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REVIEW ARTICLE

VISION BASED QUALITY ASSURANCE OF FRUITS (ORANGES) WITH PHYTOCHEMICAL CHARACTERISATION OF BIOACTIVE COMPOUNDS

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ABSTRACT

Classification of agricultural products is a necessity for agricultural marketing to increase the speed and minimize the misclassification. One of the main problems in the automation of modern farming and production regards the selection of good fruits from the whole crop. The selection process in the fruits is very difficult in the market through manually. Some attempts at automatic classification using traditional computing resources and algorithms have been made. Unfortunately the average classification times for each orange using such methods are too long for an efficient real-time application. It is easily understood that the classification of fruits based on their digitized images can be improved and simplified if useless details are removed from these images. This paper is based on the phytochemical characterization of the bioactive compounds such that the reference image can be obtained more accurately, because the color and texture of fruits are the result of its composition. And also involves the development of algorithms for quality inspection of oranges by defining three quality classes (extra, I and II) for the fresh oranges. The fruit in the extra class must be of superior quality with no defects and high volume, whereas the classes I and II are moderately and highly defective fruits with less volume respectively. The methodology involves a two step process. The first step is to segment the image into defect and non defect classes by utilizing histogram based thresholding. According to second step three different approaches have been proposed. In the first approach of the second step texture features are extracted from GLCM. Second approach combines color and texture by extracting features from color GLCM.

INTRODUCTION

A. Quality control

Quality control is the evaluation of a final product prior to its marketing, i.e. it is based on quality checks at the end of a production chain aming at assigning the final product to quality categories such as " high quality", "regular quality", "low quality" and "non-marketable". Since , at the end of the production chain, there is no way to correct production failures or upgrade the quality of the final product, the low-quality products can only be sold at lower prices and the non-marketable products have to be discarded. Their production costs, however, had been as high as those of the high and regular quality products.

B. Quality inspection of fruits

For a long time, the agro-industry has attempted to automate fruit selection in order to increase the quality of the production and decrease production costs. Citrus are one of the major fruit products in Fruit industry. Most of this production exported for fresh consumption, where consumers increasingly demand best quality. Nowadays, the competitions among the producers have increased with lower production costs and quality products. Moreover, inspection and classification tasks are made manually, which is subjective and varies among different experts or along the day. For these reasons, automatic inspection by means of machine vision is a priority in order to ensure products with an excellent quality.

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C. Bioactive compounds- phytochemicals

Plants contain certain chemicals such as carotenoids, flavonoids, biflavonoids, phenols, phytosterols, etc. that possess antioxidative properties. Carotenoids - Group of antioxidant nutrients present in many fruits and vegetables. These are further composed of α-carotene, β- carotene, Cryptoxanthin, Lycopene, Lutein & Zeaxanthin. They are present in red, dark orange & yellow fruits such as carrots, peaches, broccoli, pumpkins, sweet potatoes etc. Flavonoids - Scavenge free radicals and combat pathological disorders generated by phytochemicals' Reactive Oxygen Species (ROS). Phenols - Prevent oxidative damage of tissues from ROS of DNA, RNA, enzymes, proteins and has anti-inflammatory properties.

D. Fruit color and texture versus bioactive compounds

Citrus fruits have attractive colors, texture and flavors, in all these properties carbohydrates play a very important role. Attractive colors of many fruits are due to sugar derivatives of anthocyanidins. Major pigments gives colors to fruits are chlorophylls, carotenoids, and anthocyanidins. During growth and maturation especially in immature stage, chlorophylls predominate in the peels of the citrus fruits. There is rapid synthesis of carotenoids in the chromoplast during ripening which is accompanied by simultaneous loss of chlorophylls. While ripening, total carotenoids increases in the peel as well as in the pulp. Phenolics play an important role in plant defense and fruit coloring Phenolics determines color and flavor of fruits and also actively play role in the mechanism of resistance of fruits to disease and insects. The concentration of Flavinoids increases with decrease in fruit size and maturity.

QUALITY ASSURANCE (QA)

To provide consistent quality products to satisfy the market or the consumer the following vital criteria are to be maintained in any quality assurance system.

- Market description
- Quality Assurance plan
- Identify hazard and
- Establish control point
- Establish acceptance levels
- Monitoring system for each control point
- Corrective plan and verification procedure

The quality assurance plan can be implemented in various stages including Preharvest, Harvesting and Postharvest periods of agro management.

A.METHODS OF QUALITY ASSURANCE

The quality of fruits can be assured by two methods
o Sampling Inspection
o Cent percent Inspection

Limitations of Sampling Inspection

- Risk of making wrong decisions
- In sampling inspection only a part is inspected, it is inevitable that the sample may not always represent the exact picture obtaining in the lot and hence there will be likelihood of making wrong decisions of the lot.
- The sample may usually provide less information about the product than 100 percent inspection.
- Some extra planning and documentation is necessary.

B.Cent percent inspection

In 100% inspection all parts or products are subjected to inspection.

Manual Methods

In manual methods the inspection is carried out by labors in which the grading of fruits may not be accurate. It is a time consuming process were the labor may be stressed of handling a single job for hours together. And hence it affects the productivity drastically.

Vision Based Method

Computer vision is a rapid, economic, consistent and objective inspection technique, which has expanded into many diverse industries. Its speed and accuracy satisfy ever-increasing production and quality requirements, hence aiding in the development of totally automated processes. This non-destructive method of inspection has found a wide application in the inspection and grading of fruits and vegetable. In vision based method the standardised image is identified by training a number of fruits by suitable methods which are again on a physical basis. In this paper the reference image selection for various classes is based on its composition which is achieved by the characterisation of the bioactive compounds because the color and texture of fruits are the results of its composition.

METHODOLOGY

A.Reference selection

The reference fruits for vision based quality are arrived from phytochemical characterization of fruits.

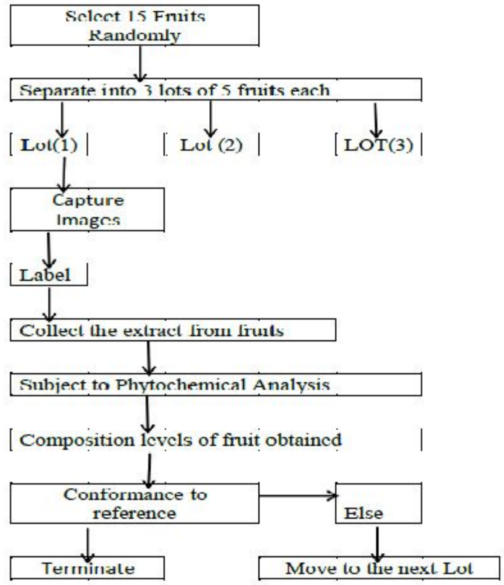

Figure 1. Reference Selection

B. Phytochemical Analysis of BioActive Compounds

Determination of total phenol content

Total polyphenol content of the extract was determined as described by Dewanto *et al*. (2002). An aliquot of 300µl of diluted exract were introduced into test tubes followed by 1.5 ml of a folin ciocalteaus reagent (10 X) dilution and 1.2 ml of Sodium Carbonate (7.5% W/V) and test tubes were vortexed for 15 seconds and allowed to stand for 30 minutes at 40ºC for color development. After incubation the absorbance as measured at 760nm. Total phenolic content was expressed as mg tannic acid equivalent per gram of DW (mg TAE g DW). Through the calibration curve with tannic acid, ranging from 0 to 10 mg/ ml. All the samples were analysed in triplicates.

Estimation Of Total Flavinoids Contents

Total flavinoids were measured by a calorimetric assay according to Dewanto *et al*. (2002). An aliquot of diluted sample was added to a 75µl of Sodium Nitrite(5%) and mixed for 6 minutes before adding 0.15ml of Aluminum Chloride(10%).After 5 minutes 0.5 ml of Sodium Hydroxide was added. The final volume was adjusted to 2.5 ml with distilled water and thoroughly mixed. Absorbance of the mixture was determined at 510 nm. Total flavinoids contents was expressed as mg catechin per gram of DW (mg CE/ g DW), through the calibration curve of catechin ranging from 0 to 100 µg/ml. All the samples were analyzed in triplicates

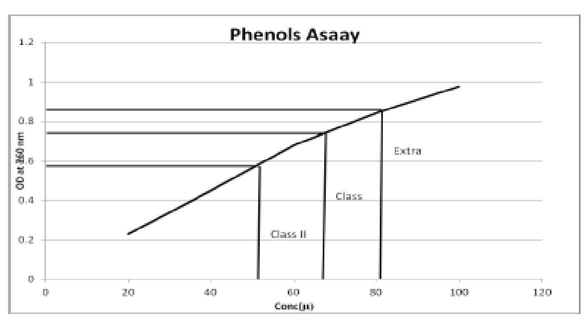

Figure 2. Plot of Total Phenol Content

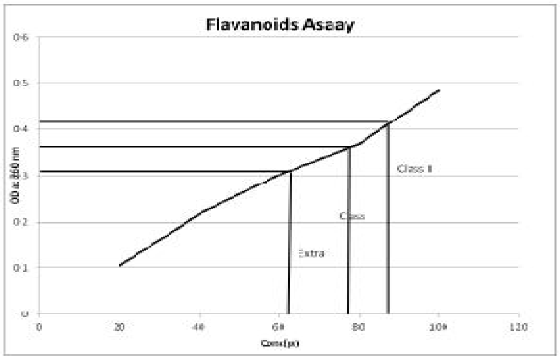

Figure 3. Plot of Flavinoids content

Estimation of Total Carotenoids

Carotenoids are some of the most vital colored phytochemicals, occurring as all-*trans* and *cis*-isomers, and accounting for the brilliant colors of a variety of fruits and vegetables. Carotenoids extensively studied in this regard include β-carotene, lycopene, lutein and zeaxanthin. Coloration of fruits and vegetables depends on their growth maturity, concentration of carotenoid isomers.

HPLC Analysis

For analytical HPLC a YMC column (4.6 mm i.d. _ 25 cm, Hampsted, NC) was used, which consisted of polymeric C-18 material that was chemically bound to 5 ím silica and not end-capped. The initial solvent composition consisted of 90% MeOH, 5% water, and 5% MTBE. The solvent composition changed in a linear fashion to 95% MeOH and 5% MTBE at 12 min. During the next 8 min (20 min of running time), the solvent composition was changed to 86% MeOH and 14% MTBE. After reaching this concentration, the solvent was gradually changed to 75% MeOH and 25% MTBE at 30 min. Final composition was reached at 50 min and consisted of 50% MeOH and 50% MTBE. All solvent changes were made in a linear fashion. Initial conditions were re-established in 2 min and re equilibrated for 15 min before the next injection. Flow rate was 1 mL/min. Injection volume was 20 íL

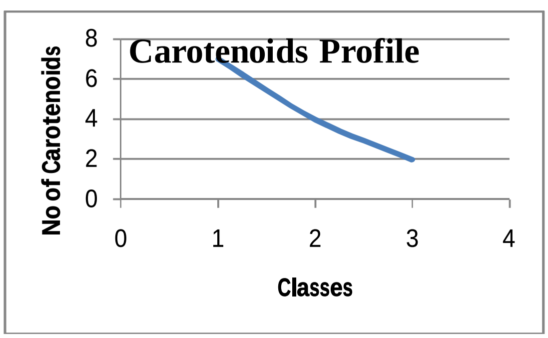

Figure 4. Carotenoids Profile

B.Vision Based Method

Many researchers have made considerable efforts in the field of machine vision based classification of oranges. Several approaches like monochrome-colored-near infrared imaging and local-global methods have been tried. This work presents an industrial application where a combined texture and colour analysis technique is used for the classification of fruits. Colour and texture have been largely studied and many methods have been proposed in order to handle machine vision problems where colour and texture features serve as a cue for segmentation and classification. Various statistical descriptors have been proposed for the measure of image textures many of these techniques were first proposed for processing greyscale images, and then were extended for colour texture processing. This project involves in the development of algorithms for quality inspection of oranges by defining three quality classes (extra, I and II) for the fresh oranges. The fruit in the extra class must be of superior quality with no defects and high volume, whereas the classes I and II are moderately and highly defective fruits with less volume respectively. This project first proposes a two step algorithm for defect detection and classification of orange fruits.

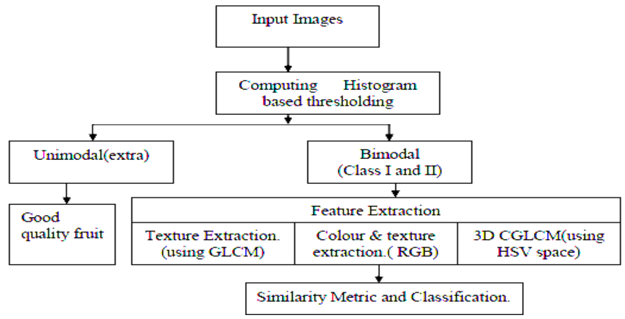

Figure 5 Vision Based Method

D. Gray-Level Cooccurence Matrix Method

Hara lick *et al* first introduced the use of co-occurrence probabilities using GLCM for extracting various texture features. GLCM is also called as Gray level Dependency Matrix. It is defined as "A two dimensional histogram of gray levels for a pair of pixels, which are separated by a fixed spatial relationship." GLCM of an image is computed using a displacement vector *d*, defined by its radius δ and orientation θ. Consider a 4x4 image represented by figure 5.2 with four gray-tone values 0 through 3. A generalized GLCM for that image is shown in Figure where #(i,j) stands for number of times gray tones *i* and *j* have been neighbors satisfying the condition stated by displacement vector d.

Following notations are used to explain the various textural features:

p_{ij} = (i, j)th entry in GLCM

$p_x(i)$ = ith entry in marginal probability matrix obtained by summing rows of

$$p_{ij} = \sum_{j=0}^{N-1} P(i, j).$$

N_g = Number of distinct gray levels in the image.

Few of the common statistics applied to co-occurrence probabilities are discussed ahead.

1) Energy:

$$ASM = \sum_{i=0}^{255} \sum_{j=0}^{255} p(i, j)^2$$

2) Entropy:

$$Entropy = -\sum_{i=0}^{255} \sum_{j=0}^{255} p(i,j) \log p(i,j)$$

3) Inertia:

$$Inertia = \sum_{i=0}^{255} \sum_{j=0}^{255} p(i, j, d) * (i - j)^2$$

4) Homogeneity:

$$Homogeneity = \sum_{i=0}^{255} \sum_{j=0}^{255} p(i, j, d) \frac{1}{1 + (i - j)^2}$$

5) Correlation:

$$correlatio\ n = \sum_{i,j=0}^{N-1} P_{i,j} \left[\frac{(i - \mu_i)(j - \mu_j)}{\sqrt{(\sigma_i 2)(\sigma_j 2)}} \right]$$

6) Mean:

$$\mu_i = \sum_{i,j=0}^{N-1} i\left(P_{i,j}\right)$$

7) Variance:

$$\sigma_i^{\,2} = \sum_{i,j=0}^{N-1} P_{i,j}\left(i-\mu_i\right)^2$$

RESULTS AND DISCUSSIONS

A. Thresholding, Segmentation and GLCM

Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. Histogram of an image with 256 levels of grey will be represented by a graph having 256 values on the X-axis and the number of image pixels on the Y-axis. Then histogram based thresholding is done for the query image in the training set. After getting the histogram plot, it have to be examined. If the plot is unimodal then the fruit has no defect and it is of extra class. And if the plot is of bimodal then it means that it is a defected fruit. Because for a fresh and undefected fruit, the colour will be uniform so the graph will be unimodal. Where as a defected fruit may have more than a colour, so the histogram plot will be bimodal. This way in this stage itself the extra class fruits are sorted out. The class I and class II images are classified in the forth coming methods. Segmentation is a process of portioning an image into non intersecting regions such that each region is homogeneous and the union of no two adjacent regions is homogeneous. Histogram is obtained from the images.

Figure 6. Images under Study

Segmentation is a process of portioning an image into non intersecting regions such that each region is homogeneous and the union of no two adjacent regions is homogeneous. In thresholding the defected parts are highlighted and segmented out.

B. Simulation Results

The GLCM technique is applied to all the oranges. This is helpful for easy implementation.

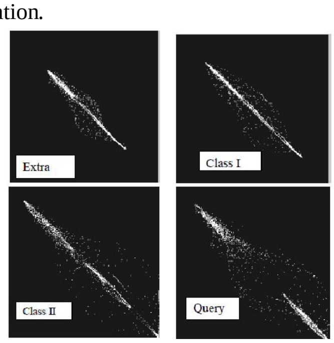

Figure 7. Simulation Results

Thus by viewing the matrix obtained in the above figures, we can categorize the quality of the orange. Thresholding gives better results. On part of segmentation if the affected area is wider, then it will be categorized under poor quality and if it is narrow, it will be classified as medium quality. Thus by easy implementation using simulation in Mat lab, the orange is classified in the appropriate quality. After histogram thresholding, GLCM method is used to extract features. This is applied only to the defect and the variations in the defect is also analyzed in depth and their Energy, Entropy, Inertia and Homogeneity are calculated for 0 radians, And these values are standardized. These values will be used for any orange to be tested.

Table 1. Texture Features of the Three Classes

	Extra	Class I	Class II
Contrast	416.5000	406.7422	227.5406
Energy	0.0200	0.0246	0.0449
d	16.6600	16.2734	10.0662
Entropy	7.8240	7.7728	7.1083
Mean	24.5000	25.0605	29.7714
Variance	18.0806	18.4594	19.2779
Coarseness	6.4000e-009	1.2517e-007	2.0487e-008
Roughness	416.5000	406.7422	227.5406

We take a sample orange and the textural features like energy, entropy, inertia and homogeneity for it is calculated and the sum of the square of their distance is calculated and we compare the result with the standardized value and will be grouped under the one which has minimum difference.

The test image computations

Feature	Values
Contrast	295.6742
Energy	0.0380
D	12.4494
Entropy	7.3707
Mean	29.7486
Variance	20.3736
Coarseness	2.4381e-008
Roughness	295.6742

From the results obtained the fruit taken for classification is identified as class II. Likewise any number of fruits can be classified

Conclusion

This thesis involves the development of algorithm for the classification of citrus fruits based on the phytochemical characterization of the bioactive compounds that influences color and texture of the fruits. We have collected a set of and orange fruits which includes both defective and non-defective fruits. The defect detection of fruits is not only based on the texture alone. More sophisticated techniques use a combination in using color bands for texture feature computation. Texture features were computed in greyscale and combined with colour GLCM. This scheme has the advantage of effectively encoding complex non homogenous textures where irregular components are present and textures lacking repetitive patterns. These textures can be characterized by the spatial co-occurrence of their color components making the GLCM a suitable method for our analysis. We first used GLCM on these fruits and the results have been tabulated.

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