Assessing internal quality of fruit and vegetables

Prof. Dr. Sci. Georgi Krivoshiev, Dr. Raina Chalucova, Eng. Nedyalko Katrandzhiev, Institute of Cryobiology and Food Technologies

The external quality attributes of fruits and vegetables detected by reflection do not bring sufficient information about the presence of internal diseases and defects, chemical composition, degree of maturity etc. That is why the problem how to be seen, observed and known the internal status of those objects without destruction of the layer (i. e. skin or peel) that protects them from damaging effects of the environment has always been a topical one.

The Project NIQAT funded by the European Commission was directed to solution of this problem with potatoes, apples and peaches assessment based on the method " Seeing Through Layers" (STL) created by G. Krivoshiev in 1996 [1].

The STL is a method for non-destructive measurement of the internal (i.e. of the fruit flesh) optical density eliminating the disturbing spectrum of the peel by means of diffuse reflectance. As this is equal to a virtual removal of the skin (peeling), the photometric camera implementing the STL method was named V-(virtual) camera [2, 3, 4, 5].

Here is presented a variant of V-camera as a part of the conveyor system for potato tubers sorting – NIQAT. There are also given mathematical models and results of non-destructive determination of the internal optical density and classification of potatoes in real time, as well as some basic technical parameters of NIQAT system.

Implementation of the STL-method for sorting potatoes in a flow.

V-camera

The measurement geometry of V-camera is shown in Fig.1.

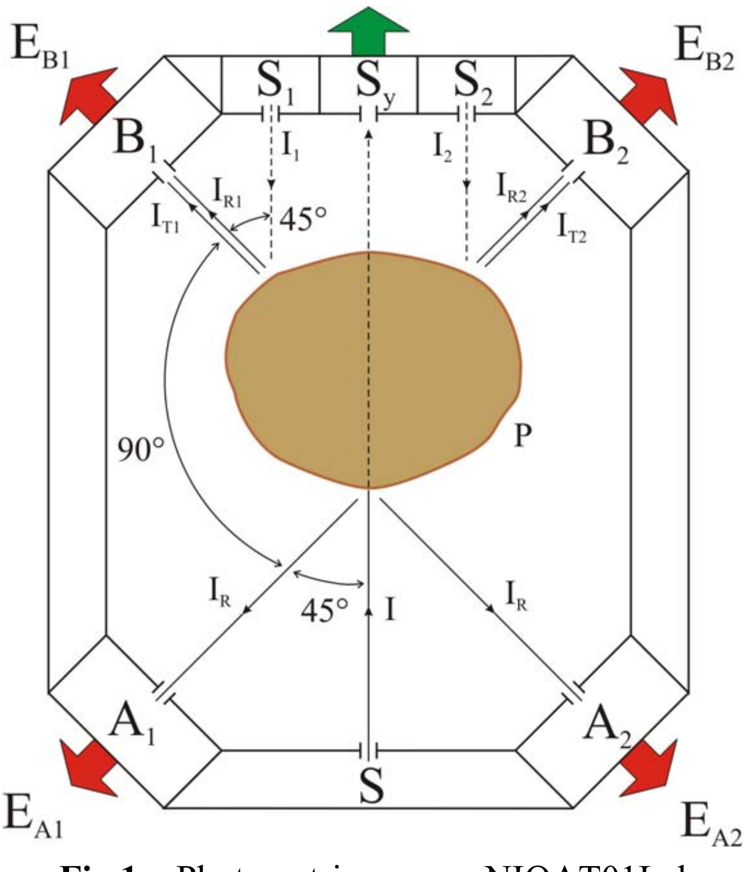

Fig.1 – Photometric camera NIQAT01Lab

The main source is a projector with halogenic lamp. It illuminates the "front" (A) side of the tuber P while the sources S1 and S2 illuminate its two "back" sides (B_1 and B_2). The reflected flux I_R is detected at geometry $R_{o/2x45}$ by a pair of symmetrically positioned optoelectronic modules A_1 and A_2. The transmitted/ emitted fluxes I_{T1} and I_{T2} are detected by the modules B_1 and B_2 at geometry $T_0/_{2x135}$ [6]. The same modules detect the reflectance from the back sides of the tuber by means of fluxes I_{R1} and I_{R2}, but geometry at $R_{45/o}$.

The tubers are passing through the measurement zone not rotating. Nevertheless, because of using geometry $T_{o/2x135}$ they are scanned along their longitudinal axis from three sides which in practice is quite sufficient in order to be identified internal diseases and local defects situated in different part of the tuber. Scanning is effected by the incident light flux I and the transmitted/emitted ones - I_{T1} and I_{T2}. The latter two are received by the modules B_1 and B_2.

Actually both the transmittances and reflectances are measured simultaneously with interval $\Delta t=0.8$ ms in result of which is computed the internal transmittance of tuber slices with individual effective thickness of 1.6 mm approximately (the average speed of the object in the measurement zone being 2 m/s approximately).

The V-camera works with five wavelengths: λ_1 and λ_2 for measurement of transmittance; λ_1, λ_2, λ_3 – for measurement of reflectance from the side A of the tuber, and λ_x, λ_y – for the one from the back sides B_1 and B_2.

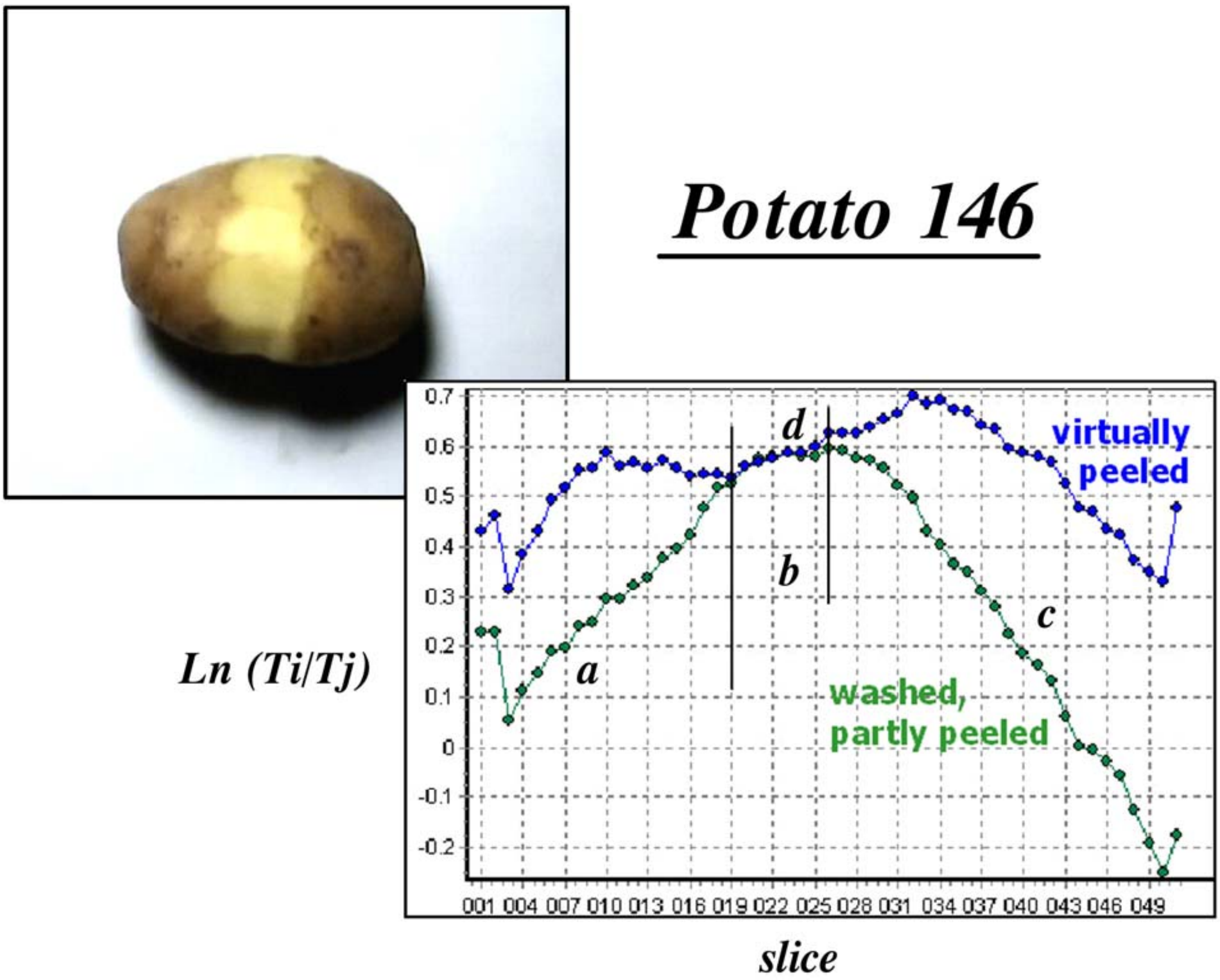

Fig. 2 – Optical density ΔOD of a tuber in the scanning process:

- **a, c** – unpeeled parts of the tuber;
- **b** - physically peeled part;
- **d** - ΔODv of virtually peeled tuber coincides with ΔOD in the physically peeled part **b;**

According to the STL-method [1, 2, 3], the internal optical density of the individual slices (of virtually peeled tubers – Fig.2)
are computed by the abridged formulae:

$$1)\quad OD_{OV}(\lambda_1) = a_o + a_1 \ln\frac{1}{T_1} + a_2 \ln\frac{1}{R_1} + a_3 \ln\frac{1}{Rx},$$

$$2)\quad \Delta OD_{OV}(\lambda_2 - \lambda_1) = a_o + a_1 \ln\frac{T_1}{T_2} + a_2 \ln\frac{R_1}{R_2} + a_3 \ln\frac{R_x}{R_y},$$

where: a_o, a_1, a_2, a_3 are coefficients of the model;

T_1, T_2 – are transmittance value at λ_1, λ_2

R_1, R_2, R_x, R_y – are reflectance values at λ_1, λ_2, λ_x, λ_y;

The reflectance R_3 is used for detection of tubers greening.

In the scanning process the functions OD(l) and ΔOD(l) (l – is the tuber length) have different shape depending on the selected wavelengths; tubers size and shape; occurrence and location of diseases and defects. Thus, the identification of the internal quality is reduced to that of random non-stationary signals. This is made using the artificial intelligence methods supplemented with logic functions for merging the results of identification obtained from the two channels AB_1 and AB_2.
The intelligent module of NIQAT consists of V-camera, and a portable PC Fujitsu Siemens with Pentium of 600 MHz frequency. The exchange of data between those components is effected via an input-output device DAQ Pad 6020E, National Instruments.
The PC has been trained to recognize the internal optical density and classify the tubers by means of 628 samples of 18 potato varieties and of two crops – 2001 and 2002 – grown in UK, Finland and Bulgaria.
The ingenuous software offers a simple system training procedure that can be applied by any customer. An option is foreseen for smooth adjustment of the limits between the sorted fractions in the process of system operation.

NIQAT can classify the object altogether into 6 classes:

- 3 classes by defectness (presence and extent of internal diseases and other defects);
- 2 classes by degree of skin greening;
- 1 fraction (waste) – for completely defective tubers and foreign matter.

Depending on the processing technology each one of the 6 fractions can be merged with the remaining ones, or to be eliminated from the classification (sorting).
The reliability of predicting the internal optical density is estimated by the values of:

- the coefficient of multiple correlation between ΔOD of physically and virtually peeled tubers MR=0.952,
- the error related to the variation range SEC/RAZ=4.5 %.

Without the use of the STL-method those values are: MR=0.917 and SEC/RAZ=5.8%, which indicates the advantage of the STL-method for non-destructive on-line prediction of ΔOD of the fruit flesh.

The errors in machine classification into three classes are shown in Table 1.

Classes	Symbol of the error	Status of the tubers		
		Unpeeled	Virtually peeled	Physically peeled
C1	δ_1, %	6.34	4.23	3.52
C2	δ_2, %	11.67	15.00	11.67
C3	δ_3, %	9.21	6.58	9.21
Total	δ_0, %	7.30	5.69	5.16

Comparing the errors δ_1 in identification of the tubers of class C1 it can be asserted that the physical or virtual removal of the skin (peeling) increases the precision of the identification for tubers with perfect internal quality. The same is valid for tubers with deteriorated internal quality assigned to class C3.The considerable errors (at the present stage of our work) in the identification of tubers belonging to class C2 is explained as due to the strong interception among the classes within the attributes space – a typical event in the subjective (by human experts) classification of agricultural – and in general sense – all kinds of biological products [6].

Feeding of the V-camera with products

The camera works when the objects are moving through it by a trajectory of free falling bodies having initial horizontal speed [Fig.3].

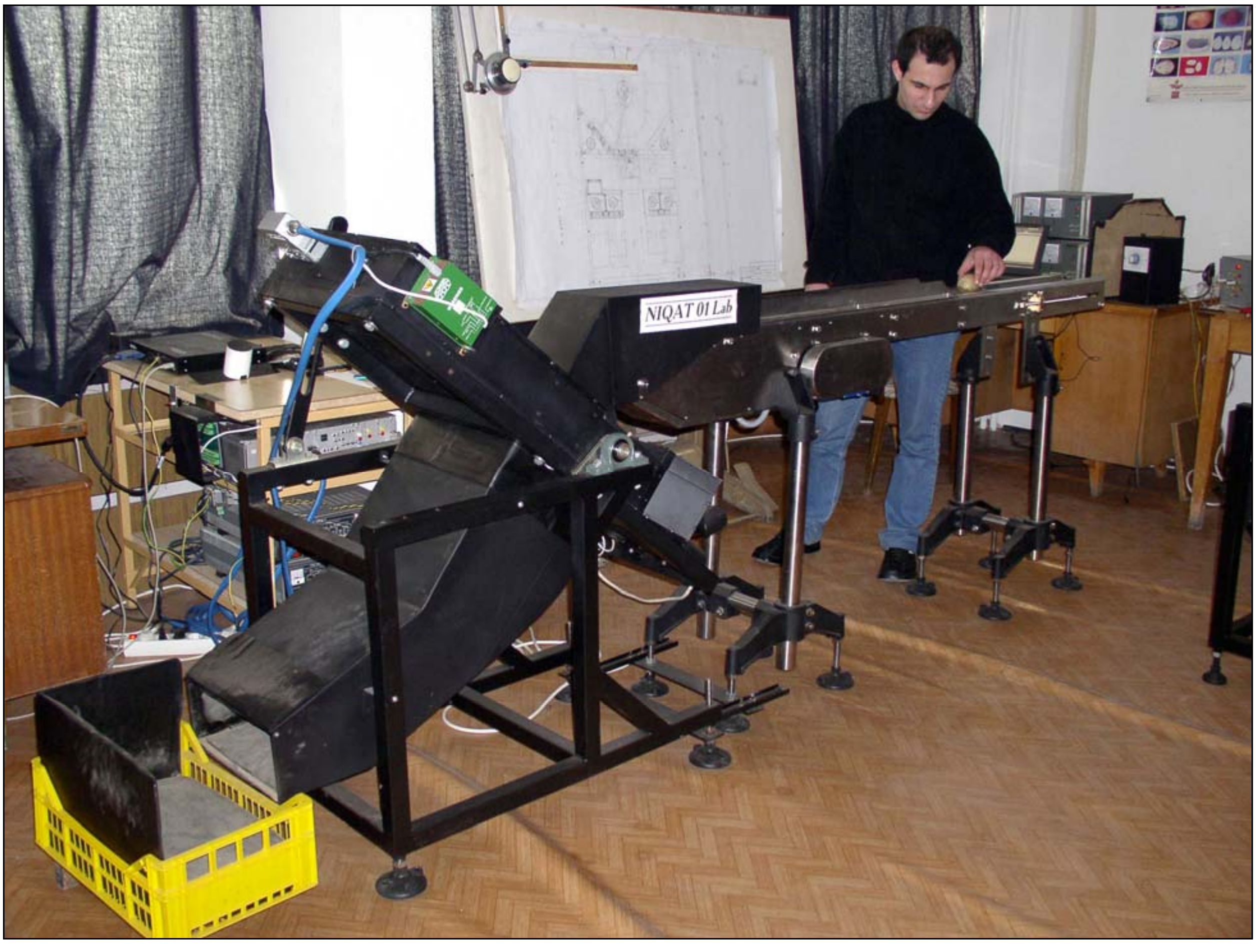

Fig. 3 – Experimental model of the system NIQAT01Lab for classification in real time of potato tubers by internal diseases and defects

This mode of operation is convenient for sorting of tubers that measures from 30 to 55-60 mm □ dimension and those are suitable for industrial processing and as seeds.

Another mode of operation is when the objects are moving horizontally. It is to be preferred for sorting of potato varieties with bigger tubers that are intended to industrial processing and public catering.

Basic characteristics and parameters

1) Objects velocity in the measurement zone - ≤2.5 m/s
2) Velocity of sorting - up to 40 tubers per second
3) Average capacity - 3.6 t/h
4) Main light source - HL 150 W/24V
5) Camera dimensions - 946/575/122 mm
6) Camera mass - 22 kg
7) Diameter of the sorted objects - 35 to 80 mm; lengths ≤120 mm
8) Distance between the objects - ≥ 10 mm
9) Ambient temperature allowed - 10 to 35^{0}C.

Conclusion

There have been proved the capabilities of the STL-method for on-line detection of internal diseases and defects in potato tubers regardless of their skin/quality.
It can be assumed that the method could be applied also for sorting of onions, citrus fruits, kiwi fruit, apples, peaches and other objects whose skin does not bring information about the internal quality.
NIQAT could be used independently or in combination with machines sorting the objects by their appearance.
The system NIQAT01LAB is suitable for quick assessment (based on a random average sample) of potatoes intended to postharvest storage, retail trade, seed material.

References

1. G. Krivoshiev. A method and a photometric camera for nondestructive classification and/or sorting of fruit and vegetables by their internal quality regardless of the skin quality. Bulgarian Patent BG No. 62304 (in Bulgaria) (1998).
2. G. Krivoshiev, R. Chalucova, M. Moukarev. NIR news 5 (11), 7 (2000).
3. G. Krivoshiev, R. Chalucova, D. Dahm, 10th Int. Conf. on Near Infrared Spectroscopy, Kyongju, Korea, 10-15 June (2001).
4. G. Krivoshiev, R. Chalucova, D. Dahm, S. Millar, D. Evans, Y. Gegov, P. Bojilov and A. Lyiungov, 11th International Diffuse Reflectance Conference, Wilson College, Chambersburg, Pennsylvania, USA, August 11-16 (2002).

5. G. Krivoshiev, R. Chalucova, P. Bojilov, A. Lyungov, V. Slavchev, V. Fidanchev, N. Katrandzhiev, Presentation at the Innovation Workshop, Flair Flow Program of the EU, Sofia, 2nd November (2002).
6. G. Krivoshiev, R. Chalucova, P. Bojilov, A. Lyungov, N. Katrandzhiev, M. Kansakoski, Y. Gegov, V. Slavchev, V. Fidanchev.Conveyor System for the Precise Determination of Internal Diseases and Defects in Potato Tubers – NIQAT. Fifth European Symposium on Near InfraRed (NIR) Spectroscopy, Comwell, Kolding, Denmark, 15th-17th September 2003.