Predicting Zebra Chip Symptom Severity in Potato Slices Post-Processing Using Image Analysis

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Introduction

Zebra chip (ZC) disease in fresh potato tuber tissue is characterized as dark striped patterns of necrosis, primarily associated with increased levels of phenolic compounds. When ZC-infected tubers are sliced and fired, they form a burnt appearance, a product of Maillard reaction in the presence of elevated levels of reducing sugars (i.e. glucose and fructose) and certain amino acids. Visual discrimination of ZC-infected potato tubers is time and labor intensive for processors, as they receive truck loads of harvested potatoes in a short time frame. Moreover, as ZC symptoms may vary in the degree of expression predicting the degree of quality loss after frying would be of importance to the processors. The objective of this study was to evaluate whether analyzing images before and after frying can be used to predict symptom expression of ZC-affected tubers after processing.

Materials and Methods

- **Treatments**
  - 194 potato tubers infested 77 or 21 days before vine-kill. Additional 216 tubers were included as non-infected control.
- **Image Processing**

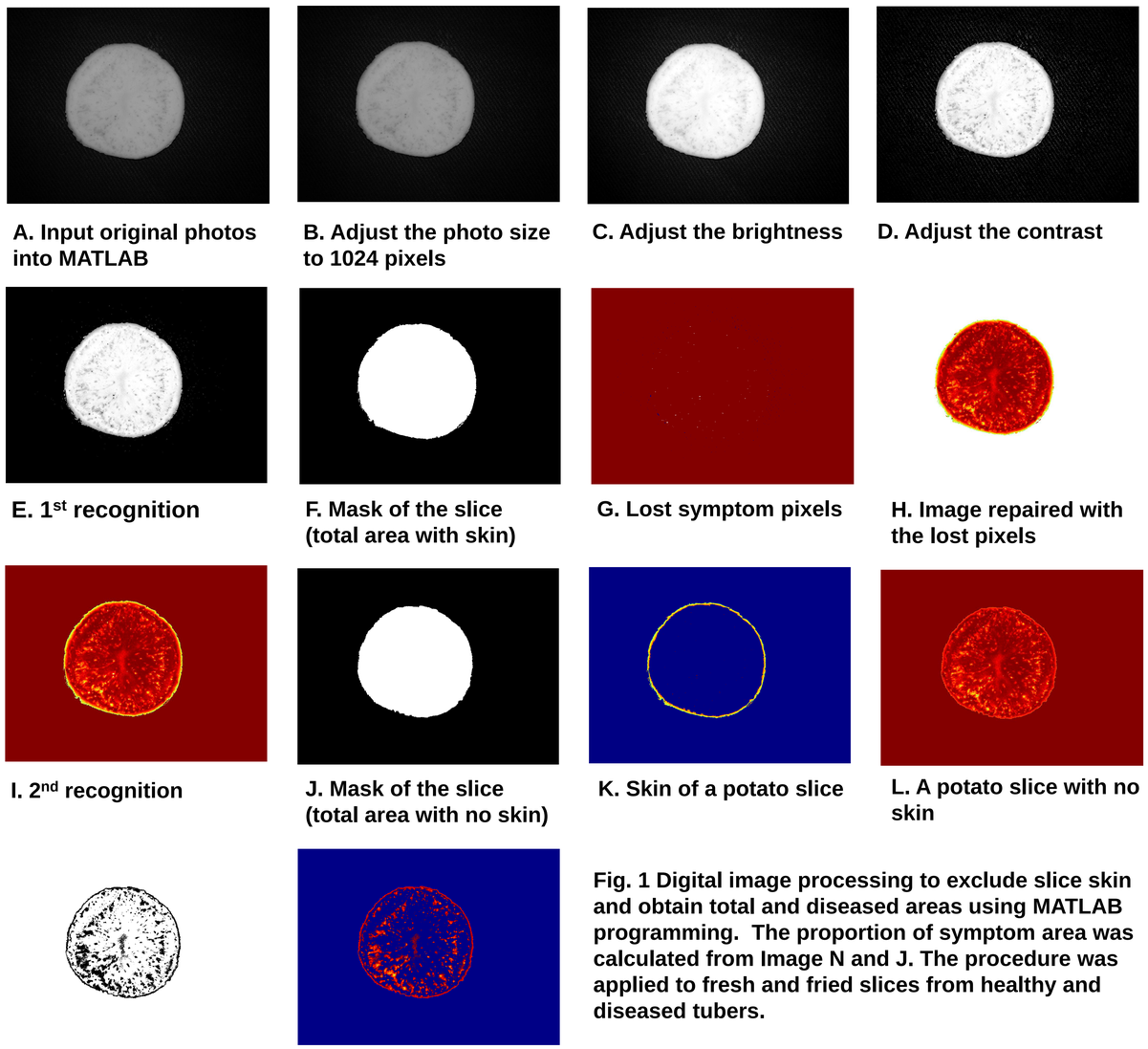

Fig. 1 Digital image processing to exclude slice skin and obtain total and diseased areas using MATLAB programming. The proportion of symptom area was calculated from Image N and J. The procedure was applied to fresh and fried slices from healthy and diseased tubers.

- **Iterative Algorithm in the Image Processing**
  - Image Segmentation includes 3 recognitions:
    - 1st recognition (Fig. 1E) to separate the background and potato slice;
    - 2nd recognition (Fig. 1I) to separate the slice skin and internal part;
    - 3rd recognition (Fig. 1M) to separate the ZC-affected and healthy area.
  - Image recognitions were performed using iterative algorithm (Eqs. 1-4; Fig. 2).
  - Image repairing strategy was to add ZC symptom areas back which was lost during noise reduction (Fig. 1G and H).

Eq. 1: define an initial threshold

$$T_0 = \frac{Z_{min} + Z_{max}}{2}$$

Eq. 2: divide into two groups using threshold T^k

$$R_1 = \{f(x,y) \big| f(x,y) \geq T^k\}$$
$$R_2 = \{f(x,y) \big| f(x,y) < T^k\}$$

Eq. 3: obtain the average value in each group

$$Z_1 = \frac{\sum_{f(i,j)\geq T^k} f(i,j) \times N(i,j)}{\sum_{j(i,j)\geq T^k} N(i,j)}$$

$$Z_2 = \frac{\sum_{f(i,j)< T^k} f(i,j) \times N(i,j)}{\sum_{j(i,j)< T^k} N(i,j)}$$

Eq. 4: define a new threshold

$$T^{k+1} = \frac{Z_1 + Z_2}{2}$$

```
%% setp 7 第一次迭代求边界域值 求动态阈值T
[x,y]=size(Im);                 % 求出图象大小
b=double(Im);
zd=double(max(max(Im)));        % 求出图象中最大的灰度
zx=double(min(min(Im)));        % 最小的灰度
T=double((zd+zx))/2;            % T赋初值，为最大值和最小值的平均值
%disp('原始中值');disp(T);
count=double(0);                % 记录几次循环
while 1                         % 迭代最佳阈值分割算法
    count=count+1;
    S0=0.0; n0=0.0;             %为计算灰度大于阈值的元素的灰度总值、个数赋值
    S1=0.0; n1=0.0;             %为计算灰度小于阈值的元素的灰度总值、个数赋值
    for i=1:x
        for j=1:y
            if double(Im(i,j))>=T
                S1=S1+double(Im(i,j));  %大于阈域值图像点灰度值累加
                n1=n1+1;                %大于阈域值图像点个数累加
            else
                S0=S0+double(Im(i,j));  %小于阈域值图像点灰度值累加
                n0=n0+1;                %小于阈域值图像点个数累加
            end
        end
    end
    T0=S0/n0; %求小于阈域值均值
    T1=S1/n1; %求大于阈域值均值
    if abs(T-((T0+T1)/2))<0.1   %迭代至 前后两次阈域值相差几乎为0时 停止迭代。
        break;
    else
        T=(T0+T1)/2;            %在阈值T下，迭代阈值的计算过程
    end
end
disp('运行次数'); disp(count);   %显示运行次数
disp('第一次滤波最佳阈值');disp(T);   %显示最佳阈值 算出T= 114.4306
```

Fig. 2 The programming of the 1st recognition in MATLAB.

Results and Conclusion

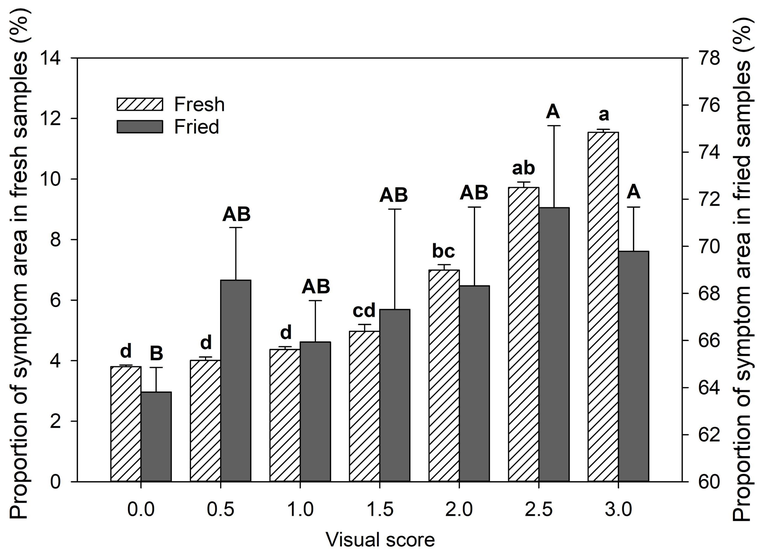

Fig. 3 Proportion of ZC symptom area over the total area of potato slices in fresh and fried samples. Statistically significant differences ($P \leq 0.05$) are presented by different small (fresh) and capital (fried) letters.

- The proportion of ZC symptom area increased with visual scores in fresh and fried samples, and showed significant differences among visual score classes (Fig. 3). Imaging analysis in the current study is thus able to separate and calculate ZC-affected area in fresh and processed samples.
- Further research is needed to build the algorithm for ZC-affected slice areas between fresh and fried samples.
- Such technology may also be applied to other diseases of potatoes and possibly other crops that cause discoloration of tissues.

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