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Rapid and nondestructive assessment of freshness of potatoes using a piezo based sensor

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Abstract
The paper has examined on the non destructive assessment of potatoes using a piezo based sensor. In assessing the freshness of the product, there are different research reports, but surface firmness is an excellent indicator and is used extensively in practice .The sensor is used as a vibration sensor where the vibration patterns are recorded and analyzed in frequency domain and then the quality parameters are displayed accordingly. It is found that dry matter is related with the firmness of potato tubers which also converts itself to starch content depending on time and storage of potato tubers as firmness is very useful for processing industry. With some minor software modifications it can be adopted for other vegetables as well.

Keywords: Firmness, Dry Matter, Non-destructive, Piezo, Potato.

Introduction

Agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India. More than seventy percent Indian population depends on farming, either directly or indirectly and around 58 per cent of the total employment in the country is through agriculture (1). Also, the agricultural sector in our country contributes to around 18 per cent of the GDP.In India potato has emerged as the fourth most important food crop after rice, wheat, and maize regarding agricultural aspect. Potato is also the third most important food crop in the world after rice and wheat in terms of human consumption. More than a billion people worldwide eat potato, and global total crop production exceeds 300 million metric tons. Potato is a critical crop in terms of food security in the face of population growth and increased hunger rates. For example, China, the world's biggest consumer of potatoes, expects that fully 50% of the increased food production it will need to meet demand in the next 20 years will come from potatoes. Potatoes are an excellent, low-fat source of carbohydrates, with one-fourth the calories of bread. Boiled, they have more protein than maize and nearly twice the calcium. An average serving of potatoes with the skin on provides about 10 percent of the recommended daily intake of fiber. Potatoes are used for a variety of purposes, and not only as a vegetable for cooking at home. In fact, it is likely that less than 50 percent of potatoes grown worldwide are consumed fresh. There are a large variety of fruits and vegetables, which are extensively cultivated in India. Some of them are exported also. But it is very much important for the consumer to know the actual quality and freshness of the vegetable or fruit. This is not only important for the domestic market, but while exporting the items, care should be taken so that the fresh products are only selected. Thus, nondestructive and rapid assessment (i.e. size, shape, color, freshness, firmness, existence of nutritional content and availability after storage or transportation, etc) of freshness of potatoes are very much needed in our country, and both the consumers and the farmers would be benefited.

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In assessing the freshness of the product, there are different research reports, but surface firmness is an excellent indicator and is used extensively in practice. The grape berries on vines were investigated with a nondestructive acoustic method by Takahashi *et al* in (1). Mizrach et al (2) developed a spring-loaded "mechanical thumb" to measure the force deformation of a peel.

In this present paper, we present the development of an instrument based on piezo-based accelerometers and the results obtained with a large number of potato samples. Firmness is related to the degree of maturation of fruits of many kinds (3).It is generally recognized that firmness changes of fruit or plant tissue are attributed to changes in the mechanical properties of the cell walls; therefore,pre- and post-version, changes in cell wall components of berries have been reported. For example, Nunan et al. (1998) revealed the alteration of specific polysaccharide components and protein composition in the cell walls of ripening grape berries(4). Subsequently, Yakushiji et al. (2001) reported depolymerization of pectin and xyloglucan, and a decreased amount of cellulose related to softening of the grape berry (5). Deytieux-Belleau et al.(2008) suggested that pectin methylesterase and polygalacturonase contribute to the softening of berry skin (6). Another group measured turgor of berries and revealed that turgor decreased along the ripening stages of grapes. These biochemical and physiological changes in the berry are supposed to be related to firmness changes through grape maturation.

Materials and Methods

The study on firmness has been done at an international and as well as national scale. Firmness being a key factor as it is related to the degree of maturation and quality. Quality determines the shelf life and sell price of fruits and vegetables (7). Grape berries show characteristic changes in firmness through ripening. Non destructive acoustic vibration techniques methods were implemented for study of firmness (1). Different methods for non destructive quality monitoring of fruits and vegetables were mentioned such as mechanical methods, optical methods including visible or NIR Spectroscopy, Ultrasonic and acoustic response methods (7).They have mentioned some possible methods which can be implemented for firmness detection. Particularly ultrasonic techniques were implemented for quality evaluation of fresh fruits and vegetables using the characteristic of sound waves in ultrasonic regions and also the propagation parameters and implemented on freshness detection of apples in specific (8).

Non destructive assessment of freshness has not been performed specifically on potato which will be a rapid assessment and also will be a handheld instrument. Dry matter which corresponds to the freshness and also the starch content has not been taken into account. This paper presents the research on the non destructive assessment of freshness of potato tubers where instrument is developed which is handheld, portable and also rapid in nature.

Potatoes are also extensively cultivated in India. A huge amount is exported also. But it is very much important for the consumer to know the actual quality and freshness of this highly important vegetable with respect to food security concern. This is not only important for the domestic market, but while exporting the items, care should be taken so that the fresh and nutritious products are only selected. Thus, nondestructive and rapid assessment of quality of different varieties of potato is very much needed in our country, and both the consumers and the farmers would be benefited. In assessing the freshness of the vegetables, there are different research reports, but surface firmness is an excellent indicator and is used extensively in practice. Starch content is determined by biochemical means. The grape berries on vines were investigated with a nondestructive acoustic method by Takahashi et al. in (1). Mizrach et al (2) developed a spring-loaded "mechanical thumb" to measure the force-deformation of a peel. There are also conventional methods (like NIR, Spectrophotometry etc.) of detecting nutritional value also, though they are not rapid and nondestructive always. There is no such instrument, which correlates freshness with the inherent significant chemical compounds (such as starch) in potato.

Theory

The first problem area is the non destructive method for determination of quality parameters of potato. For quality parameter detection three biochemical components plays a significant role regarding processing and storage time of potato tubers. These are dry matter, sucrose content, reducing sugar content, bacterial wilt.

Sucrose content gives us the indication of the storage time of potato tubers. Dry matter and reducing sugar content are significant towards the processing of potato tubers. Dry matter is intensely related with the firmness of potato tubers, thus the indication of firmness is very useful for processing industry of potatoes as dry matter is the key indication towards processing of potato. The other significant prospect behind the detection of dry matter content is the quantity of starch in the potato tuber as the dry matter actually converts itself to starch depending on time and storage aspect. Presently there is no such instrument which can predict the starch content of potato tubers in a rapid and handheld manner. The advantage of the proposed system in this paper is regarding cost, sensitivity, reliability, portability, rapidity, whereas no such system in the national mark.

Piezo film sensors are used for detection of vibration patterns. The piezo film when displaced from the neutral position, the bending creates high strain in the piezo film and thus generating voltages. When this piezo film is deflected by direct contact it may act as a switch. But when this piezo film sensor is supported by its contacts and left to vibrate in free space then the device will behave as an accelerometer or vibration sensor. We are using this sensor in this particular way.

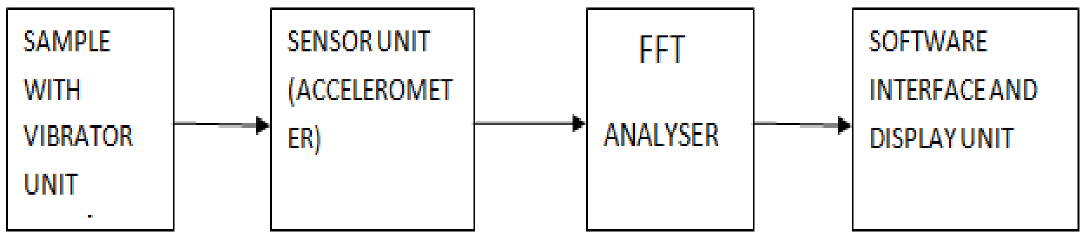

Figure 1: Block diagram of the measurement setup

The proposed device has a flexible and adjustable holding arrangement so that the potatoes of different size and shape can be held firmly with the sensor. The required sample to be tested is kept in between the sensors and held firmly with the arrangement and then the sample is left to vibrate. An external vibration source is attached so that the sample is allowed to vibrate and the vibration pattern is then captured by the piezo film sensor. The vibration patterns are recorded and analyzed accordingly. For different quality of potatoes it may give different vibration patterns and thus each of them can be analyzed separately and then be finally categorized into different qualities of potatoes.

Piezo film sensors used here is The LDT0-028K.These are flexible component comprising of 28 μm thick piezoelectric PVDF polymer film with screen printed silver ink electrodes, laminated to a 0.125 mm polyester substrate, and fitted with two crimped contacts. As the piezo film is displaced from the mechanical neutral axis, bending creates very high strain within the piezo polymer and high voltages are generated. When the assembly is deflected by direct contact, the device acts as a flexible "switch", and the generated output is sufficient to trigger MOSFET or CMOS stages directly. If the assembly is supported by its contacts and left to vibrate "in free space" (with the inertia of the clamped/free beam creating bending stress), the device will behave as an accelerometer or vibration sensor. Adding mass, or altering the free length of the element by clamping, can change the resonant frequency and sensitivity of the sensor to suit specific applications. Multi-axis response can be achieved by positioning the mass off center. The LDTM-028K is a vibration sensor where the sensing element comprises a cantilever beam loaded by an additional mass to offer high sensitivity at low frequencies

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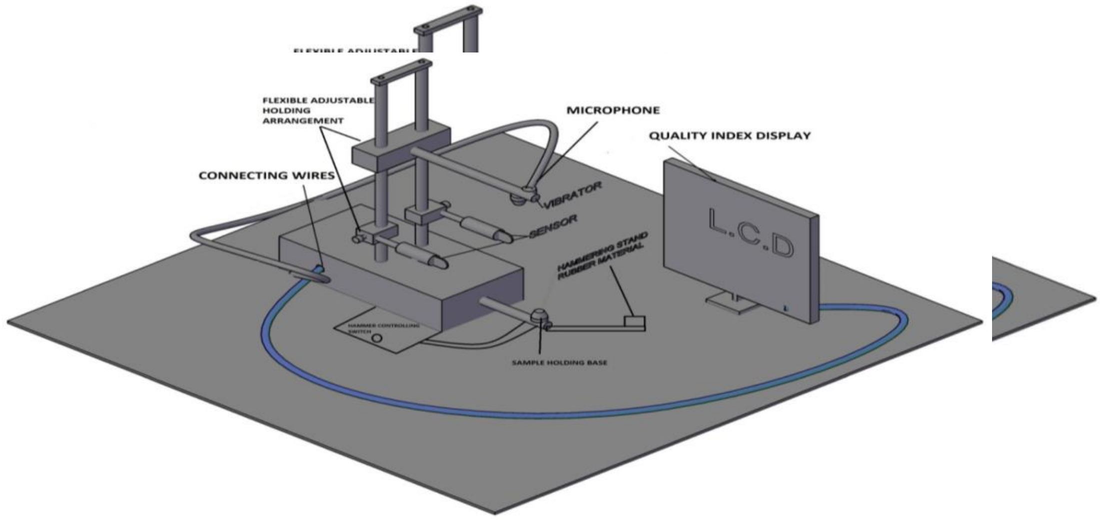

Figure 2: Proposed Piezoelectric sensor based instrument

Some features are as follows:

Solder Tab Connection
Withstands High Impact
Operating Temperature: 0ºC to 85ºC
Storage Temperature: -40ºC to 85 ºC

Figure 3**:** Photograph of the experimental setup

Before sending the signal to the micro controller the signal has to be rectified and amplified. The amplification circuit is shown below:

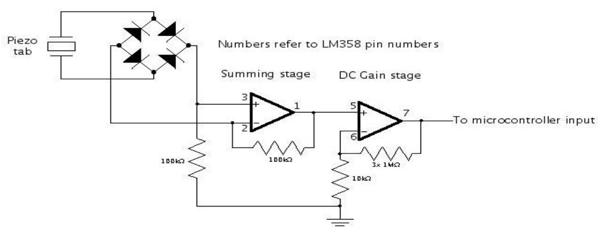

Figure 4: Amplification circuit for piezo sensor

In this schematic, a piezo is the sensor. Piezos generate voltage when physically bent or deformed, the voltage is in the mill volt range. The direction that the piezo is deformed determines the polarity: bend it one way, get a positive voltage. Bend it the other way, get a

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negative voltage. In this circuit, the piezo is put through a full-wave rectifier bridge (the four diodes) to make its voltage always positive.

During the amplification we have used LM358 which is a low power dual operational amplifier IC.LM358 has various applications such as non inverting DC gain, DC summing Amplifier, Power Amplifier, Voltage Follower etc. Here we are using LM358 as Summing amplifier and as non inverting dc gain.

The output of the bridge is sent into one of the LM358's amplifiers that are configured as a voltage summing amp. The output of that amp is then fed into the other amp on the LM358 that's configured as a DC voltage gain amp. The output from the second amp is approximately 0.2 - 3.0 V DC.As the signal from the piezo is first amplified and then send to the micro controller The same is done for the microphone as well. The circuit for the amplification for microphone is shown below:

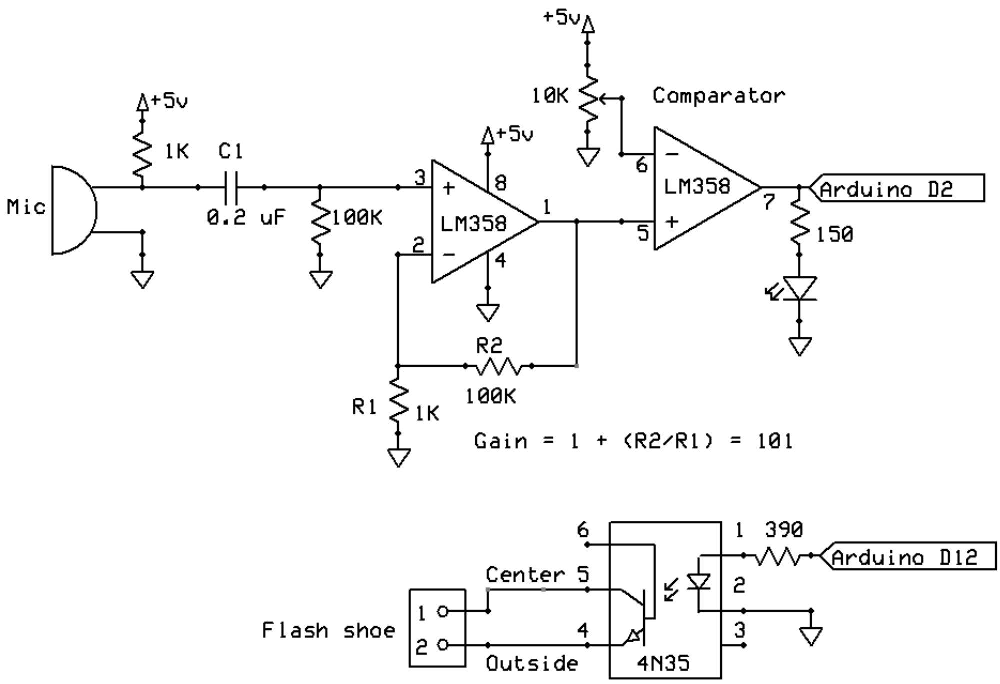

Figure 5: Amplification circuit for microphone

For displaying of quality index and harvesting time a 20x4 LCD has been used. Features of 20x4 LCD are as follows:
Type: Character
Display format: 20 x 4 characters
Built-in controller: ST 7066 (or equivalent)
Duty cycle: 1/16 • 5 x 8 dots includes cursor
+ 5 V power supply (also available for + 3 V)
LED can be driven by pin 1, pin 2, pin 15, pin 16 or A and K • N.V. optional for + 3 V power supply

The piezo sensor generates voltage depending on the vibration of the surface. The vibrating frequency shifts with the freshness of the vegetable. The sensor output is a voltage which is converted into digital form with the help of an Arduino microcontroller board (UNO) and transmitted into the PC through serial communication. The necessary code for frequency domain analysis is being coded into the Arduino UNO. After analysis of the vibrational pattern the Arduino processes and then displays the quality parameter to the LCD screen connected with the system.

Results and Discussion

Different samples of potatoes with varying freshness were collected beforehand and the approximate date of picking of the potatoes was noted. The experiment was then conducted with different samples of potatoes. The results were quiet promising when the amplitude of the frequency domain analysis is being considered. The amplitude showed quite significant changes while conducting the experiment with different potato samples each for firm quality potatoes, less firm quality potatoes and low dry matter (extensively less firm) quality potatoes respectively. Here the major peak of the frequency domain analysis has been considered. From the results we can clearly state that we can determine the quality index of the potatoes. It has also been noticed that there is a promising relation of firmness with frequency shift in frequency domain. The experimentally observed datasheet table is given below:

Table 1: Freshness and frequency shift table

Sl. No.	Freshness(in days)	Standard deviation in frequency shift
1.	10	18.21
2.	9	19.65
3.	8	20.28
4.	7	21.96
5.	6	23.66
6.	5	26.74
7.	4	27.02
8.	3	28.76
9.	2	29.21
10.	1	29.62

The unit of frequency calculation has been taken as Hertz and amplitude frequency as dB for the sake of simplified calculation. Dry matter is intensely related with the firmness of potato tubers, thus the indication of firmness is very useful for processing industry of potatoes as dry matter is the key indication towards processing of potato. The other significant prospect behind the detection of dry matter content is the quantity of starch in the potato tuber as the dry matter actually converts itself to starch depending on time and storage aspect. So far we have dealt with 20 different variant of potato tubers with distinguishable dry matter content. It is observed a suitable proportional relation of freshness of potato tubers to its firmness. The above table signifies the data variation with respect to the predictive algorithm towards the concern issue.

Conclusion:

This paper presents a low cost and simple methodology to objectively estimate the freshness of potatoes. The results are obtained with different potato samples, but the same methodology with minor modifications may be adopted for other vegetables and fruits. Thus, in the future, it is expected that the presented methodology may be adopted widely by the producers, consumers and the exporters. Commercialization of this low cost and handheld instrument would actually help at every stage starting from farmers to the consumers or exporters could easily and in a rapid manner verify the quality of this highly important produce that actually will cut down the manipulation behind consumer producer chain and maintain price stability.This instrument might also contribute quality enhancement in starch industry, and also for food security in India.

Acknowledgments

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