Detecting the external defects of potato tubers using a visible laser

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Abstract: Potato (*Solanum tuberosum,* L.) is considered as a source of the national income in Egypt, since the potato crop is exported abroad because it's high quality specifications. The aim of this study is to: find out the potential of using the optical properties as a nondestructive quality assessment for detecting surface defects of Spunta potato tubers using a low-power Helium-Neon laser. The obtained results were as following: the percentage of reflection intensity of sound tubers (7.48%) was the highest. While, the reflection percentage of superficial shatter bruise (0.83%) was the lowest. The reflection intensity percentages of He-Ne laser light from sound and defective tubers were arranged as follow: sound (7.48%) >, internal black spot (4.33%) >, greening (2.53%) >, cuts (1.83%) >, growth cracks (1.64%) >, shrinkage (1.54%) >, deep shatter bruise (1.33%) >, rots (1.32%) >, pressure bruise (1.09%) >, skinning (1.07%) >, insect damage (0.87%) >, superficial shatter bruise (0.83%). For quality evaluation processes it was concluded that: when the percentage of reflection intensity is less than 1%, (Ref.% < 1%) then the defects may be considered superficial shatter bruise or insect damage, otherwise, when the percentage of reflection intensity greater than or equal 1% and less than 2%, (1% ≤ Ref.% < 2%) then the defects may be considered skinning, pressure bruise, rots, deep shatter bruise, shrinkage, growth cracks or cuts, if the percentage is ranged between (2.5:4.5%) then the defects may be belonging to greening defect or internal black spot. The percentage of reflection greater than 7% the surface may be considered as sound tubers. It was concluded that the reflected laser light could be used as an indicator for the defective surface defects of potato tubers, so sorting and separating processes can be conducted according to the optical properties.

Keywords: Potato tuber, Hellium-Neon laser, defects, optical properties

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1 Introduction

In Egypt, potato ranked the second crop for export after orange, since the total export quantity was 427,907 tons in year 2013 with price of 481 \$ ton^{-1} (FAO, 2015). Egypt's exports of potatoes according to the demand from abroad (Russia and the European Union and the Gulf States) are ranging between 400 and 500 thousand tons per year (Ministry of Agriculture and land Reclamation, Egypt, 2016). The losses of potato crop as a result of the external defects are due to: shrinkage and rot during storage, increasing labor costs for trimming and inspecting, increasing the incidence of disease in fresh market potatoes in transit and decreasing the shelf life, reducing the appeal of fresh potatoes to wholesale and retail customers and lowering the quality of the final product (Kleinschmidt and Thornton, 1991). The mechanical injuries of potatoes, which is one of the most important external defects that cause the loss of crop quality (Peters, 1996) are classified into skinning (abrasion), shatter bruise, internal black spot, pressure bruise and cuts and the main source of these damages was the harvesting operation, shock and impact during mechanical handling. Shatter bruise is the result of mechanical impact which causes splitting or cracking of the potato, the splitting may be on the surface or inside of the potato and mainly have been noticed in poorly managed packing lines, while pressure bruise is depression of the tuber surface appears as dark, softened, and circular area on the tuber surface occurs as a result of

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external pressure at a point of contact with another tuber, storage equipment, or storage structure (Janathan, 2009; Opara and Pathare, 2014; Esehaghbeygi and Besharati, 2009). The losses of stored potatoes caused by pressure bruise are estimated as 20%-30% (Bethke, 2013). The internal black spot (IBS) occurs under the skin surface and can only be seen by removing the skin or cutting into the tuber where the small, dark, oval area exists. IBS forms as a result of an impact of the tuber against a hard surface during harvesting process (Peters, 1996; Shetty et al., 1998). The most common method that used for detection the severity of the external bruise of potato tubers is chemical method which is called Tetrazolium and Catechol test but the price of the analysis per measurement may be quite high and it produces toxic waste so destroying all potatoes used in the test are needed, it is generally not very well suited for fast, online product management (Kleinschmidt and Thornton, 1991; Alander et al., 2013). Sensory evaluation which is done by food observers is hardly suitable for a large amount of samples due to observer's eye fatigue, reducing their efficiency rapidly and the variations in judgment among individuals which lead to imprecise results on the other side optical techniques can be used as a nondestructive, fast, environment friendly and economic techniques beside it is online monitoring of all samples without touching the sample (El Masry et al., 2008; Ghazavi and Houshmand 2010). The optical properties of a matter are defined by the percentage of incident light reflected, transmitted and absorbed at each wavelength which is defined as the nature of this matter (Gunasekaran et al., 1985b). Evans (1995) mentioned that the diffuse reflectance can be measured from tissue up to *c.a.* 5 mm deep in unpeeled tubers and up to *c.a.* 8 mm deep in peeled tubers the region where bruising is found. Opara and Pathare (2014) reviewed that bruise quantification of fresh horticultural produce can be carried out using a range of non-destructive technologies including near infrared spectroscopy, hyperspectral imaging, thermal imaging and nuclear magnetic resonance imaging. Near-infrared reflectance spectra (400-1200 nm) has been used for detecting bruising in potato tubers and apples (Evans and Muir, 1999; Xing et al., 2006). Hyperspectral reflectance imaging technique was developed in spectral region between 400 and 1000nm to detect bruises on apples, peaches and apricots (El Masry et al., 2008; Zwiggelaar et al., 1996). Visible laser light such as diode and He-Ne laser was used with machine vision system as a quality indicator of tomato and apple by calculating the number of pixels in the image of scattered and reflected light as a ripeness indicator for product (Tu et al., 2000; El-Batawi, 2004). Also laser was used as non-destructive analyse in backscattering technology for quality evaluation of apples (moisture content and soluble solids content) during drying and the appearance of chilling injury in bananas, the result showed the changes of the photon migration and the backscattering parameters using laser was found to be adequate for predicting changes in moisture content and soluble solids content of apple during drying over different stages and to be chilling injury developing indicator (Romano et al., 2011; Hashim et al. 2014). Hassan (2002) concluded that the optical properties could be distinguished between sounds and blemishes of orange fruit using He-Ne with wavelength 632.8 nm and Argon laser with wavelengths 514, 496 and 488nm, respectively with power of 10 mw. The He-Ne laser is suitable to use because it gives high reflections and a criterion to identify defects for each variety of oranges. El-Raie et al. (2009) concluded that sorting and separating different types of grains can be according to optical properties of laser. They identified criteria of optical properties from sound grains using visible laser with wavelength of 632.8 nm and power 8mw. It found that the absorption percentages were higher than reflection percentages and according to the reflection intensity of laser, the criteria of optical properties from sound grains were arranged descending order as follows: the reflections were: bean (6.90%) >, flat phase-wheat (7.0%) >, hollow phase-wheat (7.63) >, rice (9.61%) >, flat phase Corn (16.31) >, and hollow phase corn (18.61%). Meanwhile, the absorptions were: hollow phase corn (81.39.61%) >, flat phase-corn (83.69%) >, rice (90.39%) >, hollow phase-wheat (92.38%) >, flat phase-wheat (93.0%) >, and bean (93.10%). El-Raie et al. (2005) found that He-Ne (632.8 nm) laser was suitable to measure optical properties of mature stages strawberry, because this wavelength was more compatible with color wavelength of mature stages strawberry than 543.4 nm. So, offering the products for export or domestic market needs fast, easy and nondestructive quality assessment to distinct between the sound and the defective tubers.

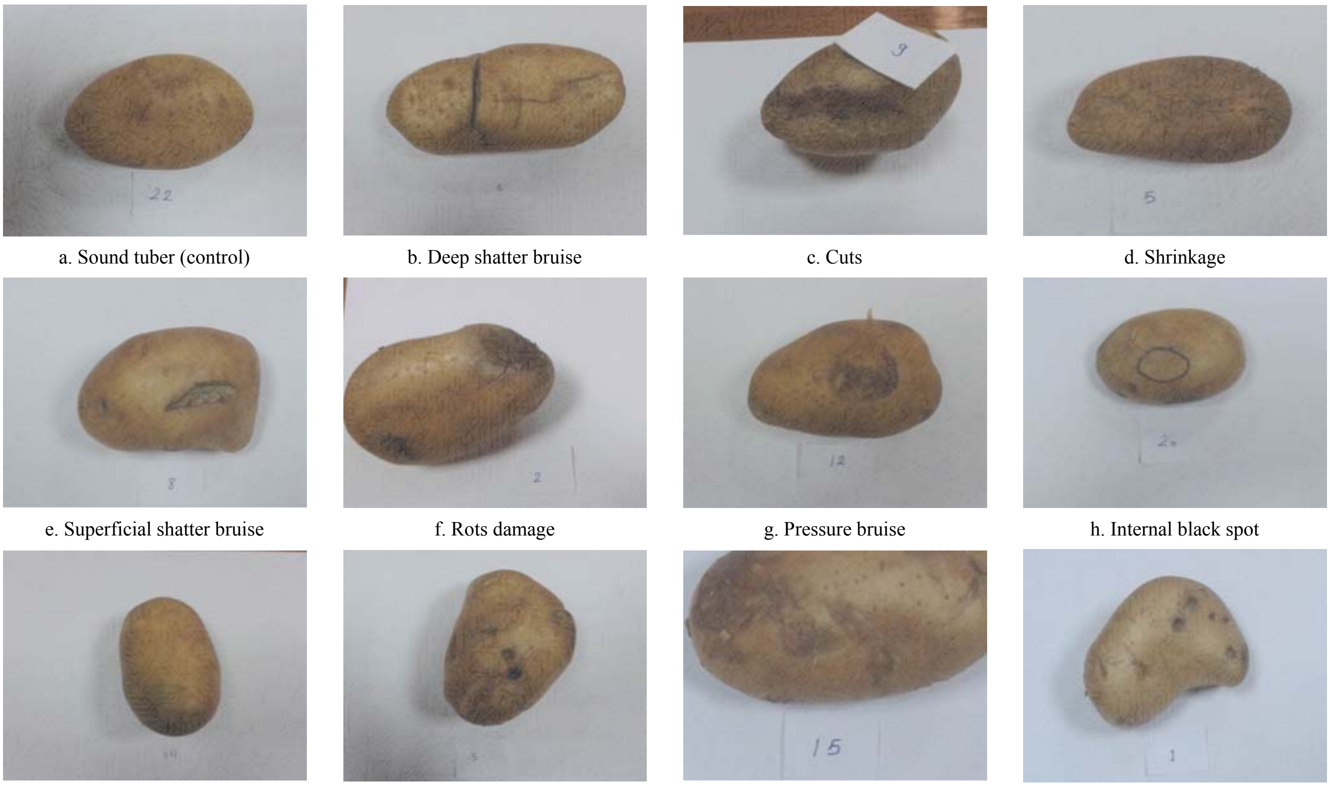
The main objective of this investigation is to measure the optical properties as a nondestructive quality assessment for detecting the surface (external) defects of Spunta potato tubers using a low power (He-Ne) laser (632.8nm) as the light source and establish quality evaluation standard for potato tuber.

2 Material and methods

The detection of external defects of potato tubers (Spunta variety) using Helium-Neon laser source as a light source. Measurements were carried out at the Laboratory of Laser Applications in Agriculture Engineering at National Institute of Laser Enhanced Science (NILES), Cairo University, Egypt.

2.1 Sample preparation:

The potato tubers “Spunta variety” was procured from a local market Giza, Egypt, in the fall season 2014. The selected sample was full of postharvest external defects such as: pressure bruise, shatter bruise, cuts, shrinkage, growth cracks, rots, insecticides injuries, skinning and greening. It was noticed that shatter bruise is divided into two categories the first was narrow and deep wound, so it was called deep shatter bruise and the other was wide wound and on the surface of the tubers, so it was called superficial shatter bruise. The tubers were cleaned from dust and clay by tap water then they were dried by air. The tubers were grouped due to the external defect types and sound tubers were taken as a control (no external defect) as shown in Figure 1.



a. Sound tuber (control) b. Deep shatter bruise c. Cuts d. Shrinkage

e. Superficial shatter bruise f. Rots damage g. Pressure bruise h. Internal black spot

i. Greening j. Growth cracks k. Skinning l. Iinsecticides injuries

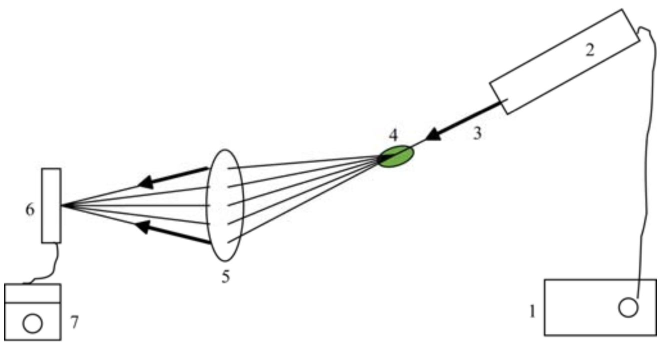
Figure 1 External defects of potato tubers

2.1.1 Impact test

The impact test should be done to make sure that the internal black spot is already exist in the chosen sample and to identify the site of bruising, sound tubers were dropped from 110 cm height on a steel surface (Esehaghbeygi and Besharati, 2009) through 10 cm cylindrical tube used as a guide. Blue chalk powder was scattered on the steel surface to identify the falling location and the site of bruise was marked by water proof marker then the blue powder was remove softly. The tubers were left at room temperature for 14 days before the detection test and a random sample was taken and peeled to make sure that the bruise had formed under tissue. For internal black spot the intensity of reflection light was measured before peeling the tubers from the sound and the defected parts after that the tubers were peeled and the readings were repeated again.

2.2 Laser setup

The setup consists of: laser source, lenses, holders, detector and digital lux-meter as shown in Figure 2. He-Ne laser in the visible light of (632.8 nm) wavelength with 8 mW power was used as light source. The laser was sitting on a vertical holder and the specification of He-Ne laser is shown in Table 1. Convex silica glass lens of 100 mm focal length with diameter 75 mm was put between the tuber and the detector with angle 45^o to focus the reflected light collected from the potato tuber surface onto the detector. A digital lux-meter with high accuracy and sensitivity was used to measure the intensity of light reflection from potato tuber surface. Digital lux-meter specifications are shown in Table 2. Holders fabricated of copper were used to hold lens and lux-meter detector.



1. Power supply 2. He-Ne laser 3. Laser beam 4. Sample 5. Convex lens 6. Detector 7. Lux meter

a. Schematic diagram of laser setup

b. Experiment setup of detection defects

Figure 2 Experiment schematic diagram of setup for detecting the external defect of potato tubers

The laser beam was incident on the surface of the potato tuber and the reflected light intensity was collected by convex lens into detector and measured using the lux-meter without transmission, where, the setup was adjusted at incident angle equal to reflected angle (45^o) to obtain high reflection.

Table 1 Specifications of (He-Ne) laser

No.	Item	Specifications
1	Source of manufacture	USA
2	Model	05-LHP-151
3	Type	Gas laser
4	Wavelengths, nm	632.8
5	Mode	Continuous wave
6	Output power, mW	8
7	Beam diameter, mm	1
8	Beam divergence, mrad	0.62
9	Polarization ratio	Random
10	Weight, kg	0.61
11	In put current, Ac, Amp.	220, 3

Table 2 Specifications of digital lux-meter

No.	Item	Lux-meter specifications
1	Source of manufacture	Japan
2	Model	Lx-101
3	Display	13 mm LCD (Liquid Crystal Display)
4	Ranges	0-50,000 Lux 3 ranges
5	Operating temperature	0^o to 50 ^{o}C. (32^o – 122^o F)
6	Dimension	108×73×23 mm
7	Weight	160 g including battery
8	Power supply	006P DC 9V, 2 mA battery

The absorption intensity was calculated from the following equation according to the energy conservation law:

$$I = R + T + A \tag{1}$$

where, *I*: The incident beam, lu; *R*: Reflective light intensity, lux; *A*: Absorption light intensity, lux; *T*: Transmission light intensity, lux, $T = 0$.

The reflective light percentage was calculated according the following equation:

$$\text{Ref., \%} = (\text{Reflective light, lux/ Incident light, lux}) \times 100 \tag{2}$$

The absorption light percentage was calculated according to the following equation:

$$\text{Absorb., \%} = (\text{Absorption light, lux/ Incident light, lux}) \times 100 \tag{3}$$

2.3 Statistical analysis

The obtained data were statistically analyzed to get the main statistical values (means, minimum, maximum, standard error (S.E.), standard deviation (S.D.), variance (S^2) and coefficient of variance (C.V., %)) using Microsoft office Excel Program. Analysis of variance (ANOVA) was conducted for the reflection light of internal black spot defect comparing with sound tubers before and after peeling using Microsoft office Excel Program and for reflection intensity means comparisons, Tukey's honest significant difference test was conducted using Vassar Stats (Website for Statistical Computation). ANOVA was conducted for the reflection light of deep shatter bruise comparing with superficial shatter bruise using Microsoft office Excel Program.

3 Results and discussions

Table 3 shows the main statistical values (mean, range, S.E., S.D, (S^2) and (C.V., %)) of the reflection and absorption intensities of external defects of potato tuber.

Optical properties of different external defects of potato tubers:

For sound tubers: the mean light intensity of reflection of sound tubers was only 52.37 lux with percentage of 7.48% and the mean intensity of absorption light was 647.63 lux with percentage of 92.52% from total incident light, this significantly difference between reflection and absorption intensities may be due to that the surface of potato tuber is opaque.

For pressure bruise defect: the reflection light intensity was ranged from 2.00 lux with percentage of 0.29% to 16.00 lux with percentage of 2.29%. Reflection light intensity mean was 7.65 lux with percentage of 1.09%. SD of reflection and absorption percentage was 0.53 and CV for reflection and absorption were 48.06% and 0.53% respectively.

For rots defect: the results show that the reflection light intensity mean of rotted tubers was 9.24 lux with a percentage of 1.32% and ranged between (5.00-17.00 lux). SD of reflection and absorption percentage was 0.51% and CV for reflection and absorption were 38.3% and 0.51% respectively.

For growth cracks damage defect: the reflection light mean of growth cracks defect was 11.5 with percentage of 1.64% and ranged between (9.0-14.0 lux). SD of reflection and absorption percentages was 0.21% and CV for reflection and absorption were 12.57% and 0.21% respectively.

For insecticides injuries defect: the reflection intensity mean of insect damage presented 0.87% of incident light while absorption mean presented 99.13% with SD of 0.32. Reflection light was ranged from the minimum value of 2.00 lux to the maximum value of 9.00 lux and CV for reflection and absorption were 36.68% and 0.32% respectively.

Table 3 Optical properties of external defects of potato tubers using He-Ne laser

Types of Defects	Optical Properties	Statistical values					
		Mean	Range	S^2	S.D.	S.E.	C.V.%
Sound Tubers	Ref., lux	52.37	33.0-70.0	96.23	9.81	0.70	18.73
	Ref. %	7.48	4.71-10.0	1.96	1.40	0.10	18.73
	Abs., lux	647.63	630-667	96.23	9.81	0.70	1.51
	Abs. %	92.52	90.00-95.29	1.96	1.4	0.10	1.51
Pressure Bruise	Ref., lux	7.65	2.00-16.00	13.51	3.68	0.63	48.06
	Ref. %	1.09	0.29-2.29	0.28	0.53	0.09	48.06
	Abs., lux	692.35	684.0-698.0	13.51	3.68	0.63	0.53
	Abs. %	98.91	97.71-99.71	0.28	0.53	0.09	0.53
Rots	Ref., lux	9.24	5.00-17.00	12.52	3.54	0.71	38.30
	Ref. %	1.32	0.71-2.43	0.26	0.51	0.10	38.30
	Abs., lux	690.76	683.0-695.0	12.52	3.54	0.71	0.51
	Abs. %	98.68	97.57-99.29	0.26	0.51	0.10	0.51
Insecticides Injuries	Ref., lux	6.11	2.00-9.00	5.03	2.24	0.43	36.68
	Ref. %	0.87	0.29-1.29	0.10	0.32	0.06	36.68
	Abs., lux	693.89	691-698	5.03	2.24	0.43	0.32
	Abs. %	99.13	98.71-99.71	0.10	0.32	0.06	0.32
Growth Cracks	Ref., lux	11.50	9.0-14.0	2.09	1.45	0.42	12.57
	Ref. %	1.64	1.29-2.0	0.04	0.21	0.06	12.57
	Abs., lux	688.50	686.0-691.0	2.09	1.45	0.42	0.21
	Abs. %	98.36	98.0-98.71	0.04	0.21	0.06	0.21
Shrinkage	Ref., lux	10.75	5.0-16.0	12.11	3.48	0.71	32.37
	Ref. %	1.54	0.71-2.29	0.25	0.50	0.10	32.37
	Abs., lux	689.25	684.0-695.0	12.11	3.48	0.71	0.50
	Abs. %	98.46	97.71-99.29	0.25	0.50	0.10	0.50
Skinning	Ref., lux	7.46	2.0-14.0	14.74	3.84	0.75	51.45
	Ref. %	1.07	0.29-2.0	0.30	0.55	0.11	51.45
	Abs., lux	692.54	686.0-698.0	14.74	3.84	0.75	0.55
	Abs. %	98.93	98.0-99.71	0.30	0.55	0.11	0.55
Greening	Ref., lux	17.71	11.0-29.0	29.62	5.44	0.88	30.73
	Ref. %	2.53	1.57-4.14	0.60	0.78	0.13	30.73
	Abs., lux	682.29	671-689	29.62	5.44	0.88	0.8
	Abs. %	97.47	95.86-98.43	0.60	0.78	0.13	0.8
Cuts	Ref., lux	12.84	8.0-21.0	12.19	3.49	0.53	27.19
	Ref. %	1.83	1.14-3.0	0.25	0.50	0.08	27.19
	Abs., lux	687.16	679.0-692.0	12.19	3.49	0.53	0.51
	Abs. %	98.17	97.0-98.86	0.25	0.50	0.08	0.51

Note: Ref.: Reflection, Abs.: Absorption, S^2.: Variance, S.D.: Standard Deviation. S.E.: Standard Error, and C.V.%: Coefficient of Variance.

For shrinkage defect: the reflection light intensity of the shrinkage defect was 10.75 lux which represents 1.54% of incident light. The minimum value of reflection light was 5.00 lux and the maximum value was 16.00 lux. SD for reflection and absorption intensity percentages was 0.5%. While CV for reflection and absorption were 32.37% and 0.5% respectively.

For of skinning defect: the results show that the mean of reflection light of skinning defected tubers was 7.46 lux which presents 1.07% of incident light and ranged from minimum value of 2.00 lux to maximum value of 14.00 lux. SD for reflection and absorption intensity percentages was 0.55% and CV for reflection and absorption were 51.45% and 0.55% respectively.

For greening defect: the results show that the mean of reflection light intensity of greening tubers was 17.71 lux with percentage of 2.53%. The minimum value of reflection light intensity was 11 lux while, the maximum value was 29 lux. SD for reflection and absorption intensity percentages was 0.78% and CV for reflection and absorption were 30.37% and 0.8% respectively.

For cuts defect: the results show that the reflection light intensity mean was 12.84 lux which presents 1.83% of incident light. Reflection light ranged from 8 lux to 21.00 lux with SD of reflection and absorption intensity percentages of 0.5% and the CV for reflection and absorption were 27.19% and 0.51% respectively.

For deep shatter bruise and superficial shatter bruise defect: the shatter bruising occurs when the skin of the tuber has been splited or broken and a thick layer that is hard to peel is produced for covering the tissue. During sample collecting process it was noticed that shatter bruise is divided into two types the first type was narrow and deep wound so it was called deep shatter bruise and the other type was wide wound and on the surface of the tubers so it was called superficial shatter bruise. The optical properties of shatter bruise defect (deep and superficial) are presented in Table 4. The results show that the reflection light intensity of a deep bruise was ranged between 5.00-19.00 Lux with mean of 9.31 lux, while reflection light intensity of superficial shatter bruise was ranged from 3.00 to 12.00 lux with 5.84 lux mean value. According to the analysis of variance (ANOVA), the results show that the reflection light intensity of deep shatter bruise is significantly higher than reflection light intensity of superficial shatter bruise. SD for reflection and absorption intensity percentages of deep shatter bruise was 0.55% and CV for reflection and absorption were 42.06% and 0.56% respectively, while, SD for reflection and absorption intensity percentages of superficial shatter bruise was 0.41% and CV for reflection and absorption were 48.6 % and 0.41% respectively.

Table 4 Optical properties of shatter bruise (deep and superficial) defect of potato tubers using He-Ne laser

Statistical values	Reflection, lux		Reflection, %		Absorption, lux		Absorption, %	
	Super.	Deep	Super.	Deep	Super.	Deep	Super.	Deep
Mean	5.84	9.32	0.83	1.33	694.16	690.69	99.17	98.67
Maximum	12.00	19.00	1.71	2.71	697.00	695.00	99.57	97.29
Minimum	3.00	5.00	0.43	0.71	688.00	681.00	98.29	99.29
S^2	8.06	15.39	0.16	0.31	8.06	15.06	0.16	0.31
S.D.	2.84	3.92	0.41	0.55	2.84	3.88	0.41	0.55
S.E.	0.57	0.78	0.08	0.15	0.57	1.08	0.08	0.15
C.V.%	48.60	42.06	48.60	42.06	0.41	0.56	0.41	0.56

For internal black spot (IBS) defect: the analysis of variance (ANOVA) showed that reflection light intensity means of sound part before peeling, internal black spot before peeling, sound part after peeling and internal black spot after peeling were significantly difference as shown in Table 5. Reflection and absorption light means are presented in Table 7. The collected data showed that the means of reflection intensity for sound part before peeling, internal black spot before peeling, sound part after peeling and internal black spot after peeling were 52.37, 30.34, 67.17 and 14.38 lux respectively and Tukey's $HSD_{(0.05)}$ = 9.92. As shown in Table 6 and Figure 3 it was concluded that the highest significant reflection intensity was for sound parts after peeling and the lowest significant reflection intensity was for internal black spot after peeling this reduction of reflection may be due to the production of dark colored melanin as a result of bruised part (Evans and Muir, 1999). The results showed that the SD of reflection percentage for (sound part before peeling, internal black spot before peeling, sound part after peeling and internal black spot after peeling) were (1.86%, 1.44%, 2.3% and 0.37%) respectively.

Table 5 Analysis of variance of reflection and absorption intensity (lux) for peeled and unpeeled (sound and internal black spot defect) of defected tubers

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit.
Between Groups	31094.6	3	10364.8	76.9	2.1E-22	2.7
Within Groups	9702.3	72	134.7			
Total	40796.9	75				

Table 6 Means comparisons of optical properties of internal black spot and sound parts of defected tubers before and after peeling using He-Ne laser 632.8 nm

Means	Internal black spot			
	Before peeling		After peeling	
	Sound	IBS	Sound	IBS
Reflection	52.37a	30.34b	67.17c	14.38d
Absorption	647.63a	669.66b	632.83c	685.62d

Note: Means in rows followed by different letter (S) are different significant. HSD (0.05) = 9.92; HSD (0.01) =12.17.

Table 7 Main statistics of optical properties of internal black spot and sound parts of defected tubers before and after peeling using He-Ne laser 632.8 nm

Internal black spot		Main statistic	Optical properties			
			Ref.	Ref.%	Abs.	Abs.%
Before peeling	Sound part	Mean	52.37	7.48	647.63	92.52
		Max.	70.00	10.00	667.00	95.29
		Min.	33.00	4.71	630.00	90.00
		SD	13.05	1.86	13.05	1.86
	Internal black spot	Mean	30.34	4.33	669.66	95.67
		Max.	46.60	6.66	683.50	97.64
		Min.	16.50	2.36	653.40	93.34
		SD	10.11	1.44	10.11	1.44
After peeling	Sound tubers	Mean	67.17	9.60	632.83	90.40
		Max.	97.00	13.86	655.00	93.57
		Min.	45.00	6.43	603.00	86.14
		SD	16.12	2.3	16.12	2.3
	Internal black part	Mean	14.38	2.05	685.62	97.95

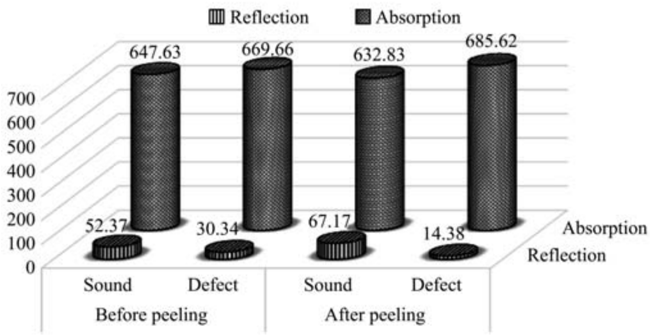


Figure 3 Reflection and absorption of internal black spot and sound parts of defected tubers before and after peeling using He-Ne laser 632.8 nm

Figure 4 shows the percentage of the reflection light intensity means of sound and the examined external defects of "Spunta" potato tubers. The collected results showed that the percentage of reflection intensity of sound tubers (7.48%) was the highest between means while, the reflection percentage of superficial shatter bruise (0.83%) was the lowest mean. It was found that the absorption percentages were higher than reflection percentages, this is may be due to the dark color of the surface of defects. The reflection intensity percentages of light source (He-Ne laser) from sound and postharvest defected tubers are arranged as follow: sound (7.48%) >, internal black spot (4.33%) >, greening (2.53%) >, cuts (1.83%) >, growth cracks (1.64%) >, shrinkage (1.54%) >, deep shatter bruise (1.33%) >, rots (1.32%) >, pressure bruise (1.09%) >, skinning (1.07%) >, insect damage (0.87%) >, superficial shatter bruise (0.83%). Meanwhile, the absorption percentage means were: superficial shatter bruise (99.17%) >, insect damage (99.13%) >, skinning (98.93%) >, pressure bruise (98.91%) >, rots (98.68%) >, deep shatter bruise (98.67%) > shrinkage (98.46%) >, growth cracks (98.36%) >, cuts (98.17%) > greening (97.47%) >, internal black spot (95.67%) >, sound tubers (92.52%).

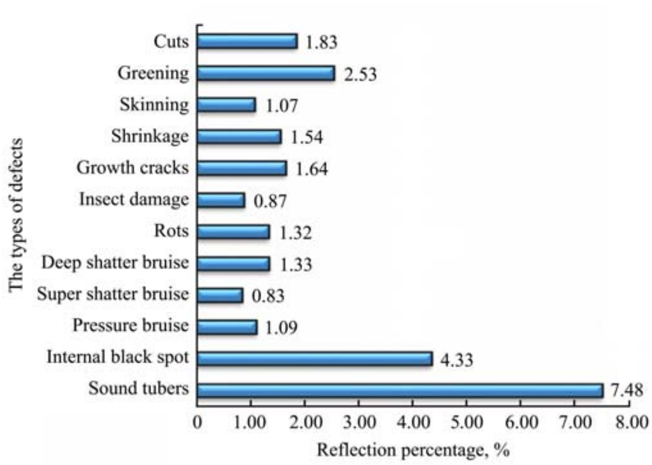


Figure 4 Means of reflection percentage of defected potato tubers using He-Ne (632.8 nm)

4 Conclusions

For optical properties of sound and external defects of "Spunta" potato tubers, it was found that He-Ne low power laser can be used as a detector for sound and postharvest defects of "Spunta" potato. The absorption intensity percentages were higher than the reflection intensity percentages. For quality evaluation on the basis the optical properties of potato tubers defects, it was concluded that when the percentage of reflection intensity is less than 1%, (Ref. % <1%) then the defects may be considered as superficial shatter bruise or insect damage, otherwise, when the percentage of reflection intensity is greater than or equal 1% and less than 2%, (1% ≤ Ref. % <2%) then the defects may be considered as skinning, pressure bruise, rots, deep shatter bruise, shrinkage, growth cracks or cuts. If the percentage is ranged between (2.5% and 4.5%), then the defects may belong to greening defect or internal black spot. If the percentage of reflection is greater than 7%, then it may be considered sound tubers.

References

Alander, J. T., V. Bochko, B. Martinkauppi, S. Saranwong, and T. Mantere. 2013. A review of optical nondestructive visual and near-infrared. Methods for food quality and safety. *International Journal of Spectroscopy*, Pp 1–36.

Bethke, P. 2013. Manipulation of pre-harvest conditions and storage ventilation systems to minimize pressure bruise in potato. Vegetable crops research unit. United States Department of Agriculture. Project number 5090-21220-002-07.

El-Masry, G., N. Wang, C. Vigneault, J. Qiao, and A. E. Sayed. 2008. Early detection of apple bruises on different background colors using hyperspectral imaging. *LWT- Food Science and Technology*, 41(2): 337–345.

El-Batawi, I. E. A. 2004. Study on apple quality non-destructively using laser beam as light source. *Misr Journal of Agricultural Engineering*, 21(3): 593–602.

El-Raie, A. E., H. E. Hassan, and A. A. Abd El-Rahman. 2005. Light and electrical reflections of visible laser for strawberry maturity stages. "Role and horizons of agricultural engineering in the contemporary world". In *the 13th Annual Conference of the Misr Society of Agricultural Engineering*, 14–15.

El-Raie, A. E., H. E. Hassan, and A. A. Abd El-Rahman. 2009. Optical and electrical properties of some grains using visible laser. *Misr Journal of Agricultural Engineering*, 26(3): 1412–1428.

Esehaghbeygi, A., and S. Besharati. 2009. Potato variety and storage for tuber sensitivity in bruising. *World Applied Sciences Journal*, 7(12): 1504–1507.

Evans, S. D. 1995. Determination of light penetration depth in potato tuber tissue. In: methods of rapid bruise assessment and the formulation of robust bruise indices for potatoes. PhD. Diss., University of Edinburgh, 52–55.

Evans, S. D., and A. Y. Muir. 1999. Reflectance spectrophotometry of bruising in potatoes. I. Ultraviolet to near infrared. *International Agrophysics*, 13(2): 203–209.

FAO, 2015. Food and agriculture organization of the United Nations. Available at: www.fao.org.

Ghazavi, M. A., and S. Houshmand. 2010. Effect of mechanical damage and temperature on potato respiration. *World Applied Science Journal*, 8(5): 647–652.

Gunasekaran, S., M. R. Paulsen, and G. C. Shove. 1985b. Optical methods for nondestructive quality evaluation of agricultural and biological materials. *Journal of Agricultural Engineering Research*, 32: 209–241.

Hashim, N., R. B. Janius, R. A. Rahman, A. Osman, M. Shitan, and M. Zude. 2014. Changes of backscattering parameters during chilling injury in bananas. *Journal of Engineering Science and Technology*, 9(3): 314–325.

Hassan, H. E. 2002. Study of sorting and grading operations of Egyptian mature oranges using visible laser. Ph.D. diss., National Institute of Laser Enhanced Science (NILES), Cairo Univ.

Janathan, C. 2009. Evaluating mechanical damage of fresh potato during harvesting and postharvest handling. M. S. thesis Horticultural Science Department, University of Florida.

Kleinschmidt, G., and M. Thornton. 1991. Bruise-free potatoes: our goal. University of Idaho Coop. Ext. System Bulletin No. 725.

Ministry of Agriculture and Land Reclamation. 2016. Arab Republic of Egypt. Available at: http://www.agr-egypt.gov.eg.

Opara, U. L., and P. B. Pathare. 2014. Bruise damage measurement and analysis of fresh horticultural produce - A review. *Postharvest Biology and Technology*, 91(5): 9–24.

Peters, R. 1996. Damage of potato tubers, a review. *Potato Research*, 39(4): 479–484.

Romano, G., M. Nagle, D. Argyropoulos, and J. Müller. 2011. Laser light backscattering to monitor moisture content, soluble solid content and hardness of apple tissue during drying. *Journal of Food Engineering*, 104(4): 657–662.

Shetty, K., M. Casada, H. Zhu, M. Thornton, and P. Notle. 1998. *Fresh-pack Potatoes Handling, Packaging, and Transportation in Refrigerated Railcars.* Idaho: College of Agricultural Cooperative Extention System, Idaho Agricultural Experiment Station.

Tu, K., P. Jancsók, B. Nicolaï, and J. D. Baerdemaeker. 2000. Use of laser-scattering imaging to study tomato-fruit quality in relation to acoustic and compression measurements. *International Journal of Food Science and Technology*, 35(5): 503–510.

Xing, J., C. Bravo, D. Moshou, H. Ramon, and J. D. Baerdemaeker. 2006. Bruise detection on 'golden delicious' apples by vis/nir spectroscopy. *Computers and Electronics in Agriculture*, 52(1): 11–20.

Zwiggelaar, R., Q. Yang, E. G. Pardo, and C. R. Bull. 1996. Use of spectral information and machine vision for bruise detection on peaches and apricots. *Journal of Agricultural Engineering Research*, 63(4): 323–331.