

Effect of Solar-Powered Household Refrigeration on Shelf-Life of Mango and Tomato

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Abstract

The use of domestic refrigerators for food storage in Nigeria is common to reduce the postharvest loss and retain the nutritional content of the food. But lack of regular power supply from the national grid has necessitated the use of alternative source of generating power for sustainability of food storage. For this reason, this research evaluated and compared the fresh vegetable and fruit quality (mango and tomato) stored under the ambient room temperature (test 1) and in the crisper compartment of a domestic refrigerator powered by solar energy (test 2). The mass loss, total color difference and sensorial analysis were conducted in order to determine the food quality during 10 days of storage. The results showed mass reduction of 58.2%; 22.8% in tomato and 23.57%; 10.65% in mango for test 1 and 2 respectively. The color difference for both storage condition of food was greater than 7 after 10 days and the sensory analysis recorded for the both storage conditions showed a significant difference in tomato preservation after day 3 and after day 6 for mango preservation. The research results presented improved preservation of the mango and tomato when kept inside the crisper compartment of domestic refrigerator as compared to conventional food storage. Briefly, these results can support the general idea of reducing the postharvest loss of food by preservation in the domestic refrigerator.

Keywords: Postharvest, Storage, Vegetables and Fruits, Mango, Tomato.

Introduction

Refrigeration is an essential method of food preservation as it slows down chemical and biological activity related to degradation and loss of quality in food products, Çengel and Ghajar (2015). Natural refrigeration has been used for many years through different methods such as snow, ice, and brines that give food lower temperatures, Ibarz and Barbosa (2014). It was only in 1913, that the refrigerator as we now know it was developed, with commercialization beginning in the 1920s (De la Cruz *et al.*, 2021). Since then, studies and updates are constantly being made to achieve the best results in food preservation, increasing food safety, and reducing losses (Onwude *et al.*, 2020). All food products have a finite period of time in which the product preserves a level of quality, with acceptable

organoleptic and safety characteristics, under well-defined storage conditions. This is described as shelf life, in the food industry (Nicoli, 2012; Giarratana *et al.*, 2020). Fresh products are subject to microbiological, enzymatic, chemical, and physical reactions during storage (De Souza *et al.*, 2022; Brizzolara *et al.*, 2020).

Minimally processed products such as fruits and vegetables continue their metabolic activity, respiration, and ethylene production even after being harvested (Hoffmann *et al.* 2021a). By lowering storage temperatures and controlling them at adequate levels, specific to the various fresh food products, different systems, and design of the refrigerator compartments of the refrigerator, can contribute to extending the shelf life of fruits and vegetables (Hoffmann *et al.*, 2021; Hertrich and Niemira, 2021). It happens because the mechanism of applying cold air in refrigeration reduces chemical reaction rates and consequently delays any possible microbial growth, prolonging shelf life by days, weeks, or even months (Roccato *et al.* 2017).

The Agricultural sector of Nigeria is a major contributor to its development (Fatoba *et al.*, 2011) thus food loss is a major concern. Microbial contamination of fruits and vegetables regularly occurs in plantation fields, contact with soil, dust, contaminated irrigation water and use of raw sewage or manure fertilizers (Razzaq *et al.*, 2014; Senjuti *et al.*, 2014; Hannan *et al.*, 2014). Therefore, the needs to guide against postharvest loss of agricultural products cannot be overemphasized in Nigeria for optimum production through preservation and conservation of the produce during harvest for off season usage.

However, there are two important reasons for considering solar energy resource for powering the refrigerator for preservation of food in tropics. First, most the countries in tropics have good solar radiation. Secondly, energy is a critical need of these countries but they do not have widely distributed readily available supplies of conventional energy resources.

The study was aimed to compare the results of different storage conditions for fruit and vegetable (mango and tomato), one is under controlled conditions inside the *compartment* of a solar powered domestic refrigerator and the other is under ambient storage condition in the laboratory. Tests and analyses were conducted to determine the product quality and safety, over time.

Statement of the Problem

Postharvest loss is a major concern in Nigeria Agricultural sector, as it is responsible for food scarcity at off season period which leads to depreciation of farmer income. So, the needs to guide against postharvest loss of agricultural products cannot be overemphasized in Nigeria for optimum production through preservation and conservation of the produce during the harvest for off season usage.

However, the use of refrigerator for food preservation have been threatened due to lack of sustainable energy supply from national grid. But, recent improvement in solar energy has made the usage of refrigerator for food preservation possible in Nigeria, especially in rural communities that lack energy supply from the national grid.

Materials and Methods

Postharvest treatment and storage conditions

The mango and tomato used were purchased from Towobowo market at Igboora in Ibarapa Central local government of Oyo State. Samples were selected based on uniformity of size, shape, color and maturity and without mechanical damage and disease. The samples were immediately transported (sterile polythene bags), within 1 hour, to the postharvest Laboratory of Oyo State College of Agriculture and Technology, Igboora, Oyo State (OYSCATECH), and prepared for storage. The mango and tomato handling steps prior to storage consisted of washing thoroughly with distilled water to remove dirt from the surface. They were equally divided into two parts, where one part was stored directly on the polythene covered floor in the laboratory whereby subjected to ambient room temperature as test 1 and the other inside the crisper compartment of the refrigerator as test 2 respectively.

The cooling storage of the fresh food samples were performed in the room temperature and in crisper compartment of a domestic refrigerator for 10 days. The mass loss, color differences and sensory analysis of both food sample were taken daily for 10 days for the two conditions.

Mass variation

The data acquisition of mass was done periodically, through an electronic balance (uncertainty of 0.01 g). Mass loss ($ML(t)$) from food samples was calculated as (Hoffmann *et al* 2021)

$$ML(t) = \frac{m_i - m(t)}{m_i} \times 100 \quad (1)$$

where m_i is the initial mass (at the beginning of both storage condition) and $m(t)$ is the food sample mass at the time (t). $ML(t)$ is expressed in %.

Total color difference and image acquisition

A colorimeter with synthetic colorants was used to measure color changes using CIE – Lab color space, the L^* (lightness), a^* (redness-greenness) and b^* (yellowness-blueness) parameters. Also, the total color difference (ΔE) was calculated as follows (Laguerre and Flick 2010):

$$\Delta E = [(L^* - L_o^*)^2 + (a^* - a_o^*)^2 + (b^* - b_o^*)^2]^{1/2} \quad (2)$$

where L_o^* , a_o^* and b_o^* are the color values of the fresh food at the beginning of storage. In addition, images of food samples were acquired during the storage using an image acquisition tray (30 cm x 25 cm) and a digital camera (spark 7 android phone).

Sensorial analysis

The samples were evaluated by a trained sensory panel, composed of 6 sensory analysts, at the beginning of the experiment and on days 3, 6 and 10 of cold storage. This evaluation was carried out in individual sensory booths, with control of lighting, temperature and absence of sounds and noises. The sensorial test was performed to analyze the appearance, texture and odor of the fresh fruit and vegetable. All samples were coded with 3-digit

random numbers and 11-point hedonic scale was used. This scale ranges from 0 (best food quality condition) to 10 (worst quality condition), with 7 being the level established as the acceptance limit.

Statistical analysis

Data from mass loss and sensory analysis were analyzed using Statistical software (SPSS), the variables used for mass loss and sensory analysis are (mass loss, time (days)) : (appearance, texture and odor) respectively. All measurements were performed in triplicate and the results were reported as the mean $\pm$ standard deviation (SD). Significance among mean values was determined at 5% level of significance ($p \leq 0.05$) by one-way analysis of variance (ANOVA) by following post-hoc Tukey's test.

Results and Discussion

Mass loss

Figure 1 showed results of mass loss of mango and tomato, submitted to different storage conditions (Test 1 and Test 2). A significant reduction in the mass of the tomato samples was observed when compared to mango. This result can be explained by the intrinsic conditions of the food samples, such as porosity and moisture content, for example. At the end of 10 days of both storage conditions, the tomato subjected to the conditions of test 2 showed a reduction ($p < 0.05$) in mass of $22.64 \pm 3.77\%$, while tomato stored in test 1, after the same period, showed more than double (2.6) of reduced mass ($58.15 \pm 4.92\%$) (Figure 1A).

Also, for the mango after 10 days of both storage conditions, the preservation of the mass, in test 1, was 2.2 times the value in test 2 (Figure 1B). The expected high humidity condition, observed in refrigerator (test 2), favored the mass retention since this food consists of approximately 95% of the mass in moisture content, when fresh (freshly harvested).

The relation between the relative humidity conditions of air and the moisture content present in fruit and vegetables play an important role in the process of mass maintenance and postharvest quality of fresh foods (Duret *et al.*, 2014). It was observed and expected that the stable and greater relative humidity of the refrigerator in test 2 led to greater mass retention in the fresh food samples stored in this condition than of test 1 storage condition.

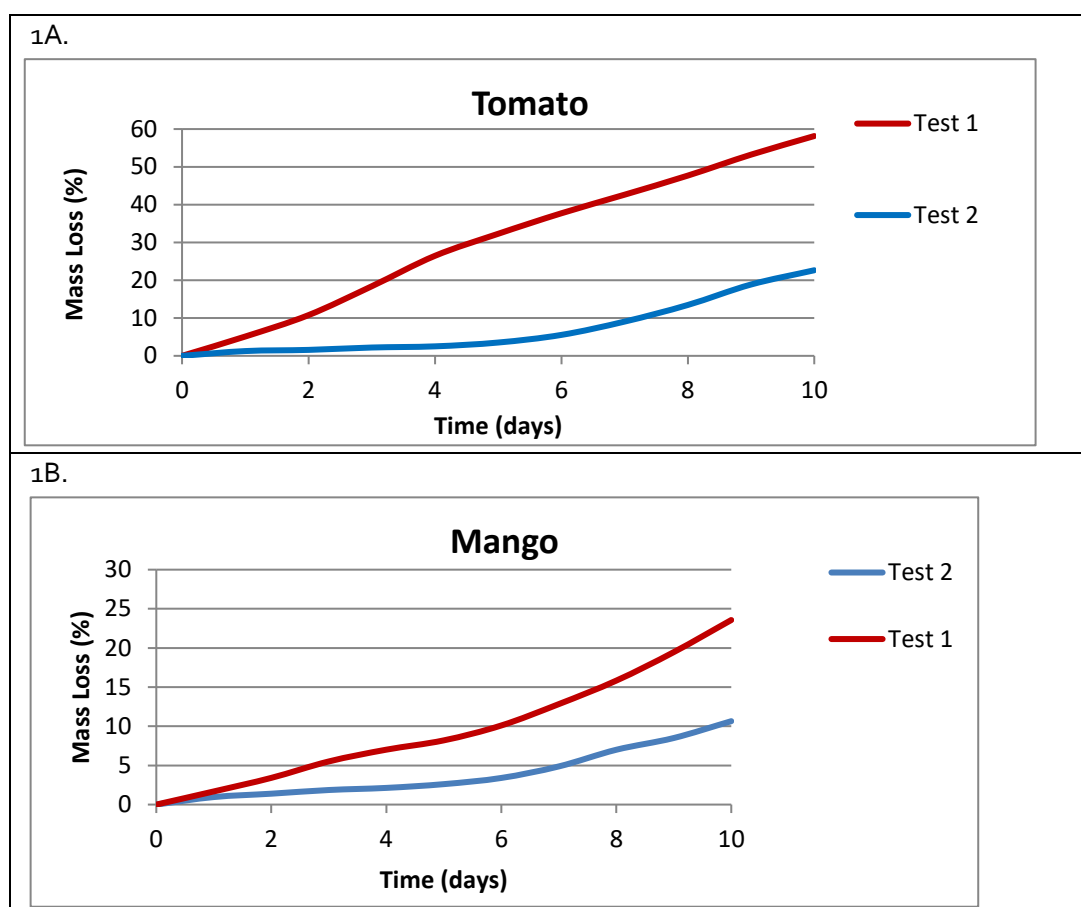


Figure 1. Mass loss from (A) Tomato (B) Mango, according to Test 1 and Test 2

Total color difference

Color is also an attribute that has the greatest influence on consumer perception, selection, preference and purchasing decisions. The peak of the quality of fruits and vegetables is at harvest time, the greater the variation in color concerning the initial condition, the further away from the color desired by the consumer the food will be. Thus, its change over time is seen as an undesirable modification. Figure 2 are presented the images of tomato and mango samples during its storage in both storage conditions.

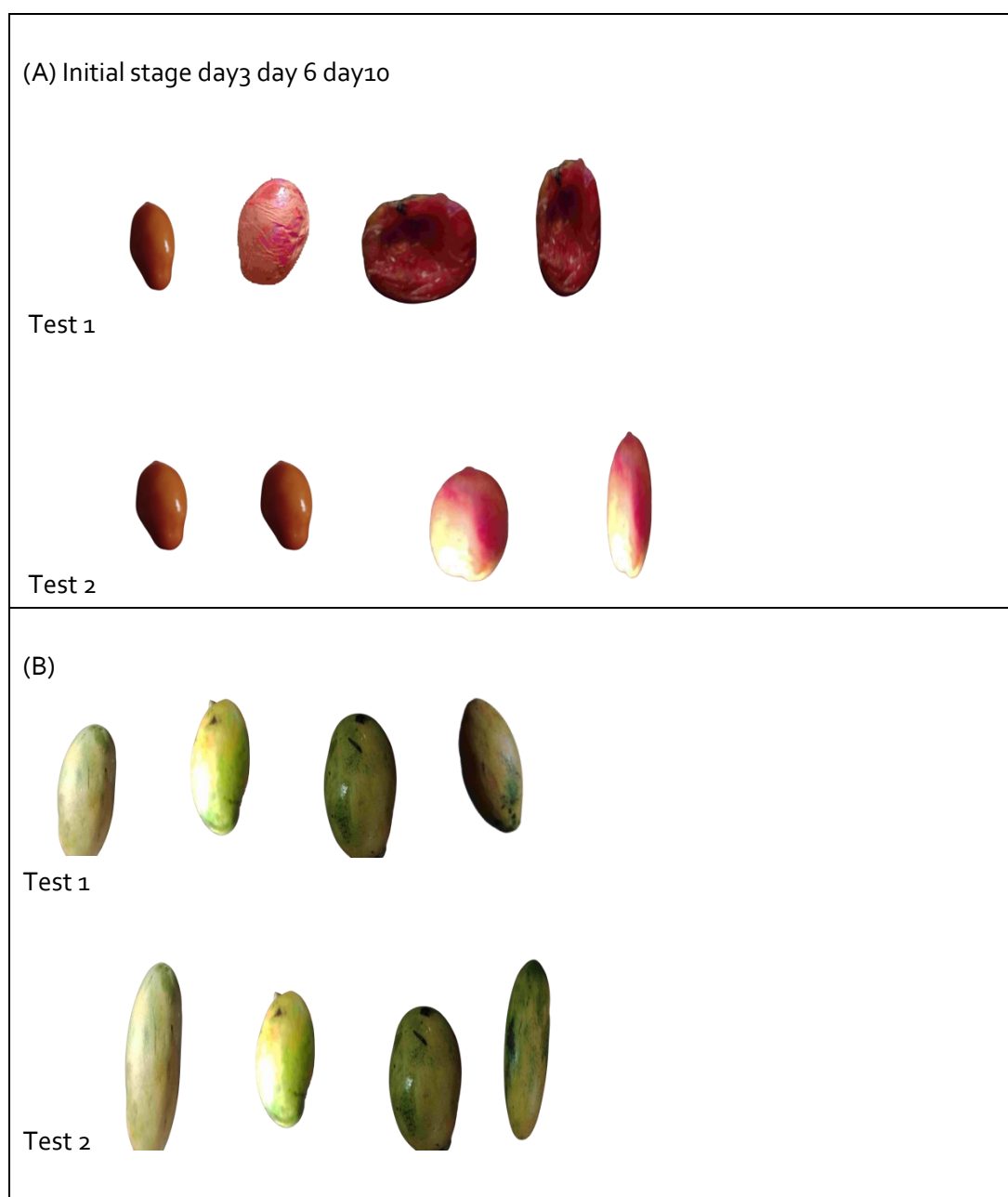


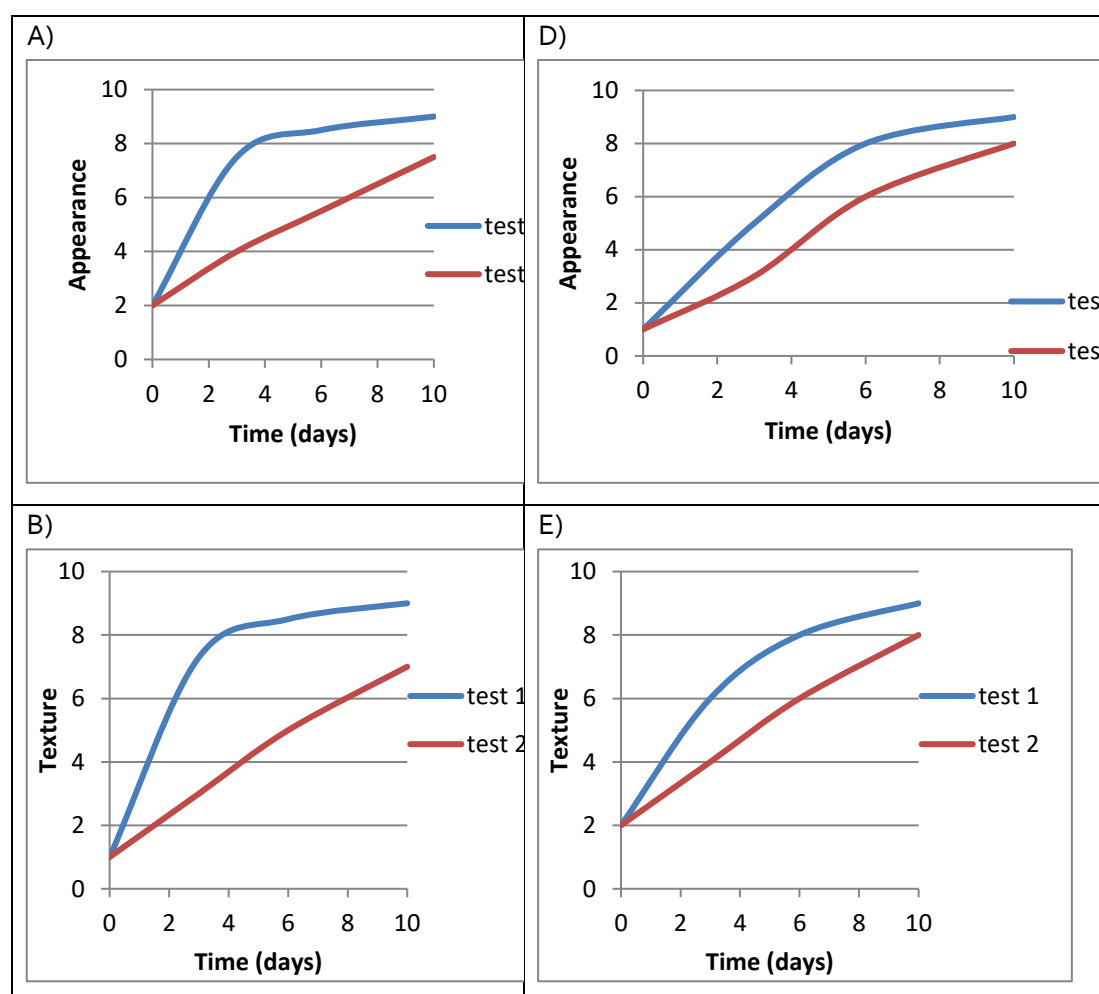
Figure 2. Images from (a) Tomato and (b) Mango during both storage conditions.

According to Pourjavaher *et al.* (2017), the value of the total color difference (ΔE) greater than 5 can be visually detected by the human eye. The mango samples showed values, of total color difference, above 7, already after the 6th day of storage in both tests. At the end of 10 days, the values were 9.9 and 8.6 for tests 1 and 2, respectively. Both conditions promoted similar alterations in the coloration perceptible to consumers ($p > 0.05$). Although the conditions of test 1 were unfavorable for mango storage, test 2 retained more moisture in the food, which is a facilitator of yellowish reactions. Thus, the different moisture conditions of tests 1 and 2 had no impact on the mango color.

The color variation of the tomato samples presented divergence on the last day of refrigerated storage (day 10). The reduction of mass and consequent compacting of the structure of the tomato, in test 1, interferes with the coloration of the food once its pigmentation (chlorophyll) becomes concentrated. One of the plant structures that suffer alteration is the vein of the tomato, which becomes less thick with the reduction of mass, thus affecting the color of the food. At the end of the storage in test 1, the samples of tomato already showed a total color difference of 14.7, while the same tomato, stored in test 2, showed a change in color of only 8.6, which presented a significant difference ($p < 0.05$) in color stability from tomato.

Sensorial analysis

Figure 3 shows the results of the sensory analysis, performed with the samples of tomato and mango. The results obtained were related to the attributes of appearance, texture and odor of each sample, during the 10 days



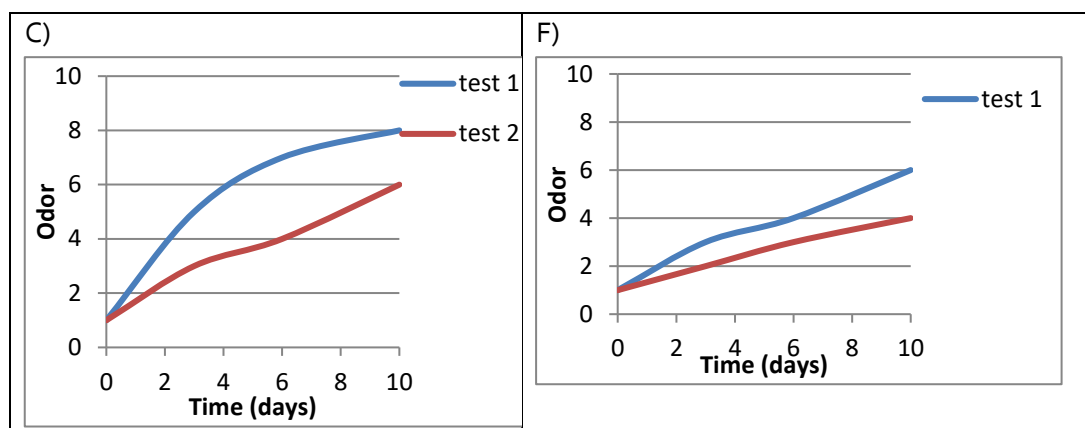


Figure 3. Appearance, texture and odor from (A-C) tomato and (D-F) mango

In test 1, the samples showed results higher than 7 for appearance and texture after 3 days of storage, which characterizes the tomato as not acceptable. The appearance and texture of the tomato suffered the direct influence of the intense loss of mass, since the reduction in moisture content promoted the shrinkage of the food, leaving it with a wrinkled aspect (no freshness) and spongy texture. According to Harker *et al.* (2019), loss of mass, of fresh foods, can lead to commercial rejection due to sensory alterations. Test 2, which favored the preservation of tomato mass, showed results within the acceptable (<7), for the three sensory parameters under evaluation (appearance, texture and odor), before the 10 days of testing. There was a significant difference ($p < 0.05$) in the preservation of the tomato, according to the storage conditions in tests 1 and 2, in all the sensory parameters evaluated. The mango showed a significant difference ($p < 0.05$) in the preservation of the sensory attributes in test 2 compared to test 1. All attributes were evaluated as acceptable until the 10th day of storage in test 2, while in test 1, appearance and odor classified the food as disposable after the 6th day. The texture of the mango in test 1, had great influence by the loss of structure resulted from mass loss of the fruit, which resulted in its rejection on day 6. However, both conditions showed a similar loss in the odor attribute, being higher than 7 on the last day of storage (10th day).

Conclusions

It can be concluded from the findings that the stable and greater relative humidity in refrigerator (test 2), favored the preservation of the food, mainly improved mass retention and shelf-life food. The tomato mass reduction was 2.6 times more in test 1 than in test 2 at day 10, while the mass reduction for mango in test 1 was 2.2 times more than that of test 2 at day 10. The color change of tomato was adversely affected by the storage conditions of test 1 and test 2. The difference in storing conditions has a significant impact on the color change of tomato, but the different moisture conditions of tests 1 and 2 had no impact on the mango color.

The sensory analysis demonstrated greater acceptance for the mango but unacceptable for tomato. There is a significant difference in the appearance parameter for the both storage

conditions. Thus, it was observed that the preservation and stability of the food characteristics, stored in the refrigerator are better favored than the one stored under the ambient room temperature.

Recommendations

- i. The use of solar power refrigerator is recommended for local farmers for preservation of their food produce to reduce the postharvest loss.
- ii. Government should subsidize solar power components to make it affordable for local farmers.

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