SCIENTIFIC NOTE

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POTENTIAL OF SPECTRAL REFLECTANCE AS POSTHARVEST CLASSIFICATION TOOL FOR FLOWER DEVELOPMENT OF CALLA LILY (*Zantedeschia aethiopica* (L.) Spreng.)

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ABSTRACT

Unsuitable postharvest management is one of the most serious problems that floriculture has to face. An option for reducing postharvest losses is to use automatic systems for flower sorting and classification, which yield consistent results, reduce costs and speed up these tasks. The objective of this work was show the potential of spectral reflectance to distinguish different postharvest development stages of calla lily flowers, *Zantedeschia aethiopica* (L.) Spreng., aiming the use of this technology within automatic systems for flower classification. The measuring equipment was a spectrometer connected to a portable computer and configured for reflectance data acquisition in the 400 to 1000 nm range. Based on the results, it was verified a differentiation between the spectral reflectance curves of calla lily flowers, with gradual decreases on the measured values according to the increase of the senescence stages. Thus, the spectral reflectance has potential to be used in the development of automatic systems for postharvest classification of calla lily flowers.

Key words: cut flowers, *Zantedeschia aethiopica*, spectrometer.

INTRODUCTION

Cut flower agribusiness is a promising activity and has great development perspective considering internal and external markets. However, it is essential to improve the product quality and sanity in order to meet the international market demand (Mutersbaugh *et al*., 2005). Among the problems that floriculture has to face, the unsuitable postharvest management is one of the most serious. In hot and wet tropical countries, as Brazil, postharvest losses could represent up to 25% of the total harvest (Weinberger and Lumpkin, 2007). Thus, researches for developing automatic systems for flower classification can contribute to the technological progress of the floriculture.

Most of flower classification job is performed by trained technicians, what could limit the improvement of services that fulfill the consumers' exigencies. Human visual classification is prone to mistakes since it is a subjective, monotonous, stressing and time-consuming task (Brosnan and Sun, 2002). An option for improving and speeding up the flower classification process is substitute the human operator by an automatic system based on the spectral reflectance of flowers. Among the characteristics of the study of the interaction between solar radiation and vegetation, spectral comportment of plants is highlighted, including the reflectance as the most analyzed phenomenon (Dickinson, 2008).

Based on spectral reflectance of vegetation is possible to identify differences and similarities between plants of same species (Vaiphasa *et al*., 2007), nutritional levels of plants (Min *et al*., 2008) and presence of pests and diseases (Goel *et al*., 2003). Information of reflectance can be obtained by satellites, images acquired from digital cameras coupled to aerial or terrestrial systems, spectrometers or other similar equipment (Gitelson *et al*., 2002).

In this context, the objective of this work was evaluating the potential of spectral reflectance of the spathes of calla lily flowers (*Zantedeschia aethiopica* [L.] Spreng.) to discriminate different postharvest development stages, aiming the use of this technology within automatic systems for flower classification.

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MATERIALS AND METHODS

Ten calla lily flowers were harvested on same day of reflectance measurements. The flowers were sorted in crescent order according to their postharvest development stages, starting with opening flowers and finishing with the senescent ones (Figure 1).

During the trial these flowers were conditioned in a recipient with water. Each stem was cut as closely as possible to the floral button before beginning reflectance measurements. Thus, it was possible to completely extend the flower spathe along the measurement table. Spathes were divided into four quadrants and punctual measures of reflectance were made in each one of them (Figure 2).

Spectral reflectance measures of calla lily flowers were carried out at the Laboratory of Artificial Vision and Machine Projects, located at the Department of Agricultural Engineering of the Federal University of Viçosa, Brazil. It was used a spectrometer (model SD-2000, Ocean Optics Inc., Dunedin, Florida, USA) connected to a portable computer. The spectrometer was configured to acquire and store reflectance data in the 400 and 1000 nm range, with a spectral resolution of 0.3 nm (Figure 2).

The spectrometer probe was composed by a bunch with seven optical fibers. Six of them are responsible for the light emission, generated by a controlled source (model LS-1 Tungsten Halogen, Ocean Optics Inc., Dunedin, Florida, USA), over the measured object (flower spathes). The other optical fiber is located in the probe center and captures the reflected fraction of the incident light under a vision field of 25º, transmitting it to the spectrometer. This probe was vertically directed downward, being inserted in a holder of anodized aluminum (model RPH-1, Ocean Optics Inc.). During the measurement period, this holder was located over the center of each quadrant of calla lily spathes. Also, a Spectralon mini panel (model WS-1, Ocean Optics Inc.) was used as white pattern to measure reflectance.

The reflectance values acquired by the spectrometer were calibrated by the software package OOIBase 32 (version 2.0), before be stored in computer. During the data acquisition, spectral reflectance was expressed as a relative percentage of the white pattern, as shown by equation described by Xing and Baerdemaeker (2005):

$$\rho_\lambda = \left\{ \left(S_\lambda^{flower} - D_\lambda^{dark} \right) / \left(\rho_\lambda^{white} - D_\lambda^{dark} \right) \right\} 100 \qquad [1]$$

where ϱ_λ is the spectral reflectance of the flower (%), S_λ^{flower} is the intensity of the reflected energy in the flower (dimensionless), D_λ^{dark} is the intensity of the reflected energy considering light absence (dimensionless), ϱ_λ^{white} is the spectral reflectance of the Spectralon mini panel (dimensionless). All these parameters are applied considering a wavelength λ.

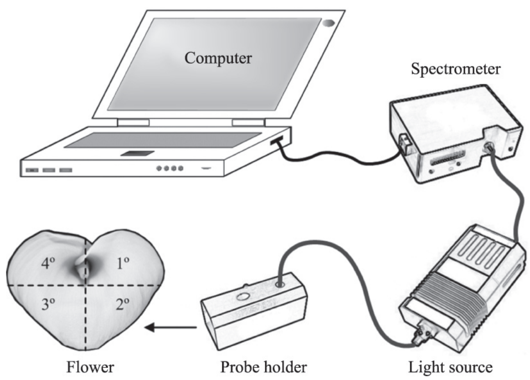

Figure 2. Scheme of the equipment used for measuring the spectral reflectance of calla lily flowers.

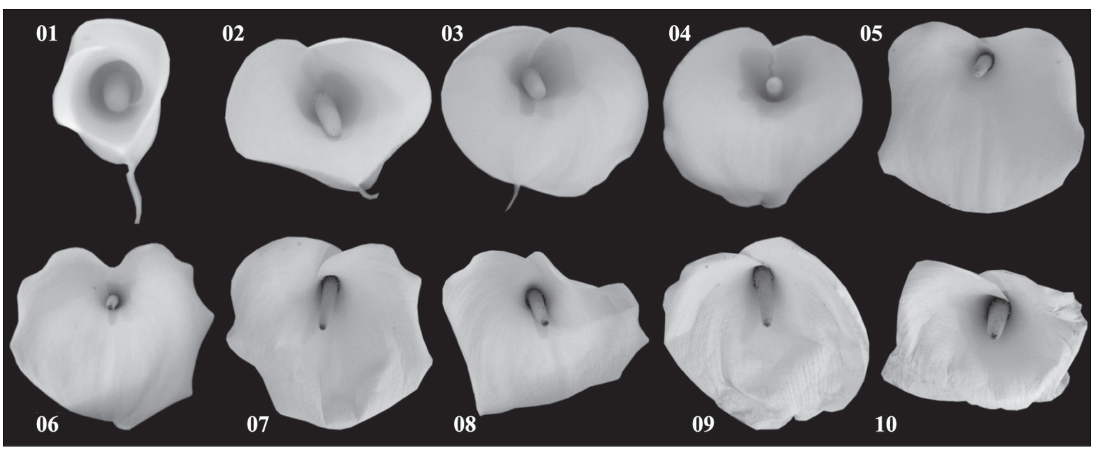

Figure 1. Digital images of calla lily flowers sorted according different postharvest development stages.

The intensity of the reflected energy considering light absence was obtained by obstructing the light input at the aluminum holder and turning off the light source. Also, the total reflectance of each spathe was calculated by using the arithmetic average of its four quadrants.

To analyze statistically the postharvest development stages of calla lily flowers, a randomized experimental design was used with 10 treatments (postharvest development stages) and four replications (spectral reflectance measures of the four quadrants of each spathe). For each treatment it was plotted a spectral reflectance curve based on the average values of the measures, considering wavelengths in the 400 and 1000 nm range. Using the SigmaPlot software (version 10.0) a nonlinear regression analysis based on the Hill sigmoidal model with three parameters was applied to each spectral reflectance curve. With this model, coefficients of determination (R^2) greater than 95% were obtained for all regressions. Finally, the coefficients of the three parameters obtained in each regression were submitted to a confidence interval analysis ($P < 0.05$).

RESULTS AND DISCUSSION

In a general way, reflectance was high for all flowers, so much for spectral range of visible light (400 to 700 nm) as for spectral range of infrared radiation (700 to 1000 nm) (Figure 3). This result can be mainly justified by the presence of pigments, called flavonoids, which are responsible for the white color of the spathe of calla lily flowers. These pigments absorb radiation in the ultraviolet region of spectrum and reflect in the visible one (Yu *et al*., 2006). However, in spite of the similar spectral comportment of the curves, it was verified that the measured values decreased with the increase of senescence. Gates and Tantrapporn (1952), cited by Ponzoni (2001), also verified that the reflectance of leaves in the visible region of spectrum decreases with the senescence intensification.

Moreira (2007) affirmed that the main factors that influence spectral comportment of leaves are the amount and types of pigments, water and air contents, internal cellular structures and maturation and senescence stages. This affirmation is also valid for petals and sepals since, according to Esau (2000), these floral organs are similar to leaves when considering their internal structure and biochemical composition.

Specifically in the spectral region comprehended between 400 and 460 nm, it was observed an expressive increase of reflectance, which was more accentuated for flowers in initial development stages. From 460 to 920 nm, high and about constant values of spectral reflectance were verified. In the other hand, observing the near infrared region (920 to 1000 nm), it was verified progressive reductions in the reflectance of all calla lily flowers. This decreasing tendency can be attributed to the radiation absorbed by the water contained in spathes. According to Niemann *et al*. (2002), one of the absorption peaks occurs at 970 nm.

Flowers in advanced senescence presented an increase in reflectance at wavelengths between 800 and 920 nm (Figure 3, flowers 7 to 10). This rise can be explained by the changes in the optical properties of spathes due to reflection, transmission and absorption of incident radiation. That is, during the senescence process, the yellow pigmentation of the external borders of spathes was evidenced, as well as, according to Moreira (2007), an increase in the intercellular spaces of spathes occurred.

The confidence intervals of the three parameters obtained with the Hill sigmoidal model for each nonlinear regression are presented in Table 1. Despite some confidence intervals associated with parameters B and C overlap, the spectral reflectance curves were considered statistically different due to the confidence intervals of parameter A never overlap ($P < 0.05$).

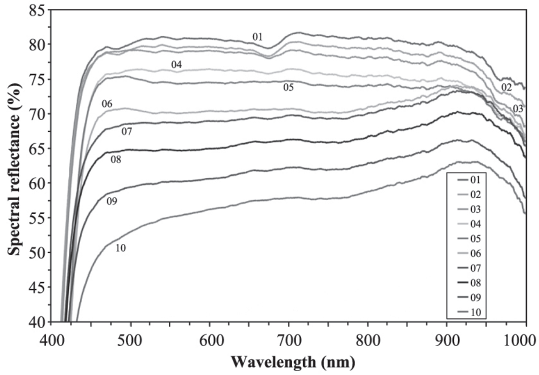

Figure 3. Spectral reflectance curves of calla lily flowers.

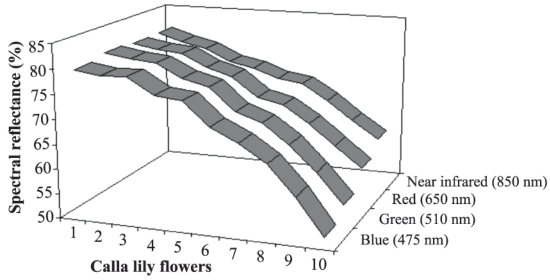

Figure 4. Spectral reflectance curves of calla lily flowers for typical wavelengths of blue, green, red and near infrared.

Table 1. Confidence intervals of the three parameters of the Hill sigmoidal model for each nonlinear regression associated with the postharvest development stages of calla lily flowers.

Postharvest stages	Confidence intervals		
	Parameter A	Parameter B	Parameter C
1	[79.737, 79.903]	[45.405, 47.539]	[413.091, 413.497]
2	[78.360, 78.549]	[45.111, 47.610]	[412.495, 412.969]
3	[77.362, 77.585]	[47.954, 51.054]	[414.134, 414.668]
4	[74.850, 75.044]	[52.031, 54.730]	[423.901, 424.348]
5	[73.607, 73.772]	[51.877, 54.227]	[421.984, 422.373]
6	[70.964, 71.087]	[49.302, 50.960]	[423.449, 423.757]
7	[69.771, 69.924]	[40.967, 42.822]	[415.832, 416.275]
8	[66.431, 66.599]	[40.711, 42.835]	[415.896, 416.407]
9	[62.125, 62.327]	[35.051, 37.276]	[417.335, 418.045]
10	[58.233, 58.510]	[23.201, 24.950]	[424.265, 425.534]

Figure 4 presents the spectral reflectance curves of the calla lily flowers for typical wavelengths of blue (475 nm), green (510 nm), red (650 nm) and near infrared (850 nm). Despite wavelength band of the near infrared extends to around 2500 nm, the average value of the 700 to 1000 nm range was used because of a limitation in the measurement span of the spectrometer.

The spectral reflectance curve associated with the wavelength of blue presented the greater variation considering all postharvest development stages of calla lily flowers. However, the spectral reflectance values associated with the wavelength of near infrared allowed a best differentiation between the postharvest development stages from 1 to 5. Besides, for distinguishing the postharvest development stages from 6 to 10, it was verified that the spectral reflectance of the wavelength of blue presented best results (Figure 4).

CONCLUSIONS

Based on the results, it could be affirmed that the different postharvest development stages are characterized by temporal and intrinsic changes in calla lily flowers, which also impose significant changes in spectral reflectance. Therefore, it was concluded that spectral reflectance has large potential to distinguish different postharvest development stages and can be used within automatic systems for calla lilies classification.

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RESUMEN

Potencial de la reflectancia espectral como herramienta para la clasificación poscosecha del desarrollo floral en cala (*Zantedeschia aethiopica* [L.] Spreng.). El manejo poscosecha inadecuado es uno de los problemas más serios que la floricultura tiene que enfrentar. Una opción para reducir las pérdidas poscosecha es emplear sistemas automáticos para ordenar y clasificar las flores, los cuales permiten resultados consistentes, reducen gastos y aceleran estas tareas. El objetivo de este trabajo fue demostrar el potencial de la reflectancia espectral para discriminar las diferentes fases de desarrollo poscosecha de flores de cala (*Zantedeschia aethiopica* [L.] Spreng.), visando el uso de esta tecnología en sistemas automáticos para la clasificación de flores. El equipo de medición fue un espectrómetro conectado a un computador portátil y configurado para la adquisición de datos de reflectancia comprendidos en la región espectral de 400 a 1000 nm. Con base en los resultados, se constató una diferencia entre las curvas de reflectancia espectral, con reducciones graduales en los valores medidos de acuerdo con el aumento de la senescencia. Por tanto, la reflectancia espectral tiene potencial para ser empleada en el desarrollo de sistemas automáticos para clasificación poscosecha de flores de cala.

Palabras clave: flores de corte, *Zantedeschia aethiopica*, espectrómetro.

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