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OPTIMIZATION OF HYPERSPECTRAL SYSTEM OF FLUORESCENT TESTING OF FOOD PRODUCT

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Introduction

In modern conditions quality assessment and rational use of food raw material in implemented on the base of study of its composition and chemical-physical properties by using modern organoleptic and instrumental analysis methods.

Application of modern instrumental methods of analysis allovers to study complexly the structure. Composition and features of food raw material and products processing for objective assessment of their quality and safety.

Modern investigation methods are immutable also for establishing harmlessness of the food raw material in connection with possible ingress of various chemical compounds to them used for agricultural pest control (pesticides), radioactive isotopes artificial dyes, chemical preservatives, polycyclic aromatic carbon.

Furthermore, they allow to study deeply the composition and properties of food products, their quality and nutritional value, reveal the changes undetectable by organoleptic or ordinary physical and chemical methods, to predict the change, to establish storage method and terms of use. The remote methods for determining temperature, humidity, and other storage conditions (illumination, composition, and air movement) are of great importance to control storage of food raw material and products of its processing.

Description of the system and problem statement.

As was noted in [1], spectroscopic pointwise assessment of a food product has some shortcomings compared to the method of spatial spectral assessment of the set of the tested production. It is enough to note that the spatial imaging system of diagnostics of food materials allows to detect various localized effects leading to food production spoilage. According to [2], online imaging diagnostic systems of food product should have multispectral possibilities to determine the product state.

This time, the problem of choice of optimal spectral channel is solved with regard to many factors as type of product, type of food pollution, product condition. All this shorts that the system of diagnostic of food product should have imaging feature and possibility of hyperspectral analysis.

Calculation method

At present, fluorescent methods are widely used to for spectral diagnostic of the quality and state of food product. The fluorescent effect is (1) in absorption by chloroform the energy of a certain length value and (2) emission of this chloroform of optic radiation at longer wavelength. The fluorescent radiation of food product can change under the action of many factors such as exogenous pollution, pathogenic substances, internal changes in food product, etc.

The paper [3] deals with development of automatic setting of hyperspectral fluorescent diagnostics of fluids state, 1.

As in shown in [3], at a wavelength of 50 nm, an almost linear relationship was recorded between the exposure time and the output signal of the photodetector.

The results [3] experimental diagnostics of some fruits (including apples) are given by the above-mentioned setting. The obtained spectrum of fluorescence radiation of apple product is in fig.2.

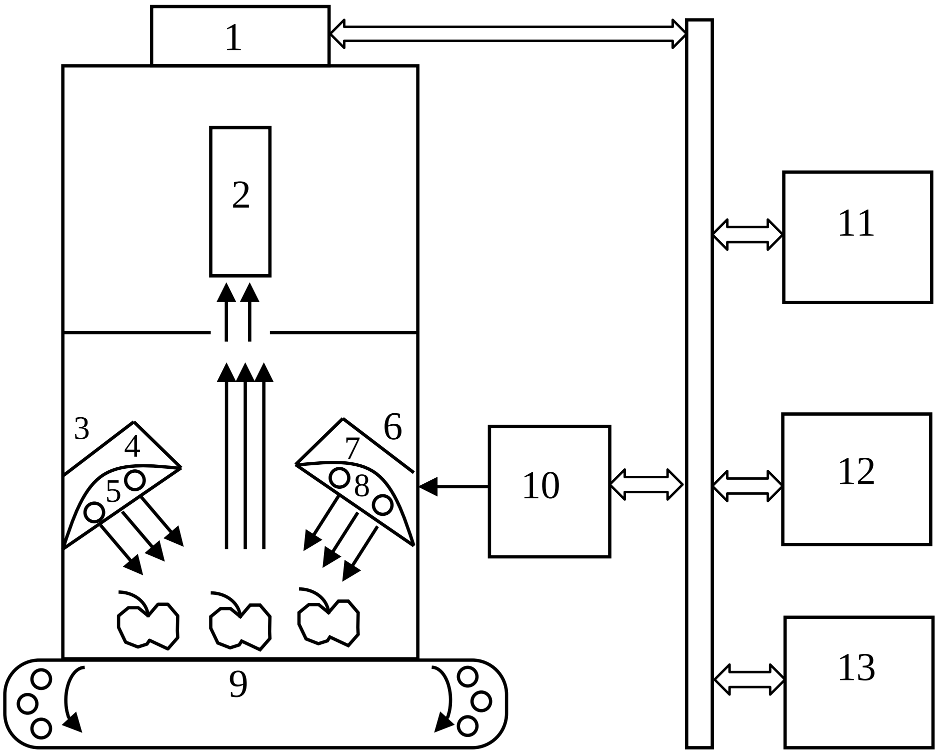

Fig. 1. Schematic representation of the setting hyperspectral fluorescent diagnostics of food products [3]

The numbers indicate: 1 – photodetector controller with charge optics; 2 – charge-coupled photodetector unit with input optics; 3, 6 – blocks of luminescent emitters; 4, 7 – reflectors; 5, 8 – luminescent lamps; 9 – conveyer for the promotion of diagnosed fruit products; 10 – fluorescent lamp power assembly; 11 – computer; 12 – analog to digital converter; 13 – conveyer power supply.

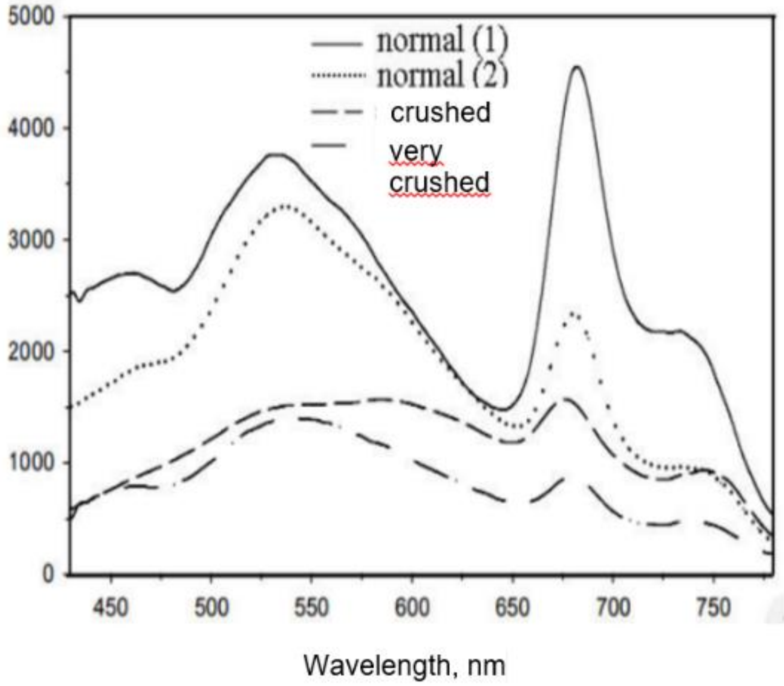

Fig. 2. Experimentally measured curve of the spectrum of fluorescent radiation of apple product when illuminated by halogen lamps of 150 Watt [3]

As can be seen from the curve fluorescent spectrum, shown in fig.2 the obtained spectrum has two maximums

1. Maximum in the range if 450-530 nm. The main cause of fluorescence radiation in the given range are phenolic compounds, riboflavin, carotenoid.

2. Maximum in the range of 650-750nm. The cause of fluorescence radiation in this range chlorophyll a.

And it is noted that the chlorophyll fluorescence emission value a is inversely proportional to photosynthetic activity of the plant.

The good of this section is develop an optimal method of diagnostic of fluid product. In this case the optimality criterion is formed as followers:

1. With regard to noise in the system formed as a sum of noises because of container belt scraps, the noises a fluorescence lamp radiation and optoelectronic paths noises it in necessary to carry out multiple measurements that according to the laws of classic measuring technology allows to improve the ratio the signal-noise and by the same token to conduct more reliable diagnostics.

2. Optimal procedure for performing a diagnostic measurement should the designed in such way that newly introduced indicator:

$$\gamma = \frac{M}{P_{\Sigma}}.$$

where: M – is amount of the obtained measurement information; P_{Σ} – is the total amount of the diagnosable product, remain unchanged for the case of diagnostics with single and multiple measurements.

Further, in this section we consider order of formation of optimal procedures of diagnostic measurements.

Assume that the diagnostics of states of fruit product is implemented cyclically in the mode of single measurements. We denote duration of one step by T_1. We determine the amount of cycles *N* as:

$$N_1 = \frac{T_0}{T_1} \quad (1)$$

where T_0 – is the total diagnostic time.

We determine the total amount of diagnosed product $P_{\Sigma 1}$ as:

$$P_{\Sigma 1} = P_1 \cdot \frac{T_0}{T_1} = \frac{A_0}{T_1}, \quad (2)$$

where: $A_0 = P_1 \cdot T_0$; P_1 – is the number of diagnosed fruits for a cycle.

We determine the total amount of information received for the whole diagnostics period as:

$$M_1 = \frac{A_0}{T_1} log_2 \frac{k_1 T_1}{\sigma_m}, \quad (3)$$

where: $k_1 T_1$ – the magnitude of the charge-coupled signal that according to the graph shown in fig.3 can be approximated by a straight line; σ_m – are noises in the measuring channel.

We calculate T_1, for which M_1 attains extremum value. We have:

$$\frac{dM_1}{dT_1} = -log_2 \frac{k_1 T_1}{\sigma_m} + \frac{1}{ln2}. \quad (4)$$

From the expression (4) we obtain:

$$log_2 \frac{k_1 T_1}{\sigma_m} = \frac{1}{ln2}. \quad (5)$$

From the equality (5) we find:

$$T_1 = \frac{\sigma_m}{k_1} 2^{(1/ln2)}. \quad (6)$$

We amount of information in extremal mode according to (3) and (6) is determined as follows:

$$M_1 = \frac{A_0 \cdot k_1}{\sigma_m \cdot 2^{(1/ln2)}} log_2 2^{(1/ln2)} = \frac{A_0 \cdot k_1}{\sigma_m \cdot 2^{(1/ln2)} \cdot ln2} \quad (7)$$

We calculate the value of the parameter $P_{\Sigma 1}$. We have:

$$P_{\Sigma 1} = \frac{A_0 \cdot k_1}{\sigma_m \cdot 2^{(1/ln2)}}. \quad (8)$$

Calculate the value of γ. We have:

$$\gamma_1 = \frac{M_1}{P_{\Sigma 1}} = \frac{\frac{1}{2 \cdot ln2}}{\frac{1}{2}} = \frac{1}{ln2}. \quad (9)$$

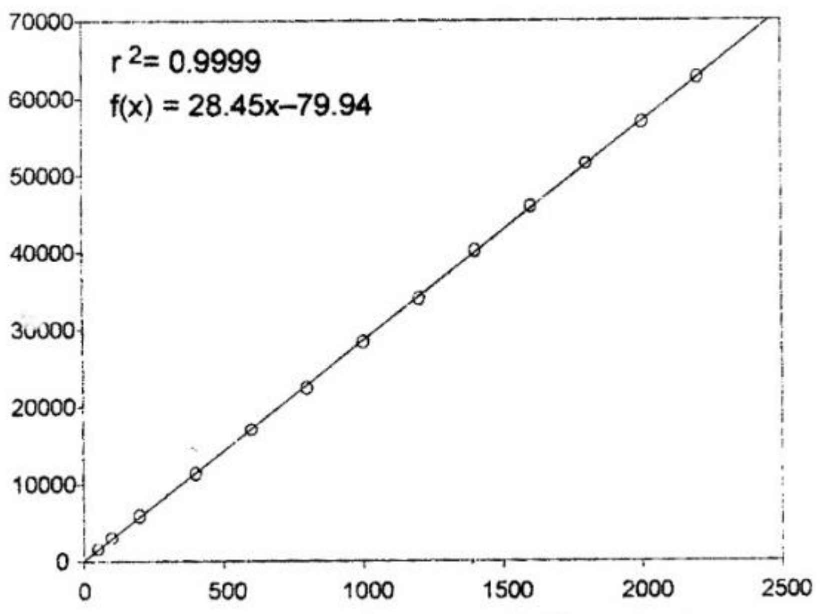

Fig. 3. Dependence of the output change-coupled signal corresponding to pixel intensity on operation time on [3]

Now, let us assume that to reduce measurement noises we use the mode of multiple measurements.

In that case the total amount of diagnosed product $P_{\Sigma 2}$ in determined as:

$$P_{\Sigma 2} = P_1 \cdot \frac{T_0}{n \cdot T_1} = \frac{A_0}{n \cdot T_1}, \qquad (10)$$

where: n – is the multiplicity of conducted measurements. It is well known that as n-fold measurements noises decrease for $\sqrt{n}$ times.

We determine the total amount of information received for the diagnostics time as:

$$M_2 = \frac{A_0}{n \cdot T_1} \cdot log_2 \frac{k_1 T_1 \cdot \sqrt{n}}{\sigma_m}. \qquad (11)$$

We have:

$$\frac{dM_2}{dT_1} = -log_2 \frac{k_1 T_1 \sqrt{n}}{\sigma_m} + \frac{1}{ln 2}. \qquad (12)$$

From the expression (12) we obtain:

$$log_2 \frac{k_1 T_1 \sqrt{n}}{\sigma_m} = \frac{1}{ln 2}. \qquad (13)$$

From the expression (14) we finally find:

$$T_1 = \frac{\sigma_m}{k_1 \cdot \sqrt{n}} 2^{(1/ln 2)}. \qquad (14)$$

Let us calculate the value of M_2 in the extremal mode. Allowing for expression (11) and (14) we obtain:

$$M_2 = \frac{A_0 \cdot k_1 \cdot \sqrt{n}}{n \cdot \sigma_m \cdot 2^{(1/ln 2)}} \cdot log_2 2^{(1/ln 2)} = \frac{A_0 \cdot k_1}{\sigma_m \cdot \sqrt{n} \cdot (ln 2) \cdot 2^{(1/ln 2)}} \qquad (15)$$

Allowing for expression (10) and (14) we obtain:

$$P_{\Sigma 2} = \frac{A_0 \cdot k_1}{n \cdot \sigma_m \cdot 2^{(1/ln 2)}} = \frac{A_0 \cdot k_1}{\sqrt{n} \cdot \sigma_m \cdot 2^{(1/ln 2)}} \qquad (16)$$

Let us calculate the magnitude of the parametr γ_2. We have

$$\gamma_2 = \frac{M_2}{P_{\Sigma 2}} = \frac{\frac{1}{(ln 2) \cdot 2}}{\frac{1}{2}} = \frac{1}{ln 2} \qquad (17)$$

As can be seen from expression (9) and (17) the value of the parameter γ_2 in the two considered modes is the same.

However, comparison of expression (11) and (3) shows that in the second mode the amount of, distinguishable gradation increases for $\sqrt{n}$ times and two allows to conduct better diagnostics of a fruit product. As the same time, according to the expressions (2) and (10) the total amount of the diagnosed product decrease n.

Thus, depending on the requirements for performance and quality of the diagnostics, it becomes possible to select a single or multiple measurement mode.

Conclusions

In the conclusion we formulate the main conclusions of the use arch:

1. Optimality criterion of fluorescence hyperspectral diagnostics of a food product is formulated.

2. Formulas for fluorescence hyperspectral diagnostics in single and multiple measuring modes, were obtained.

3. It was shown that single measurement modes are equivalent to newly introduced mode parameter. However, in multiple measurement mode the amount of different gradation increases for $\sqrt{n}$ times, and this allows the conduct more qualitative diagnostics. The total amount of the diagnosed product this time decreases for n time, where n – is the multiplicity the conducted measurements.

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OPTIMIZATION OF HYPERSPECTRAL SYSTEMS OF FLUORESCENT TESTING OF FOOD PRODUCTS

Spectral analysis – based on the study of the emission spectra of various substances. Samples of the analyzed substance are "burned" under certain conditions, the substance evaporates and dissonates into atoms, which, when excited, give a spectrum. The light emitted in this case, passing through the glass prism of the spectroscope, is decomposed into its constituent parts (different light) and the experimenter observes a number of different lines (linear spectrum). The lines judge the presence of a particular element in the analyzed product.

The higher the intensity of the lines, the higher the concentration of the substance. With the help of spectrographs, it is possible to photograph the radiation and, by the degree of blackening of the lines on the photographic plate, determine the concentration of a substance. The method is highly sensitive; impurities of substances determine up to 0.0001% – decimal fractions of a percent. The method is used to determine the mineral composition of products of plant and animal origin.

Luminescence is the glow of atoms, ions, molecules, and more complex particles of matter, which occurs as a result of the transition of electrons in them upon returning from an excited state to a normal one. To transfer particles to an excited state, the definition of the amount of energy is summed up. Glow or part of the energy is released in the form of luminescence quanta. This method is used to determine vitamins, proteins, and fats in milk, to determine the *freshness of meat and fish and various spoilage of vegetables, fruits, to detect preservatives, drugs, carcinogens, pesticides in food products.*

When assessing the quality of food products, great importance is given to their consistency. There are rheological methods for assessing consistency – the primary assessment of food products. Rheology studies the structural and mechanical properties of materials (deformation). Rheological properties include viscosity, elasticity, elasticity, and strength.

Perhaps the emergence of new, more advanced methods that will become widespread, i.e., each consumer will have the opportunity to determine the quality of the product with the help of a mini device (such as a radioactive background meter, etc.) when buying.

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ОПТИМІЗАЦІЯ ГІПЕРСПЕКТРАЛЬНИХ СИСТЕМ ФЛУОРЕСЦЕНТНОГО ТЕСТУВАННЯ ХАРЧОВОЇ ПРОДУКЦІЇ

Спектральний аналіз – ґрунтується на вивченні спектрів випромінювання різних речовин. Проби аналізованої речовини «спалюють» за певних умов, речовина випаровується дисонує на атоми, які збуджуючись дають спектр. Світло, що випромінюється при цьому, проходячи через скляну призму спектроскопа, розкладається на свої складові частини (різні світла) і експериментатор спостерігає ряд різних ліній (лінійний спектр). По лініях судять про присутність того чи іншого елемента в продукті, що аналізується.

Чим вища інтенсивність ліній, тим вища концентрація речовини. За допомогою спектрографів можна сфотографувати випромінювання та за ступенем почорніння ліній на фотопластинці визначити концентрацію речовини метод високочутливий, домішки речовин визначає до 0,0001% – десяткових часток відсотка. Метод застосовується щодо мінеральних складу продуктів рослинного і тваринного походження.

Люмінесценція – світіння атомів, іонів, молекул і складніших частинок речовини, що виникає в результаті переходу в них електронів при поверненні зі збудженого стану до нормального. Для переведення частинок у збуджений стан підводять визначення кількості енергії. Світіння чи частина енергії виділяється у вигляді квантів люмінесценції. Цей метод використовується для визначення вітамінів, білків та жирів у молоці, для визначення свіжості м'яса та риби та різного псування овочів, плодів для виявлення в продуктах харчування консервантів, лікарських препаратів, канцерогенних речовин, пестицидів.

Оцінюючи якості харчових продуктів велике значення приділяється їх консистенції. Існують реологічні методи оцінки консистенції – первинної оцінки продуктів харчування. Реологія вивчає структурно-механічні характеристики матеріалів (деформацію). До реологічних властивостей відносяться в'язкість, пружність, еластичність та міцність.

Можливо, поява нових досконаліших методів, які набудуть масового характеру, тобто. кожен споживач матиме можливість при покупці визначити якість продукту за допомогою міні-приладу (таких як вимірювач радіоактивного фону тощо).