Quality evaluation of strawberry fruit using visible laser

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Abstract: The main objectives of this work are to conduct experiments and measurements for the optical, electrical, physical and chemical properties of strawberry fruits. Strawberry was classified into three grades according to the varieties of strawberry (Festival, Fortona and Red Marline Strawberry). The strawberry fruits were exposed to visible laser to determine optical and electrical signal reflections of strawberry. The samples were classified into six kinds of defects of strawberry according to codex specification of strawberry. It was found that the high value of physical properties was Fortona variety while the low value was Festival variety, but the physical properties of Red Marlin variety intermediately between values of fortona and festival variety. It was found that mass increased also gradually with volume. The density of strawberry fruits increased by the increase of the mass of fruit. Also, the high value of chemical properties Brix value was Festival variety (7.5), while the Brix low value of Red Marlin variety (6.78), but the chemical properties Brix of Fortona variety (7.14) intermediately between values of Festival and Red Marlin variety. The electric signal high values were from control samples (standard) while the low values were from green tip defect for Festival, Fortona and Red Marlin varies of strawberry defects. It was found that, the values of electrical signals were gradually decreased for control (standard, mold, insect green tip, white shoulder and green of strawberry defects). It was noticed that the high values of reflection intensities were from control samples (standard) while the low values were from green tip defect for festival, fortona and red marlin varies of strawberry defects. Thus, the values of reflection intensities were gradually decreased for the control (standard, mold, insect, green tip, white shoulder and green of strawberry defects.

Keywords: quality valuation, strawberry fruit, visible laser, physical properties

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1 Introduction

Giampieri et al. (2012) showed that the strawberry (Fragaria X ananassa, Duch.) represented a relevant source of micronutrients, such as minerals, vitamin C, folate and phenolic substances, most of which were natural antioxidants and contributed to the high nutritional quality of the fruit.

All these compounds are essential for health and, in particular, strawberry phenols are best known for their antioxidant and anti-inflammatory action, and possess directly and indirectly antimicrobial, anti-allergy and anti-hypertensive properties, as well as the capacity to inhibit the activities of some physiological enzymes and receptors properties.

Shahin et al. (2002) compared between features obtained from optical measurements by LASER technique and the standard RGB images for classifying tomatoes in different ripeness classes. LASER features have been captured under different wavelength conditions. For comparison and classification, Fisher's linear discriminate analysis was used. This technique is very suitable for tomatoes classification in different ripeness classes.

Kondo et al. (2000) inferred that the inspection of internal quality of the fruits was almost impossible via the sole use of visible imaging. However, in some cases where a considerable correlation exists between the observable characteristics and internal quality of the product, such correlations can be used as criteria to

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estimate the internal quality of the fruit. For instance, some correlation between the shape and colour of Iyokan orange with its sugar content is obtained.

Costa et al. (2011) reported that the appearance of unities of products was evaluated by considering their size, shape, form, colour, freshness condition and finally the absence of visual defects. All these characteristics contributed to the overall appearance, which is globally evaluated either in a metric or a subjective manner as an important quality indicator.

Throop et al. (2003) designed two conveyors, one for capturing x-ray images for internal defects and the second for capturing images of surface defects on apples. A small wheel protruding 1.2 mm up through the center of a small ring contacted the apple surface rotating the apple until the concave stem or calyx moved over the wheel causing the wheel to lose contact.

Hassan (2002) designed a photoelectric setup for sorting and grading of Egyptian oranges according to the reflection properties. The He-Ne LASER was used as a light source in the machine. The optimum speed of machine belt and the mean capacity for orange varieties were found to be 0.47 m s^{-1} and 0.82 Mg h^{-1}, respectively.

Hassan (2003) mentioned that, the electrical signals from sound tomato were consistently affected by the presence of various surface defects and discolor of tomatoes. This is the basis for optoelectronic instrument for sorting and grading tomato.

Xing et al. (2005) stated that the imaging techniques had been developed and successfully applied as inspection tools for quality assessment of a variety of apple fruits.

The purposes of this study are to:

1. Estimate some physical and chemical properties of three strawberry varieties

2. Determine optical properties of strawberry fruits using visible laser.

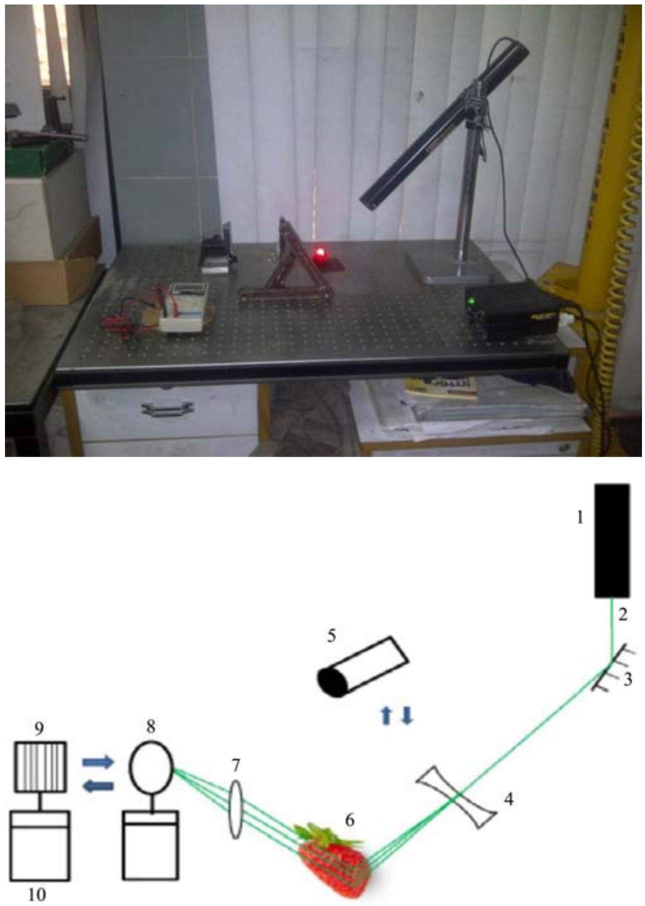
3. Using laser in detection various defect of strawberry fruits.

4. Establish quality indices to sound strawberry for export according to world standard.

2 Materials and methods

The experiments were carried out at the Laboratory of Laser Application in the Agricultural Engineering Lab., at National Institute of Laser Enhanced Science (NILES), Cairo University, Egypt. The experiments and measurements for the optical, electrical, physical and chemical properties of strawberry fruits were carried out according to the following procedures.

Laser setup: The experimental setup was adjusted at incident angle equal to reflected angle (45°) to obtain high reflections and to establish measuring for identifying optical properties of strawberry fruits. The experimental setup was shown in Figure 1.



1. He-Ne laser 2. Laser beam 3. Mirror 4. Concave lens 5. Beam expander 6. Sample 7. Convex lens 8. Lux meter 9. Photovoltaic cell 10. Avometer

Figure 1 The experimental setup used measurements for the optical properties

The He-Ne laser: The helium-neon (He-Ne) laser in the visible band (wavelengths 543.5 and 632.8 nm with low power about 8 mW was used as a light source in the present work. The specifications of He-Ne laser were shown as follows.

Lens: Convex silica glass lens of 100 mm focal length with diameter 75 mm was used. The lens was put between the fruit sample and the luxmeter with angle of 45 degree to focus the reflected light and collect it on the luxmeter detector.

Holders: Holders fabricated from copper were used to hold lens, sample, and luxmeter detector. Holder also, which allowed the photovoltaic cell to move at any direction.

Digital avometer: Model CDA-701 made in Japan was used to measure the electrical signal with volt which result from converted reflection of light from fruit surface by a photovoltaic cell. This avometer was with accuracy 0.1 of mV (direct current, DC), measuring range 1 mV to 1000 V (DC).

Digital luxmeter: A digital luxmeter with high accuracy and sensitivity was used to measure the intensity of light reflection from fruit surface and then reflection light was collected by concave lens to luxmeter detector. Measurements of Digital luxmeter with ranges of 0-50,000 Lux. Digital luxmeter specifications

The absorption of strawberry fruit was calculated from the following equation according to the energy conservation law:

$$I = R + A \qquad (3)$$

where, I : The incident beam, lux; R - reflective beam, lux; and A - absorptive beam, lux

Photovoltaic cell: Dimensions were 60 and 40 mm for length and width, respectively. It was mounted on a holder which allowed the cell to move at any direction. The intensity of reflected light was transformed to voltage by photovoltaic cell which was transferred to an avometer.

3 Results and discussion

3.1 Physical and chemical properties of three different strawberry varieties

Table 1 showed the average height, width, long, mass, volume and density of three different strawberry varieties (Festival, Fortona and Red marlin).

It was found that the high values of physical properties were Fortona variety while the low value was Festival variety, but the physical properties of Red Marlin variety was intermediate between values of Fortona and Festival varieties.

For the volume, mass and density of strawberry fruits, it was found that mass increased gradually with volume. Also, the density of strawberry fruits increased by increasing mass of strawberry fruits.

It was illustrated in Table 1 as follows, the high value of chemical properties was Festival variety, while the low value for Red Marlin variety, but the chemical properties of Fortona variety was intermediate between values of Festival and Red Marlin varieties.

Table 1 Some physical and chemical properties of three different strawberry varieties.

Strawberry varieties	Height (mm)	Width (mm)	Long (mm)	Volume (mm^3)	Weight (g)	Density (g/mm^3)	Brix	ph
Festival	32.12	26.55	24.83	11.63	12.99	1.12	7.5	3.6
Fortona	32.75	31.2	30.18	16.446	16.84	1.025	7.14	3.45
Red marlin	32.28	27.39	23.51	12.262	12.25	1.005	6.78	3.42

3.2 Optical and electrical properties of strawberry fruits defects by laser with wavelength of 543.5 nm

3.2.1 For refection intensity of strawberry fruits defects

Table 2 and Figure 2 showed that reflection intensity of different for strawberry verities using laser with wavelength 543.5 nm.

From the result, it was found that the high values of reflection intensity were 36.42, 18.5 and 23.13 lux for Festival, Fortuna and Red Marlin verities at control sample (standard), respectively.

That is mean; - the value of reflection intensity less than 36.42 lux of Festival variety, 18.50 lux of Fortona variety and 23.13 lux of Red Marlin variety were considered as defected samples. While, the reflection intensities were equal or more than these values, which will be as high quality.

Table 2 Reflection intensity of strawberry defect using visible laser of 543.5 nm

Defects types	Strawberry varieties		
	Festival	Fortona	Red marlin
	Reflection intensity of 543.5 nm (lux)		
Standard	36.42	18.5	23.13
Mold	26.37	14.63	20.5
Insect	20	12.71	19.58
Green tip	19.19	10.88	14.69
Whit shoulder	17.826	8.286	12.54
Green	12.32	5.16	10.2

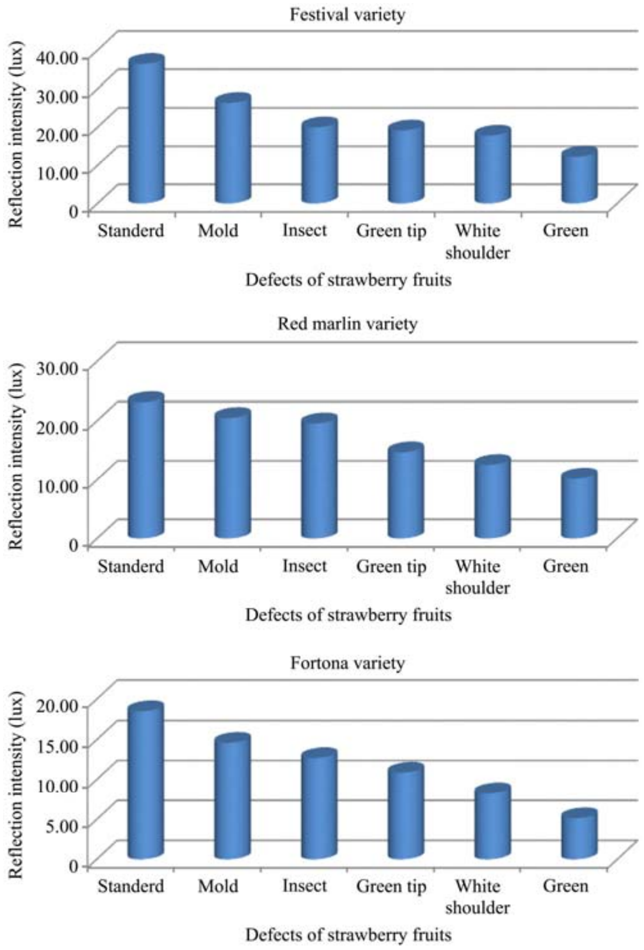


Figure 2 Reflection intensity of fruits defect for strawberry using wavelength laser in 543.5 nm

3.2.2 For electrical signal of strawberry fruits defects

Table 3 and Figure 3 show that electrical signal of different for strawberry verities using laser with wavelength 543.5 nm.

Table 3 Electrical signals of strawberry defects using visible laser of 543.5 nm

Defects types	Strawberry varieties		
	Festival	Fortona	Red marlin
	Electrical signals of 543.5 nm (mV)		
Standard	19.31	14.58	16.8
Mold	16.69	11	13.92
Insect	12.8	9.33	11.91
Green tip	10.92	6.93	9.83
Whit shoulder	10	6.09	9.5
Green	8.13	4.58	7.47

It was found that the high values of reflection intensity were 19.31, 14.58 and 16.8 mV for Festival, Fortuna and Red Marlin verities at control sample (standard), respectively.

That is mean; the value of electrical signal less than 19.31 mV of Festival variety, 14.58 of Fortona variety and 16.80 of Red Marlin variety the sample was defected. While, the electrical signal equal or more than these values will be considering high quality.

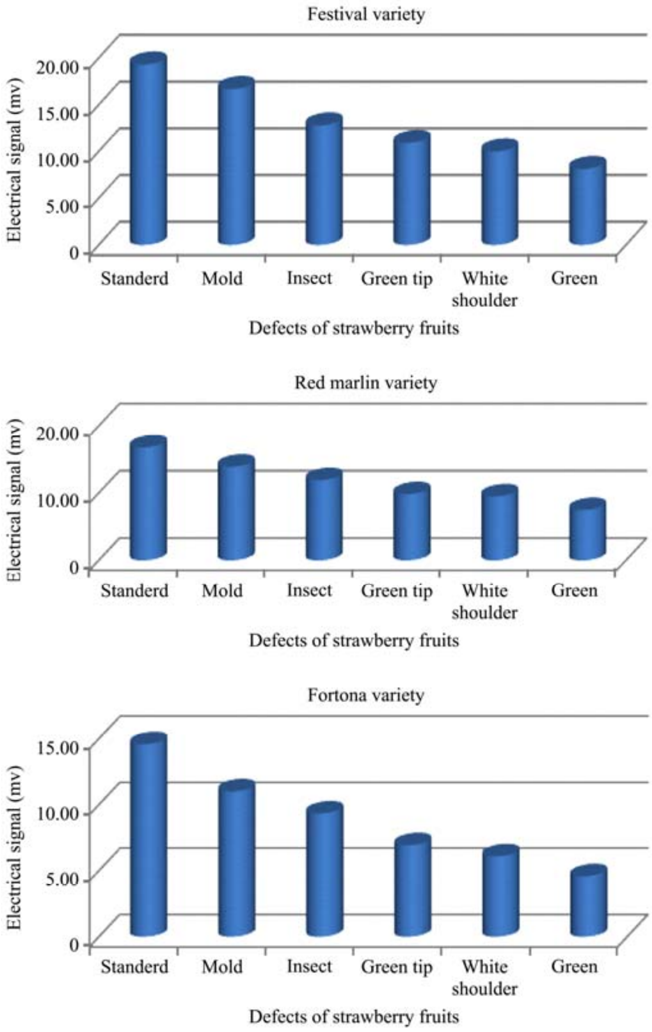


Figure 3 Electrical signal of fruit defect for strawberry varieties using wavelength laser in 543.5 nm

3.2.3 For absorption intensity of Strawberry fruits defects

Table 4 and Figure 4 showed the different absorption intensity for strawberry verities using laser with wavelength 543.5 nm.

From pervious result, it was found that the lows value of absorption intensity were 4063.58, 4076.88 and 4081.50 lux for Festival, Fortuna and Red Marlin verities at control sample (standard), respectively.

That is mean; the value of absorption intensity more than 4063.58 lux of Festival variety, 4076.88 lux of Fortona variety and 4081.50 lux of Red Marlin variety were considered as defected. While, the absorption intensity was equal or more than these values will be high quality.

Table 4 Absorption intensity of strawberry defect using visible laser of 543.5 nm

Defects types	Strawberry varieties		
	Festival	Fortona	Red marlin
	Absorption intensity of 543.5 nm (lux)		
Standard	4063.58	4076.88	4081.5
Mold	4073.63	4079.5	4085.38
Insect	4080	4080.42	4087.29
Green tip	4080.81	4085.31	4089.12
Whit shoulder	4082.17	4087.46	4091.71
Green	4087.68	4089.8	4094.84

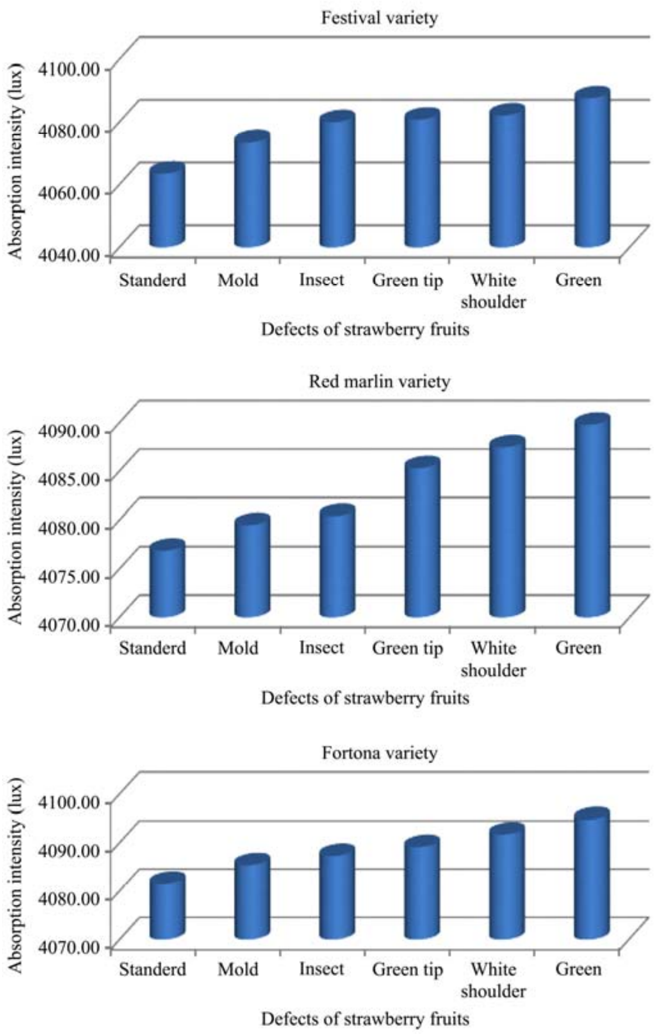


Figure 4 Absorption intensity of fruit defect for strawberry varieties using wavelength laser in 543.5 nm

2.3 Relationship between optical and electrical properties using laser with wavelength of 543.5 nm

3.3.1 Reflection intensity and strawberry fruits defects

Figure 5 showed the relation between reflection intensity and strawberry defects using laser with wavelength 543.5 nm.

The following relationship will be determined the type of defect of strawberry fruits, where y: is reflection intensity value according to type defect and x: is the type of defect (from 1 to 6 for each variety, 1: Standard, 2: Mold, 3: Insect, 4: Green tip, 5: Whit shoulder and 6: Green).

For detecting defect types of strawberry Festival variety

$$y = -4.1984x + 36.713$$

For detecting defect types of strawberry Fortona variety

$$y = -2.5015x + 20.448$$

For detecting defect types of strawberry Red marlin variety

$$y = -2.6687x + 26.113$$

For correlation factor (R^2), high correlation between reflection intensities values and strawberry defects was observed. The correlation factors were 0.8812, 0.9871 and 0.9766 for Festival, Fortona and Red Marlin varieties of strawberry defects, respectively.

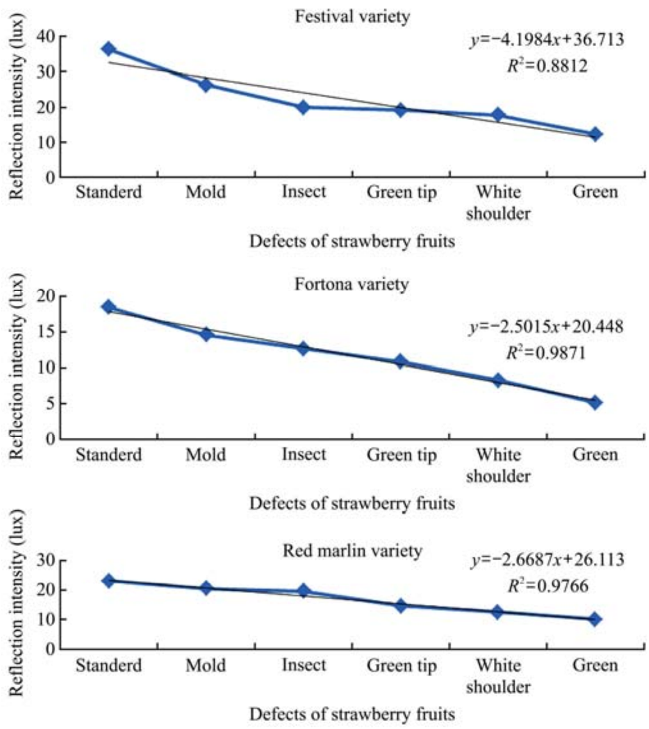


Figure 5 Relationships between reflection intensity and defect types of strawberry fruits using laser wavelength 543.5 nm

3.3.2 Electrical signal and strawberry fruits defects

Figure 6 showed the relation between electrical signal and strawberry defects using laser with wavelength 543.5 nm.

The following relationship will determine the type of defect of strawberry fruits, where y: is electrical signal value according to type defect and x: is the type of defect (from 1 to 6 for each variety, 1: Standard, 2: Mold, 3: Insect, 4: Green tip, 5: Whit shoulder and 6: Green).

For detecting defect types of strawberry Festival variety

$$y = -2.225x + 20.761$$

For detecting defect types of strawberry Fortona variety

$$y = -1.9179x + 15.467$$

For detecting defect types of strawberry Red Marlin variety

$$y = -1.7714x + 17.772$$

For correlation factor (R^2), it was found high correlation between electrical signal values of strawberry defects. The correlation factors were 0.9566, 0.9585 and 0.9614 for Festival, Fortona and Red marlin varieties of strawberry defects, respectively.

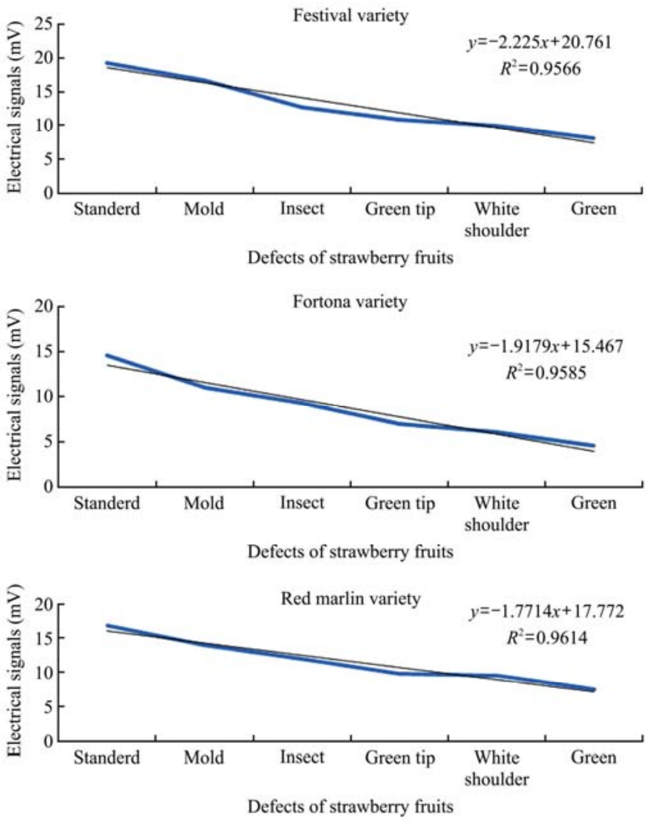


Figure 6 Relationship between electrical signals and defect types of strawberry fruits using laser wavelength 543.5 nm

3.3.4 Absorption intensity and strawberry fruits defects

Figure 7 showed the relation between absorption intensity and strawberry defects using laser with wavelength 543.5 nm.

The following relationship will determine the type of defect of strawberry fruits, where *y*: is absorption intensity value according to type defect and *x*: is the type of defect (from 1 to 6 for each variety, 1: Standard, 2: Mold, 3: Insect, 4: Green tip, 5: Whit shoulder and 6: Green).

For detecting defect types of strawberry Festival variety

$$y = 4.1984x + 4063.3$$

For detecting defect types of strawberry Fortona variety

$$y = 2.6687x + 4073.9$$

For detecting defect types of strawberry Red Marlin variety

$$y = 2.5015x + 4079.6$$

For correlation factor (R^2), high correlation between absorption intensity values of strawberry defects were found. The correlation factors were 0.8812, 0.9766 and 0.9871 for Festival, Fortona and Red marlin varieties of strawberry defects, respectively.

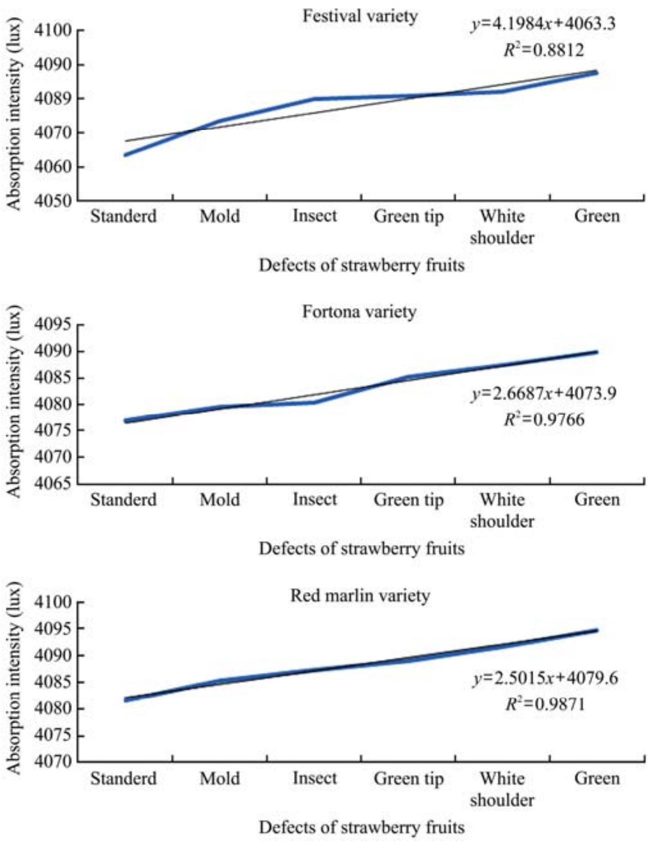


Figure 7 Relationship between absorption intensity and defect types of strawberry fruits using laser wavelength 543.5 nm

4 Conclusions

1. Based on the above, it was found that laser light could be used to evaluate the quality of strawberry fruits, since the external appearance of fruits , which indicated the quality factors of strawberry fruits .

2. Using these results in a small models works to identify the defects of strawberry fruits during the process of trading and sorting .

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