Advances in measurement and application of physical properties of agricultural products

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Abstract: The physical properties of agricultural products are very important in many aspects, such as to determine some physical characteristics (such as shape, volume, size, density, porosity, color and appearance), fruit firmness, ripeness level and quality, to evaluate mechanical damage in grains, seed quality and integrity, genetic change and others. The present work is a review about some of the most commonly used physical properties of agricultural products such as electrical conductivity, optical properties, mechanical properties and thermal conductivity, which can be used in determining other parameters and properties such as the moisture content, density, microwave dielectric frequencies, ripeness levels, firmness and many other parameters in fruits, vegetables and grains. Many research results in this sector in the last three decades are also highlighted.

Key words: physical properties; agricultural product; measurement; mechanical damage; fruits and vegetables
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1 Introduction

The physical properties of agricultural products in the last 40 years have been investigated by many authors due to its importance in relation to the determination of some physical characteristics (such as shape, volume, size, density, porosity, color and appearance), fruit firmness, ripeness level and quality, to evaluate mechanical damage in grains, seed quality and integrity, genetical change and others. Many aspects are discussed by the researchers to establish what to measure, how to measure it, and what values can be considered generally acceptable by the persons or institutions requiring such measurement, available technology, economic factors and others. These properties have been investigated by researchers for more than 60 years, actually these have a widespread use, and it is hoped that many new technologies in relation to fruit and vegetable quality detection will appear in this new century beginning. The main objective of this work is to present an up-to-date information about the most important physical properties of agricultural products and their uses, in order to determine some physical parameters and to protect and evaluate fruit and vegetable quality.

2 Some physical properties of agricultural products and their uses

2.1 Electric and dielectric properties

It has been demonstrated in previous scientific work the existing relation among electrical conductivity properties of agricultural products and moisture content, due to a regular variation between them. Over the years changes in electrical properties such as conductivity, impedance, dielectric constant, dielectric loss, or power factor have been useful for the measurement of the moisture content in cereals and cereal products, dried fruits, dehydrated vegetables and other products. Indeed, moisture content in many cases is used to correlate the electrical "conductivity" properties of agricultural products. Moreover electrical conductivity has been used on seeds to predict: germination potential, vigor, growth rate, to test cellular membrane integrity, genetic characteristics and mechanical damage resistance[1~4]. The principle of electrostatic separation has been investigated for separating and cleaning of agricultural seeds depending upon physical characteristics such as weight, size, shape and surface texture. The electrical

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conductivity can be influenced by substance composition and physiological quality of the seeds. Although used only for seed quality evaluation the electrical conductivity tests demonstrate some characteristics that could be useful in establishing a damage evaluation test for grains. However, time consumption is the major drawback of this method[1]. The electrical properties may also be used to determine quality among the ions transference, it allows the establishment of some quality levels in fruits, vegetables and seeds.

Actually the dielectric properties are widely used specifically in microwave dielectric heating processes. The dielectric properties are highly correlated with moisture content, because, the dielectric properties of water are much greater than those of dry matter, and thus, these properties are useful for sensing the moisture content and density through electrical measurement of these parameters. The dielectric properties determine to a large extent the behavior of the material in interacting with high frequency or microwave field in dielectric heating processes or cooking. Knowledge of the dielectric properties of the materials to be processed or measured is important in the design of the equipment to be used for these purposes[5, 6]. On the other hand dielectric properties of fruits and vegetables taking into account their frequency dependence, may eventually be used to determine some quality factors (as ripeness for example) using non destructive measurements.

Microwave dielectric properties of selected fruit and vegetables measured with the opened-end coaxial probes and network analyzer, have been reported by Tran.[7] from 0.1 to 10 GHz and by Seaman[8] from 0.15 to 6.4 GHz. Seaman and Seals[8] compared the permittivities of the pulp and skin of pome fruits ("Red Delicious" and "Golden Delicious" apples), stone fruit (peaches), citrus fruits (tangelos and oranges) and bananas, at room temperature. Significant differences between the dielectric constants and loss factors for the pulp and skin were found by them[2].

2.2 Optical properties

According to optical principles intact agricultural products are dense, light scattering materials which require a highly sensitive and especially designed spectrophotometer for measuring their spectral transmittance characteristics[9]. Optical reflectance has been used to evaluate certain characteristics near the surface of the product, including maturity evaluation of fruit. Optical properties are based on reflectance, transmittance, absorbance, or scatter of light by the product. When a fruit or vegetable is exposed to light, as shown in Fig. 1, about 4% of the incident light is reflected at the outer surface, causing specular reflectance or gloss, and the remaining 96% of incident energy is transmitted through the surface into the cellular structure of the product where it is scattered by the small interfaces within the tissue or absorbed by cellular constituents[9, 10].

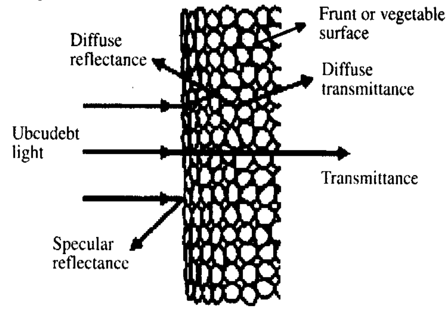

Fig. 1 Incident light on a fruit or vegetable results in specular reflectance (gloss), diffuse reflectance from features at depths to about 5 mm (body reflectance or interactance), diffuse transmittance, or absorbance. Color results from very shallow diffuse reflectance

Currently multi-wavelength or whole-spectra analytical methods are being developed for non-destructive determination of soluble solids, acids, starches and ripeness. Starch or soluble solids (SS) content can be determined in intact fruit (apple, citrus, kiwifruit, mango, melons, onion, peach, potato and tomato)[10].

Oil content is important in seeds, nuts, and avocados and can be determined using NIR. Differences between sound and damaged tissues in visible and NIR diffuse reflectance are useful for detecting bruises, chilling injury, scald, decay lesions and numerous other defects[10]. Differences in images taken at specific wavelengths multispectral or hyper spectral imaging and computerized image processing techniques are being used to automate detection and classification of many defects on line. In addition to imaging technologies, the major advances in spectral analysis in recent years have been in statistical methods which are being satisfactorily developed for quality assessment.

2.3 Thermal propierties

Knowledge of thermal characteristic such as specific heat, thermal conductivity, thermal diffusivity, surface conductance and emissivity, as well as physical characteristics like density, shape and size are essential for design of equipment and predicting of the processing of heating or cooling of agricultural products[11]. The convection heat transfer coefficients are important energy transport properties in the design and operation of food thermal processes, they depend strongly on the apparent viscosity of the fluid food or consistence of the fruit and the processing equipment. From literature review, the structural model is suggested to predict the effective thermal conductivity of starch-based solid food from the thermal conductivities of the solid and gas phases, and the porosity of the material[12]. Its dependence with the material porosity permits the use of thermal properties to determine fruit firmness.

Based on Fikiin et al. and Abbot[10~13] observations, the thermal behavior of fruit layers in trays may encounter some difficulties. First, the dependence in the heat transfer analysis for every separate fruit using local or product-average surface heat transfer coefficients within product position within layer. This method may become extremely difficult from the beginning with the experimental determination of the heat transfer coefficient that needs a large number of measurements to be calculated. Secondly, when the whole heterogeneous system of both fruit and outer surrounding air is regarded as a single unified system object, where the system thermal behavior depends on equivalent (effective) thermophysical properties and surface heat transfer coefficient[14].

The thermal conductivity between fruit and fruit increases ripeness state over time, also each fruit presents thermal conductivity from skin to core, independent of shape and size. These difference in some parts of the fruit favors the presence of some insects, for this reason the fruit producers are using different thermal treatments alone or in combination with cold or controlled atmosphere (CA) storage conditions in order to eliminate these insects. The fact that the use of thermal treatments can affect fruits qualities, it is very important to have a complete understanding of the influence of various factors on heat transfer in fruits, to minimize adverse effects on fruit quality.

2.4 Force and mechanical properties

The use of force and mechanical propierties in most cases is concentrated in the determination of fruit firmness. The impact force has a close dependence on impacting velocity, mass, radius of curvature, elastic modulus and characteristics of contact surface. In addition, the existence of high correlation between impact force with fruit mass and fruit firmness has been demonstrated. Using impact parameters some fruits as apples, pears and avocados, can be classified into different firmness groups[15].

Diaz Perez et al.[16] reported that fruits that feel firm to the hand are found to be soft when checked with a penetrometer, these fruits feel as firm as similar fruit assessed earlier in the cold storage period. Some differences between penetrometer and non-destructive measurements are due to the fact that these non-destructive techniques involve fruit stiffness measurements and that fruit stiffness does not necessarily decrease in a monotonic way during storage[10].

Using force impact methods the effect of changes in fruit parameters, can be determined, such as (mass, radius of curvature, elasticity) and impact parameters such as (contact speed or drop height) on time-domain characteristic of impact forces; different methods for sensing the frecuency components indicative of firmness can be evaluated[17].

Under mechanical loading, fruits and vegetables exhibit viscoelastic behavior which depends on both, the amount of force applied and the rate of loading. However, for practical purposes, they are often assumed to be elastic and loading rate is largely ignored. Measurement of elastic properties requires consideration of only force and deformation, whereas viscoelastic measurement involves functions of force, deformation and time[10].

Elastic modulus can be measured non-destructively, whereas bioyield and rupture by definition require some cellular damage. The best relationships among sensory firmness, hardness and crispness are obtained with forces at or beyond deformations that cause tissue damage[11]. Therefore a non-destructive measurement is unlikely to produce excellent prediction of these textural attributes or of Magness-Taylor (or similar) test values, although useful levels of prediction may be attained in tissues where elastic modulus and rupture strength are closely correlated[10]. Quasi static tests do not predict impact properties.

3 Overview and conclusions

1) The use of force and mechanical properties is suitable in the determination of fruit firmness. By using impact parameters some fruits can be classified into different firmness groups.

2) Under mechanical loading, fruits and vegetables exhibit viscoelastic behavior which depends on both the amount of force applied and the rate of loading. For practical purposes, elastic and loading may be ignored.

3) Electrical conductivity is suitable to evaluate

mechanical damage in grains, and separate small seeds based on density. Electrical conductivity test is also capable of identifying genetical variability, cellular membrane integrity, and germinative potential in different cultivars, as well as establishing some quality levels in fruits

4) Using dielectrical properties, moisture contents, density and the behavior of some materials subjected to high frecuency like microwave fields dielectric heating processes can be determined.

5) Thermal properties are essential in the design of equipment and in the prediction of cooling and heating processes of agricultural products They can be used in determining fruit firmness through the porosity of the material and it is also very important in postharvest treatments in order to eliminate insects that may reside in some commodities

6) Optical properties have been used to evaluate some characteristics near the surface of the product, including maturity evaluation of fruit, color, appearance, etc.

7) Through sophisticated methods such as multi wavelength or whole-spectra analytical methods, which are based on optical properties, soluble solids and oil contents, acids, starches and ripeness, in many fruits and vegetables, varieties can be determined.

8) Optical systems, especially in the NIR region, and newer software has made it possible to detect some factors that may improve quality indexes

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农产品物理特性的检测与应用研究进展

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摘 要: 农产品物理特性在测定农产品的物理特征(如: 形状、体积、尺寸、密度、颜色、外观)、水果的坚实度、成熟度和品质及估算谷物的损坏程度、种子的品质、完整性和遗传变化等方面起着非常重要的作用。介绍了几种被广泛应用的农产品物理特性: 电导率、光学性质、力学性质和热传导性, 并分析了它们在测定水果、蔬菜和谷物的湿度、密度、微波介电频率、成熟度、坚实度及其它一些参数中的具体应用, 同时还介绍了专家们在这个领域近三十年来的研究成果。
关键词: 物理特性; 农产品; 测量; 机械损伤; 水果和蔬菜