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Design A Computer Vision Machine to Detect Added Iron to Fortified Flour

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Abstract: Food fortification is an alternative to deliver required micronutrients to the population. In Iran, Iron is added to flour in form of edible ferrous sulfate. Atomic Absorption Spectroscopy is a common method to detect Iron in fortified flour. This method is expensive and time consuming. In this study a new method was used based on computer vision technique to detect Iron in fortified flour. Iron sulfate particles in fortified flour is detected as red colored dots after adding oxidant materials mixture including of three solution containing hydrochloric acid, hydrogen peroxide and potassium thiocyanate. These dots are visible from flour surface and the proposed method is based on image processing and enumeration of these dots and their area. The results of the assessment conducted on test samples with computer vision methods and Atomic Absorption Spectrometry, as the reference standard, showed a high correlation between two methods (R^2 = 0.988) which indicates the reliability of the proposed method.

Key words: Fortified flours · Computer vision · Iron detection · Food fortification · Atomic Absorption Spectrometry

INTRODUCTION

Many countries fortify foods and one example is fortification of flour with Iron. Iron added to flour is premix, which is an edible Iron sulfate in powder form. Premix is added to flour in the final stage of production process by a device called Microfeader. Premix contains 42% Iron sulfate, 0.75% folic acid and 57.25% corn starch as the filling [1]. The detection of the amount of added iron in fortified flour is of great importance. Atomic absorption spectrometry is the most common method for iron detection but it is an expensive and time consuming method. Therefore, a new, simple, fast and high accuracy method is essential. Computer vision is a relatively young technique originated since 1960s [2]. The usage of digital image processing with computer in food quality control tests has been developed in the past few decades [2]. The food industry ranks among the top 10 industries using computer vision technology. The usage of automated assessment is now increasing rather than sensory evaluation as it is very accurate, consistent and economic [3]. During the last decade, considerable research effort has been directed to develop techniques for food quality evaluation [4]. Computer vision provides a mechanism in which human thinking process is simulated artificially and can help in making complicated judgments accurately, quickly and consistently over a long period [5]. Computer vision is based on image processing and analysis with numerous algorithms and methods available to achieve the required classification and measurements [6]. This gives us the possibility to evaluate different parts of the landscape including color, size, shape and texture very intelligent and close to the threshold limit of human vision, but with large scale and without fatigue [7]. This method is based on a non-experimental vision evaluation with no limitation for the type of food products [8]. If quality evaluation is achieved automatically, speed and efficiency of production can be improved in addition to evaluation accuracy increment, which also leads to cost reduction [9]. This technique has also been proven to be a non-destructive quality evaluation on food products [10]. As a rapid, economic, consistent and even more accurate and objective inspection tool, computer vision systems have been used increasingly in the food industry for quality evaluation purposes [9]. Computer vision has long been recognized as a potential technique for the

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guidance or control of agricultural and food processes [11]. This study was conducted in order to detect the amount of added Iron to fortified flour by computer vision technique. Since after pouring oxidant material including hydrochloric acid, hydrogen peroxide and potassium thiocyanate on the surface of fortified flour, Iron sulfate particles changes to the red spots that are quite distinct from the surface of flour, it gives us the possibility to explore added Iron to enriched flour with image processing and analyze these spots in a software analyst, according to a logical algorithm.

MATERIALS AND METHODS

Control Samples Preparation: Control sample were prepared by mixing certain amounts of premix with unfortified flour (Table 1) and poured some oxidant materials on a flat surface of control. Unfortified white flour was obtained from Sina Food Industries, Hamedan, Iran and Premix powder was obtained from Hashtgerd Food Industries, Qazvin, Iran. According to Table 1, premix and unfortified wheat flour were weighed with an analytical lab scale (METTLER AE-160) and were mixed well with a Vertical- Horizontal mixer (Rotabit) building by Saman Zist, Iran for 30 minutes in 100 rpm. After the appearance of red spots in samples, the samples were transferred to the machine and two parameters, number and area of spots were measured. Two calibration curves, one based on Iron content (ppm) and the other based on number of points was drawn. Finally 33 control samples were randomly selected and the amount of Iron in each was measured with both computer vision machine and atomic absorption spectrometry (as the reference standard method) to explore the accuracy of the first method.

Computer Vision Machine Design

Imaging Unit: Image acquisition unit consist of an aluminum dark chamber (30×40×40 cm) that embedded a digital camera (Canon X200, 12.1 MP) on the top and four fixed halogen lamps (60 W) in the top inner corners. The digital camera was plugged to a laptop model SONY VPCAA22EG. Each image was acquired in JPEG format with a resolution of 1721×1721 pixels. Figure 1 shows a simplified scheme of the machine.

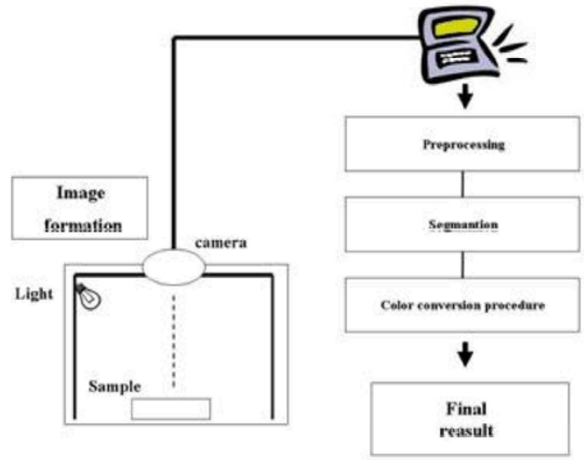

Fig. 1: A simplified scheme of the machine

Image Acquisition: Two reagents were used in order to visualize Iron spots in fortified flour. Reagent 1contained 20 ml potassium thiocyanate solution(10% w/w), 17 ml hydrochloric acid (2 M) in a total volume of 100 ml. Reagent 2 contained 9 ml hydrogen peroxide (30% v/v) and 91 ml distillated water. 15 control sample was then spread on a flat surface with an approximate 5×5 cm dimensions and a height of approximately 4 cm and its surface was gently been flatten. 2 ml of reagent 1 were poured slowly to the surface of each sample and after 30 seconds, 1 ml of reagent 2 was poured slowly to the surface of the samples. After 60 seconds the red spots were identified and samples were transferred to the dark room in order to prepare images. After shooting, pictures were transferred to the analyzer unit.

Images Segmentation: Image processing was carried out using threshold color capability of Clemex Vision PE/Lite^{TM} 3.5 (Clemex Technologyies, Inc. 800 Guimond, Longueuil Canada J4G 1T5) software. A 4x4 cm crop of each image was selected in order to unify processing conditions. Software settings were as follows: Threshold degrees with 80 degrees of BP1 which automatically changed images to a black and white picture so that Iron sulfate particles were identical. Two parameters, number of spots and area of points were measured by using Binary Operation and the output data were recorded in Excel software.

Table 1: Control samples preperation

Sample Number	1	2	3	4	5	6	7	8	9	10	11
Premix (gr)	0	0.003	0.006	0.01	0.013	0.016	0.02	0.023	0.026	0.03	0.033
Flour (gr)	100	100	100	100	100	100	100	100	100	100	100
Final amount of Iron (ppm)	0	10	20	30	40	50	60	70	80	90	100

Calibration Curves: Analysis of each image in machine vision computer obtained two outputs from each image. One the number of spots and second the area of spots. Two scatter graphs, one for numbers of spots and the other for area of spots were plotted according to the obtained data. In the first graph the X axis refers to the Iron amount of each sample (according to Table 1) and the Y axis shows the number of spots. In the second the X axis refers to the Iron amount of each sample (according to Table 1) and the Y axis shows the area of spots. By connecting the dots, calibration curves were plotted.

Atomic Absorption Spectrometry: In this study, all atomic absorption spectrophotometry experiments was measured according to AOAC[1] official method 999.11 (2000) with Furance Atomic Absorption Spectrophotometer Model - 210 BRAIC WFX [12].

RESULTS AND DISCUSSIONS

As mentioned in Materials and Methods section, the results of image processing in computer vision machine were two parameters; number of spots and area of spots. Fifteen pictures were prepared from each control sample and obtained 15 numbers of spots and 15 area spots per each sample and data were analyzed. Table 2 shows statistical analysis results for numbers of spots and area of spots.

The results indicate a good distribution and low standard deviation. Figure 2 shows the distribution of spots number and Figure 3 shows the distribution of spots area based on standard deviation.

Figures 4 and 5 are calibration curves drawn based on Table 1 data for number of spots and area of spots respectively. As mentioned in both figures (4 and 5) a very highly correlation was obtained between the amounts of premix with number of spots (R^2=0.995) and area of spots (R^2=0.997).

By comparing fortified flour with unknown Iron amount with the calibration curves (each number of spots or area of spots) the Iron amount of the sample could be determined by the computer vision machine. In order to confirm the accuracy of this method, 33 samples of fortified flour was randomly selected and the Iron amount of each sample was detected simultaneously by both methods (computer vision and atomic absorption as the standard reference). The results are shown in Table 3.

Table 2: Statistical analysis of image data analysis

Sample number	1	2	3	4	5	6	7	8	9	10	11
Numbers of replications	15	15	15	15	15	15	15	15	15	15	15
Highest number of spots	0	21	31	42	54	61	72	82	92	102	109
Lowest number of spots	0	14	25	35	43	52	63	73	84	95	103
Mode of number of spots	0	17	28	39	48	56	76	78	88	99	105
Standard deviation of number of spots	0	2.64	1.99	2.09	3.17	2.49	2.72	2.49	2.61	1.92	2.08
Highest total area of spots µ)m ^{2})	0	15450	29219	35334	49561	58849	69503	76317	88989	98268	109247
Lowest total area of spots µ)m ^{2})	0	11700	22360	31862	40007	50263	60024	70631	82110	91235	103569
Mode of area of spots µ)m ^{2})	0	13107	26165	33168	43713	53264	65422	72343	85796	94618	104495
Standard deviation of total area of spots	0	1492	2360	1220	3196	3265	3092	1844	2073	2359	1800

Table 3: Accuracy confirmation of computer vision

	Method			Method			Method	
Sample	C.V	A.A	Sample	C.V	A.A	Sample	C.V	A.A
0	0	n23	0	0	n12	0	0	n1
15.02	9.62	n24	18.67	20.32	n13	17.22	14.26	n2
28.23	23.01	n25	32.51	30.26	n14	30.13	25.26	n3
32.51	38.7	n26	32.82	31.35	n15	31.45	33.36	n4
54.52	44.92	n27	60.24	58.39	n16	54.51	49.22	n5
65.29	67.05	n28	52.53	49.23	n17	62.52	55.35	n6
71.23	58.57	n29	69.65	65.99	n18	65.51	59.32	n7
94.16	85.23	n30	74.22	70.39	n19	71.24	78.22	n8
90.82	85.23	n31	90.86	88.96	n20	91.14	82.95	n9
101.17	96.2	n32	112.91	110.63	n21	101.82	98.49	n10
101.54	95.68	n33	142.24	140.28	n22	116.85	112.23	n11

A.A: Atomic Absorption
C.V: Computer Vision

[1]Association of Official Agricultural Chemists

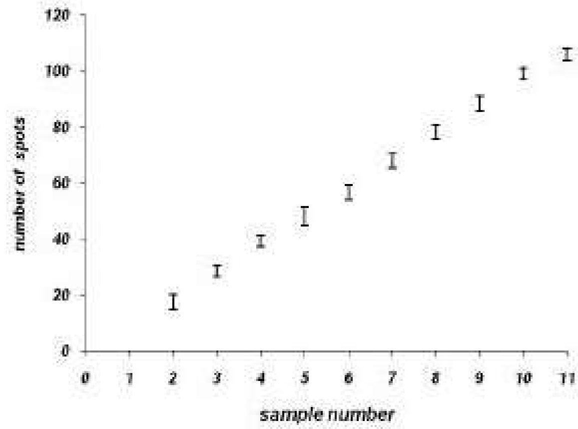

Fig. 2: Samples numbers of spots distribution based on standard deviation

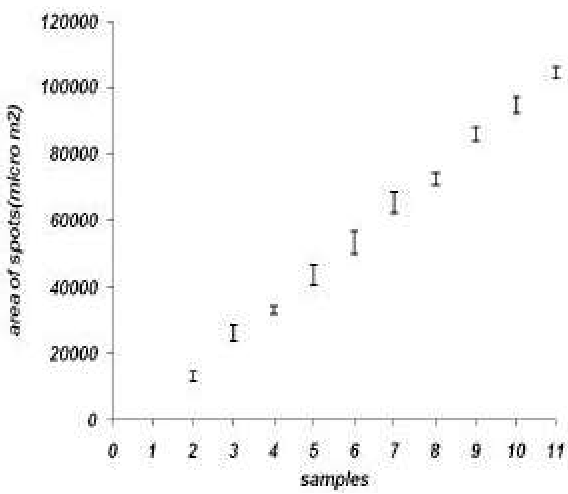

Fig. 3: Samples area of spots distribution based on standard deviation

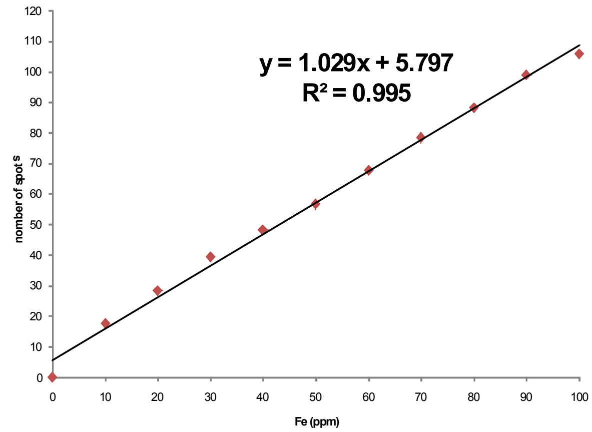

Fig. 4: Calibration curve based on number of spots

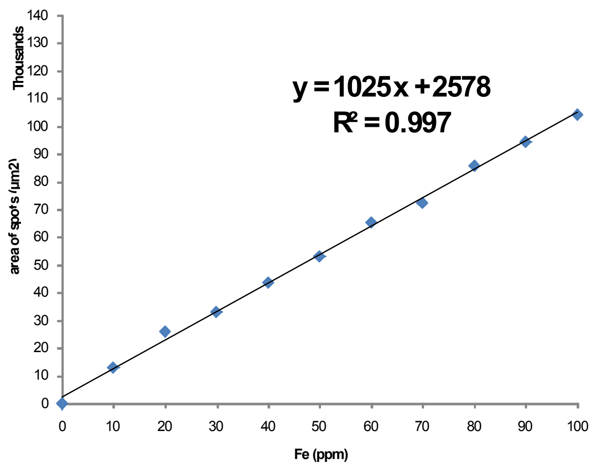

Fig. 5: Calibration curve based on area of spots

The correlation coefficient between two methods (computer vision and atomic absorption as a standard reference) showed a high correlation (R^2 = 0.988). According to latest statistics, 300 active flour factories in Iran are currently producing enriched flour. The computation of 300 working days per year and two working shifts per day and only one sampling per each shift leads each factory to 600 sample experiments in order to control amount of added iron to flour. The usual samples testing methods in factories is spot test method that has a huge error and the possibility of supplying atomic absorption for all factories due to the high cost of supplying materials and laboratory apparatus is not possible. Due to its importance, samples should be tested by atomic absorption method by governmental Institutes and Ministry of Health and Medical Education annually. If the numbers of samples which should be sampled randomly by the Institute of Standards and Industrial Research and Ministry of Health and Medical Education be reduced to only 33%, a total of 120,000 (60,000 samples and a control for each) sample for 300 factories and if each sample approximately costs 60 USD, the public sector should spend 3,600,000 USD annually while the cost of testing each sample with computer vision system is 0.5 USD and therefore the total spending for the public sector reduces to 60,000 USD. This amount includes only the cost of testing and does not include preparation and maintenance cost. A main problem which usually occurs is that the methods of measuring iron in factories and the public sector are not the same and the difference cause legal disputes between factories and public sector. Since computer vision system is simple, inexpensive and available, it is a proper and accurate alternative to the spot test method and atomic absorption technique.

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