PREDICTION OF TOMATOES FRESHNESS USING INFRARED THERMOGRAPHY

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ABSTRACT

The importance and benefits of Infrared thermography has been extended beyond industrial applications and now found more usefulness in different areas of agriculture, especially in predicting the quality of harvested produce. In Africa, Tomatoes consumption is very high as most African delicacies are incomplete or cannot be processed without the use of tomatoes. However, the authenticity in terms of quality and safety of the highly consumed tomatoes is subject to doubt. This problem is compounded by lack of fast and appropriate technologies to predict quality of agricultural produce. Fresh samples of Roma VF tomatoes (150 samples) seen to be free from any physical defects were acquired from three different vegetable markets in Ile-Ife, Nigeria to compare the level of freshness of the tomatoes available for consumption. The thermograms of the samples were taken using a FLIR T200 Infrared Camera. The thermograms were captured on the day the tomatoes were purchased (1) and thereafter every 24 hours for 5 consecutive days under a standard room temperature storage-condition. Thermograms were analyzed with a quick-report FLIR software. The result of the analysis at day 1 shows that 80% of the tomato samples had anomalies with a mean minimum temperature of 30 ºC and classified not as fresh as physically justified. The defected samples deteriorated faster than the remaining 20% without any noticeable anomaly that were classified fresh with a mean minimum temperature of 32.2 ºC. The fresh tomatoes were observed to have an extended shelf life and therefore recommended for consumption until after five days of storage when their mean temperature dropped below 31ºC. This study showed that infrared thermography is appropriate for tomatoes quality assessment as against visual inspection. Thermography is thereby presented as suitable in building a fast online system for predicting deterioration rate in tomatoes and other perishable food produce.

KEYWORDS: Infrared thermography, thermograms, tomatoes freshness, infrared camera, thermal imager.

1. INTRODUCTION

Tomatoes constitute an essential component of the daily delicacies of millions of households in Nigeria. It is an essential part of most meals, if not eaten as fruits and this made tomatoes a very good source of livelihood for peasant farmers and some city dwellers that sell –perishables (Adenuga *et al.,* 2013). Nigeria is one of the countries identified with the major production of tomatoes globally with about two million tonnes production in 2012 (FAOSTAT, 2014) but the quality of produce has been questionable due to recurrent on-farm to post-harvest losses caused by damages. Generally, perishables such as vegetables must be carefully handled from harvest to consumption. Maturity at harvest is one key-factor that affects the quality of tomatoes which makes harvesting of tomatoes in its green state better, especially when required to be transported for long distance (Moneruzzaman, 2009). Methods of harvesting and handling have been reported as the major factors responsible for the bruises that often deform perishable crops (Manickavasagan *et al*., 2005; Hurst, 2010). Furthermore, these deformations can later introduce diseases that degrade the quality and reduce the overall shelf life of the produce (Toivonen, 2007; Dandago *et al.*, 2019). To prevent economic losses and deformation of tomatoes during harvesting, Kitinoja (2008) recommended the harvest of tomatoes in plastic bags and avoiding overloading. It is widely acknowledged that tomatoes have numerous health benefits ranging from improving male fertility, contributing to strong immune systems for human and thus, prevention of other diseases (Tvrda *et al*., 2021; Edward *et al.,* 2022). On the other hand, it has been reported that it also has some detrimental effects which includes heartburn, urinary problems, hepatitis A, infections etc (Carvalho *et al*., 2012; Salehi *et al*., 2019; Edward *et al.,* 2022) which has been attributed to the rate of consumption of tomatoes or consumption of deteriorated tomatoes that are presumed physically good.

In Nigeria, there are several local markets designated for the sales of vegetables supplied by farmers and are usually sorted by the physical appearances of the tomatoes for purchase (Al-Dairi, 2021). However, there have been several imaging techniques used for detecting damages on fruits and vegetables which include multispectral and hyperspectral NIR based techniques. However, the infrared thermography approach has been found to offer a better solution (Roseline and Abutaleb, 2014). The thermography-based method requires a thermal imager and good knowledge of camera handling for different applications. It is important to understand the configuration and have a prior knowledge of the emissivity values of the targeted agricultural produce where quantitative surveys are required. The application of infrared thermography has been extended beyond industrial applications cutting across different aspects of agriculture to several areas of agricultural engineering. In the industry, truck loads are received into the processing plants after spending some days on the road due to the distance from the farm to the processing plants or markets and in some cases, the trucks or vehicles carrying the tomatoes gets damaged on the road and these affects the freshness of tomatoes but are received into the factory with no physical deterioration, sometimes. Also, at the general vegetable markets, people procure available samples of tomatoes in the market subjected to physical examination and judgement but eventually procure tomatoes with very short shelf life because there are no appropriate technologies to detect the state or freshness of the tomatoes. Meanwhile, Infrared thermography cameras have now been found suitable to predict the freshness of tomatoes and as such can be used as a monitoring technique for tomatoes during storage.

2. MATERIALS AND METHODS

2.1 Tomato Samples

Three major pepper and tomatoes markets (Akinola, Adedoyin and Oja Tuntun Markets) were visited at Ile-Ife (latitude 07º 28' N and longitude 04º 33' E), Osun State, Nigeria where samples of fresh Roma VF tomatoes were procured. Here, the majority of consumers are attracted to these markets and purchase their tomatoes there because they often appear physically fresh. Fifty (50) samples of fresh tomatoes were procured from each market and were transported carefully in polyethylene bags to a post harvesting laboratory at the Department of Agricultural and Environmental Engineering Department, Obafemi Awolowo University, Ile- Ife. Figure 1 shows the digital picture of various samples of the tomatoes purchased from the different local markets while Figure 2 shows the pictures of 8 samples of tomatoes in a flat plate from one of the markets on the first day of purchase for classification purpose.

Figure 1: Samples of Tomatoes from the market`

Figure 2: Samples of tomatoes during sorting

With a FLIR T-200 infrared camera, samples of tomatoes from each market were placed on a flat plate and the thermograms captured to sort and classify the samples into consumable and good. The consumables are the samples the camera detected to have some anomalies that cannot be identified physically but are assumed physically fresh and consumable while the samples classified as good are those that the camera identified and confirm fresh and better then the consumables. The samples of the two categories were stored under room temperature for a period of five days to confirm the prediction of the thermal-imager, physically.

2.2 Instrumentation

A FLIR T-200 thermal imager (with temperature range -20 to 350ºC, 43,200 pixels (120 × 180) infrared resolution, scalable picture in picture (PIP) fusion and a rotating lens) that gives a reliable temperature measurement (± 2% accuracy) was made available by the Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife with a FLIR tools software for on-desk analysis of captured thermal images.

A thermo-hygrometer was used to measure the ambient temperature and relative humidity of the work area and the results were recorded into the thermal camera with the emissivity and distance value of the camera set to 1.0 and 0 respectively which makes the survey and prediction easy, hence, giving us an apparent temperature close to true temperature values.

2.3 Methods

Eight samples of tomatoes from each market were subsequently stored in a flat plate and captured using the T-200 FLIR camera (against possible reflections), for analysis and classified to consumable and good tomatoes. Samples classified as good according to thermal imager were free from rot or any internal decomposition and too soft as against those classified as consumable despite there is no physical difference in both categories.

The percentage of tomatoes classified as good to consume were obtained and reported as required, on the first day. The tomatoes were stored under the same room temperature and monitored for any physical defect or anomalies for a period of five days.

3. RESULTS AND DISCUSSION

3.1 Prediction of the Infrared Camera

The result of classification of the tomatoes into consumable and good grades, as predicted by the infrared camera is shown in Table 1. The thermograms of the samples taken showed that a total of only 30 out of 150 samples, were classified to be in the good class which amount to just about 20% of all the samples that were physically observed and accepted to be fresh from the various market (Figure 3). Some of the tomato samples despite their appealing physical appearances (as in Figure 4a) were seen by the infrared camera to have a mark or spot indicated by a lower temperature region which identified an anomaly or area where the nearest damage of the tomatoes will emanate from (as shown in Figure 4b). The thermogram in Figure 4b showed a batch sample during the classification of the tomatoes and it indicated that the tomatoes with lower minimum temperature values were predicted and classified to consumable(s) and majority of the tomatoes in this category have minimum temperature values less than 31ºC as reported in Table 2 while those that have minimum temperature values higher than 31 ºC are classified as good (as in Table 2).

Table 1: Classification of Tomatoes to Good and Consumables

No	Samples	Market A		Market B		Market C	
		F	C	F	C	F	C
1	8	1	7	2	8	3	5
2	8	3	5	1	7	3	5
3	8	2	6	2	6	4	4
4	8	0	8	2	6	2	6
5	8	0	8	1	7	0	8
6	10	2	8	1	9	2	8
Total	**50**	**8**	**42**	**9**	**41**	**13**	**37**

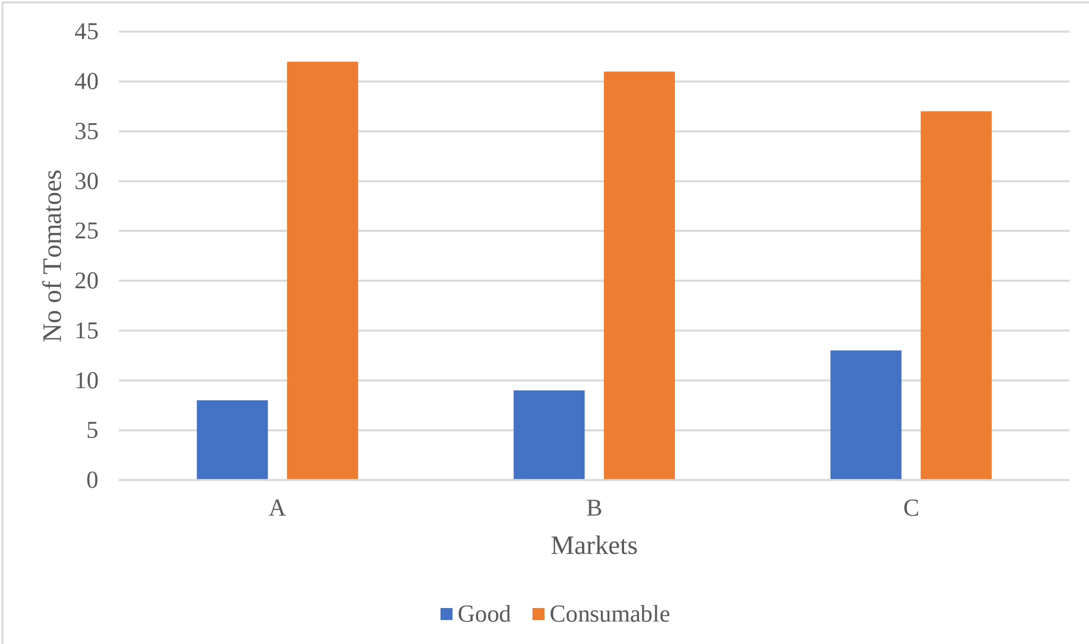

Figure 3. The classification of fresh tomatoes per market.

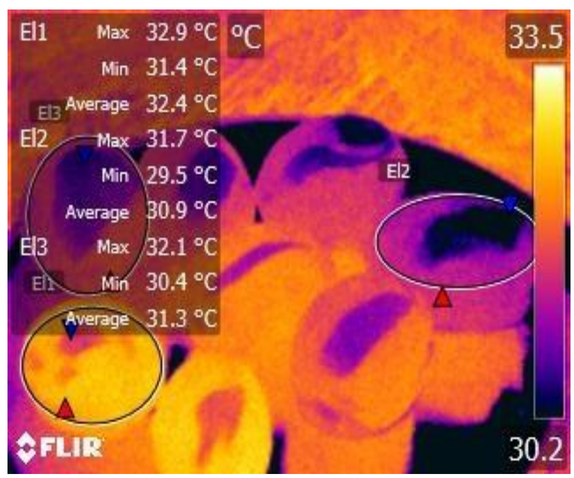

Figure 4a: Thermogram during sorting

Figure 4b: Thermogram Analysis.

Table 2: Result of Minimum, Maximum and Average Temperature of Tomato Samples

S/N	Consumable			Good			
Samples	Av. Min Temp	Av.Max Temp	Mean Temp	Samples	Av. Min Temp	Av.Max Temp	Mean Temp
8	30.8	33.6	32.2	2	32.0	33.2	32.6
8	30.0	32.5	31.3	2	31.6	34.0	32.8
8	28.4	32.2	30.3	2	31.9	33.7	32.8
8	30.4	32.1	31.3	2	32.7	33.8	33.3
8	30.8	33.3	32.1	2	32.9	33.0	33.0
8	30.4	33.5	32.0	2	31.8	32.5	32.2
8	29.0	33.6	31.3	2	31.7	34.3	33.0
8	30.0	34.2	32.1	2	31.9	34.0	33.0
8	31.0	33.0	32.0	2	32.9	33.8	33.4
8	31.5	34.2	32.9	2	33.0	33.6	33.3
8	30.9	33.5	32.2	2	31.6	34.0	32.3
8	30.8	33.5	32.2	2	32.0	32.5	32.8
8	29.0	34.0	31.5	2	32.0	33.6	32.3
8	29.0	33.6	31.3	2	32.0	33.4	32.7
8	28.5	33.6	31.1	2	33.1	33.8	33.5
2	30.0	33.5	31.8	2	31.6	31.9	31.8
Mean	**30.0**	**33.36**	**31.79**		**32.2**	**33.55**	**32.87**

For the samples of the consumables, the tomatoes have no physical bruises which makes the marks seen by the thermal imager points to internal deformation which might be due to overloading during harvest or transportation which was yet to manifest on the tomatoes skin for physical observation (Isaac, 2015), provided the samples were not affected by any form of diseases on the farm, during or after harvest (Robinson and Kolavalli, 2010). Meanwhile, infrared thermography has been reported to be useful in the timely detection of diseases in vegetables (Gunjan *et al*, 2021) as also supported by this study.

Figure 4b further analyzed the difference in the average temperature of one of the defected sample or consumable and a fresh tomato to be 1.5ºC. With the discovered anomaly and temperature difference, it is better for any sample or tomatoes in such state to be consumed immediately, as the marks were expected to open up the flesh of the tomatoes and attract bacteria which will lead to rot.

3.2 Condition of Tomato Samples under Storage

As predicted by the camera and duly analyzed, the tomatoes classified as consumable that appeared physically fresh were seen with on-going deterioration as shown in Figure 5.0 after 12 hours of storage under room temperature which might be due to respiration or water loss (Guo *et al.*, 2014) that will eventually make the tomatoes looks undesirable for consumers in due time. The predicted marks by the infrared camera appeared physically with some white discharge from the spot as shown in Figure 6 after 24 hours of storage while Figure 7 shows the thermogram of the tomatoes showing different rates of rot of the samples which is useful for further sorting of the samples. After 60 hours of storage, some samples with high rate of rot or deterioration appeared bad as physically shown in Figure 8 and a thermal image as in Figure 9. It was observed during this period that the worst samples of tomatoes had lesser minimum temperature values (as earlier predicted by the camera) of 27 ºC or less and they already appeared unfit for consumption as they had physically rotten. This study makes infrared thermography survey a very essential tool or technology for sorting and grading tomatoes as it is expected that fresh tomatoes should have a temperature not less than 31ºC with no brutal defect, hence will rot so fast.

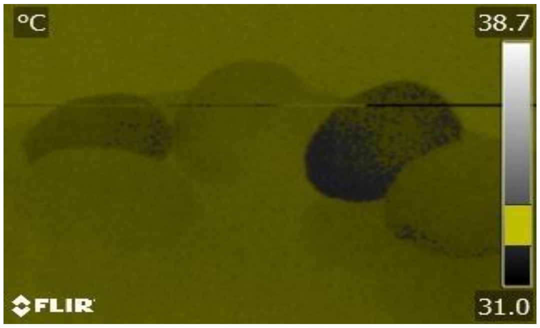

Figure 5: Thermogram showing decomposition of tomatoes

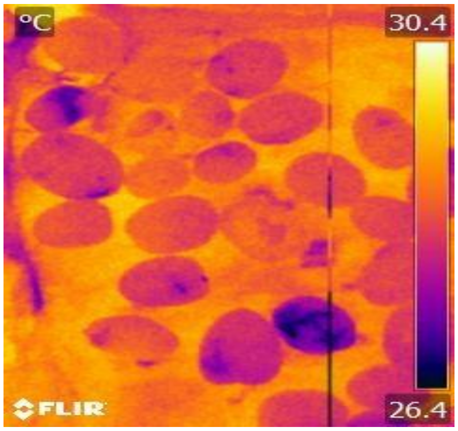

Figure 6: State of tomato samples after 24 hours of storage

Figure 7: Thermogram showing state of tomato samples after 24 hours of storage

Figure 8: State of tomato samples after 48 hours of storage

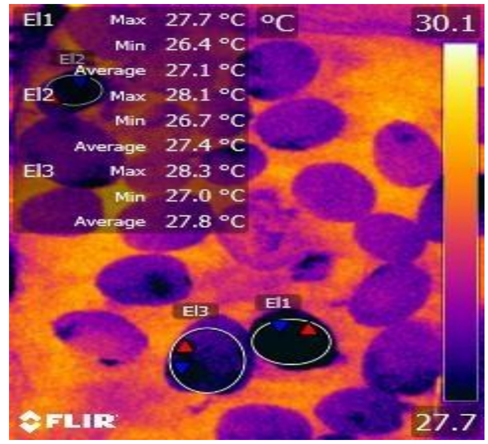

Figure 9: Thermogram showing state of tomato samples after 48 hours of storage

3.3 Shelf Life of Stored Tomato Samples

The graph shown in Figure 10 showed the decreasing rate of the consumables and good tomatoes samples to the number of days under storage. It was discovered that some of the tomatoes decompose or rot to an unsafe state for consumption from the second day of storage while the rot emanated from the point the camera spotted or predicted marks. After the third day, many samples under consumable were lost to rot as majority of the tomatoes does not look appealing anymore for any good purpose as earlier shown in Figure 8. However, the tomatoes samples in the good class despite the varying condition have an extended shelf-life beyond the consumables with an insignificant loss after the fourth day. Meanwhile, the losses recorded might be due to the nature of the vegetable and or the storage environment (Micheal and Kolawole, 2020) as majority of the samples in the good category still looks fresh as in Figure 11 physically after five days of storage with an average minimum temperature of 31.4ºC as thermograms were analyzed after five days of storage as shown in Figure 12. This implies that, if tomatoes can be really fresh at the point of purchase, shelf life can be either maintained or extended. This study established the importance of infrared thermography to grading of perishables against physical inspection.

4. CONCLUSION

The use of thermal camera for predicting tomatoes freshness will help the mass from eating perishables that could be detrimental to health and provide information on the storage technology for tomatoes. Infrared thermography technology will aid the survey of tomatoes in processing factories and a good tool required for storage condition monitoring of perishables. It is recommended to determine the emissivity values for various agricultural produce to aid quantitative surveys of agricultural produce or bio-materials.

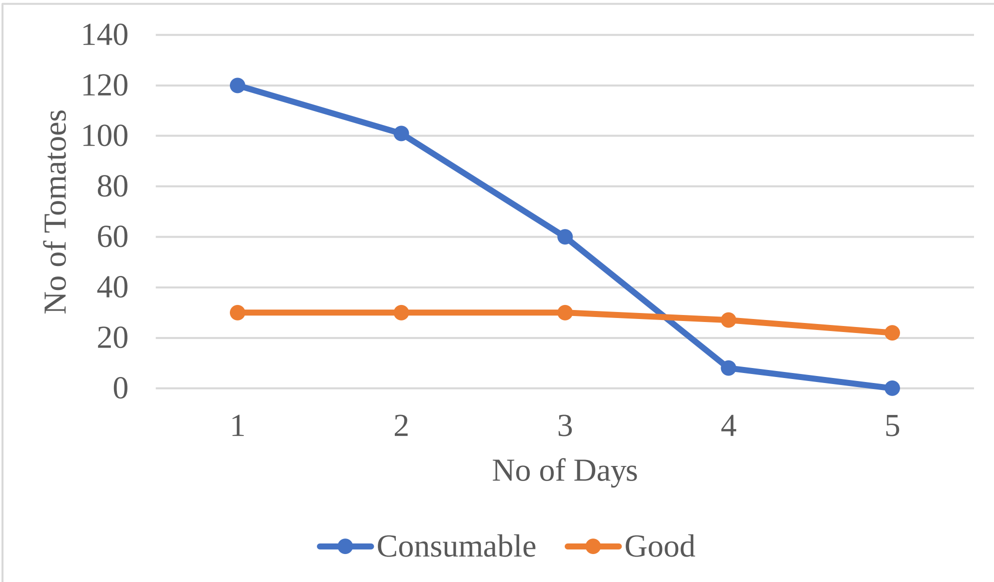

Figure 10: Tomatoes grade and quantities during Storage

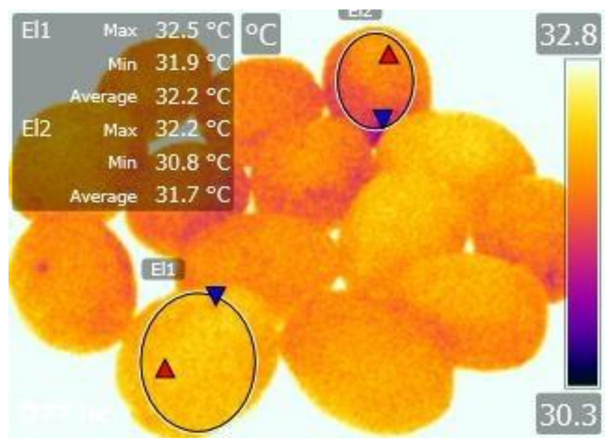

Figure 11: State of good tomato samples after 5 days of storage

Figure 12: Thermogram showing state of good tomato samples after 48 hours of storage

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