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Image processing based acrylamide detection from fried potato chip images using continuous wavelet transform

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A R T I C L E I N F O

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A B S T R A C T

Fast foods like potato chips and French fries are very common and easily available. The preparation process of such food items is a detrimental factor in deciding if the item is suitable for consumption. Identification of presence of toxic substances like acrylamide in potato chips through conventional methods are time consuming and destructive and needs trained manpower. In the proposed work, an automatic image processing based technique is proposed to detect presence of acrylamide in fried potato chips. The potato chip area is segmented from its background followed by extraction of discriminatory features in the continuous wavelet transform domain using Morlet wavelet. The discriminatory features are analysed strategically and fed to LOOCV based Support Vector Machine classifier to identify presence of acrylamide in the potato chips. The proposed method has an accuracy of 98.33% with 100% specificity. Convincing results and fast computational time indicates that the proposed work can be used for development of non-destructive real-time applications for food quality monitoring.

1. Introduction

Fast foods like potato chips and French fries are cheaply and easily available in the market and people consume it on the regular basis. They find it tasty and more importantly convenient. These food items are popular among all age groups of people. Although, the preparation of such food items is easy and tastes good, yet the preparation process of these items is one important thing which should be taken care of. The oil and its temperature used for preparation play an important role in keeping these food items healthy and edible (https://nutritionfacts.org/2015/07/21/why-deep-fried-foods-may-cause-cancer/).

When food items, particularly containing carbohydrate, are fried, baked or roasted at the higher temperature (above 120 °C) generates harmful carcinogenic compound (Krishnakumar and Visvanathan, 2014). In potato, this harmful carcinogenic chemical is known as acrylamide. Acrylamide generally does not occur naturally in the potato. It is formed when a reaction of a chemical compound asparagine occurs with reducing sugar. Study based on cancer risk from French Fries has also shown that if a pregnant woman takes such highly deep-fried chip or fries daily then it causes inflammation as well as progression in the cancer (Rommens et al., 2008). Cancer risk level depends upon the percentage of the acrylamide present in the potato chips which in turn depends how long and at what temperature they are fried (Thonning Olesen et al., 2008). Researchers had found out that French fries and potato chip which are baked or fried at higher temperature and for long duration contains acrylamide whose level are more than the considered level of safety to be consumed (Svensson et al., 2003).

Various traditional and conventional laboratory methods exist to detect the presence of acrylamide in fried food items. Such methods involve breaking or damaging of the samples prior to analysis. Examples of such analysis are liquid chromatography (VuralGökmen et al., 2005) and gas chromatography (Reza Ghiasvand, 2016). But these associative analysis takes a lot of time as well as they are very expensive and not easily available in the many food inspection laboratories. It also requires trained manpower to carry on these processes (Pedreschi et al., 2010).

In last few years some work has been reported in non-conventional work for identification of toxic substances from carbohydrate foods and some relevant work are included below.

A colorimetric detection method to detect acrylamide from thermally processed item was proposed by Hu et al. (2016). It can visually detect acrylamide on the basis of Michael addition reaction which is based on nucleophile initiated thiolene. The amount of acrylamide can be determined by visible change in colour which is caused by dispersion/aggregation of gold nanoparticles (AuNPs).

Pedreschi et al. (2006) developed a method to measure color of heterogeneous food items using their shape and color in different color space. Also, they had established a relation between the kinetics of

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change in color of the potato chips when it is fried at different temperatures. They concluded that change in color of potato chips can be related to formation of acrylamide.

Dutta et al. (2015) proposed a work which involve image processing technique of identification of acrylamide chips from normal chips samples. They had applied discrete wavelet transform domain to analysis the discriminatory features of both classes of chips samples and then applied k-NN classification technique for proper and efficient identification of acrylamide samples. They had also proposed (Dutta et al., 2016) a non-destructive method to find out presence of acrylamide, neurotoxin substance which is common in starch containing food items when they are fired at higher temperature like potato chips. In this work analysis and identification is done in spatial domain. Textural and statistical features are obtained in time domain from the segmented image. SVM classifier is used for identification of acrylamide chip samples and reported an accuracy of 94%.

Yorulmaz (2012) proposed a method for inspection of food that includes the detection acrylamide in cookies when they are fried or cooked at higher temperature and detection of fungal infection in corns. Mottram et al. (2002) had shown that acrylamide is formed in the starchy food items when it is subjected to high heating condition. This occurs due to Maillard reaction between amino acids. Many other researchers also worked on the problem and reported presence on this harmful substance in baked or fried potato food items.

Results of the above-mentioned works are encouraging and may develop interest for many researchers to work more in this field. These works present automatic machine vision which employs non-destructive image processing system for analysis of different classes of potato chips. This might help in increasing the quality of fried food items, which in turn may prove beneficial for people to consume healthy food items and protect them from cancer causing possibilities. Such automated systems have an advantage over conventional methods as these methods provide non-destructive inspection of food item (Brosnan and Sun, 2003). They are cheap and can provide a decision in real time scenarios. Although some work has been already done in this field, yet there is still a need for development of an image processing based real time algorithm which can be helpful in determining the presence of cancer causing chemicals in food items based on visual changes that occur in the samples during preparation.

The main contribution of this work is an automatic method which is a non-destructive and efficient image processing algorithm to identify acrylamide containing potato chips samples. The proposed method employs the segmentation of the area of potato chips from the sample images using an adaptive intensity based threshold to make methodology accurate and invariant of illumination conditions. Wavelet transformed image coefficients are analysed properly and strategically using machine learning. Wavelet domain has with a specific property of performing time-frequency analysis which suits the detection of acrylamide from the images as the occurrence of acrylamide makes discriminatory changes in spatial as well as frequency distribution of the chip image. Discriminatory features are strategically selected and then subjected to classifier based on machine learning. The proposed method has achieved an accuracy of 98.33%. The results are convincing and suggest that the proposed work can be used for development of some real-time application.

The rest of the paper is structured as follows: Section 2 discusses the databases that has been used in the proposed work. Section 3 describes the image processing methods which have been used in the proposed work for the segmentation of the potato chips from the sample image and feature extraction from the segmented image. Section 4 includes experimental results which have been obtained after implementing the proposed method on the dataset of potato chips samples. Section 5 presents the conclusions derived from the results obtained in previous section.

Fig. 1. Setup for image acquisition of the potato chips sample.

2. Materials and methods

2.1. Formation of potato chips samples

For the proposed work, the potato chip samples were prepared in the laboratory. Raw materials required in potato chips preparation are potato and edible vegetable oil. Firstly, the raw potatoes are peeled and washed thoroughly to remove the relatively humidity. Then the washed potatoes are sliced into slices of thickness of 2 mm. Immediately, the sliced potato are rinsed to remove the starch from the surface of sliced potato chips. These sliced potatoes are fried at different temperature and duration in refined oil to form the potato chips (temperature varies from −120 °C to 180 °C) (Pedreschi et al. (2006)).

2.2. Image acquisition system

Images of the potato chips samples used for experimentation were acquired using an image acquisition set up as shown in Fig. 1. It consists of 4 CFL bulbs and 3 fluorescent lights for illumination purpose as well as to avoid reflections. These lighting bulbs have been placed at an angle of 45° so that uniform intensity of light can be given to the samples. Digital camera has been installed vertically just above the sample at a distance of 25 cm. For avoiding lighting effect and reflection from the surrounding, inner wall and the base of the setup box was painted with white color. The digital camera used in the proposed work for image capturing is of 8 mega-pixels and the image captured by this camera has resolution of 3100 × 1746 pixels. The sample images taken by the camera are in JPEG format.

2.3. Analysis of acquired images for acrylamide identification

The images of the potato samples were captured and subjected to image processing techniques for analysis. Every image is independent as it has characteristics and properties different from others. So, in order to apply a single evaluation technique to all sample images, some pre-processing steps are applied which may prove beneficial in highlighting the object of interest in the images. Next, the pre-processed images are subjected to segmentation techniques in order to segment the highlighted regions from the image. A segmentation algorithm may contain some noises which can hamper the accuracy and effectiveness of the system. Thus, such noises are removed using some post-processing modules. Finally, the feature extraction and classification is done on all samples to correctly differentiate the normal samples from the acrylamide samples. This is demonstrated using a block diagram in Fig. 2.