ESPECTROSCOPIA DO VISÍVEL E INFRAVERMELHO PRÓXIMO (VIS/NIR) NA AVALIAÇÃO DA QUALIDADE DE MANGAS TOMMY ATKINS [1]

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RESUMO- A espectroscopia na região do visível (VIS) e do infravermelho próximo (NIR) apresenta-se como uma promissora e rápida tecnologia de avaliação das características internas de várias espécies de frutas. A diferença de absorbância, provenientes dos frutos, ao serem submetidos a um espectro emitido entre dois comprimentos de onda próximos ao do pico de absorção da clorofila-a, foi utilizada para o desenvolvimento de um índice (Índice DA- IDA) que se correlaciona ao estádio de maturação dos frutos. Neste trabalho, objetivou-se avaliar as relações existentes entre o índice DA, obtidos com o equipamento DA-meter®, e os parâmetros físico-químicos de maturação utilizados em mangas da cultivar Tommy Atkins, na separação dos frutos em categorias distintas. Para isto, foram utilizados frutos pertencentes a um mesmo lote e adquiridos em um centro de distribuição local, na cidade de Pelotas-RS. Com os resultados obtidos, através do índice DA, foi possível separar os frutos em categorias de acordo com o grau de maturação, demonstrando a grande heterogeneidade com que os frutos são oferecidos ao consumidor, e as relações entre os valores dos índices DA e os parâmetros de qualidade, determinadas através dos coeficientes de determinação (R^2), foram significativas para os atributos estudados.
Termos para indexação: Mangifera indica, qualidade, técnicas não destrutivas.

VISIBLE SPECTROSCOPY AND NEAR INFRARED (VIS/NIR), IN ASSESSING THE QUALITY OF MANGOES TOMMY ATKINS

ABSTRACT – Visible spectroscopy (Vis) and near infrared (NIR) are presented as promising and fast technologies in the evaluation of internal characteristics of several fruits. The difference in absorbance, from the fruits, when subjected to a spectrum emitted between two wavelength next to the absorption peak of chlorophyll-a, was used for the development of an index (DA-IDA), which correlates with the stage of maturation. This work aimed to evaluate the relationship between the index (DA-IDA), obtained by the equipment DA-meter®, and the physicochemical parameters of ripening used in mangoes from the cultivar Tommy Atkins, to separate the fruits in distinct categories. Fruits belonging to the same lot and purchased in a local distribution center, in Pelotas, RS, were used. The results obtained through the (DA-IDA) allowed dividing the fruits in categories, according to the ripening stage, showing the high heterogeneity of fruits available to consumers. The coefficients of determination (R^2) obtained through the (DA-IDA) index and the quality parameters were significant for the attributes studied.
Index therms: Mangifera indica, quality, non destructive techniques.

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INTRODUCTION

The production of mangoes is one of the main activities of agribusiness in Brazil, presenting a increasing performance in the past years, reaching the ranking of sixth biggest world producer in 2008 (FAOSTAT, 2011).

The success of the Brazilian participation in the foreign market is allied to the technological level adopted, which allows the service to international quality standards and the harvest still in the early stages of maturation. This allows her achieve a good quality for consumption and resist the procedures for handling and transport (LIMA et al., 2009).

In mango, the ripening identification is based, mainly, in the observation of the roughness and brightness of the shell, the filling or the formation of the "shoulder" in the region of the peduncle, firmness and color, both peel and pulp, soluble solids (ºBrix), ratio of soluble solids and acidity, and others. However, it is recognized that these elements are prone to the error and has not been used successfully in some cultivars (SUBEDI et al., 2007).

One of the main problems found in mangoes destined for fresh consumption, *in natura*, or processing, is the unevenness of fruit ripening on the same lot. Although numerous goals and maturation rates are available, almost none of them are used in practice because they are mostly destructive and hard to perform in the field (SIGRIST et al., 2004).

According to Xavier et al., (2009), another aspect that must be emphasized is that the mangoes offered to the consumer become less attractive, losing their value. Because they do not present a good appearance, are commercialized in a no uniform stage of ripening, getting close to another kind of fruits, beyond being stored without any kind of refrigeration and in non strategical places in supermarkets, reaching temperatures relatively high, reducing the useful life from the fruit.

Visible Spectroscopy (Vis) and near infrared (NIR) is presented as a promising and fast technology in the evaluation of internal characteristics of several fruits. The spectroscopy explores the light proprieties, measuring the energy generated by the interaction with the sample molecules in a spectrum of variable length (OSBORNE, 2000). Studies involving the application of infra-red to evaluate the ripening in mangoes are reported by literature (SCHMILOVITCH et al., 2000; SARANWONG et al., 2004; SUBEDI et al., 2007; VALENTE et al., 2009), however, this approach still requires a complex processing of data to build models of calibration and prediction (CEN; HEN, 2007).

The development of an index (DA-IDA) which characterizes changes of maturation in fruits calculated with base in the difference of absorption between two wavelength emitted next to the peak of absorption of chlorophyll-a (chl-a). Related in studies from Ziosi et al., 2008 and characterized as a evaluation of the system above said, proposing detect a value without the requirement of calibrations (COSTA et al., 2008a).

In climacteric fruits, the difference of absorption obtained between two wavelengths next to the chl-a peak (index of absorption difference IDA) was related with high content of chlorophyll in the fruit skin. This relation was checked through the levels of emission of ethylene, quality characteristics and transcription of genes related to both the maturity at harvest and in processes that occur in the shelf life of fruits (ZIOSI et al., 2008).

Estimating chlorophyll content present inside the fruit, and being this an indicative of the ripening point, the DA index may allow the knowledge of the state of maturity of fruits of an independent way in the climate progress, which influences others parameters traditionally used. The DA index presents a scale from 0 (very mature fruits) to 5 (extremely green fruits) and this index allows supervise the physiological alterations that occurs during the ripening. Each type of fruit has a particular index as each phase of ripening (TURONI, 2009).

From the foregoing, the objective is to evaluate the potential of the spectroscopy, through separation of fruits, from a distribution center site, in categories according to maturity and the relationship between the DA index (DA-IDA), obtained with DA-meter® equipment and parameters used in ripening mango cultivar Tommy Atkins.

MATERIAL AND METHODS

Mangoes fruits of the cultivar Tommy Atkins presented different maturations degrees from the San Francisco Valley, PE, Brazil, were obtained in a fruit distribution center in the city of Pelotas/RS and used for the determination of the ripening level.

It was used a total of 120 fruits (3 boxes belonging to the same lot), which in each fruit it was obtained the DA level through the use of the portable spectrophotometer DA meter® (Turony/ Italy). The reading were realized in a standardized way at the dorsal and ventral bases in the mangoes (picture 1) in which using the average obtained between the readings, the mangoes were grouped in 4 categories which are established in accordance with the recommendations of Assis, (2004).

CAT01 - Index DA >2: equivalent to categories 1 and 2 (ASSIS, 2004);
CAT02 - Index DA between 1,0 and 2,0: equivalent to categorie 3 (ASSIS, 2004)
CAT03 - Index DA between 0,5 and 1,0: equivalent to categorie 4 (ASSIS, 2004);
CAT04 - Index DA < 0,5: equivalent to categorie 5 (ASSIS, 2004).

The DA index was evaluated in two periods: first, in the moment of the categories division (0h) and after two days (48h) in order to monitor the ripening of fruit in ambient conditions (±25ºC).

Past the 48h period, beyond the DA index, were analyzed the physicochemical parameters in a individual way in order to characterize the categories and correlate this values with the DA index obtained. The analysis were: color – realized by the colorimeter Minolta 450, with illuminant D65, and 8 mm opening, in the system registered by Comission Internacionale of I'Eclairage L*, a* and b* (CIE-Lab), expressed in degrees, by the formula hº= tan-1b*/a*, flesh firmness (FF) with a digital penetrometer (model 53205, TR, Forli, Italy) being the results articulated in Newtons (N), soluble solids (SS) with a digital refractometer (Atago PR32), the results expressed in ºBrix, to evaluate the fruit acidity, the method was based on the neutralization of acids in the fruit juice with a base solution (NaOH 0,1N) and acidity values were expressed in meq NaOH/100mL. All the physicochemical analyses were realized in the basal and dorsal regions of fruits, with exception acidity, which was, realized the full extraction of fruit juice.

DA Index

The DA index are obtained through the portable spectrophotometer DA-meter brand Turoni-Italy (picture 1). The light beams are emitted at wavelength of 670 nanometers (visible) and 720 nanometers (infra-red), in which the product obtain the signals of interctance (I) and absorbance (A) of the fruits and the index calculation is based, according to Noferini et al., (2009), in the Lambert Beer law ($A = \log 10\ I^{-10}$) being calculated as:

$$I_{DA=} A_{670} - A_{720}$$

A_{670} and A_{720}, were the Absorbance values of fruits in wavelength of 670 and 720 nanometers, respectively. DA index is a patent belonging to University of Bologna/Italy (2005). The equipment consists of a light source composed of six LEDs, positioned around a photodiode. Three diode LEDs emit wavelengths of 670nm and other three in length 720nm. The fruits are submitted to light of short duration with two monochromatic sources and within each, the amount of light remitted from the fruit is captured and measured by the central photodiode. The light received then is converted in one "Adc conver- ter" ("analog to digital con- verter") and elaborated by a micro-controller for the DA index calculation. (COSTA et al., 2010).

The design of the experiment consisted in a single factor (class) with three repetions of 10 fruits each class, for data analysis was used a average comparision test (Tukey, P<0,05). The statistical analysis of data is also consisted in the construction polynomial regression between the averages of the destructive parameters (physical-chemical) and DA indexes obtained by using the program WinStat version 2.0 (MACHADO; CONCEIÇÃO, 2002).

RESULTS AND DISCUSSION

With the DA index averages obtained and based on the classification used by Assis, (2004) the fruits were distribute in four categories according to ripening stage that they presented as demonstrated in picture 2. With the formation of these categories it was possible the fruit division in homogeneous classes according to them maturation stage. Studies realized in peaches (ZIOSI et al., 2008), apples (McGLONE et al., 2002) also reported the division of the fruits based on the index presenting differences on the quality parameters as in the harvest time as in the shelf-life of these fruits.

The DA index measuring with an interval of 48 hours, demonstrated a difference in the mean values obtained during this period, as demonstrated in Picture 3, in which there was a decrease of this index in all categories evaluated. The DA index is obtained through the answer emitted by the fruit to the light emission in wavelengths next to the chlorophyll-a peak, then the correlation with chlorophyll concentration present in the skin fruit is high (ZIOSI et al., 2008). This result is consistent with previous studies from Noferini et al.,(2008),(2009), which, working with apricots, peaches and nectarines characterized the DA index decreasing during the ripening process as reflex to chlorophyll degradation in the flesh.

The structural decomposition of this pigment occurs due several factors that act singly or in conjunct during the maturation process, among them can be cited the pH changes caused mainly by the accumulation of organic acids and others compounds in the vacuoles; activation of the enzyme chlorophyllase and the presence of oxidant systems (CHITARRA; CHITARRA, 2005).

In the physyco-chemical characterization

of the formed classes, was observed a significant difference for the maturation parameters evaluated (Table 1).

For skin color, the visual observation were confirmed by the system CIE L*a*b*, by calculating the hue angle (Table 1). In the category of highest DA (>2,0)(class 1), was observed an angle of 88,89º (next to green), while the lowest category (<0,50) (Class 4) the value found was 50º(yellow). Changes in the hue angle assure difference of color in mature and immature fruits, mainly when confirmed with high determination coefficient and in mangoes, the fruit must be colorful, because the green color is associated with a immature fruit (LUCENA, 2006).

Similar behavior was watched for flesh firmness and acidity parameters, where the fruits classified as class 4 (highest DA-IDA), present significant difference compared to others classes, featuring fruits more firm and acid. The decrease of the acidity values can be associated to ripening and maturation, due to the consumption of acid in the respiratory process (MORAIS et al., 2002) or in routes of conversion of the flavoring components. According to Jerônimo et al. 2007, loss of acidity is desirable in most fruits and outstanding in the ripening process.

Lucena et al. (2000), studying the physico-chemical characterization of mango Tommy Atkins in different ripening stages, verified that the average of firmness in fruit is decreasing with the advance of maturation, fact confirmed in this study. The firmness changes during the ripening result, predominantly, in the disruption of the cell wall (TUCKER, 1993), involving a complex interaction of the activities of amylose, galactose and pectinases with physical-chemical changes in the wall, (JERÔNIMO et al., 2007), causing, by this, the fruit mollification.

In literature, Medlicott and Reynolds (1988) recommended the mango harvesting with firmness ranging from 107,84 to 127,45 N and Alves et al., (2002), with firmness of 129,41 N. The values detected in this study are found below the reported, this fact is justified by fruits belonging to distribution center localized in a market away from the producer zone.

About the soluble solids, it is observed that although the Class 4 (DA <0,5) presents the highest mean, this is not different from other classes formed. According Assis, (2007), levels above 10º Brix indicate the the harvest has been reached. The soluble solids are dependent on the maturation satge of harvest, ang generally increase during ripening dueto the biosynthesis or degradation of reserve polysaccharides (Chitarra & Chitarra, 2005).

Through linear regression analysis, it was possible to verify that the DA index has a good relation with the quality parameters color (R^2 0,80), flesh firmness (R^2 0,71), acidity (R^2 0,68) soluble solids (R^2 0,50) (picture 4), being these normally used to define the point of harvest in mangoes.

The fruits from the different classes are not only uniformed according to qualitative characteristics, but according a study developed by Ziosi et al., 2008 in peaches and nectarines f in two years in a row it was observed that the emission of ethylene also has high correlation with the DA index, may indicate indirectly the evolution of the ethylene emission in fruits that show climacteric behavior. By this, the values from the determination coefficient found can be explained by the behavior of emission of ethylene which mango fruits present.

Correlations between the DA index with quality parameters depend on the attribute studied and the specie in study (DERKX et al., 2010), due the tropical culture of the mango, data used in the DA index with the called harvest index are incipient , however, in cultures like apples (DERKX et al., 2010), different cultivars of peaches and nectarines (ZIOSI, et al., 2008), kiwi, (NOFERINI et al., 2009) are related in literature, with efficient application of this technique as in the field monitoring (COSTA et al., 2008b) as in the commercializing period of the fruit.

According to Sigrist et al., 2004 if the harvest is determined by using any tool or equipment, it is recommended to be calibrated periodically to be in accordance with the Technical Norms for the National Mango Integrated Production (LOPES et al., 2003), however this technology is not interfered with the temperature of the fruit, requires virtually no calibration and can be used on fruits of various cultures and species around a certain DA values of the indices, typical of each cultivar, these remain constant each year regardless of the values of quality parameters, which are usually employed and that change every year in response to climatic conditions (ZIOSI et al., 2008).

FIGURE 1- Portable Spectrophotometer DA-meter (Turoni/Italy). Foto: Betemps,2010

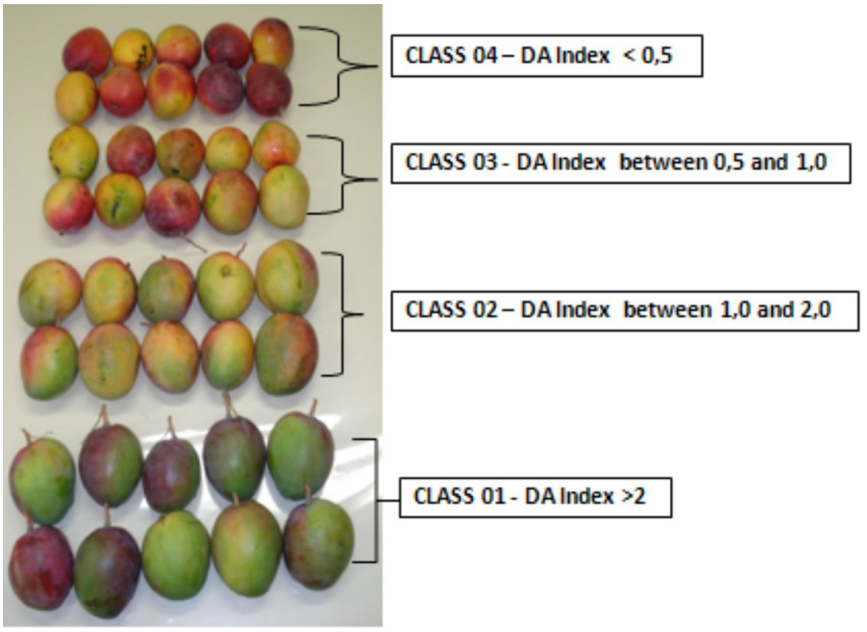

FIGURE 2- Different categories formed according to the DA index obtained in "Tommy Atkins" mangoes using the spectrophotometer DA-meter ® - Pelotas, 2010.

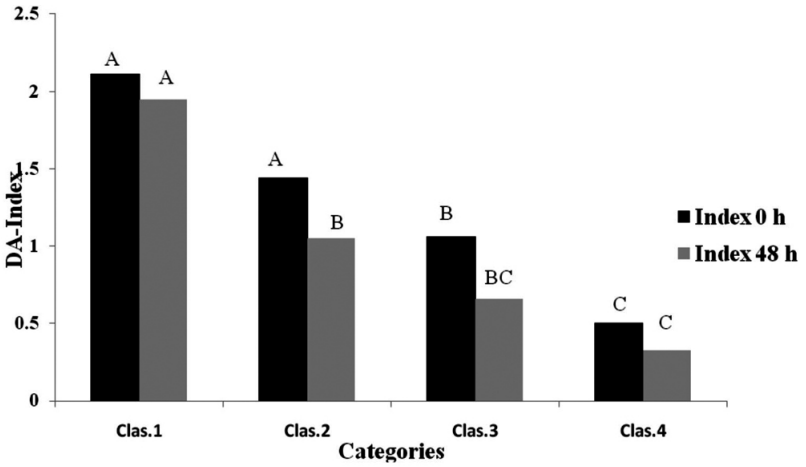

FIGURE 3- Mean values of the DA index obtained in the classes formed with "Tommy Atkins" mangoes in the 0 h (zero) and 48 h of evaluation- Pelotas, 2010.

TABLE 1- Mean values found to color (hue angle), soluble solids (ºBrix), flesh firmness (Newtons) and acidity (meq in NaOH/100ml) in mango fruits in different categories formed.

Categories	° Color	Soluble Solids	Firmness	Acidity
Class 1	88,89 a*	11.25 b	57.74 a	13,21 a
Class 2	71,57 b	12.37 ab	50.66 b	6,34 b
Class 3	66,62 c	12.21 ab	12.35 c	4,04 c
Class 4	50,00 d	13.13 a	4.34 c	3,76 c
CV	**2,39**	**4,79**	**8,95**	**10,10**

* Averages followed by the same letters do not differ significantly by the Tukey test (5%).

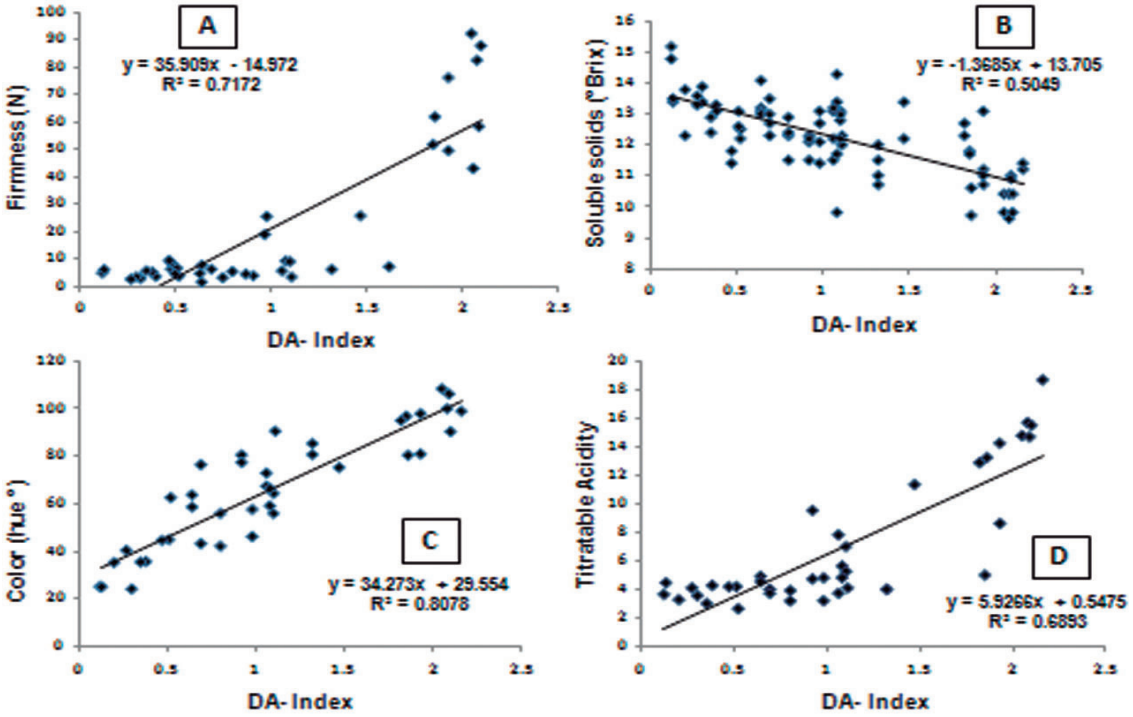

FIGURE 4- Correlation among the DA index and the flesh firmness (A), soluble solids (B), hue angle (C) and acidity (D) in Tommy Atkins mangoes fruits – Pelotas/RS- 2010.

CONCLUSIONS

The DA index allows the separation of the fruits in different categories of maturation. The values of the DA index presented excellent relation with the attributes of quality normally used in 'Tommy Atkins' mangoes.

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