Bulgarian Journal of Agricultural Science, 19 (No 4) 2013, 866-874
Agricultural Academy

EXPRESS METHOD AND DEVICE FOR DEFINITION OF POTATO TUBERS PARAMETERS

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Abstract

ALIKHANOV, D., Z. SHYNYBAJ, P. DASKALOV and R. TSHONEV, 2013. Express method and device for definition of potato tubers parameters. *Bulg. J. Agric. Sci.,* 19: 866-874

An express method is developed for calculation of morphological parameters of potatoes, based on acquisition and processing of potato images. The informative features describing potato form sizes are: length (*a*), width (*b*), area of longitudinal section (*S*) formed in a XY plane and perimeter of longitudinal section (*L*). The definition of the potato form includes two coefficients: the traditional (K_1), equal to the ratio between potato length (*a*) to potato width (*b*) and a new coefficient of the form (*K*) equal to the relation of the squared image perimeter (L^2) to the area (*S*). For carrying out the experimental part of the research a device is developed consisting of web camera, computer equipped with LabVIEW software (National Instruments Vision Assistant 8.5 and LabVIEW), and a working surface. The algorithm for acquisition and processing of the images is developed in LabVIEW environment (Laboratory Virtual Instrumentation Engineering Workbench) using graphic programming language “G”. The experimental installation provides also an opportunity of visual inspection of the object images. Nine varieties of potatoes from Kazakhstan 2011 crop selection are tested. The tests are held in the Kazakh scientific research institute of potato and vegetable growing and the institute has confirmed the express method efficiency and device work reliability. The express method increases 5 times the analysis productivity and enables storing the quantitative information for the potato features in a digital form.

Key words: morphological parameters of potatoes, image processing, LabVIEW

Abbreviations: ПЗС - Device with charging communication {connection}; *a* - Length of potato, mm; *b* - Width of potato, mm; *S* - The area, mm^2; *L* - Perimeter, mm; *K* - Factor of the form; $K_1 = \frac{a}{b}$ - Factor of the form; π - Constant factor equal 3.14

Introduction

Among agricultural crops, the potato is one of the most important food products, taking fourth place in the world after wheat, rice and corn. In Kazakhstan the potato is one of the basic food products, being on second place by significance after bread. The agricultural areas in Kazakhstan, used for potato growing, are about 170 thousand ha, but despite that the population needs cannot be satisfied due to low productivity. The main reasons are heavy conditions - hot and droughty climate in the majority of Kazakhstan regions and the existence of many diseases among all the potato varieties. This leads to decrease of potato production, seed quality and potato degradation after the second or third reproduction year. The elimination of this problem is based on good selections and seed growing. Therefore, the basic aims of research works are: potato sort selection, improvement of heat and drought potato resistance and creation of new varieties, suitable for industrial processing of high-quality food products and starch (Banadysev, 1988; Banadysev, 2002; Baranovskaya, 1966; GOST 7306-73, 1973; Kozlova et al., 2007; Kokin et al., 2001; Lazauskas, 1998; Starovoitov, 2006; Shinkarev, 1988). The selection process implicates great volume of work, connected with the definition of potato geometrical parameters. The potato form varies widely, from round up to very long. Even potatoes from the same sort can have unequal weights and shapes. Therefore it is recommended to use not just one but several prevailing forms for one potato variety. The carried out researches have shown, that the

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rounded potato tubers from all varieties possess the best seed qualities (Efremov, 1969; Kiriyenko, 1978). The majority of authors are using as a potato tuber form quality parameter the ratio between the length and the greatest width (Ermoliev at al., 1959). The following designations are accepted in accordance with this parameter: round form (less than or equal to1.09), round oval (1.10 – 1.29), oval (1.30 – 1.49), elongated-oval (1.50 – 1.69), long (1.70 – 1.99), very long (2.00 and higher) (Efremov, 1969; Kiriyenko, 1978). Due to the lack of a uniform technique for potato form quantitative estimation, an expert estimation of the potato form is applied (GOST R 53136-2008, 2010). Usually manual work is performed for measurement of length, width and thickness for description of distinctive morphological features, in particular the sizes and the form of hybrids and varieties in the selection and seed-growing work, and estimation of sort suitability to industrial processing. The present mechanical measuring devices do not provide sufficient process productivity for potato tuber analysis and additional time for processing the measurement results is needed. Two operators carry out measurements and registrations of the required parameters. The first operator measures the potato tuber sizes, using caliper-gauge, and the second operator registers the received data in journal. The time needed by the two operators to perform the operations for one potato tuber is 6,0 seconds average. This gives around 300 potatoes per hour labor productivity. Therefore a development of an express method for automatic potato tuber morphological features determination, by means of camera and computer, is rather actual and duly. A method and device for sorting potato tubers by morphological features has been developed, based on optical ruler (ПЗС) with existential development of image of potato tuber, moving on conveyor (Alikhanov, 1983). Disadvantages of the mentioned method and device are the limited functionalities, which do not allow receiving of sufficient information on morphological parameters of the potato tubers. Another disadvantage is low accuracy image parameters measurement, which is due to the way of scanning of the moving tuber and use of optical block with low resolution. Another device for estimation of seed quality of potato tubers, based on morphological parameters, is known (Pokidov, 2005.). A disadvantage of this device is the impossibility of determining the area and perimeter potato tuber image and the corresponding form factor.

In connection with the rapid development of computer technologies and monitoring systems for determination the quality of agricultural products and foods, based on principles of artificial vision and artificial intelligence (Vizilter at al., 2007; Shapiro and Stockman, 2006). Such systems provide an estimation of parameters of quality of production in real time and allow increasing the productivity of the process in some times. Systems for automation and control of process of sorting of many agricultural products are offered. Systems for detection of various diseases connected with change of structure of potato (rots, mechanical damage, and firm impurity) based on distinction in spectral characteristics in visible and infrared region of the spectrum are developed (Draganova and Tshonev, 2007; Draganova and Daskalov, 2007; Daskalov et al., 2008; Prik, 1998). The considered systems are intended for detection and branch of poor-quality production in lines of sorting of products and not intended for carrying out by selection work. The purpose of work is creation of effective system for definition and analysis of parameters of potatoes that will increase the productivity of the process of analysis at carrying out of selection work.

Materials and Methods

Potato samples

Sets of potato seeds representing nine varieties, stored in repository, are tested. Average potato weight in one set is 30 kg. The quantity of potatoes in every set varies, depending on the potato sizes, but it is limited between 435 and 480 pieces. Qualified expert, who has selected only 70 pieces, representing the best from each sort, manually estimated the selected potatoes. For this research have been selected high-quality pieces in regards to all attributes (sizes and shape) from sorts corresponding to the pattern. Potatoes have been selected for each grade that has non-standard form for the considered sort. The percent of non-standard form potatoes for each set is between 16 and 23 percent. The selection was carried out by scientific employees from the "Kazakh scientific research institute for potato and vegetable growing", under the direction of the doctor of agricultural sciences professor Krasavina V.F.

Images of several sorts from the Kazakh scientific research institute for potato and vegetable growing, selected by experts, are shown in Figures 1 - 6.

Variety "Jolbars". The sort is received by intraspecific hybridization (Ute x Teniz) with subsequent repeated clonally selection. The form is round-oval, moderately deep eyes, are slightly painted in pink color. Pulp white, equal, not darkening the ambassador are sharp in cheese and in a cooked kind. The grade is mid early, with universal purpose, high-yielding, heat resistant, drought-resistant, possesses field stability to the illnesses distributed in Kazakhstan, suitable to industrial processing in high-quality food stuffs and starch. The variety Jolbars maintains 7 reproductions of cultivation in a zone of strong degeneration (Figures 1 and 2).

Variety "Kogaly". The tubers have oval-elongated shape. Depth of eyes fine, the basis of eyes red. A peel smooth, yellow. Pulp cream. The grade midearly, suitable for frying. Potential productivity - 40-50 tons per hectare. Taste and keeping quality are good. It is zoned since 2008 in Almaty area.

Variety "Maxim". The tubers have round oval form, eyes superficial, a peel smooth, yellow, and pulp light yellow, not darkening during cooking and thermal treatment. The variety is middle, universal purpose, high yielding, heat resistant, drought-resistant, possesses field stability to the illnesses distributed in Kazakhstan, suitable to industrial processing in high-quality foodstuffs and starch. The variety Maxim maintains 7 reproductions of cultivation in a zone of strong degeneration (Figures 3 and 4).

The variety "Sofia" is received by intraspecific hybridization (Salami x Aksor) with subsequent clonal selection. The form is long, top blunt, eyes superficial, a peel smooth, yellow, pulp light yellow, not darkening during cooking and thermal treatment. The variety Sofia – early growing, universal, high-yielding, heat resisting, drought-resistant, possesses field stability to the illnesses distributed in Kazakhstan, suitable to industrial processing in high-quality food stuffs on chips and fries. The variety Sofia maintains 7 reproductions of cultivation in a zone of strong degeneration.

Variety "Текеs". The tubers have round – oval form, eyes superficial, a peel smooth, yellow, pulp light yellow, Mid early growing, not darkening during cooking and thermal treatment, high-yielding, heat resisting, drought-resistant, possesses field stability to the illnesses distributed in Kazakhstan. The variety Tekes maintains 7 reproductions of cultivation in a zone of strong degeneration (Figures 5 and 6).

For comparison in figure 6 the images of non-standard pieces of variety Текеs is shown.

Experimental installation

The basic technological parameters of the electronic device are: the maximal and minimal sizes of the objects un-

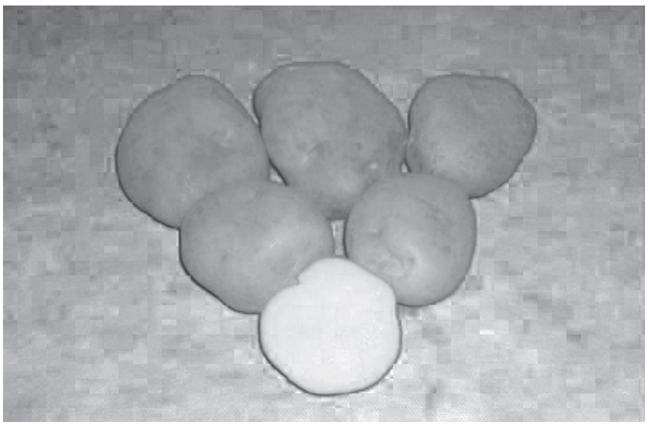


Fig. 1. Variety "Jolbars"

Fig. 2. Variety "Kogaly"

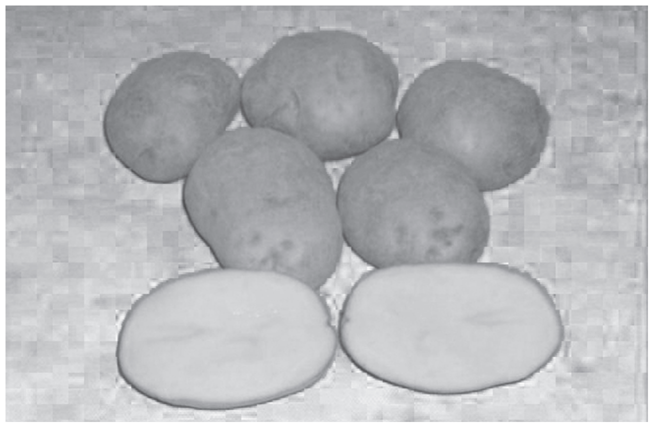


Fig. 3. Variety "Maxim"

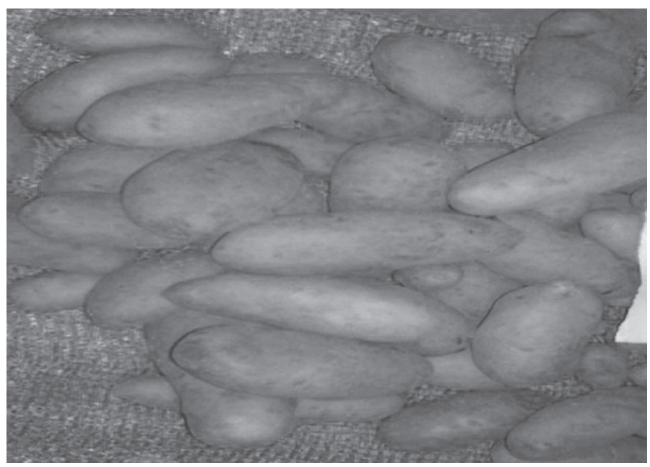


Fig. 4. Variety "Sofia"

der inspection, the distance from the working surface up to the camera, the contrast of the object to the working surface background material.

For carrying out the experimental research is developed an electronic device, consisting of web camera, a computer with software National Instruments Vision Assistant 8.5, a supporting frame and a working surface. A Logitech HD C310 web camera has been chosen, having the following characteristics:

- Video calls of high clearness (1280 x 720 pixels);
- Video recording: Resolution up to 1280 x 720 pixels;
- Certificated for high-speed USB 2.0 interface.

The used supporting frame allows regulation of the distance between the working surface and the web camera in two planes – horizontal and vertical. The personal computer has RAM memory of 512 MB and a video card with 256 MB memory. The working surface is covered with a black - matte material and is 1.2 times bigger in size, than the maximal size of the object (200x150 mm). A general view of the experimental device is shown in Figure 7.

The procedure for determining the potato tuber parameters are shown in Figure 8.

The investigated potato tuber is placed on the working surface under the web camera and the device automatically generates the image of the object according to the block diagram. The output results are displayed on the screen. The operator has an opportunity to analyze the results, determine the parameters of the potato tubers and compare them with the standard ones for the analyzed sort. The obtained data is saved in an Excel table.

Definition of informative morphological features for sorting potato seeds

Potato tuber can be represented as a triaxial ellipsoid, whose axes correspond to the three major sizes: length *(a)*, width *(b)* and thickness *(c)*. To determine the three axes, the measures must be performed in two or more planes, i.e. to get a 3D image of the potato tuber. However, given the existing relationship between the ratios of the linear dimensions of the tuber, length *(a)* greater than the width *(b)*, and the width is greater than the thickness *(c)* that the ellipsoid body in a state of stable equilibrium, tends to take a position so that its potential energy tends to a minimum. Consequently, potato tuber mainly oriented so that its maximum cross section is parallel

Fig. 6. Variety "Tekes", non standard pieces

Fig. 5. Variety "Tekes"- standard pieces

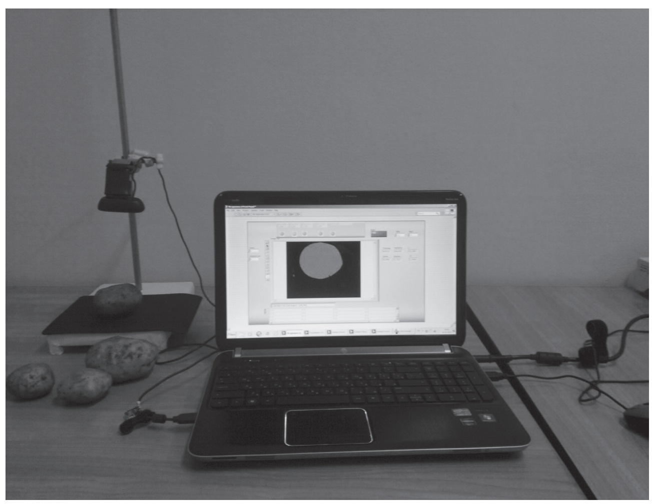


Fig. 7. General view of the experimental device

to the plane of movement. Camera mounted perpendicular to the plane to find the tuber gets an image section, formed by its length and width, having the form of an ellipse with axes *(a)* and *(b)* (Bronstein and Semendeev, 1981).

$$S = \frac{\pi}{4} a \times b \text{ , mm}^2 \qquad (1)$$

$$L = \pi \left[0.75(a + b) - 0.5\sqrt{a \times b} \right] \text{ ,mm} \qquad (2)$$

It is advisable to use the coefficient of form as a quantitative assessment feature of the potato tuber. The coefficient represents the ratio between squared perimeters to the area (Alikhanov, 1983):

$$K = \frac{L^2}{S} \qquad (3)$$

The feature, representing the complexity of the form *K*, does not depend on the sizes and arrangement of the objects under the camera. The coefficient has minimal value for a circle. If the form deviates from the circular shape, the coefficient increases. The transformation between the two factors of the form (*K*) and the widespread factor (K_l) is based on analytical relationship (Alikhanov, 1983):

$$K = \frac{4\pi}{K_l} [0.75(K_l + 1) - 0.5 \sqrt{K_1}]^2 \qquad (4)$$

As is known, the sizes and the form of potato tubers change over a wide range and differ from the accepted oval model. Therefore, for definition of objective quantitative dependences between quality parameters and informative quantitative features it is necessary to make experimental researches of size/weight characteristics of potato tubers.

A virtual instrument is developed, consisting of front panel and block diagram. The block diagram of the device for automated determination of potato tuber parameters of is shown on Figure 9.

Description of the block diagram elements for determination of geometrical parameters of the object is presented in Table 1.

Results of parameters determination can be seen on the monitor. A screen image is shown in Figure 10.

On the right side of the screen are shown the image processing results for the current potato tuber, including the following parameters: area, perimeter, length, width, shape and coefficients (*K*) and (K_l). Above them are positioned the boundary limits of the form factor (*K*) for the researched grade (from 12.7 up to 14.0). To the left of the form factor boundary limits is placed an indicator for waste potato. If form factor value is between the boundary limits, the light becomes green, otherwise it is red. On the top of the screen, for operator convenience, are displayed the values of the form factor (K_l), used by agriculturists in their practice. It is seen on figure 10, that with the current value for (K_l) the

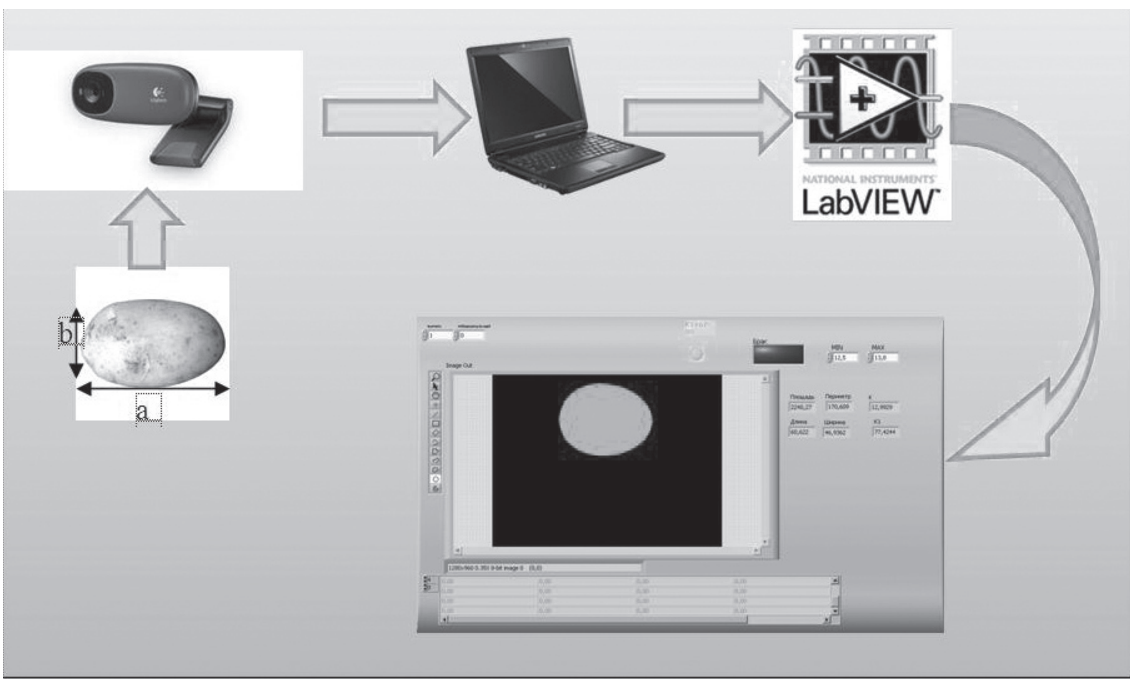


Fig. 8. Scheme for determining the parameters of potato tubers

tuber is associated to the round form ((K_l) is in limits from 0.8 up to 1.09).

Results and Discussion

630 potato tubers (70 pieces for each of the 9 varieties) has been tested with the described optical-electronic device, which measured the length (*a*), width (*b*), area (*S*) and perimeter (*L*) of each image tuber. According to the obtained values for the shape factor (*K*),(K_l) was automatically calculated as well. The results from the production experimental data statistical processing are shown in Table 2. The variety description in accordance with passport varieties and a quan-

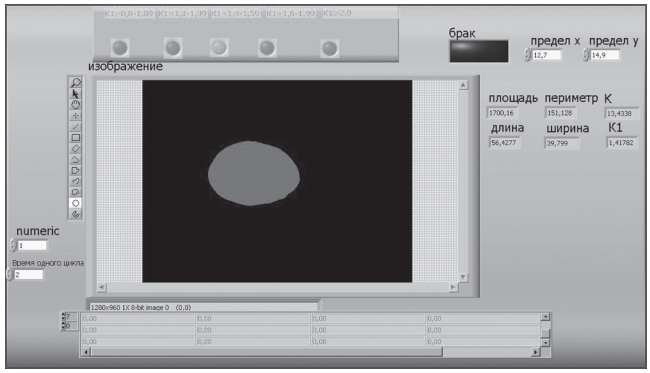


Fig. 10. Virtual instrument for determination the potato tuber parameters

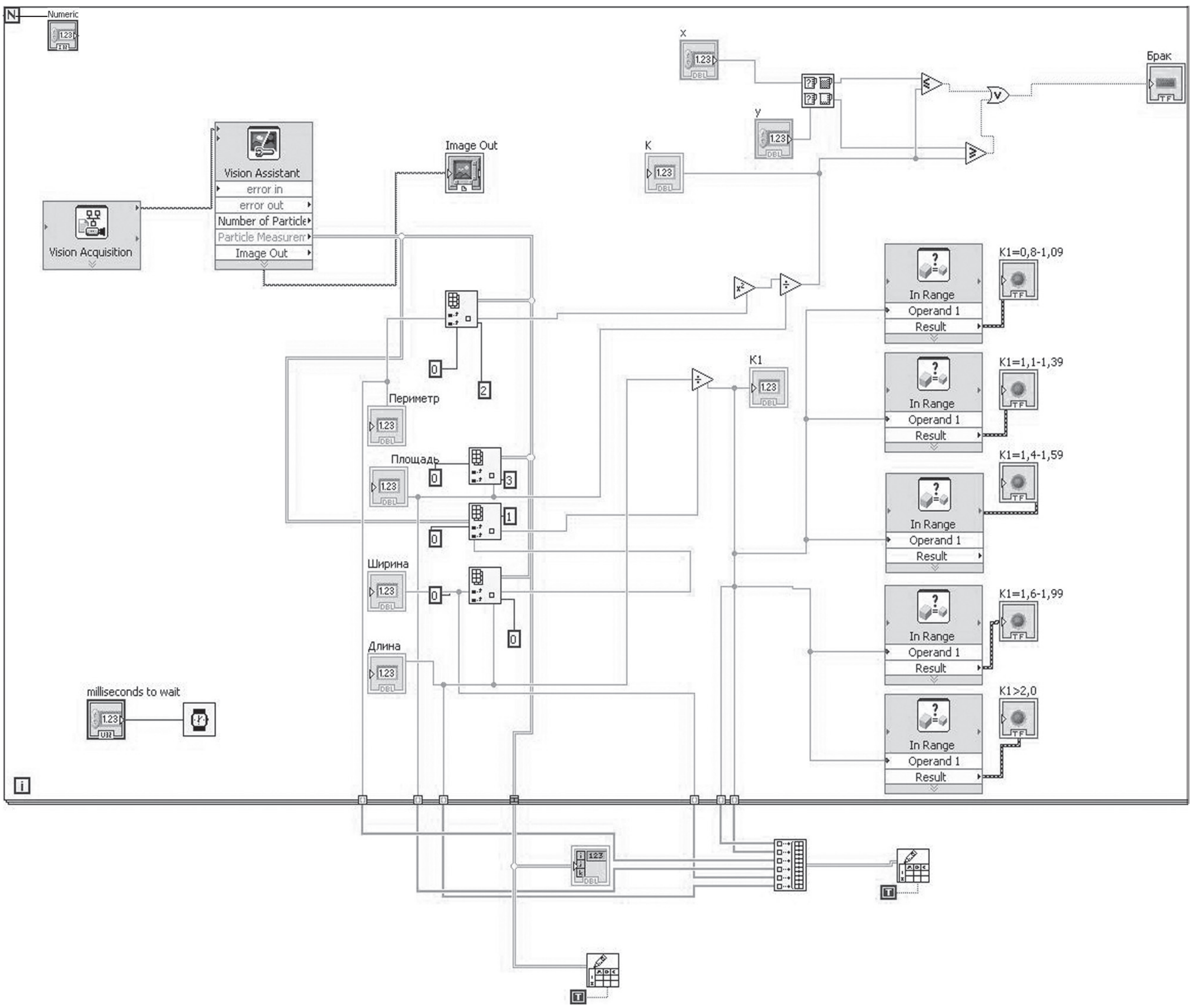


Fig. 9. Block diagram of the device for automated determination of potato tuber parameters

Table 1
Description of block diagram elements

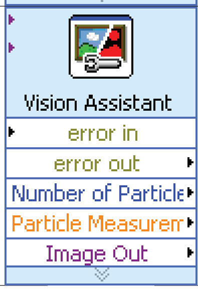
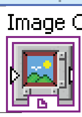
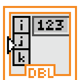
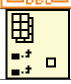
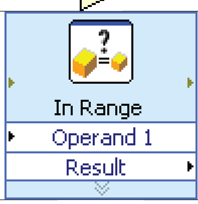
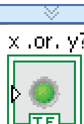
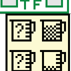
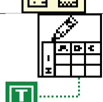
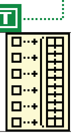
Symbol	Description
	Image capture, color contrast, the time of capture, the image resolution
	Module vision assistant for selecting an object from the background, translated into monochrome image type, calibration and measuring the size of the object in the metric system
	Indicator to display the captured image on the screen
	Table to display the results (length, width, area, perimeter)
	Library to isolate the area and perimeter of the table for calculation of the coefficient form
0 2	Constants defining the rows and columns in the table to highlight the area and perimeter
	Indicator of the outstanding results for the calculated coefficient forms
	mathematical element division
	mathematical element squared
	Comparators for the shape factor in a given range
	Indicator of waste object
	Library comparison to the maximum and minimum values
	Library for exporting the data in Excel table
	Library association of individual parameters in the table row

Table 2
Point estimates indicators of 9 varieties of potato tubers obtained from the results of production tests

Parameters	Value	Variety								
		Jolbars	Kogaly	Maxim	Moshniakovski	Noor-Alem	Nerly	Sofia	Tekes	Teniz
Description of form	$K_1 = a/b$	K_1= 1.1-1.29	K_1 = 1.5-1.69	K_1 = 1.1-1.29	K_1 = 1.1-1.29	K_1 = 1.5-1.69	K_1 = 1.1-1.29	K_1 = 1.5-1.69	K_1 = 1.3-1.49	K_1 = 1.3-1.49
Lenght (*a*), mm	m_x σ_x	61.12 7.87	63.15 6.90	63.12 7.78	59.38 7.18	66.19 5.82	57.02 6.84	72.26 8.92	59.56 8.13	53.07 8.01
Width (*b*), mm	m_x σ_x	52.67 5.90	49.47 5.07	49.79 4.69	52.03 6.04	50.52 4.03	48.89 4.89	43.59 4.57	45.89 5.74	48.30 6.73
Perim (*L*), mm	m_x σ_x	181.93 22.41	182.64 19.70	182.42 18.38	180.60 20.24	192.27 16.02	171.64 18.42	189.35 21.97	169.73 21.38	164.04 25.42
Area(*S*), mm^2	m_x σ_x	2527.7 585.52	2451.6 504.10	2451.3 481.90	2392.4 552.33	2552.6 361.53	2184.2 468.12	2473.8 530.43	2146.5 505.66	2041.2 584.49
Coefficient, $K = L^2/S$	m_x σ_x	13.60 0.57	13.87 0.53	13.78 0.54	13.91 0.57	14.41 0.89	13.73 0.59	14.71 0.57	13.70 0.56	13.54 0.56
Coefficient, $K_1 = a/b$	mx σx	1.16 0.08	1.28 0.09	1.27 0.12	1.14 0.07	1.32 0.09	1.17 0.07	1.66 0.13	1.30 0.14	1.10 0.06

titative estimation of the tuber form, that is used by specialists in their selection work and which is equal to the ratio of the tuber length to the maximum tuber width (K_1), are also shown in Table 2. Along with the calculated coefficient, another shape factor has been calculated, which does not depend on the size of potato tubers and which is determined only by the computer image processing facility. According to the descriptions of the varieties “Jolbars”, “Maxim”, “Moshniakovski” and “Nerli”, their corresponding tubers have oval form (K_1=1.1-1.29); the varieties “Kogaly” and “ Noor-Alem” - has oblong-ovate shape (K_1=1.5-1.69); variety “Tekes” has round-oval to oblong-ovate form; variety “Teniz” has oval (K_1=1.3-1.49) and variety “Sofia” – elongate shape (K_1=1.5-1.69). According to the results of the experimental studies of the nine varieties, the form factor of varieties “Kogaly” and “Noor-Alem” does not correspond to the data given in the sorts’ passport. The other tuber varieties correspond to the data given in the passport. The received data indicate that the assessment, done by experts is subjective and difficult to quantify served. Therefore, for assessing the form of potatoes, it is necessary to use quantitative parameters. From the data listed in Table 2 it can be deduced that the experimental form factor is somewhat greater than the value obtained from the formula (4), depending on the type of the (5.4-9.6) percent, which testifies to the degree of deviation of the tuber actual shape of on the model adopted in the derivation of (4).

Conclusion

Analysis of the requirements for varietal seed potato tubers and existing methods for determining the morphological features of tubers showed that existing methods and tools have low productivity (300 tubers per hour) and) and do not provide reception of the quantitative information necessary in selection work.

Rapid method, based on an image processing of potato tubers, provides quantitative, objective information on varietal traits of potato tubers in electronic form. Informative quantitative features characterizing the varietal performance of tuber and suitable for machine processing have been selected (the perimeter and the area of the longitudinal section). As effective feature the shape factor, which represents the ratio of the square of the perimeter to the area, has been chosen.

Experimental laboratory test of the described method and device have shown the efficiency of the developed technical device. Technological and technical parameters of the experimental electro-optical setup are proved: the processing of images of the tuber is not more than 0.2 seconds.

Tests in industrial conditions with nine potato promising potato varieties confirmed the efficiency of optoelectronic device. Rapid method provides increased process performance analysis for single tuber compared to the manual method 5 times (1500 tubers per hour) and enables available quantitative information on the features of potato tubers in electronic (digital) form.

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Received July, 2, 2012; accepted for printing February, 2, 2013.