Science and Technology Indonesia
e-ISSN:2580-4391 *p*-ISSN:2580-4405
Vol. 3, No. 2, April 2018

Research Paper

Non-Destructive Measurement of Green Bitter Gourd Quality Component Using Near Infrared Spectroscopy (NIRS)

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Abstract
The quality component measurement of horticultural products becomes more important to achieve better quality products also to obtain uniform product. Recently, measurement by non-destructive methods turns out to be more needed, because consumers become more selective and demand producers to develop a quick, effective and accurate quality assessment system. Near Infrared Spectroscopy (NIRS) can measure plant contents quickly, relatively economical in a bigger scale, and importantly non-destructive. The measurement of quality components of green bitter gourd, such as firmness, water content, total soluble solid, and color, are important but have not been widely conducted. This research was conducted from June to August 2013 at Post Harvest Laboratory, Faculty of Agriculture, Padjadjaran University, Sumedang, Indonesia with PLS regression modeling method. The results show R-value and standard error of 0.91 and 0.47 for water content, 0.93 and 1.03 for firmness, and 0.95 and 0.49 for a* value of fruit color.

Keywords
bitter-gourd, fruit-vegetable, near-infrared, non-destructive method, quality measurement

Received: 20 November 2017, Accepted: 5 March 2018
http://doi.org/10.26554/sti.2018.3.2.59-65

1. INTRODUCTION

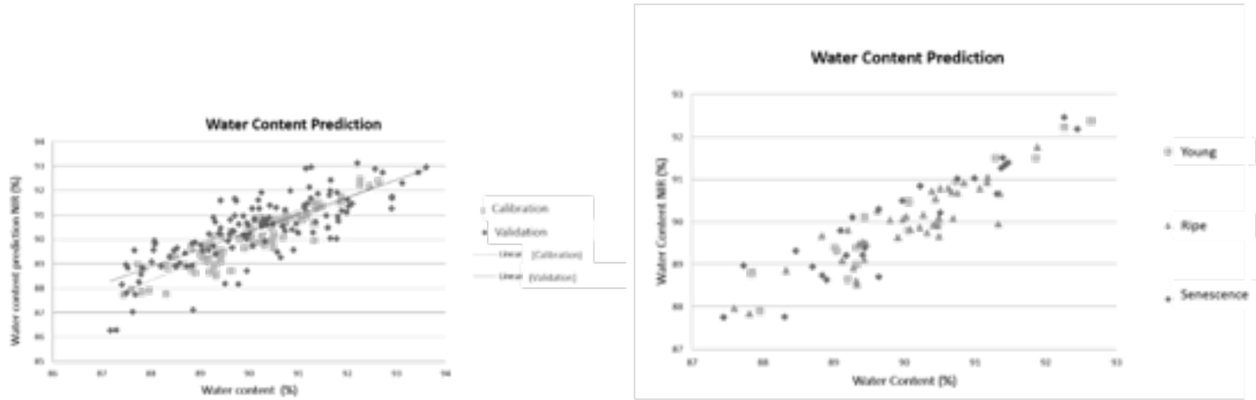
In Indonesia, bitter gourd is one type of vegetables that have quite high economic and social value; in addition to being consumed as a vegetable, bitter gourd has also been used as a traditional medicine. The bitter gourd farmer uses ripeness state to determinate appropriate harvest time. Level maturity is determined by fruit color change or calculating flowering and planting time. Based on machine sorting, yield loss is caused by uneven quality. In sorting, fruit hardness is used as an indicator of physical fruit quality, which determines storage feasibility and consumer acceptance of the fruit (Kader, 2002). Quality criteria are also determined by the chemical content such as total soluble solid, water content, sugar content, and composition (Saltveit, 2005).

All of the measurement of the quality criteria mentioned above can be predicted and sorted in an objective and non-destruction method by using a spectrometer (Saltveit, 2005). Several studies using a portable near-infrared spectrometer have been successfully carried out for fruits, including mango (Pornprasit and Natwichai, 2013), citrus (Magwaza et al., 2012), apple (Liu and Tang, 2015), and strawberry (Amodio et al., 2017). For the fruit-produced vegetable, the use of portable NIRS is still very limited for example to evaluate quality of tomato and eggplant (Kusumiyati et al., 2007; Martínez, 2013).

Lots of local Indonesian vegetables are potential to be exported but face constraints due to the uniformity of quality. Therefore, the portable NIRS - that has been widely recognized as a potential tool to determine the quality of vegetables and fruits - can be used to help obtain uniformity, in order to encourage the export of Indonesian vegetables in the world market. However, studies using portable NIRS on the vegetable in Indonesia are still very limited, especially on the bitter gourd that has never been done in a non-destruction method by using a portable NIRS.

Quality measurement using a non-destructive method enables bitter gourd quality measurement without physically damaging the fruit. Non-destructive measurement is very important to ensure the postharvest quality of bitter gourd and also to match the fruit quality rapidly and efficiently. The determination of the quality components of bitter gourd is firmness, water content, total soluble solids, and color.

Portable Near-Infrared (NIR) has advantages such non-destructive and in situ analyses, their development must consider some critical factors, such as cost, size, weight, power consumption, robustness, safety, user friendliness, durability, accuracy of measurement, and high performance reliability (Santos et al., 2013). In addition, this tool can also measure the quality of each component simultaneously. Many studies have been conducted to measure various different qualities of



(a) (b)

Figure 1. Graph of (a) comparison of water content value by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method and (b) Calibration of water content on different maturity stage of Bitter Gourd

food and other agricultural products (Cen et al., 2007). Near-Infrared (NIR) spectroscopy in the 700-1100 nm short wave or better known as the short wavelength near infrared (SW-NIR) spectroscopy has the potential to build a reliable system of quality assessment of fruit and vegetables in a non-destructive, rapid and accurate way (Suhandy, 2008).

2. EXPERIMENTAL SECTION

2.1 Materials and Instrumentation

The experiment was conducted in Postharvest Laboratory, Faculty of Agriculture, Padjadjaran University, Sumedang, Indonesia from June to August 2013. The materials used in this experiment are 300 bitter gourd samples. Harvested bitter gourd has different maturity stage which consists of young (100 pieces), mature (100 pieces), and senescence (100 pieces).

The devices used in this study are a portable NIRS (Nirvana Model AG410, Integrated Spectronics Pty, Ltd, Australia), calipers (CD-20 CPX, Japan), digital scales, a tension gauge (model AD-4932A AND-50 N, Taiwan), a refractometer (Atago Model 41 325, Japan), infrared thermometer, an oven for drying, stationery set, makers, knife, grater, aluminum foil cup, box CIE L * a * b * and the camera.

2.2 Methods

Component quality is observed in conventional and non destructive method on water content, fruit firmness, total soluble solids and color of bitter gourd. Measured components of bitter gourd fruit quality in two ways (non-destructive measurement using NIRS and destructive measurements) are the main objective of this research.

The research material harvested from the garden in Curugrendeng village, Jalan Cagak district, Subang, West Java, Indonesia, in the different maturity stage. The bitter gourd which needed for the experiment was 300 samples with five times harvest, each 60 fruit taken at each time of testing. Bitter gourd through the precooling stage for 12 hours at room temperature, then carried the NIR data collection in each sample, followed by measurement of the quality of each sample.

This research used the experimental method with multivariate data analysis by modeling. Data were collected by means of the conventional and non-destruction method by using a portable Near-Infrared Spectrometer, continued by raw data processing and advanced software using ISIS (Integrated Spectronics Pty, Ltd, Australia). Finally, the data were analyzed by Unscrambler multivariate data software (version 7:51, CAMO, Oslo, Norway). Absorption spectra of NIR transformed using ISIS software. Then the data will be analyzed using multivariate Unscrambler software (version 7:51, CAMO, Oslo, Norway) to create models of Mathematics in the analysis of water content, fruit firmness, total soluble solids, and color of bitter gourd fruit. Further analysis of the data followed by the calculation of calibration and validation.

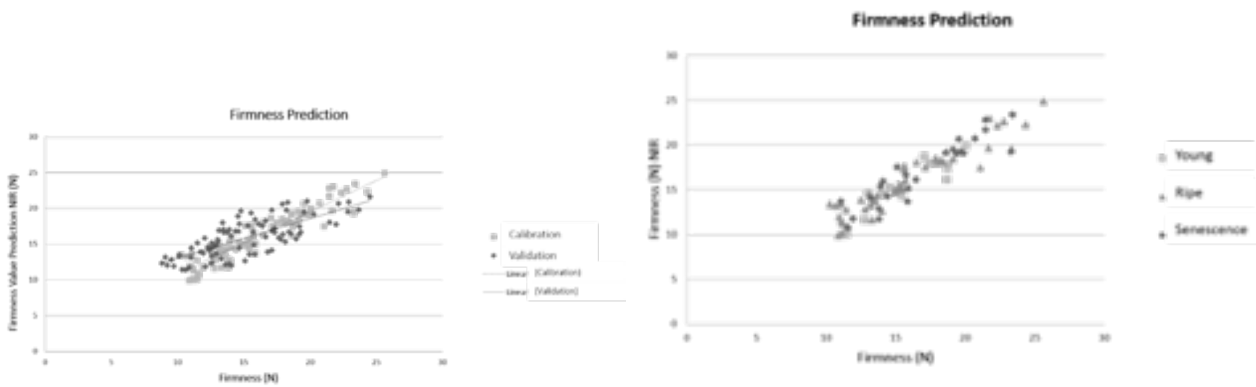
3. RESULTS AND DISCUSSION

3.1 Destructive Data Analysis of Bitter Gourd

Destructive measurement result of component bitter gourd used as reference data in calibration models development. This data will determine the success of predicting values of quality parameters using NIR. The results are presented in Table 1.

3.2 Near-Infrared Data Analysis of Bitter Gourd

Data analysis of bitter gourd was measured by reflectance and NIR absorbance data using multivariate data analysis with partial least square (PLS). PLS is used to predict the dependent variable from a set of independent variables are huge numbers, has a systematic structure of linear or non-linear, with or without missing data and has high collinearity. PLS is a bilinear modeling that many widely used to connect the physical properties of the material and content of the data spectrum.



(a) (b)

Figure 2. Graph of (a) comparison of fruit firmness by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method and (b) Calibration of firmness on different maturity stage of Bitter Gourd

Table 1. Conventional measurement data analysis result of 300 samples bitter gourd

Component	Ripening state	Mean	St dev	Min	Max
Water Content	Young	89.77	2.88	70.22	93.12
	Mature	90.08	1.63	84.18	93.38
	Senescence	90.24	2.08	81.74	94.03
	Combination	90.05	2.12	70.22	94.03
Firmness	Young	16.15	3.03	10.07	22.2
	Mature	15.93	3.4	9.37	25.63
	Senescence	16.4	4.03	9.35	28.61
	Combination	16.11	3.47	9.35	28.61
Total Soluble Solids	Young	3.77	0.44	2.83	4.97
	Mature	3.65	0.42	2.7	5
	Senescence	3.57	0.36	2.87	4.4
	Combination	3.66	0.42	2.7	5
L*	Young	80.3	1.99	74.95	85.61
	Mature	79.14	2.42	71.57	86.15
	Senescence	78.15	2.25	73.47	83.73
	Combination	79.18	2.39	71.57	86.15
a*	Young	-26.86	1.54	-30.76	-23.51
	Mature	-27.15	1.4	-30.2	-21.18
	Senescence	-26.67	2.02	-29.98	-20
	Combination	-26.96	1.62	-30.76	-20
b*	Young	38.7	3.82	32.4	55.18
	Mature	38.55	3.24	31.96	51.82
	Senescence	38.66	2.91	30.08	45.06
	Combination	38.62	3.31	30.08	55.18
Hue	Young	-55.13	2.01	-62.3	-50.69
	Mature	-54.78	1.84	-62.1	-50.43
	Senescence	-55.37	2.27	-62.3	-50.6
	Combination	-55.01	2.01	-62.3	-50.43
Chroma	Young	47.14	3.76	40.84	62.32
	Mature	47.17	3.2	39.97	59.16
	Senescence	47	3.03	38.61	52.95
	Combination	47.12	3.29	38.61	62.32

Table 2. Data analysis of calibration and validation phase of water content assessment based on absorbance data with partial least square method

	n	R	Min	Max	Ave	SD (%)	SE (%)
Cal	83	0.91	87.75	92.45	89.98	1.09	0.47
Pred	126	0.78	87.18	93.61	90.08	1.49	0.94

Table 3. Data analysis of calibration and validation phase of firmness assessment based on absorbance data with partial least square method

	n	R	Min	Max	Ave	SD (%)	SE (%)
Cal	82	0.93	9.92	24.89	16.12	3.59	1.39
Pred	89	0.75	8.84	24.54	15.13	3.61	2.39

3.3 Water Content Assessment

Correlation coefficient (R) for predicting values bitter gourd water content was 0.91, this value is quite good because close to one. In the calibration phase resulting standard error of calibration (SEC) of 0.47%. Validation phase estimation bitter gourd water content using the calibration of different samples of as many as 126 samples of the data and the NIR absorbance measurement data conventionally. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) was 0.97%. The standard error of validation is quite good because the value was close to zero.

In Figure 1b can be seen estimating water content bitter gourd taken at different maturity stage. The obtained water content data was not different because at the time of sampling bitter gourd done, maturity stage range is about 6 days of each maturity stage, so the range of water content values obtained are also not too different.

3.4 Firmness Assessment

Value of the correlation coefficient (R) for predicting values bitter gourd hardness is 0.93. In the calibration phase resulting standard error of calibration (SEC) of 1.39%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) is produced by 2.39%, while the standard error of validation is not good because the value exceeds one (1).

In Figure 2a, firmness value of bitter gourds sample from mature stage is higher than young and senescence stage because in mature stage, chemical content composition of bitter gourd become solidified. Whereas chemical content composition of bitter gourd in senescence stage decreased, so the firmness value become low. In addition, young stage bitter gourd not formed yet, so the fruit still tender that affected to firmness value.

3.5 TSS Assessment

Value of the correlation coefficient (R) to estimate the value of total dissolved solids in bitter gourd fruit was 0.96. In the calibration phase resulting standard error of calibration (SEC) of 0.13%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) was 0.25%. It was quite good because the value was close to zero (0).

In Figure 3, TSS of bitter gourd which tested from different maturity stage (young stage, mature stage, and senescence stage). The young stage showed higher TSS value than others stage and senescence stage fruit TSS is the lowest.

3.6 Color Value Assessment

Measurement of color is one of the methods used in assessing the quality of appearance (visual) of fresh horticultural products. Color measurements using a numerical color codes the data in the form of L*, a*, b* or often referred to as the notation "Hunter ". The notation L* states that the reflected light produces achromatic colors white, gray and black (0: black, 100: white). Decreasing or increasing the brightness value of L* means the darker the color of the fruit or even brighter. The a* values expressed a mixture of chromatic colors red and green with a+ value from 0 to 100 for red and -a from 0 to -80 for the color green. b* Values expressed chromatic colors mix blue and yellow with +b values of 0 to +70 for yellow and value -b to -70 for blue. Munsell method is based on three notation methods, Hue (green, red, blue, yellow), value (L value, or brightness that moves from light to dark or dark/bright or sunny) and Chroma (levels of colors that move from young color to old).

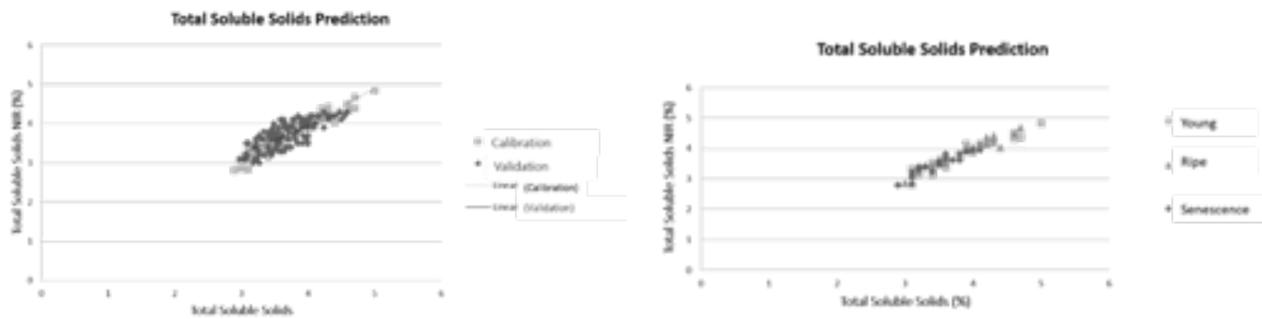
3.6.1 L* Value

Value of the correlation coefficient (R) to estimate the value of L* of 0.92. In the calibration phase resulting standard error of calibration (SEC) of 1.05%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) that is generated is 1.76 while the standard error of validation is not good because the value exceeds the value of one (1).

In Figure 4, can be seen the highest to the lowest of L* value was in mature, young, and senescence stage fruit. The higher the L* value the brighter bitter gourd color, so it can be

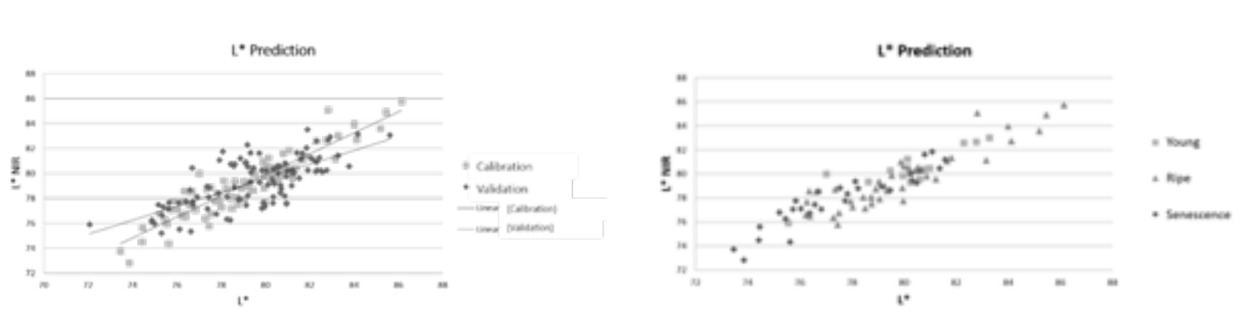
Table 4. Data analysis of calibration and validation phase of TSS content assessment based on absorbance data with partial least square method

	n	R	Min	Max	Ave	SD (%)	SE (%)
Cal	83	0.96	2.81	4.84	3.72	0.45	0.13
Pred	123	0.75	2.97	4.59	3.64	0.36	0.25



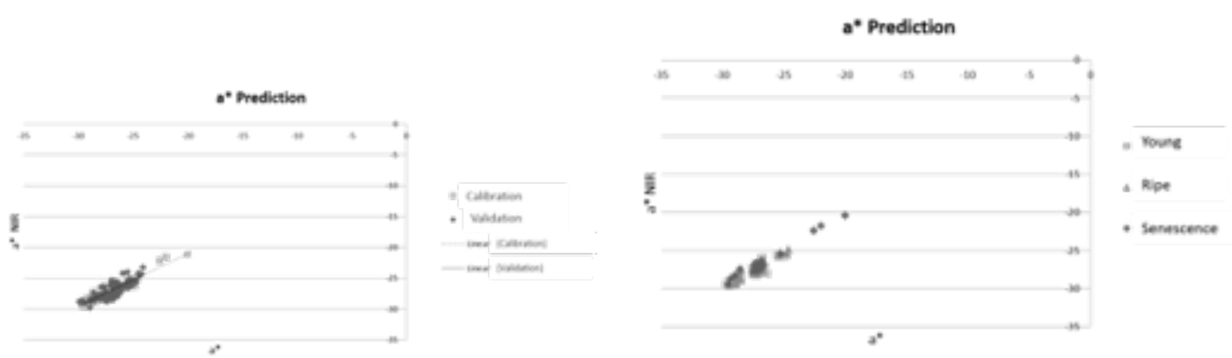
(a) (b)

Figure 3. Graph of (a) comparison of total soluble solids by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method (b) Calibration of TSS on different maturity stage of Bitter Gourd



(a) (b)

Figure 4. Graph of (a) comparison of L* value by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method and (b) L * value charts bitter gourd the different stadia maturity stage calibration



(a) (b)

Figure 5. Graph of (a) comparison of a* value by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method and (b) Calibration of a* on different maturity stage of Bitter Gourd

Table 5. Data analysis of calibration and validation phase of color value assessment based on absorbance data with partial least square method

		n	R	Min	Max	Ave	SD (%)	SE (%)
L*	Cal	83	0.92	72.82	85.75	79.14	2.48	1.05
	Pred	100	0.7	72.08	85.62	79.51	2.46	1.76
a*	Cal	82	0.95	-29.56	-21.12	-27.22	1.53	0.49
	Pred	127	0.8	-29.92	-24.07	-26.86	1.25	0.81
b*	Cal	81	0.83	31.99	45.03	38.67	2.68	1.78
	Pred	95	0.78	32.39	48.08	39.37	2.89	1.85
Hue	Cal	80	0.95	-62.35	-51.45	-54.82	2.09	0.7
	Pred	101	0.69	-57.95	-50.99	-54.21	1.39	1.15
Chroma	Cal	83	0.94	40.29	61.72	46.66	3.38	1.25
	Pred	86	0.64	41.25	59.45	47.98	3.94	3.03

seen that the mature stage fruit brightest than the senescence stage fruit which darker.

3.6.2 a* value

Value of the correlation coefficient (R) to estimate the value of a* of 0.95. In the calibration phase resulting standard error of calibration (SEC) of 0.49%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) is produced by 0.81%. The standard error of validation is quite good because its value is close to zero (0).

In Figure 5 below, can be seen the value of a* is the highest to the lowest was on the senescence, mature, and young fruit stage. a* values expressed a mixture of chromatic colors red green with a+ value from 0 to 100 for red and -a from 0 to -80 for the color green. The value of a* below gave effect on fruit maturity bitter gourd. The older bitter gourd, the highest green color which can be seen from higher a* value. Green color will lower at younger fruit of bitter gourd, this can be seen also from lower a* value in the graph below.

3.6.3 b* value

Value of the correlation coefficient (R) to estimate the b* value was 0.83. In the calibration phase resulting standard error of calibration (SEC) of 1.78%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) is generated by the standard error is 1.85% while the validation is not good because the value exceeds one (1).

In Figure 6a, can be seen the b* value from the highest to the lowest was on senescence, mature, and young stage fruit. b* value showed chromatic colors of blue yellow mix which +b values of 0 to +70 for the color yellow and value -b to -70 for blue. In the graph below we can see that b* value effect on fruit maturity bitter gourd stage. The older the bitter gourd, the higher yellow color of bitter gourd. It can be seen from the b* value that higher as well. While the young bitter gourd fruit show lessen yellow color, which also can be seen from lower b* value in the graph below.

3.6.4 Hue Value

Correlation coefficient (R) for Hue value prediction of bitter gourd was 0.95, respectively with the SEC and SEP value 0.70% and 1.15%. Based on the validation results obtained, the standard error of validation is not good because the value exceeds one (1).

In Figure 6b, can be seen the highest to the lowest Hue value was the senescence, mature, and young stage. Hue values affect the bitter gourd maturity. The older the fruit of the bitter gourd, green and yellow fruit color will be higher which can be seen from the higher of Hue value as well. Younger stage of bitter gourd fruit will have lower yellow color, this can be seen also from the lower Hue value in the graph below.

3.6.5 Chroma value

Value of the correlation coefficient (R) for Chroma value assessment was 0.94. In the calibration phase resulting standard error of calibration (SEC) of 1.25%. Based on the validation results obtained, it can be seen that the standard error of validation (SEP) is produced by 3.03% while the standard error of validation is not good because its value exceeds the value of three (3).

In the graph below (6c) can be seen the highest value to the lowest Chroma is young, mature, and senescence stage. Chroma values are levels of color that moves from young to senescence stage. Good graphics would be obtained if the value of the chroma of senescence stgae bitter gourd is higher than young and mature stage fruit. However at the chart below error occurs so that the highest chroma values obtained in young stage.

4. CONCLUSIONS

Non-destructive method using a portable NIRS can predict the quality of the components bitter gourd the different maturity stage.

Value of non-destructive method accuracy of the results obtained by using a portable NIRS study almost the same com-

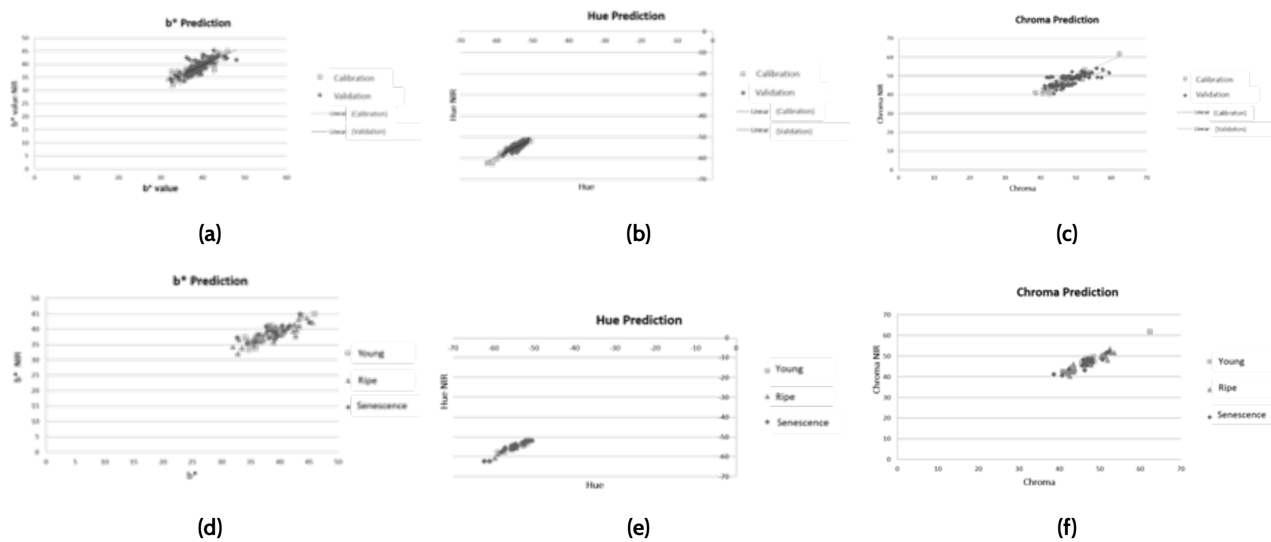


Figure 6. Graph comparison of (a) b*, (b) Hue, and (c) chroma value by NIR absorbance and conventional methods on the calibration and validation stages with the PLS method and (d) a*, (e) Hue, and (f) Chroma value charts bitter gourd maturity at different stadia in the calibration phase

pared to conventional method. At each observation variable correlation coefficient values obtained are close to one. Correlation coefficient of water content, firmness, total dissolved solids, L * value, a* value, b * value, Hue value, and Chroma value calibration was 0.91, 0.93, 0.96, 0.92, 0.95, 0.83, 0.95, and 0.94.

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