etc. can be determined for quality assessment of products.

The existing non-destructive methods for internal quality evaluation are based on the optical permeability and reflectivity of the product in the different fields of the electromagnetic spectrum (Inteaz , 2003; Ozaki et al., 2007). Obviously, the combined usage of the reflectivity and permeability characteristics and the establishment of a clear-cut connection between them and the fundamental quality parameters of the foodstuff would lead to more representative “images” of the products to be researched, in the form of electric signals in the time or space-frequency zones.

Classical organoleptic, histological, physico-chemical and microbiological methods are mainly used for milk, meat, and meat and milk product quality assessment. They are destructive, slow, tedious, give retrospective information and depend on expert qualification. There are new methods based on molecular genetics, which are successful, but they require time, expensive instruments and consumables, and highly trained staff to be performed adequately. A radically different approach is based on spectroscopic techniques. Near infrared spectroscopy has been examined as a reliable method for real time analysis in food industry (Workman and Weyer, 2008). This technique allows fast, non-destructive, reagent-free, multicomponent analysis of milk, meat, milk and meat products (Al-Qadiri et al., 2008; Spitzer et al., 2007; Tsenkova and Toyoda, 2002). Possibilities for determination of some technological parameters, adulteration and bacterial contamination by near infrared spectroscopy have been investigated (Horvath et al., 2008).

There are partial solutions concerning the application of advanced thechnologies for assessmenmt of quality properties and safety of food agriculture products. There is no common aproach, which can be used as a technological platform for food quality and safety assessment. That's why the goal of this project is to develop such a technological platform.

Results and Discution

Intechn platform conceptual model. The project concept is related to the development of a new technological platform for assessment of quality and safety of widespread food agricultural products. It includes a set of technologies, methods and tools for automated extraction of information about investigated objects, analysis and assessment of their properties. These technologies are based on application of modern technical systems for forming and analyzing information about agricultural products, like computer vision systems, systems for spectral analyses etc. Advanced methods for analyses and decision making will be used for the analysis and classification of objects. They are based on pattern recognition, cluster analysis, neural networks, fuzzy logic, Wavelet transformations, multiple statistical methods etc. This platform will be used for assessment of cereals, fruits, vegetables, milk, dairy products, meat and meat products in the frame of the project. It will give a possibility to be easily adapted for quality assessment of other food products. In this way the platform will be a basis for development of a new generation of technologies for quality assessment of food products.

It is foreseen the INTECHN platform to include the following main components in conformity with the project concept:

1. Module for assessment of quality properties of cereals.

2. Module for assessment of quality properties of fruits and vegetables.

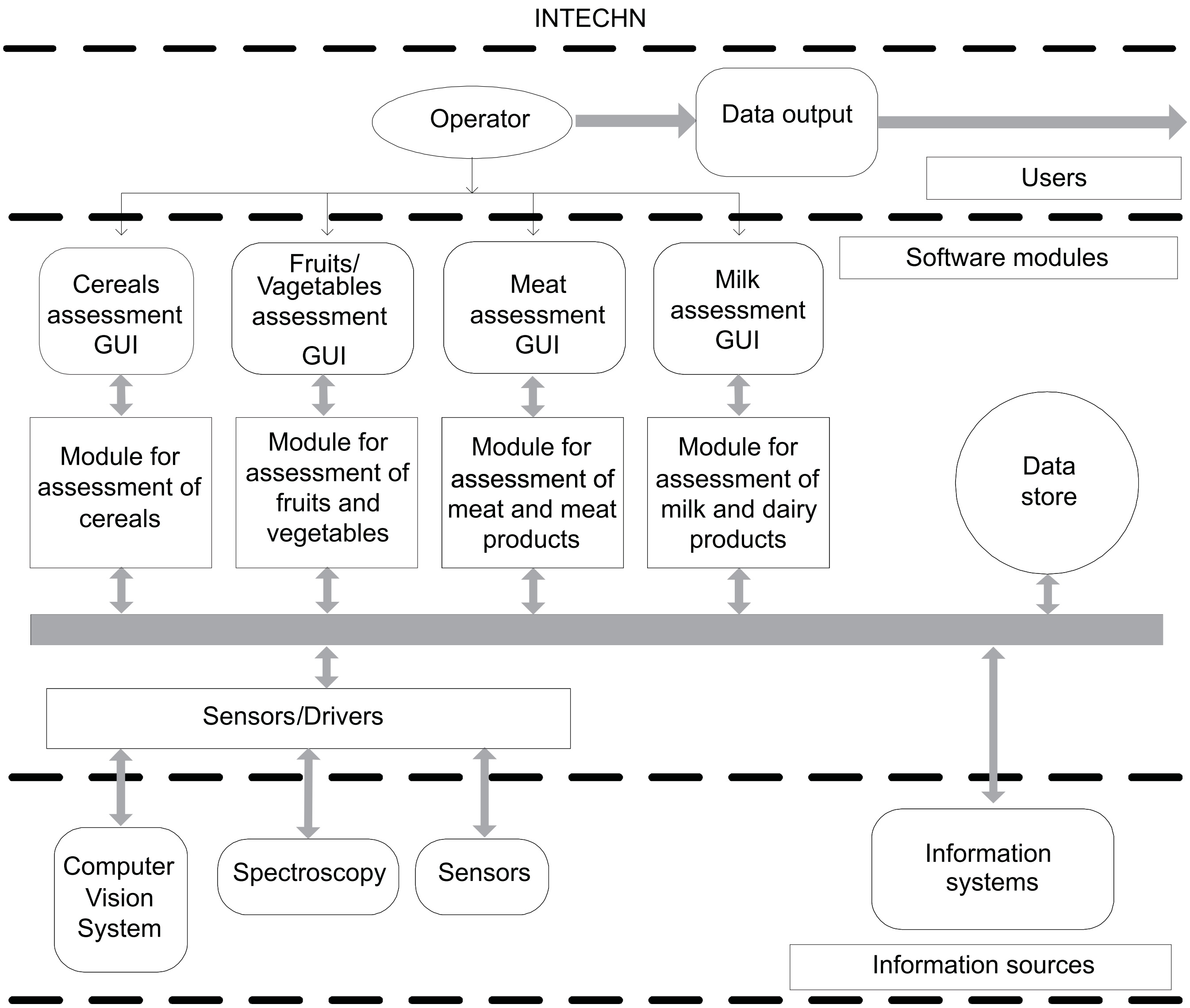
3. Module for assessment of quality properties and safety of milk and dairy products.

4. Module for assessment of quality properties and safety of meat and meat products.

It is foreseen each of the INTECHN platform modules to have relatively independent structure, functions and tools because of the specific character of the technologies for quality assessment of different products. The modules will be integrated in an appropriate programmable environment.

The conceptual structure of the INTECHN platform is presented in figure 1. It is organized in three levels:

Fig.1. INTECHN platform conceptual model



Information sources level. This level includes needed minimum of information resources for assessment of main quality and safety properties of the investigated objects. First, these are specialized sensors, sources and systems for acquisition of essential information for products quality assessment. A computer vision system, spectrophotometers, specialized sensors like moisture meter, conductivity meter, pH meter and new sensor modules will be used as main information sources. This level also includes other external information resources such as standards, requirements, information systems and other sources related to the subject area.

The computer vision system will be used to acquire and analyze digital color images of the investigated objects (grains, fruits, vegetables, meat products, dairy products). Two images in two orthogonal planes will be captured. Different quality properties related to the shape, size, morphology, color and other visible features of the tested agricultural products will be assessed on the basis of this information.

Quality and quantitative properties of grains, meat, milk, meat and milk products, fruits and vegetables will be assessed through the spectral analysis.

It is foreseen the specialized sensors to be used for assessment of features such as weight, moisture, pH and other quality features together with digital color images and spectral information.

Software modules level. This level includes software tools related to the preliminary processing of the input information, analysis and decision-making concerning quality feature assessment. It is foreseen programmable environments such as MATLAB, specific software such as Pirouette and other available software resources, as well as new software products to be used. Appropriate graphical user interface will be developed for each of the modules.

The preliminary processing of the sensor information includes object data quality improvement using measurement noise filtering, improvement of data homogeneity, reducing the sensor data size, etc.

The main goal of the sensor data analysis is to extract informative features from the digital color images, spectral data and data from specialized sensors. Data from different sensors will be used for developing models for quantitative determination of main chemical components, estimation of important quality and safety parameters of tested products. Different properties will be used for quality and safety assessment:

- Features related to the object shape and geometry will be used for assessment of grain purity, broken grains, other grains, weed seeds, sprouted grains, impurities (organic and inorganic), grain authenticity and stoutness, fruit and vegetable shape and size.

-Color and color-texture features can be used for assessment of authenticity and diseased grain, typical and non-typical grain color, meat and meat products quality parameters such as color, tenderness, histological analysis of various kinds of meat, visible external defects of fruits and vegetables.

- Visible and near infrared reflectance spectroscopy will be used for milk, meat, milk and meat products quality evaluation. Several important chemical parameters such as fat, protein and water content of meat and meat product, fat, protein, lactose and total solids in raw milk, fat and protein content in cheese will be determined. Simultaneously with the analysis of chemical composition, we intend to use near-infrared spectroscopy for estimation of some quality parameters in meat and meat products. Models for sorting meat into a quality class in terms of tenderness and juiciness will be developed. Another important task will be the investigation of possibilities to discriminate between fresh and frozen-thawed products, which is of high interest for the control of fraudulent frozing-thawing cycle. NIRS will be used for the objective identification of meat origin, confirmation of the authenticity of meat products, and to provide quality controls at various stages once the finished product was obtained: finished product, storage, distribution and marketing.

- Spectral methods will be used for estimation of milk and milk product quality. Investigation of possibilities of NIRS for monitoring milk coagulation, as well as monitoring cheese ripening and quality parameters will be done. Development of fast and non-destructive methods for discrimination between different dairy products and confirmation of their authenticity is another challenge for scientists in the project team.

- The important part of the project is investigation of possibilities of NIRS in combination with multi-variety chemometrics techniques for detection of surface and internal contamination of foodstuffs with some foodborne pathogens important for human health such as, Salmonella spp., Listeria spp. and others.

- Spectral features will be also used for assessment of grain moisture, diseases, internal object structure, fruit and vegetable external and internal defects, content of dry substances, sugar substances, etc.

The formal object descriptions will be based on these features. These object descriptions will be used for product grading in conformity with the normative requirements. Advanced intelligent classifiers based on the artificial neural networks, fuzzy logic, tools for spectral analysis and other tools will be used for object classification in quality groups.

An important part of software modules will be the data store, which will include a library of digital images and a library of spectral data. The basic assumption behind the application of spectroscopic techniques for estimation of food quality relies on the generation of the "fingerprint" of foods. An individual product with a given chemical composition and quality exposed to a light source will have a characteristic spectrum, which is a result of the absorption by various chemical constituents. Since the exact composition of any natural material varies somewhat, depending on variety, season, location, etc., there is a range of typical spectra for this material. Therefore, what is needed is a library of representative spectra, to which the spectrum of a test material may be compared in order to establish its quality or authenticity.

User level. This level foresees development of appropriate tools for presentation of the results from analysis and object quality assessment.

Conclusion

The INTECHN project consolidates the scientific and research resources of teams from leading universities in the field of food quality assessment, their knowledge and experience for development of an advanced effective technological platform for assessment of quality and safety of agricultural food products. The project team hopes this platform will be the basis for a radical change and modernizing of extant technologies.

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