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FOOD PRODUCT SHELF-LIFE PREDICTION

Vule Reljić[1], Laslo Tarjan[1], Stevan Stankovski[1], Milovan Lazarević[1], Gordana Ostojić[1]
[1]Faculty of Technical Sciences, University of Novi Sad, Serbia (vushe90@hotmail.com, laci@uns.ac.rs, stevan@uns.ac.rs, laza@uns.ac.rs, goca@uns.ac.rs)

Abstract. *The paper shows analysis of how to detect diseases of tomato leaf, caused by leaf miner, or mechanical damage to the leaves and fruit of tomatoes, and how to predict the shelf-life of fresh tomatoes, that are to be used in dishes. In order to, as accurate as possible, determine shelf-life, all information, that covers the entire life cycle of product, in this case tomatoes, as well as products intended for human consumption, must be available. This information can be also used to inform consumers if the food product becomes unusable.*
Key words: *tomato, shelf-life, disease, damage, leaf, fruit.*

1. INTRODUCTION

For different types of products there is a finite length of time, after production, in which product retain a required level of quality under stated conditions of storage. This period of time is short for: chemical, medical, cosmetic and food products. In case of food products the required level of quality is conditioned by organoleptic and safety properties.

Time period in which food preserves all this properties is generally defined as the shelf-life. Shelf-life can be calculated by measuring the amount of degradation that occurs during the food aging process.

In order to better calculate and in some cases predict shelf-life of most importance is to track and trace food product during its life cycle. For each food product, it is necessary to record data starting from the stage of raw products farming, through food processing, transport, warehousing, to retailing and reaching the end consumer [12]. This data together with data about storage [3] conditions will help improving product's shelf-life prediction.

Temperature is one of the most important parameters of quality control and food freshness is almost an exclusive function of time and temperature. Thus the temperature is becoming an important function for perishable food and visibility and traceability is especially important in its cold chains [14].

Recently, a number of researches are focused on shelf-life. In the paper [4] analyzes the changes in the shelf-life of tomatoes placed in the warehouse using a sensor system for detecting odours. The application of wireless sensor networks for monitoring of food products in the cold chain logistics is represented in paper [7].

Another important parameter that can affect shortening of shelf-life is early detection and elimination of diseases of fruits and vegetables in order to get a good quality yield and to reduce production and economic losses [9]. If the disease is detected in early stage, timely treatment could initially suppress its spread, and also completely remove it. It is clear that the presence of the disease influences the predicted shelf-life and maintaining the freshness of fruit and vegetables. On the other hand, mechanical damage that may occur during transport also affects shelf-life. In this case it is advisable to detect damage and alert consumers about the change in the shelf-life.

Disease or leaf damage, or fruit and plants can be detected using different methods e.g. various spectroscopic methods (near infrared spectroscopy, magnetic resonance spectroscopy), fluorescence imaging and others [1, 5, 13].

The paper shows analysis of how to detect diseases of tomato leaf, caused by leaf miner, or mechanical damage to the leaves and fruit of tomatoes, and how to predict the shelf-life of fresh tomatoes, that are to be used in dishes.

2. METHODOLOGY

In order to as accurate as possible predict the shelf-life of a food product, it is necessary to use adequate mathematical model and to collect the data of interest.

There are several mathematical models, but kinetic model is used in most cases [11].

$$K = K_0 \cdot e^{\frac{-E_a}{R \cdot T}} \quad (1)$$

$$A_{t_0} = A_0 - K \cdot t_0 \quad (2)$$

$$\ln A_{t_1} = \ln A_0 - K \cdot t_1, \quad (3)$$

where K is called a rate constant depending on temperature, product and packaging characteristics; K_0 is a pre-exponential factor, integration constant; R is the gas constant in [J/K*mol], and equal to 8.3141; T is an absolute temperature in K (273 + °C); E_a is an activation energy in [J/mol], the minimum energy that a system must have for reaction to start; A_0 is initial concentration of reactant; A_{t_0} , A_{t_1} concentration of reactant in t_0, (storage time before treatment of product) t_1 (storage time after treatment of product) [day].

The (1) represents Arrhenius plot often used to analyze the effect of temperature on the rates of chemical reactions. Equations (2) and (3) are equations that describe chemical reactions of zero and first order.

Concentration of reactant can be measured, while the values K and E_a are estimated on the basis of linear regression analysis. Product shelf-life can be determined with equations (4) and (5), which derives from previous equations:

$$t_0 = \frac{A_{t_0} - A_0}{K_0 \cdot e^{\frac{-E_a}{R \cdot T}}} \quad (4)$$

$$t_1 = \frac{\ln A_{t_1} - \ln A_0}{A_0 \cdot e^{\frac{-E_a}{R \cdot T}}} \quad (5)$$

t_0 and t_1 are determined in number of [day].

Several elements like: firmness, elasticity or viscosity, moisture content, level of decomposition degree of wilt, the presence of soluble solids, the presence of some significant acids and others, have great influence on the food product shelf-life. All these parameters can be measured using appropriate instruments. For firmness, elasticity or viscosity testing e.g. dedicated instruments can be used (Fig. 1.) [2].

Parameter values are collected in pre-defined time intervals and these measurements are done in the following manner: the product is stored at several temperatures until it becomes unusable and the dependence of the influential elements, for example, firmness, elasticity or viscosity, temperature and time elapsed are determined.

Figure 1. Food Rheology Tester [2]

Since there are many parameters that affect the product shelf-life, only most important must be chosen. Sensory estimation can also help in choosing these parameters. This estimation includes evaluation of the: quality, color, taste, smell, and other characteristics of the product which is done in the same time intervals when making measurements and data collection.

After that, it is observed, based on the Pearson correlation coefficient, which parameters show the highest correlation. For calculating the Pearson coefficient the software [10] can be used. The parameters of interest are selected if the value of the Pearson coefficient is greater than 0.9 (or less than -0.9, if it is a negative correlation).

When the parameters, which influence the shelf-life, are chosen and when their value is measured, then values of the K_0 and E_a for selected fruits and vegetables are estimated, using linear regression analysis.

For conducting experiments it is necessary to prepare several crates (at least 5) with fresh tomato fruit. Each crate should be stored at different temperature and monitored until the moment when it fruit becomes unusable for human consumption. Meanwhile, in a pre-defined time intervals, would be measured data of importance about which were discussed in the previous paragraphs, on randomly selected samples (minimum 10 pieces).

Following the procedures described above, K and E_a for tomatoes would be determined. Based on the obtained values of the K and E_a shelf-life can be calculated according to equations (4) and (5).

Based on data obtained in this way it is possible to monitor the state of the tomato in any stock or any retailer only by monitoring room temperature where the tomato is. This data can be gathered using a temperature sensor placed in the corresponding sensor assembly. This information would be forwarded to the server through communication network (e.g., wireless). In this case server is used to control entire database and for forwarding the information about changing the shelf-life of products to the retailers.

For detection of disease and plants damage, whose symptoms are visible or not, a variety of spectroscopic and other methods, can be used [9]. One of them is near infrared spectroscopy (NIR). This method can be used for detection of tomato leaf miner and mechanical damage to the leaf, or the fruit of tomatoes.

Leaf miner is small fly whose body length is between 1.5 mm and 2.3 mm and can be differently colored. The larvae, which cause damage to the leaf by feeding on leaf tissue, do not have legs and a distinct head. On infected leaves arise typical corridors - mines, which are visible from the face and the surface of leaf (Fig. 2). Additional damage on leaves is caused by female pests. This damage is

in the form of bright spots, which are caused because supplementary feeding or laying eggs [8].

Figure 2. Leaf of tomato pestilent by leaf miner [6].

A slowdown of growth and development of plant, and thus reduce production and economic losses are the results of this damage.

NIR can be used for detection of leaf miner and mechanical damage because it includes part of approximately between 0.8 microns and 2.5 microns of the electromagnetic spectrum and may arouse harmonic vibrations. The most commonly used element for this technique is spectrometer with Fourier transformation.

For conducting experiments it is necessary to collect a number of healthy leaves and fruits of tomatoes, as well as mechanically damaged, and the leaves that are infected with leaf miner. The leaves and fruit of tomatoes should be illuminated by the spectroscope at appropriate intervals (every 3 nm). The process is repeated for more than 10 times. Since the leaf miner and mechanical damage are visible from the face and the surface of leaf, all measurements should be made firstly on face side and then on back side of the leaf. All data collected from the spectrometer can be transferred to a computer via analog-to-digital converter, where the appropriate calculations will be performed. Collected data is placed in a separate file, which can be initiated only with appropriate software package that spectrometer producers supplied with the device. This procedure is then followed with appropriate statistical analysis of the data and adoption of the appropriate conclusions.

3. RESULTS

It is very important to know food product shelf-life and stick to it in order to avoid food poisoning. Therefore it is required to enabling tracking and tracing product during its life cycle, through all stages.

In the early stages of production, it is possible to use spectroscopic methods to detect the disease, if any, and to remove it. In addition, it is possible to detect mechanical damage of leaves and fruit, which can occur at any stage of the product life cycle. Of course, it should be noted that spectroscopy is not the only method for the detection of plant diseases. There are many others. One of them, used in the paper [5] implies fluorescence imaging and image processing using CCD (Eng. Coupled Charge Device) devices. In this research it is shown that the detection of disease can be very quickly achieved (only 50 hours after putting pest in the leaf), but a large number of images is needed.

It is also very important to take care of food product freshness, and it is important to keep it to a pre-defined temperature. Only in this case, prescribed shelf life is valid. What is characteristic is that the temperature, at which the product is kept throughout its life cycle, is constantly changing (depending on whether the product is in stock, transport, or retail). Therefore, it is necessary to constantly monitor temperature changes and predict new shelf-life. This can be achieved using sensor networks and promptly sending data to the appropriate server. It should be noted that this method is not the only one for predicting shelf-life. In the paper [4] a shelf-life prediction of tomatoes is made using the sensor system for the detection of odors, but the results were not satisfactory.

Methodology described in this paper helps eliminating any possibility of food poisoning consumers, a thus the main objective has been met.

4. CONCLUSIONS

One of the most important things in the food industry is the tracking and tracing product during its life cycle. Tracking must be done in order to avoid putting harmless food on the market. Tracing is done in case of contamination. Then tracking information can help detecting where the contamination took place during process. In this paper it is shown a concept how can be possible to track life cycle of the tomato – from farming products, till using it for nutrition, or, until it becomes unusable for human consumption. In order to set this concept two experiments are shown.

In the first experiment a detection of tomato leaf miner, using the spectroscope, during plant growth is done in order to prevent or completely remove miner. This spectroscope can also be used to detect mechanical damage to the leaf and fruit of the tomato, which is used in the food industry. It is clear that all damage, whether caused by the presence of pests, or otherwise can substantially affect the shelf life of tomatoes.

The second experiment involves monitoring the life cycle of tomato and shelf-life prediction, depending on the appropriate conditions, such as, for example, the storage temperature for tomato. Results show that shelf-life is very variable and it depends on the storage temperature, temperature during transportation and temperature in retail.

Methodology presented in paper gives a novel approach which combines food product (plant) monitoring through all stages of its life cycle, and timely provision of information, about changing of product shelf-life, to consumer in order to enable using only fresh food product for nutrition.

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