APPLICATION OF SPECTROMETRY AND COLORIMETRY FOR ASSESSMENT OF FRUITS AND VEGETABLES IN BULGARIA

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Part of results received from several years work upon the instrumental qualification and automatic sorting of fruit and vegetables in Bulgaria by color, maturity and presence of defects are presented. The difference of the optical density is used to characterize the maturity of peaches, apricots, pears, plums, strawberries, tomatoes and pepper. The maturity of green peas is determined by transmittance into the entire peas in spectral parts from the NIR region. Sorting machines are developed for tomatoes and peaches according to their external and internal color and also potato sorters according to the presence and size of defects both on the peel and in the fruit flesh. An original method is developed to eliminate the skin influence and for precise sorting only by internal defects. The method is applied for potato tubers sorting in a flow.

Представени са част от резултатите, получени при дългогодишна работа върху инструменталното окачествяване и автоматичното сортиране в България на плодове и зеленчуци по цвят, зрялост и наличие на дефекти.

Използвана е разликата в оптичните плътности, за да се характеризира зрелостта на праскови, кайсии, круши, сливи, ягоди, домати и пипер. Зрелостта на зеления грах е определена чрез пропускливостта на цели зърна в спектрални участъци от NIR областта. Създадени са машини за сортиране на домати и праскови според външния и вътрешния им цвят, а също и сортировачи на картофи по наличието и големината на дефекти по кората и в плодовото месо. Създаден е оригинален метод за елиминиране влиянието на кората и за прецизно сортиране само по вътрешни дефекти. Методът е приложен за сортиране на картофи в поток.

Keywords: fruits, vegetables, quality, sorting machines

More than three decades we are working on the instrumental assessment and automatic sorting by color and spectral properties. The authors of this report are representatives of three Bulgarian scientific generations who worked with their colleagues from several European countries. The purpose of the report is part of the results to be presented pointing a small part of the corresponding scientific publications. The results from 1994 on are achievement of international projects with the financial assistance of the European commission – contracts ERBCIPECT 926124, CIPA-CT-0188 and QLK1-2000-00455.

INSTRUMENTAL ASSESSMENT OF FRUITS AND VEGETABLES QUALITY

Fruits and vegetables color characterizes well their maturity and presence of defects. For a lot of products like tomatoes, apricots, peaches and others are important both the external and the fruit flesh color. For other products the internal (of the fruit flesh) color is even more important, than the external – for example at internal defects in the potatoes. Very often the quality index is not straightly (directly) connected with the color but it is based on spectral parts from the near infrared (NIR) region – for example dry matter content of green peas.

The transmittance and reflectance spectra have been measured in Canning Research Institute (now RCSAS) with the device shown on fig. 1 - BENTAM monochromator and the photometric camera is own development. The fruits are put whole one by one and the peas – put in a special cuvette [1].

The optical density difference for two wavelength of whole fruits is correlated with the standard data for color, received by visual assessment or instrumental measurement – table 1 [2,3,4]. The color is measured by Hunter system with three stimuli colorimeter Colorgard System 2000, model 05 (geometry 45°/0°, light source C, standard observer from 1931). It is obvious that for the separate variety of one and the same product the wavelengths are repeated or are near in between. This gives a possibility to select one couple wavelengths for each product, by which is simplified the development of filter NIR analyser or machine, sorting the fruits in a flow.

Multiple linear regression is applied for the green peas with the participation second derivatives. The results obtained for the content of alcohol insoluble substances (AIS), total dry matter (DM) and firmness (°F) are shown on table 2 by NIR regions spectrometry [1]. The transmittance spectra are used and is approved that with them the maturity indices are measured more precisely rather than with the reflectance spectra [5].

TABLE 1 - VALUES OF THE CORRELATION COEFFICIENTS BETWEEN LOG OF THE TRANSMITTANCE RATIO OF WHOLE FRUITS FOR THE WAVELENGTHS λ_i AND λ_j AND THE STAGE OF MATURITY

Species and variety	λ_i (nm)	λ_j (nm)	Coefficient of rank (Q) or linear (r) correlation	$\eta_{max} = \frac{(T\lambda_i / T\lambda_j)_{max}}{(T\lambda_i / T\lambda_j)_{min}}$
1	*2*	*3*	*4*	*5*
Peaches				
Fortuna	750; 775	650	Q = - 0.860	52
Baby Gold 5	750; 800	675	Q = - 0.914	24
Elberta	750; 775	650	Q = - 0.887	100
Halle	750; 775	675	Q = - 0.940	98
Corona	750; 775	650	Q = - 0.896	49
Apricots				
Magyar Boys	650	550	$r^{*}_{ext} = 0.920$ $r^{**}_{int} = 0.920$	335
Pears				
Bartlett	650	725	Q = 0.959	91
Bosc	675	750	Q = 0.889	28.7
Passe Crassane	675	750	Q = 0.838	90.5
Plums	725 to 800	575	Q = 0.988	43.3 to 47.4
Greengages	700 to 775	625	Q = -0.900	8.7 to 24.8
Strawberries				
Gorella (frozen)	700 to 800	575	Q = 0.931	103 to 114
Tomatoes				
Extase	650; 675	575	Q_{ext} = 0.938; 0.950	165; 388
Panase C_3F	650; 675	575	Q_{ext} = 0.975 Q_{int} = 0.965; 0.953	1528; 1835
Virase	650; 675	575	Q_{ext} = 0.990; 0.986 Q_{int} = 0.984; 0.979	676; 1280
VF 316	675	575	r = 0.992	$52 \cdot 10^3$
VF 198	675	575	r = 0.979	$39 \cdot 10^3$
VF 145	675	575	r = 0.959	$219 \cdot 10^3$
Chico III	675	575	r = 0.970	$4 \cdot 10^3$
Ventura	675	575	r = 0.989	$18 \cdot 10^3$
Mechest	675	575	r = 0.991	$193 \cdot 10^3$
Papers				
Kapiya	675	550	Q = 0.979	$4.8 \cdot 10^3$
	675	575	Q = 0.962	$3 \cdot 10^3$

r^{*}_{ext}, Q^{*}_{ext} – coefficient of linear resp. rank correlation with the external fruit colour (skin colour)

$r^{**}_{int}, Q^{**}_{int}$ – coefficient of linear resp. rank correlation with the internal fruit colour (flesh colour after cutting)

By investigation of the potato tubers spectral transmittance are found the wavelengths suitable for the detection of internal and external defects [6,7]. Because the defective skin and /or flesh fruit parts very often are a small part of its weight is necessary the tuber to be scanned by its length – consecutively are observed separate slices of the potato [4,8].

Fig. 1 - The laboratory for spectral measurement of whole fruits and vegetables in VIS NIR regions (RCSAS- Plovdiv at NCAS)

Fig. 2 - NIQATLAB model, which classifies potatoes according to internal defects and the influence of skin (peel) is eliminated (RCSAS- Plovdiv at NCAS)

TABLE 2 - CALIBRATION AND PREDICTION OF AIS, DM, AND °F (FIRMNESS) OF FRESH PEAS OF TWO YEARS OF CROPPING

Index	C / P	R	R_{MSEC}/R_{MSEP}	Wavelengths	Range	CV(%)
AIS (%)	C	0.973	1.05	955, 910 885	10.2-28.3	6
	P	0.970	1.12		11.5-27.1	6.2
DM (%)	C	0.976	0.79	960, 910 875	19.9-34.1	3.1
	P	0.964	0.95		20.9-33.0	3.6
°F	C	0.973	2.35	800, 875 910	30.3-65.4	5.3
	P	0.964	2.85		30.3-64.9	6.3

C - calibration; P - prediction.

Because the potatoes skin usually is not used as a food its color and state must not be taken into account during their assessment. From the other side the skin spectrum influences upon the spectrum of the whole tuber and is an obstructive to the precise assessment of the fruit flesh. That is why is necessary to eliminate the skin influence i.e. virtual peeling of the tubers to be done by the Bulgarian STL ("Seeing Through Layers") method [9,10,11]. At this original method are measure simultaneously the reflected and transmitted light and by means of a special mathematical approach are identified separately the external (on the skin) from the internal defects.

The investigation of tomatoes, peaches potatoes is developed further to assess these products during their movement in a flow.

FRUIT AND VEGETABLES COLOR PATTERNS

At the Canning Research Institute in parallel with the color and spectral properties measurement are developed color patterns for tomatoes peaches and apples.

The tomato pattern is 8-degree scale of maturity. Photo is done of the fruits selected by measurement of their transmittance at 575 and 675 nm. Comparing visually the tomato fruits with the photo groups were set aside, whose ripening is observed during several days (at a corresponding temperature regime). So are applied in a larger scale the earlier found mathematical models for tomato color changes during storage and transport. The color patterns are included in branch official documents and implemented in all Bulgarian green houses.

The color patterns for apples Golden Delicious were used a decision to be taken for the appropriate harvest moment of the fruits.

Patterns for peaches fruit flesh color are developed with the same purpose. They are used during harvesting to supply the enterprise with fruits for processing of high quality cans from peeled peaches.

MACHINES FOR SORTING OF FRUIT AND VEGETABLES IN A FLOW

The first Bulgarian machine ASC 1/11 for sorting of tomatoes by color appeared in the beginning of the seventy [4,12].At first it is examined with tomatoes for processing and later on it is included into a technological line for packing of tomatoes intended for fresh consumption. During this period our country exported tomatoes for West Europe and the automatic sorting by color ensured optimal maturity when they were delivered to the corresponding market.

The second generation is two channel machine (ACS-D2) which also was sorting tomatoes but with two times bigger capacity. This modification with small changes can be used for sorting of peaches by the fruit flesh color.

During the eighty is developed the model ASC-3K for potatoes sorting by the presence and the size of defects in them. At the end of the period appeared the variant ASM 5-01 with the same function [8].

As a result of the collaboration between Bulgarian scientists and machine producers from the French company INAME during 1994-95 twelve sorting machines AQS began to work in several European countries [13].These machines are part of technological lines for potatoes sorting and packaging intended for the commercial network.

From 2001 to 2004 Canning Research Institute in Plovdiv is a coordinator of international project with partners from: Great Britain (Campden and Chorleywood Food Research Association), Finland (VTT Electronics) and Bulgaria (INDEX-6 Production of Machines for Canning Industry). NIQATLAB model was developed (Fig. 2), which applies the STL method and by it precisely recognizes the potatoes flesh fruit defects, regardless of their color and skin quality [14, 15, 16]. The new machine makes the sorting by defectiveness on 4 classes (fractions) and as addition function it can separate potatoes with thin perfect skin, slightly greened and strongly greened tubers.

Now at the processing enterprises the fruit flesh defects are detected after potato tubers peeling and slicing, but this requires a lot of objects (potato slices) to be inspected. The new machine gives the possibility tubers with internal defects to be separated before their peeling and slicing. Besides this by STL is realised economy of raw material because potatoes with skin defects but perfect fruit flesh are sorted as good for processing and are utilized.

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