Effect of Solar Drying on the Proximate and Microbial Composition Of *Abelmoschus esculentus*

*Kolawole, O.M* ¹,  *Ajiboye, A.E* ²,  *Aturu, E.E* ¹,  *Anibijuwon, I.I* ¹

¹Infectious Diseases and Environmental Health Laboratory, Department of Microbiology, Faculty of Science, University of Ilorin, P.M.B 1515, Ilorin, Nigeria.
²Department of Microbiology, College of Pure and Applied Sciences, Kwara State University, Malete

ABSTRACT

Okra fruits were subjected to drying using a local solar fabricator designed by the Department of Physics, University of Ilorin, Nigeria. There was significant differences between the mean temperatures of the colour light frequencies compared with the control (p <0.05) throughout the period of drying. Okra dried with deep green and light purple colour frequencies had the highest crude protein content (23.2%), and carbohydrate (76.8%) respectively, light red and deep brown had the lowest vitamin C content (4.21) when compared with the control (9.47). Also light green (1.07%), light purple (0.80%) and black (10.07%) had the highest crude fat, crude fibre and ash respectively compared with the control ash (0.99%), crude fat (0.71%), crude fibre (9.85%). It was revealed that these colours were significantly different (p<0.05) from the control. The relative humidity ranged from 53.0% to 64.3%. There was reduction in the acidic content of the dried okra compared with the fresh fruits for all colour frequencies and control. The light blue had the highest average bacterial count of 8.7 x 10⁴ cfu/ml while the light green had the lowest count of 5.0 x 10⁴ cfu/ml. The microorganisms isolated were widely distributed in all the okra samples.

Key words: Solar drying, frequencies, bacterial, okra, proximate, storage.

INTRODUCTION

Traditionally, solar drying has been used as a method of preserving foodstuffs in Nigeria and other developing countries. Drying preserves food by removing enough moisture from the food to prevent decay and spoilage. In many countries of the world the use of solar thermal systems in
agriculture to conserve vegetables, fruits, coffee, and other crops has been shown to be practical and economical [1, 2, 3].

Abelmoschus esculentus (Okra) belongs to the family Malvaceae. It is highly grown as a vegetable crop in the tropics and sub-tropics and also in the warmer temperate areas. It is a plant of African origin and is known under various local names; Abelmoschus esculentus which was earlier designated as Hibiscus esculentus established by Carlos Linnaeus in 1737. In Nigeria, it is known as “Ila” in “Yoruba”, “Kubewa” in “Hausa” and “Okwale” in “Igbo” land [4]. Okra is a prominent fruit and leafy vegetable grown for domestic consumption of the highly nutritious immature leaves and fruits in Nigeria [5]. Most of the cultivation is done during the dry season either as a follow up crop to early maize or in fadama cultivation, especially in the South West Nigeria [6].

The nutritional composition of ripe seed of okra has been reported to contain 20% edible oil, 2.0% protein, vitamin A (0.2mg/100g), vitamin C (25mg/100g), high calcium content (92mg/100mg) [7]. The edible portion of the fruit on average contains approximately 86.1% moisture, 2.2% protein, 9.7% carbohydrate, 1.0% fibre, 0.2% fat and 0.9% ash. Okra is a good source of Vitamin A and B and also contains Vitamin C and Minerals especially iodine [8]. Vegetables such as okra from the nutrient point of view can support the growth of bacteria, mold and yeasts [9, 10, 11].

Vitamin A is usually retained during drying; however, because vitamin A is light sensitive, food containing it should be stored in dark places. Vitamin C is destroyed by exposure to heat, although pretreatment of foods before drying increases the Vitamin C content [2, 12].

The wavelength of the rays of sunlight used for drying consists of a broad spectrum [13]. Although the spectrum is continuous, there are no clear boundaries between one color and the next. The electromagnetic spectrum is made up of rays of light that are damaging to microorganisms and will affect the bacterial growth observed in any food sample at a given time. Almost all type of foodstuff is susceptible to decay and microbial activities [12]. Various reasons have been adduced for the spoilage of okra fruits. These include: poor method of preservation, transportation problems, and low price of farm products during harvest season among others. Hence the need to preserve okra fruit cannot be overemphasized.

Traditional sun drying often yield poor quality, since the produce is not protected against dust, rain and wind, or even against insects, rodents, birds and domestic animals while drying [12]. In this study, these problems are tackled by the use of a fabricated enclosed container for drying the okra, thereby minimizing the risk of soiling, contamination with microorganisms, formation of mycotoxins and infections that would have resulted from disease-causing germs.

This study therefore intend to investigate the effects of solar drying on the proximate and microbial composition of okra fruits using a local solar fabricator designed by the Department of Physics, University of Ilorin, Nigeria.
MATERIALS AND METHODS

Collection of samples
A large quantity of fresh okra was bought from “Oja-Oba” a major market in Ilorin, Nigeria. The okra fruits were healthy and free from all forms of mechanical injury, which might be a possible source of contamination.

Description of the fabricator used for drying
The fabricator is a long wooden box with 8 holes. Plastic containers were then placed in the drilled holes, which have perforations at the sides and base. The inside was coated black. The black colour inside the bucket is a good absorber and poor reflector of heat and light. The perforations at the base and side of the bucket are to prevent the accumulation of water and enable free flow of air [12, 14].

The okra to be dried was placed at the base of the bucket. The bucket was covered with varying colour cloth material of the same textile as the case maybe except for the control and then placed in the hole.

Preparation of sample for drying
The okra fruits were all properly washed and sliced. 200g was weighed and placed in a container in one of the holes in the fabricated wooden box, covered properly with a white textile material, corked properly and left in the sun to dry. The procedure was repeated for other colours that is, black, red, orange, blue, green, purple and brown in duplicates for the light and deep colours of the same textile material. The control was without any covering of cloth material [14].

Wavelengths of the light rays on the cloth material
The range of light intensities for the colour textile materials was adapted from the work of [12].
1. Violet (380 – 450 nm)
2. Blue (450 – 495 nm)
3. Green (495 – 570 nm)
4. Yellow (570 – 590 nm)
5. Orange (590 – 620 nm)
6. Red (620 – 750 nm)

Determination of Temperature
The temperature of the okra fruit was determined using a clean mercury bulb thermometer which was passed through a hole located by the side of the container into the center of the sample. The thermometer was allowed to stay for about 5 minutes after which the temperature of okra in degree centigrade was read. This was carried out 6 times daily at an interval of 3 hours.

Determination of pH
Laboratory Radiometer – Acid-Base analyzer with glass electrodes was used to measure the pH. This was done by inserting the electrode into 10ml suspension containing 1g of the sample homogenized in 9ml of sterile distilled water. The apparatus was standardized with (buffer) solution of pH 6.9, 4.2, 9.0 before used.
Determination of Proximate Composition
The moisture content, crude protein, fat, fibre, carbohydrate and ash of the okra fruit were determined using the methods of [15, 16].

Determination of Vitamin C
Five grammes of dried okra was ground and homogenized in 45ml of distilled water. The suspension was then filtered. Five milliliters of the filtrate was pipetted into a 250ml conical flask & 0.1ml of glacial acetic acid was added. Dichlorophenol indophenol was titrated against the filtrate in the flask until the solution become faint pink. The titre value was taken and the Vitamin C content was then calculated using the method of [15].

Preparation of Media, Isolation Techniques and Characterization of Isolates
The materials used such as glasswares were properly sterilized in the oven (Gallenkamp) at 160°C for 1h. All the media used were prepared according to the manufacturer’s instructions and then autoclaved at 121°C for 15 min. The isolation and characterization of bacterial and fungal isolates were carried out according to the methods described by [17]. The Bergey’s Manual of Determinative Bacteriology was used for identification of bacterial isolates [18].

Statistical Analysis
The results were presented as mean ± SEM. Data collected were analyzed by ANOVA. While significant differences among the mean were determined using Duncan’s multiple range test and results were considered statistically significant at p<0.05.

RESULTS
The result of the mean temperature during the periods of drying showed that there was no significant difference between varying colour frequencies compared with the control. However, there was significant difference (p <0.05) among means of the same light frequencies over the seven days period of drying (Table 1).

The results of the relative humidity showed the relationship between the atmospheric temperature and amount of water available in the air of the environment during the drying process. The range of measurement was between 53.0% and 64.3%. The average relative humidity was found to be highest on the third day while it was lowest on the first day (Figure 1).

As observed in Figure 2, the values of pH are found to alternate between the weak acid regions. The black had an initial pH of 4.8 on the first day, which then increased to 5.5 on the seventh day. Results showed a significant reduction in the acidic content of dried okra as compared with the fresh fruit. This trend also occurred in the control sample.

Table 2 compared the results of the mean values of the proximate composition of the okra fruit during the drying period. The results revealed that % moisture content, % crude protein, % carbohydrate, % crude ash, and % vitamin C are not significantly different from each other while % crude fat and % crude fibre showed significant difference.
### Table 1: Average daily temperature of okra during the period drying (°C).

<table>
<thead>
<tr>
<th>Box</th>
<th>Frequency range (×10^{12})Hz</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Red</td>
<td>384-482</td>
<td>31.8±2.24a</td>
<td>32.3±2.64ab</td>
<td>28.7±2.30c</td>
<td>31.4±2.51b</td>
<td>29.5±1.54c</td>
<td>32.2±2.93c</td>
<td>31.8±2.14b</td>
</tr>
<tr>
<td>D Red</td>
<td>482-503</td>
<td>31.1±2.24a</td>
<td>32.2±2.64ab</td>
<td>30.3±2.30d</td>
<td>31.4±2.51c</td>
<td>29.5±1.54d</td>
<td>32.2±2.93d</td>
<td>31.8±2.51b</td>
</tr>
<tr>
<td>L Orange</td>
<td>503-520</td>
<td>31.7±2.32a</td>
<td>31.5±2.59ab</td>
<td>30.0±2.18d</td>
<td>31.2±2.48c</td>
<td>31.2±2.08d</td>
<td>33.1±2.72d</td>
<td>31.8±1.99b</td>
</tr>
<tr>
<td>D Orange</td>
<td>520-610</td>
<td>30.8±2.11a</td>
<td>31.8±2.47ab</td>
<td>29.4±2.11c</td>
<td>31.2±2.74c</td>
<td>29.0±1.63c</td>
<td>33.0±2.94c</td>
<td>32.7±2.32b</td>
</tr>
<tr>
<td>L Yellow</td>
<td>610-659</td>
<td>31.7±2.64a</td>
<td>32.7±2.63ab</td>
<td>29.7±2.33d</td>
<td>31.2±2.46c</td>
<td>29.0±1.75d</td>
<td>32.5±2.95d</td>
<td>32.2±2.20b</td>
</tr>
<tr>
<td>D Yellow</td>
<td>650-769</td>
<td>30.8±2.15a</td>
<td>32.5±2.78ab</td>
<td>2.93±2.21d</td>
<td>30.5±2.51c</td>
<td>28.8±1.72d</td>
<td>32.8±2.85d</td>
<td>31.8±2.06b</td>
</tr>
<tr>
<td>L Green</td>
<td>430-750</td>
<td>31.4±2.40a</td>
<td>32.5±2.92ab</td>
<td>29.8±2.22d</td>
<td>31.7±2.47c</td>
<td>29.5±1.63c</td>
<td>33.2±3.01c</td>
<td>32.0±2.07b</td>
</tr>
<tr>
<td>D Green</td>
<td>60-690</td>
<td>31.0±2.39a</td>
<td>32.2±2.56ab</td>
<td>29.6±1.88d</td>
<td>31.2±2.65c</td>
<td>29.0±1.70d</td>
<td>32.2±3.14d</td>
<td>32.0±2.32b</td>
</tr>
<tr>
<td>L Blue</td>
<td>430-750</td>
<td>32.3±2.96a</td>
<td>32.2±2.70ab</td>
<td>29.3±2.42d</td>
<td>30.3±2.46c</td>
<td>28.8±1.42d</td>
<td>32.5±3.10d</td>
<td>32.7±2.19d</td>
</tr>
<tr>
<td>D Blue</td>
<td>&lt;430</td>
<td>32.0±2.22a</td>
<td>33.1±2.82ab</td>
<td>29.9±2.44d</td>
<td>30.8±2.36c</td>
<td>28.8±1.54d</td>
<td>33.0±2.83d</td>
<td>32.2±2.10b</td>
</tr>
<tr>
<td>L Brown</td>
<td>31.7±2.68a</td>
<td>32.0±2.30ab</td>
<td>27.9±2.69d</td>
<td>30.9±2.30c</td>
<td>29.5±1.69d</td>
<td>32.5±2.78d</td>
<td>32.2±1.30b</td>
<td>31.8±2.14b</td>
</tr>
<tr>
<td>D Brown</td>
<td>31.0±2.24a</td>
<td>32.3±2.72ab</td>
<td>29.0±2.49d</td>
<td>30.2±2.62c</td>
<td>28.6±1.63t</td>
<td>32.7±2.02d</td>
<td>33.2±2.17b</td>
<td></td>
</tr>
</tbody>
</table>

Values are means of six replicate ± standard error of mean (SEM); Values with different letters are significantly different at p<0.05.

Available online at www.scholarsresearchlibrary.com
Figure 1: Percentage Average Humidity

Figure 2: pH values for the okra samples under different light frequencies.
The result of the % crude protein revealed no significant difference at p<0.05 among light yellow, light orange, and light green. However, the control showed significant decreased from the black and white frequencies.

The light purple (76.79%) showed the highest % carbohydrate and the black had 63.25% as the lowest value. Deep brown and light red showed the lowest vitamin C value of 4.21% while the light brown was highest at 37.90% as compared with the control. The results also revealed that light green (1.07%), light purple (0.80%) and deep purple (12.38%) had the highest % crude fat, fibre and ash contents respectively as compared with the control.

Table 2: Proximate composition and vitamin C content of okra dried under different colour frequencies of light

<table>
<thead>
<tr>
<th>BOX</th>
<th>Frequency range (×10^12 H3)</th>
<th>Moisture (%)</th>
<th>Crude protein (%)</th>
<th>Ash (%)</th>
<th>Crude fat (%)</th>
<th>Crude fibre (%)</th>
<th>CHO (%)</th>
<th>Vitamin C (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Red</td>
<td>384-482</td>
<td>90.35[^]</td>
<td>22.90[^]</td>
<td>0.95[^]</td>
<td>0.76[^]</td>
<td>8.55[^]</td>
<td>67.65[^]</td>
<td>4.21[^]</td>
</tr>
<tr>
<td>D Red</td>
<td>482-503</td>
<td>89.55[^]</td>
<td>23.19[^]</td>
<td>0.90[^]</td>
<td>0.75[^]</td>
<td>8.76[^]</td>
<td>66.35[^]</td>
<td>12.63[^]</td>
</tr>
<tr>
<td>L Orange</td>
<td>482-503</td>
<td>90.40[^]</td>
<td>17.52[^]</td>
<td>0.99[^]</td>
<td>0.75[^]</td>
<td>8.80[^]</td>
<td>71.94[^]</td>
<td>29.47[^]</td>
</tr>
<tr>
<td>L Yellow</td>
<td>503-520</td>
<td>89.75[^]</td>
<td>14.88[^]</td>
<td>0.90[^]</td>
<td>0.70[^]</td>
<td>9.87[^]</td>
<td>73.43[^]</td>
<td>11.59[^]</td>
</tr>
<tr>
<td>D yellow</td>
<td>610-659</td>
<td>84.05[^]</td>
<td>15.90[^]</td>
<td>0.94[^]</td>
<td>0.74[^]</td>
<td>9.86[^]</td>
<td>72.56[^]</td>
<td>15.79[^]</td>
</tr>
<tr>
<td>L Orange</td>
<td>520-610</td>
<td>88.70[^]</td>
<td>12.47[^]</td>
<td>1.07[^]</td>
<td>0.75[^]</td>
<td>10.05[^]</td>
<td>75.66[^]</td>
<td>20.00[^]</td>
</tr>
<tr>
<td>D Orange</td>
<td>610-659</td>
<td>89.10[^]</td>
<td>23.19[^]</td>
<td>1.05[^]</td>
<td>0.70[^]</td>
<td>8.65[^]</td>
<td>66.41[^]</td>
<td>12.63[^]</td>
</tr>
<tr>
<td>L Blue</td>
<td>520-610</td>
<td>88.15[^]</td>
<td>17.72[^]</td>
<td>0.94[^]</td>
<td>0.79[^]</td>
<td>8.88[^]</td>
<td>71.67[^]</td>
<td>12.63[^]</td>
</tr>
<tr>
<td>D Blue</td>
<td>659-769</td>
<td>84.53[^]</td>
<td>16.10[^]</td>
<td>0.94[^]</td>
<td>0.80[^]</td>
<td>5.37[^]</td>
<td>76.79[^]</td>
<td>15.79[^]</td>
</tr>
<tr>
<td>L Brown</td>
<td>&lt;430</td>
<td>86.75[^]</td>
<td>22.31[^]</td>
<td>1.04[^]</td>
<td>0.76[^]</td>
<td>9.65[^]</td>
<td>66.24[^]</td>
<td>37.90[^]</td>
</tr>
<tr>
<td>D Brown</td>
<td>&lt;430</td>
<td>89.75[^]</td>
<td>21.29[^]</td>
<td>1.03[^]</td>
<td>0.74[^]</td>
<td>8.55[^]</td>
<td>68.39[^]</td>
<td>4.21[^]</td>
</tr>
<tr>
<td>Black</td>
<td>90.50[^]</td>
<td>24.14[^]</td>
<td>0.97[^]</td>
<td>0.77[^]</td>
<td>9.65[^]</td>
<td>66.24[^]</td>
<td>37.90[^]</td>
<td>26.32[^]</td>
</tr>
<tr>
<td>White</td>
<td>430-750</td>
<td>88.55[^]</td>
<td>21.00[^]</td>
<td>0.99[^]</td>
<td>0.70[^]</td>
<td>10.02[^]</td>
<td>67.29[^]</td>
<td>26.32[^]</td>
</tr>
<tr>
<td>Control</td>
<td>430-750</td>
<td>88.60[^]</td>
<td>18.38[^]</td>
<td>0.99[^]</td>
<td>0.71[^]</td>
<td>9.85[^]</td>
<td>69.99[^]</td>
<td>9.47[^]</td>
</tr>
</tbody>
</table>

Values are means of six replicate ± standard error of mean (SEM); Values with different letters are significantly different at p<0.05.

A total of 5 bacterial species were isolated from the okra sample during the period of drying. The bacterial isolates are *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Micrococcus luteus*, *Pseudomonas aeruginosa*, and *Proteus vulgaris*. As shown in Figure 3, the total bacterial count...
for each of the colour light frequency revealed that light brown had the highest count while the light blue had the lowest average count. The control have same average count as the dark brown and light red but differ significantly in the value of their bacterial count for each inoculation.

![Figure 3: Average bacterial count in each of the light frequencies.](image)

**DISCUSSION**

During the periods of drying as shown in Table 1 the mean temperature revealed no significant difference between varying colour frequencies for each day. However, there was significant difference between the daily temperatures of each light frequency for the period of drying. As observed in the study the recorded temperature range could favour the growth of all the types of organisms that was isolated from the okra. These results agreed with the works of [8, 19].

The research showed the percentage relative humidity of okra to be between the range of 53.0% and 64.3%. The average relative humidity was found to be highest on the 3rd day while it was lowest on the 1st day (Figure 1). The low relative humidity observed from the 4th – 7th day may have accounted for the reduction in bacterial counts on the last day of drying. This finding showed a similar trend to the work of [12] who reported that temperature and relative humidity are important extrinsic factors in determining whether a food will spoil. At high relative humidity microbial growth is initiated more rapidly.

The pH values obtained before and after drying revealed that the pH of okra is in a region of weak acid (between 4.4 and 6.1). This is in agreement with the research of [20, 3] who reported that the internal pH of vegetables falls between 4.5 and 6.4. Also, [9] explained that the pH values of vegetables being weakly acidic allows the growth of certain microorganisms.
There was no significant difference among the % moisture content, % crude protein, carbohydrate, % crude ash, and % vitamin C as the results in Table 2 revealed. As described by [20, 2, 1], drying of vegetables has a great impact on the proximate composition of the food substance. However, significant difference was observed between those of % crude fat and % crude fibre. Since there is the availability of moisture and nutrients in okra, the growth of microorganisms are greatly favoured in line with the availability of nutrient. According to [14] any food substance especially vegetable crops with high moisture will favour the growth of microorganisms at a high growth rate.

The result of the % crude protein revealed no significant difference at p<0.05 among light yellow, light orange, and light green. However, the control showed significant difference from the black and white frequencies. The light purple (76.79%) showed the highest % carbohydrate and the black had 63.25% as the lowest value. The vitamin C value of deep brown and light red was lowest at 4.21% while the light brown was highest at 37.90% respectively as compared with the control. The results also revealed that light green (1.07%), light purple (0.80%) and deep purple (12.38%) had the highest % crude fat, fibre and ash respectively as compared with the control. Similar works done by [8, 19] have revealed that okra has percentage fibre content of between 0.80 and 1.00. The value of percentage moisture content was also reported to have a value of 86.1% for okra.

The differences in bacterial composition and distribution among samples could also be adduced to the frequencies of light and variations in the amount of heat reaching the food. This is in agreement with [21, 12] that food dried in solar driers are free from microbial reach and as such are better preserved and of good quality.

The total bacterial count for each of the light frequency revealed that the light brown has the highest count while the light green has the lowest average count (Figure 3). The control have same average count as the light brown and light red but differ significantly in the value of their bacterial count for each inoculation.

In almost all of the okra samples except the white, light green and light orange *Staphylococcus aureus* was isolated. *Micrococcus luteus* was absent in about two-third of the light frequencies. The presence of these bacterial agrees with the work of [22, 23, 10] which reported that some common source of food contamination includes *Staphylococcus* sp and *Micrococcus* sp.

**CONCLUSION AND RECOMMENDATION**

In conclusion, drying is useful because water is an absolute necessity for life. Thus dried foods are unable to support microbial life. In this study, there was no light frequency that gave a complete desirable product but the deep brown had the vitamin C content highly reduced. An increase in crude fat, crude fibre and ash is found in the light green, light purple and black respectively. The light blue had an increase in microbial count but if contamination is carefully avoided the light green frequency may be better if used for drying since it had the lowest microbial count. This work has open room for further investigations into the effect of varying light frequencies on the proximate composition of several other foods storage and preservation.
REFERENCES


