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Estimation of Percentage of Adulteration using Structural Similarity Index

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Abstract*: Adulteration in food supplies to reduce the cost and thereby compromising in its quality is an ever-growing problem in the food industry. In the past, adulteration estimation was done using chemicals and infrared spectroscopy methods. In this paper, adulteration estimation of chili powder contaminated with brick powder is done by means of Structural Similarity (SSIM) Index and the performance for various levels of contamination is evaluated. SSIM provides a measure of structural similarity between two images i.e. test image and reference image. This work has been carried out to identify contamination in a given sample of chili powder and estimate the approximate level of contamination. Experimental results show that SSIM measure provides an accurate estimate of the degree of contamination.

Keywords*: : Computerized Adulteration, Luminance masking, Pseudo Noise Ratio, Structural Similarity.

I. INTRODUCTION

Food is essential for sustaining life. Additional substances which when added to food that can degrade its quality is termed as adulteration. Contamination in food may occur due to the greed of some producers who compromise with the hygiene of uninformed consumers. This ultimately results in the consumer being a victim of food malpractices. Contaminated food also poses a serious threat to the health of consumers. Since the adulteration in food occurs in the most primitive form, consumers are unable to verify its authenticity by visual inspection or odour. Adulteration may either involve mislabeling the products or introducing a cheaper item to an expensive item having similar color and texture.

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It is in the interest of the consumers that we detect the contamination in food and look for ways to estimate the degree of contamination.

For long, detection in adulteration has been done using chemicals. Using chemicals for adulteration detection has its own risks. With the emergence of better image capturing devices and image processing algorithms, we can replace these conventional methods with a much less harmful method. Analysis of textures is a subdomain in image processing that has seen great development in the past recent years. Difference in the surface textures is an important criterion for detecting the adulteration. We use this criterion to test for adulteration in chili powder. SSIM (Structural Similarity Index) is a metric which helps to capture the perceptual difference between two reference images.

II. PRIOR WORKS

Earlier works involved the use of chemicals and infrared spectroscopy to test adulteration in the food products. As certain adulterants could go undetected while using chemicals it cannot be considered as an efficient way for detection. Most works involve detecting the contaminants when in liquid form. Infrared spectroscopy performs well for liquid foods but doesn't perform the same way solid foods like spices. Infrared spectroscopic methods [2] have not proven effective for the detection of adulterated spices since common packaging materials have shown various signatures in frequency range. Hence it would prove difficult to differentiate between the packaging material and that of the adulterants. Moreover, this method does not give us any estimate on the degree of contamination.

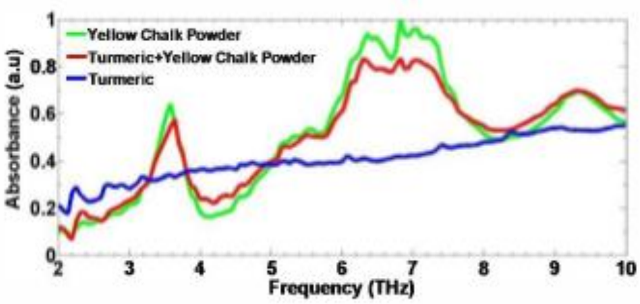

Fig. 1. Results of spectroscopic analysis of turmeric sample adulterated with chalk powder. [3]

Detection of adulterants using simple color based chemical reactions [4] have been in use for a long time.

These are performed with available chemical reagents. Major drawback of these techniques lies in the fact that these are valid only for particular concentrations and not sufficiently precise.

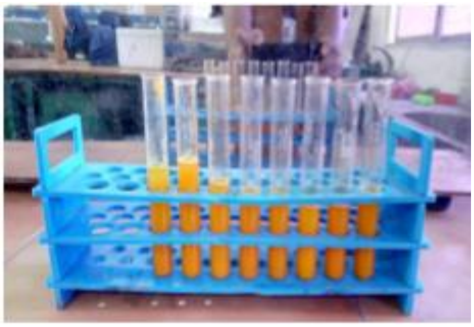

Fig. 2. Chemical means of adulteration detection for turmeric powder [5]

III. PROPOSED SYSTEM

The experimental setup consists of two powdered samples which is analyzed using MATLAB to compute the Structural Similarity Index [6] (a method for determining the perceived quality of digitalized images which help us to have a further understanding regarding its textural properties) and Peak Signal-to-Noise Ratio values [7].

3.1 Requisites

Chili powder is one of the most important ingredients required while food preparation. Brick powder, having similar color and texture as chili powder has been used as a contaminant. Consumption of such adulterated chili powder may lead to nausea, vomiting and could even cause cancer due to long time consumption. Conventional methods such as checking for grittiness are based on human sense of touch are not always accurate. Furthermore, these methods do not give us the degree of contamination. Hence, we use the Structural Similarity Index which is an image processing metric that considers image degradation as a change in structural information while also incorporating perceptual phenomena, including both luminance masking and contrast masking terms. SSIM [8] offers an advantage over traditional methods such as PSNR and mean squared.[9] This provides a cumulative comparison of two images based on attributes such as average, variance and covariance among others. [10] [11] Structural information works on the idea that pixels having strong inter-dependencies are close.

3.2 Methodology

Samples of pure chili powder are mixed with varied levels of brick powder (10% - 90%). These samples are now captured using a camera (12 Megapixels). The image is converted to grayscale before using it for further processing. Initially, we compare the SSIM index between pure chili powder and pure brick powder and observe the degree of difference. Now we introduce computerized adulteration into the pure chili powder samples. The important point to be noted is that for using SSIM we need two images of equal dimensions. Random pixels from pure brick powder image are taken and "mixed" with the pure chili powder image. Let pure chili powder image be referred to as I_1 and pure brick powder image be referred to as I_2. For example, in the case of 10% contamination, when the size of I_1 is 8840, we randomly choose 10% of pixels i.e. 884 pixels from I_2 and scatter these pixels across I_1 and hence referring to this new image as I_3. This process is repeated for other percentages (20-90) and we assign names to these new images. We now get the input sample say image I_i from the user. We calculate the pairwise SSIM for image I_i and images generated through computerized adulteration. This is implemented using MATLAB (imread, randperm, rgb2gray, ssim).

3.3 Complexity

The SSIM formula [12] is based on three differentiability criteria between the input image and the reference image which are luminance, contrast and structure. It then calculates a weighted average of these comparative attributes. The computerized adulteration provides us a standard to compare our samples. On computing the SSIM difference between two levels of contamination, for instance between 10% and 30% we get the approximate degree to which the sample may be contaminated. For example, when a sample gives a large SSIM value on comparison with a level, it is then compared to the levels after it to determine how far it is contaminated. The important property of SSIM is ordering of pixels doesn't matter, which ensures that irrespective the way the pixels are scattered we obtain approximately the same results on multiple iterations.

$$SSIM(m,n) = \frac{(2\mu_m\mu_n + c_1)(2\sigma_{mn} + c_2)}{(\mu_m + \mu_n{}^2 + c_1)(\sigma_m{}^2 + \sigma_n{}^2 + c_2)}$$

Where, μ_m is the average of m, μ_n is the average of n, σ_m^2 is the variance of m, σ_n^2 is the variance of n, σ_{mn} is the covariance of m and n and

$$c_1 = (k_1L)^2 \quad c_2 = (k_2L)^2$$

where L is the dynamic range of pixel values and k_1 and k_2 are constants with values 0.01 and 0.03 by default.

IV. RESULTS AND DISCUSSION

Various test samples are taken to test the performance of the code. The test samples are compared with pure brick powder (let the SSIM value be denoted by T_1) and the simulated samples (let the SSIM value be denoted by T_2). We obtain the difference between T_1 and T_2. Greater the difference in SSIM between two percentages, indicates the test sample belongs closer to the lower interval range.

Fig 3. Image of pure chili sample

Fig 4. Image of pure brick sample

On finding the difference between SSIM of most contaminated mixture with brick powder and that with the simulated sample (10%) we obtain 0.0898, 0.0808 (second most), 0.094 for third most and 0.1202 for least contaminated sample.

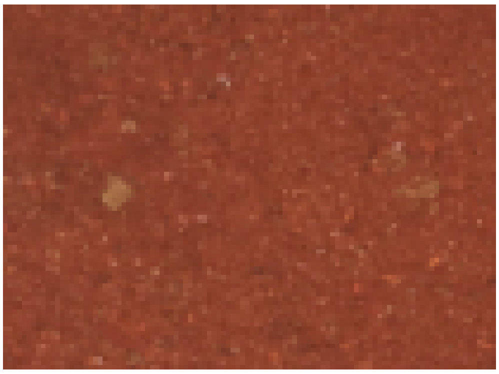

Fig 5. Most contaminated sample

On further finding the difference between the respective percentages we obtain 0.0676, 0.097, 0.097, 0.106, which indicates that the most contaminated sample indeed lies closer to the 20% mark whereas the rest lie around various levels of 10% contamination level.

Fig 6. Contaminated mixtures vs pure samples

Sample	Pure brick	Pure chili
Most Contaminated Mixture	0.4232	0.4538
Second most contaminated mixture	0.4522	0.5106
Third most contaminated mixture	0.499	0.5611
Least contaminated mixture	0.5215	0.5585

It was found that the most contaminated mixture was found to have a SSIM index of 0.4232 relative to pure brick and an index of 0.4538 relative to pure chili. The least contaminated mixture is seen to have a SSIM index of 0.5214 on comparison with pure brick and relatively higher index of 0.5585 on comparison with pure chili. These results provide us with a clear understanding over the various degrees of contamination. Greater the similarity with pure chili as compared to pure brick indicates lower levels of contamination.

V. CONCLUSION

We can conclude from the above results that SSIM proves to be an accurate measure when it comes to detecting adulteration in chili powder. We also get an approximate information regarding the degree of contamination. One important feature which could be added is storing the results obtained after each analysis and using multi-class Support Vector Machines for classification to make further predictions.

Fig 7. Contaminated mixtures vs Percentage wise samples

Permutation percentage	10%	20%	30%	40%	50%	60%	70%	80%	90%
Comparison with Most Contaminated mixture	0.3334	0.2658	0.2041	0.158	0.1385	0.1262	0.1199	0.10555	0.0978
Comparison with Second most contaminated mixture	0.3714	0.2819	0.209	0.168	0.1554	0.1244	0.1101	0.1087	0.0978
Comparison with Third most contaminated mixture	0.4049	0.2989	0.2232	0.1757	0.1598	0.135	0.1125	0.1102	0.0971
Comparison with Least most contaminated mixture	0.4012	0.3042	0.2257	0.1753	0.1617	0.137	0.1187	0.1118	0.1008

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