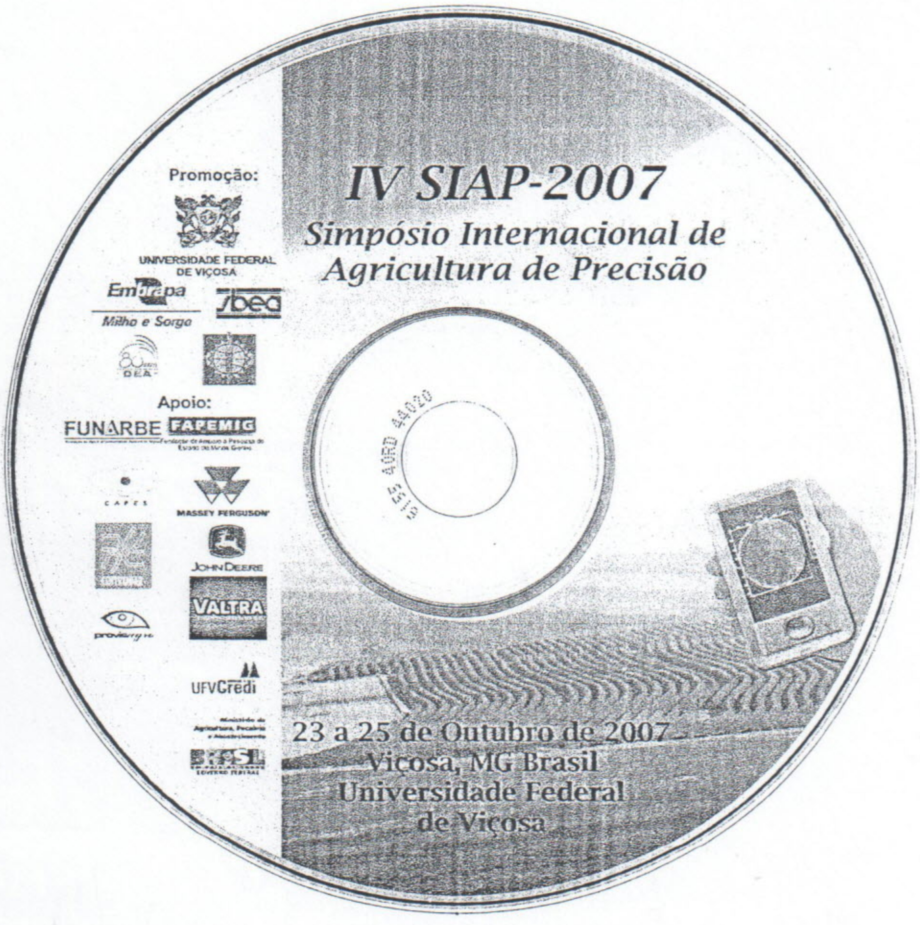
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NEW SENSORS FOR QUALITY MONITORING IN PRECISION AGRICULTURE

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ABSTRACT: Different sensors can be used in food production to ensure product quality on site specific management, but their developments are still a challenge. The concept of quality in agriculture must require a particular standard, the general term quality is very subjective and means very little. Once a particular standard is set a critical additional component of quality becomes a product's consistent adherence to that standard and aggregates value to the final product. This paper presents potentialities on new sensors for quality monitoring in precision agriculture.

KEYWORDS: Sensors, Precision Agriculture, Quality.

1. INTRODUCTION

Food production and consumption will change dramatically within the next 30 years. Water problems, energy use and climate change are the key reasons besides increasing population. For many people food are not available, although there are enough supplies somewhere else. Most people around the world will welcome the possibility to shape food on a molecular level, because it will be locally available everywhere around the world. More and more food companies and agriculture are aware about this future development and work on concepts to enter the science and technologies.

It is quite possible that in the near future will be common the use of food with a correct nutritional composition and no longer affected by limited resources, bad crop weather, water problems or others. However, to reach such state of art in food production is still necessary to select an adequate way to handling an agriculture field to reach an adequate level of productivity, quality, and sustainability.

In the most generic sense, quality refers to the combination of characteristics that are critical in establishing a product's consumer acceptability. In the food agriculture, this is usually an integrated measure of purity, flavor, texture, color, appearance and workmanship. In a highly-competitive market, other criteria of quality can be the value or a consumer's perception of the worth of the product based upon the funds available for it. This requires a particular standard, only the general term quality is very subjective and means very little. Once a particular standard is set, however, a critical additional component of quality becomes a product's consistent adherence to that standard.

The agreement on sanitary and phytosanitary measures dealt with the problem of health and safety concerns as disguised trade barriers. Countries could still set their own safety standards, but they would have to be based on scientific evidence. The use of accepted international standards would be encouraged wherever possible and the adoption of scientifically accepted quarantine treatment technologies would provide a much greater potential for consumer's acceptance.

The methods used to measure quality in the field can be subjective, as in taste tests or they can be objective, such as physical, chemical or microscopic analysis. Subjective methods are based on the opinions of the examiners and because they require the use of our various senses, they are often called

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sensory analysis. Recently various computerized sensory evaluation systems are designed to ensure that sensory responses are accurately reported and statistically interpreted.

The physical, chemical and microscopic analytical methods are considered to be objective because they are designed to exclude any subjective opinions of the examiner. These methods are usually standard scientific tests which should be able to be reproduced with the same result by any trained technician. Physical measurements include product attributes such as size, weight, color, texture, headspace, and even impurities such as filth and insects.

Chemical methods are usually more complex and often require instrumentation that can be rather sophisticated. Precise tests for moisture, protein, carbohydrates (total and specific), ash and fibre have become standard practice along with a myriad of others pertaining to specific components of ingredients or products. Microscopic methods are used to determine the presence of mold, insect fragments or foreign materials as well as for any spoilage or disease microorganisms the product may harbor.

As a new paradigm of society a new wave of development brings the necessity of radical improvement in productivity. Today is already possible to observe the modern field production systems, which have evolved to unprecedented levels of production efficiency. These advances have resulted from germ plasm improvement, use of synthetic fertilizers and pesticides, and use of advanced agricultural machinery. These production inputs have resulted in greater efficiency despite the fact that detailed management data regarding the particular crops was generally unavailable.

The availability of new kinds of information about production fields, farmsteads, products, and markets opens the door to new ways of practicing agriculture. Information technologies offer an unparalleled ability to characterize the nature and extent of variation in agricultural fields. At the field and subfield scale, information of site characteristics makes it possible to manage the variation rather than using the same treatment for agricultural inputs.

Although commercially available now, significant research is still needed to establish cost-effective procedures for the new equipment being used, especially for the tools elaborated for data interpretation, as well as training programs must be developed to help producers to take advantage of them.

The precision agriculture in near future will be focused on drought- tolerant crop varieties with superior yield potential and quality, irrigation technologies and decision-aid models to improve water use efficiency and products quality. Additional work will develop management strategies for weeds, insects, and diseases through integrated biological, chemical, and cultural controls and genetic resistance; production models for different soil, water, and regional scenarios, and other practices for improving agricultural production systems with sustainability.

The innovations in new sensors are expected to be a challenge, and this paper presents possibilities for quality monitoring in precision agriculture.

2 SENSORS AND PRECISION AGRICULTURE APPLICATIONS

2.1 Sensors Fundamentals

Sensors are devices that provide an interface between electronic equipment and the physical world. They help electronics to see, to hear, to smell, to taste, and to touch the physical world by converting input objective physical or chemical signals into electrical signals. The design of sensors began with mechanical sensors, which were later replaced by electronic ones. More recently, types based on emerging technologies have been suggested as replacements.

Usually sensors are classified according to their mode of use. For agriculture applications they can be didactically organized in four groups: on-line, at-line, off-line, and on-the-go sensors.

On-line sensors operate directly and fixed in the process, allowing a real-time signal, which is related to the quality factor under investigation. At-line sensors are devices to be used for instance in flow measurements requiring equilibration and reaction times. Off-line sensors are in general used as laboratory devices, responding within hours or days. On-the-go sensors have the ability to collect data during the movement of its holder, which allows the conduction of the variable rate in different steps.

Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth. In general it is possible to select at least six signal domains and related sensors:

- The thermal signal domain: the most common signals are temperature, heat flux, or heat flow. Related sensors are called thermal signal sensors;
- The mechanical signal domain: the most common signals are force, pressure, velocity, acceleration, and position. Related sensors are called mechanical signal sensors;
- The chemical signal domain: the signals are the internal quantities of the matter such as concentration of a certain material, composition, or reaction rate. Related sensors are called chemical signal sensors;
- The magnetic signal domain: the most common signals are magnetic field intensity, flux density, and magnetization. Related sensors are called magnetic signal sensors;
- The radiant signal domain: the signals are quantities of the electromagnetic waves such as intensity, wavelength, polarization, and phase. Related sensors are called radiant signal sensors;
- The electrical signal domain: the most signals are voltage, current, and charge. Related sensors are called electrical signal sensors.

To parameterize a sensor is important to take into account the following parameters:

- Absolute sensitivity - the ratio of the change of output signal to the change of the measured (physical or chemical quantity);
- Relative sensitivity - the ratio of a change of the output signal to a change in the measurements normalized by the value of the output signal when the measurement is zero;
- Cross sensitivity - the change of the output signal caused by more than one measurement;
- Direction dependent sensitivity - a dependence of sensitivity on the angle between the measurements and the sensor;
- Resolution - the smallest detectable change in the measured that can cause a change of the output signal;
- Accuracy - the ratio of maximum error of the output signal to the full-scale output signal expressed in a percentage;
- Linearity error - the maximum deviation of the calibration curve of the output signal from the best-fitted straight line that describes the output signal;
- Hysteresis - a lack of the sensor's capability to show the same output signal at a given value of measured regardless of the direction of the change in the measurement;
- Offset - the output signal of the sensor when measured is zero;
- Noise - the random output signal not related to the measured;
- Cutoff frequency - the frequency at which the output signal of the sensor drops to 70.7% of its maximum;
- Dynamic range - the span between the two values of the measured (maximum and minimum) that can be measured by sensor;
- Operating temperature range - the range of temperature over which the output signal of the sensor remains within the specified error.

2.2 Agricultural applications

Concerning to precision agriculture sensor's development one can consider: soil chemical and physical properties in precision farming sites; crop management with a position-sensitive, multiple-rate spray applicator; detection of damage to different crop species; rapid determination of seasonal nitrogen status and spatial variation in different crop species, and others (AKIRIDGE & WHIPKER, 1996).

Precision production innovations available on the market include mainly: global positioning systems (GPS), which employ satellites and radio signals to map land areas with pinpoint precision; geographic information systems (GIS), mapping software that displays and analyzes data stored as a value and location; variable rate technologies (VRT), machines that can automatically change their application rates (of fertilizers or pesticides for example) in response to their position; yield monitors, devices that can measure the amount of a crop being harvested at any spot in the field.

A recent overview on recent development of wireless sensor technologies and standards for wireless communications as applied to wireless sensors was presented by Wang et al (2005). Examples of wireless sensors and sensor networks applied in agriculture and food production for environmental monitoring in precision agriculture includes facilities on automation radio frequency-identification-technology based traceability systems (HSU et al, 1998). They can be used on the farm for irrigation management, frost detection and warning, pesticide application, harvest timing, bio-remediation and containment, and water quality measurement and control. A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions at different locations.

The basic objectives of site-specific management of agricultural inputs are to increase profitability of crop production, improve product quality, and protect the environment. Numerous researchers and manufacturers have attempted to develop on-the-go soil sensors to measure, so far, mechanical, physical and chemical soil properties (VIACHESLAV, 2007). Rather than using real-time, on-the-go sensors with controllers, a map-based approach may be more desirable because of the ability to collect and analyze data, make the prescription, and conduct the variable rate application in two or more different steps. In this case, multiple layers of information including yield maps, a digital elevation model, and various types of imagery could be pooled together using a GIS software package designed to manage and process spatial data. Variation in soil characteristics that influence yield are related to:

- Cation exchange capacity;
- Depth of any root restricting layer;
- Macronutrient level (mainly N-P-K concentration);
- Soil compaction;
- Soil moisture and temperature;
- Soil organic matter (carbon) content;
- Soil pH;
- Soil structure and bulk density;
- Soil texture (clay content).

Besides, the most important set of quality parameters and concepts in production control are related to:

- Early microbial growth (Microbial safety: Listeria, Salmonella, E. Coli, others);
- Integrity control;
- Nutritional quality, including health implications (cholesterol information, allergens information);
- Pollutants, including environmental pollutants, drugs, agricultural chemicals and mycotoxins;
- Sensory quality related to appearance, flavour, taste, texture, and stability.

Additionally, a different set of sensors for quality measurements of fresh fruits and vegetables can be observed. In such way it is possible to find nondestructive firmness measurement of fruits and vegetables, chlorophyll fluorescence for measuring produce firmness and maturity, near-infra-red (NIR) spectroscopy for determination of internal and maturity attributes technologies for detection of external and internal defects, VIS-Fluorescence sensors for freshness, and ripeness of fruits, electronic noses for measuring fruit quality in terms of sugar content and maturity (HERRMANN et al, 2007), magnetic-resonance (MR) imaging techniques for determination of firmness and maturity attributes. Fresh fruits and vegetables are a multibillion-dollar international industry, and wider adoption of existing technologies for assessing their quality can increase profitability for growers and processors (ASRAR et al, 2007; JØRGENSEN & JØRGENSEN, 2007, NIELSEN et al, 2007)

On the other hand, nanotechnology and nano-bio-info sensors are in the agriculture of the future. Tomorrow nanoscale biotech and nano-bio-info will have big impacts on the food and food-production farms. Such future will belong to new products, new processes with the goal to customize and personalize the products, where improving the safety and quality. In this context one will find further breakthroughs in crop DNA decoding and analyzing enable to predict, control and improve the agricultural production. With such possibility of monitoring, the future crop quality control, probably, will have powerful method to design food with much more nutritional capability, lower costs and sustainability.

3 CONCLUSION

In summary, the dynamics of world trade are rapidly changing and all countries must gear up to keep pace with it and particularly to take advantage of it. The global changes taking place present very wide possibilities, but only for those who are competitive enough to pursue them. Quality is a critical factor in accessing competitive new markets and all efforts must be made to ensure that products meet and exceed established standards. The main reason for having quality control is to ensure that products are made to the standards demanded by management. The fundamental purpose of a quality control program is to acquire dependable information on all the attributes of a product which affects its quality. Quality control ensures that raw materials meet set standards and consumer confidence. The assurance of quality depends to a large extent on how a program is organized and top management system must want and actively support quality control.

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