

Effect of Curing Treatments on Seven Key Farmers' Yams (*Dioscorea* spp.) in Ghana

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Abstract

Curing of freshly harvested yams (*Dioscorea* spp.) is a process for wounded yams during harvest to heal. In this work the effectiveness of straw, polypropylene and jute sack on curing of seven key farmers' yam varieties over a duration of 7, 14 and 21 days was studied. Seven key farmers' yam varieties identified as *Pona*, *Lariboko*, *Dente*, *Mutwumudoo*, *Serwah* belonging to *D. rotundata*, *Matches* and *Akaba* belonging to *D. alata* were studied under different curing treatments. The percentage weight loss of yam tubers varied among the treatments over curing period. Curing under jute sack showed all yam varieties had weight losses less than 2.0%, within 7 days of curing. Five different varieties had weight loss less than 2.0% except *Dente* under the straw treatment. *Mutwumudoo* variety showed the highest water loss (8.4%) for polypropylene sheet and 6.9% for *Lariboko* in the control treatment. During 7 days curing the control and polypropylene treatment did not support yam curing. After 14 days of curing of tubers, similar trends were observed as in 7 days curing. After 14 days of curing under jute sack, percentage weight loss of the tubers ranges from 2.0% - 3.7%. In the straw treatment, the percentage weight loss ranges between 1.0% - 4.7% in all other varieties except *Dente* (*D. rotundata*) (8.2%). Polypropylene sheet treatment showed the highest percentage weight loss in *Mutwumudoo* variety (18.4%). A similar trend was observed for the yam tubers cured for 21 days as percentage weight loss of tubers under jute sacks was 2.5 - 9.8%. Curing temperature and humidity ranged between 27°C - 40°C and 87% - 100% rh for yam tubers under the three different treatments of polypropylene, jute and straw. However, the control treatment recorded lower humidity of 60% - 80% rh. Curing material, duration, climatic conditions and yam varieties influenced curing and *Serwah* variety, which is a *D. rotundata* is the best bet yam variety to cure under jute sack for 7, 14 and 21 days of curing.

Keywords

Yam, *Dioscorea* spp., Curing, Water Loss, Temperature, Humidity, Jute Sack, Grass Straw,

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Polypropylene

1. Introduction

Yams (*Dioscorea* spp.) are major staple foods in most tropical countries [1]. There are six species that are important staples and these are white yam (*D. rotundata*), water yam (*D. alata*), yellow yam (*D. cayenensis*), trifoliate yam (*D. dumetorum*), aerial yam (*D. bulbifera*) and Chinese yam (*D. esculenta*) [2]. There are about 200 different varieties of yams with fresh colour varying from white, ivory and yellow with long and cylindrical shapes often having offshoots referred to as “toes” while their exterior texture is rough and scaly.

Yams serve as an important source of carbohydrate for many people of the sub-Saharan region, especially in the yam zone of West Africa [3]. According to Ene and Okoli [4] over 50% of the daily carbohydrate intakes of West Africans are derived from the consumption of yams. It is a high value crop and significant source of dietary energy in Ghana. It provides a good source of vitamin B6, vitamin E, potassium and manganese [5] [6]. They are good sources of carbohydrate and fibres needed for health and vitality. Yams contain a unique fat-like substance called diosgenin, which is technically classified as a hormone-like molecule with probably anti-cancer effects [7] [8].

Ghana is the third largest producer of yams in the world, following Nigeria and Cote d'Ivoire [9] [10]. Yams are utilized all over Ghana and are important in the Ghanaian culture to the extent that yam festival ceremonies are held annually to usher in newly harvested yams in the Northern and Volta regions of Ghana. Yams are cultivated in every region of Ghana by subsistent farmers however it is concentrated largely in the Brong Ahafo and the Northern regions constituting about 37% and 34% of the total yam production in Ghana, respectively. Acreage under yam cultivation in 2011 was estimated at 403,798 Ha with corresponding production of approximately 5,855,138 MT with 27,000 MT for export [11]. Per capita consumption of yam in Ghana is estimated at 42 kg/annum. Interestingly, the high water content of root and tubers influences their low price per unit, and secondly makes transportation difficult with corresponding losses and this includes yam tubers [12] [13].

The increasing demand for yam on the local Ghanaian and international markets requires improvement in its production, storage, transportation and marketing. When yams are being harvested, some tubers are injured in the form of cuts, bruises and abrasions. These openings act as entry points to wound pathogens to attack the yam. According to Booth [14], 15% of the annual yam production in West Africa alone is lost during storage caused by wound pathogens. In curing, injured yams respond to the injury by forming suberin beneath the exposed cells, followed by the formation of periderm (cork) of thickened cells. This acts as a protective barrier against wound pathogens. The process of curing was initially tested on potatoes and sweetpotatoes and was extended to yams by Demeaux and Vivier [15] and Bautista [16]. Curing of sweetpotato roots was reported to improve their storage [15] [17]. Bautista [16] observed that increased temperature and humidity stimulates the yam tubers to form cork cells, which hermetically close the lesions. Thus, cork cells are formed in the cork cambium and transferred into wound areas, which they close with several layers of wound periderm. This layer greatly reduces the desiccation process and prevents infection by bacteria and fungi [18]. According to Bautista [16] in the formation of the wound periderm, metabolic processes take place, which uses energy gained by expiring starch stored in the tuber releasing water, carbon dioxide and heat into the atmosphere. The losses in weight of the tubers during curing depend on the temperature and humidity at the time of curing [16]. FAO [19] reported approximately 1% loss in fresh weight of tubers at a curing temperature of 35°C - 40°C and humidity of 80% - 90% for duration of 3 days as the curing process allows injured roots and tubers with high water content to heal and protect them from storage diseases and excessive shrinkage [15].

Extensive studies have been done on the physiological processes associated with wound repair in yams during curing but limited information is available pertaining to the effect of different materials on curing of yam tubers. This study investigates the effectiveness of straw, polypropylene and jute sack on curing of the seven key farmers' yam varieties over a cumulative period of 21 days.

2. Materials and Methods

2.1. Materials

Freshly harvested seven key farmers' yams (*Dioscorea* spp.) identified as *Pona*, *Lariboko*, *Dente*, *Mutwumudoo*,

Serwah belonging to *Dioscorea rotundata*, *Matches* and *Akaba* belonging to *Dioscorea alata* were obtained from farm gates at Atebubu in the Atebubu-Amantin District of the Brong Ahafo region in Ghana through the Ministry of Food and Agriculture. The yams were carefully transported to the Pilot Scale Processing Unit of the CSIR-Food Research Institute, where the study was conducted.

Curing materials used were straw, polypropylene and jute sack. The straw was obtained from farmers' fields in Atebubu. The polypropylene and jute sack were purchased from shops in Atebubu.

2.2. Method

Freshly harvested mature tubers of each of the seven selected varieties consisting of 84 tubers per variety were used in the study. The tubers were artificially wounded (4.0 cm × 5.0 cm) using a sharp stainless knife. The wounded tubers were then weighed and the initial weights were recorded. The wounded tubers were arranged in a circular form with the wounded side facing upwards. A temperature/humidity logger was placed on the arranged yams after which it was covered with jute sack. The samples were weighed after curing for 7, 14 and 21 days. The experiment was repeated using polypropylene, straw and a control, which was not covered (**Figure 1**).

2.3. Determination of Percentage Water Loss

In order to account for the initial mass differences of yam tubers, water loss of yam tubers during curing was expressed in g per g initial mass (g/g). Percentage water loss (% WL_{*t*}) is given as:

$$\% \text{ WL}_t = \left[(W_{it} - W_{ct}) / W_{it} \right] 100 \quad (1)$$

where W_{it} , W_{ct} are the initial and final weight of tuber after curing at time t (t = duration in curing treatment).

2.4. Determination of Curing Temperature and Humidity

Curing temperature and humidity within each experiment was determined using a Data Logger (Lascar Electronics UK) obtained from Natural Resources Institute, United Kingdom. The data recorded was then analyzed using Data Logging Software Version 5.51 (EasyLog).

2.5. Statistical Analysis

Analyses were carried out in triplicates and data expressed as means ± standard deviation. Analysis of variance was performed and Duncan multiple test range was used to separate means using the Statgraphics Centurion 16.1.11 (StatPoint Technologies Inc, USA, 2010). Comparisons between sample treatments and correlation analysis were done with a probability $p = 0.05$.

3. Results

3.1. Percentage Weight Loss of Cured Yam Tubers

In studies reported by Been *et al.* [20], Demeaux and Vivier [15] and FAO [19] there are various process of wound healing, which is influenced by technical methods, temperature and humidity of the environment and duration of treatment. Similar observations were made in this study. After 7 days of curing the percentage weight loss of yam tubers varied among the treatments. Curing under the jute sack showed all yam varieties weight loss less than 2.0%. Under the straw treatment, five varieties weight loss were less than 2.0% except *Dente*. The highest water loss (8.4%) occurred in the polypropylene sheet for *Mutwumudoo* and 6.9% for *Lariboko* in the control treatment (**Figure 2**). The control and polypropylene sheet did not support yam curing within 7 days of curing. The best curing for 7 days was observed for jute sack and straw treatment for *Serwah* (0.9%), a *Dioscorea rotundata* and *Matches* (0.2%), a *Dioscorea alata*, respectively.

After 14 days of curing of tubers, similar trends were observed for tubers cured for 7 days. In the jute sack, percentage weight loss of the tubers ranges from 2.0% - 3.7%. Only *Lariboko* variety was 8.4%. In the straw treatment, the percentage weight loss was between 1.0% - 4.7% for all other varieties except *Dente* (*Dioscorea rotundata*) (8.2%). Polypropylene sheet treatment showed the highest percentage weight loss in *Mutwumudoo* variety (18.4%). Percentage weight loss of the other varieties ranges from 1.5% - 4.9%. In control treatments,



Figure 1. Curing of yam under different conditions. (a) Wounded tubers and covered with jute sack for curing; (b) Wounded tubers and covered with polypropylene sack for curing; (c) Wounded tubers and covered with straw for curing; (d) Wounded tubers and uncovered as control for curing.

percentage weight loss ranges between 1.3 - 13.9%. It recorded the highest percentage water loss of 13.9% in *Lariboko* variety (Figure 3).

A similar trend was observed for the yam tubers under curing after 21 days of curing as percentage weight loss of tubers under jute sacks was 2.5% - 9.8%. Percentage water loss of tubers curing under straw ranges between 2.2% - 10.7%. The highest percentage was 21.6% observed in *Mutwumudoo* under polypropylene sheets. The percentage weight loss (17.0%) of *Lariboko* variety was the highest among the tubers under control treatment. In the remaining varieties the percentage water loss was 2.2% - 5.7% (Figure 4). The percentage water loss from

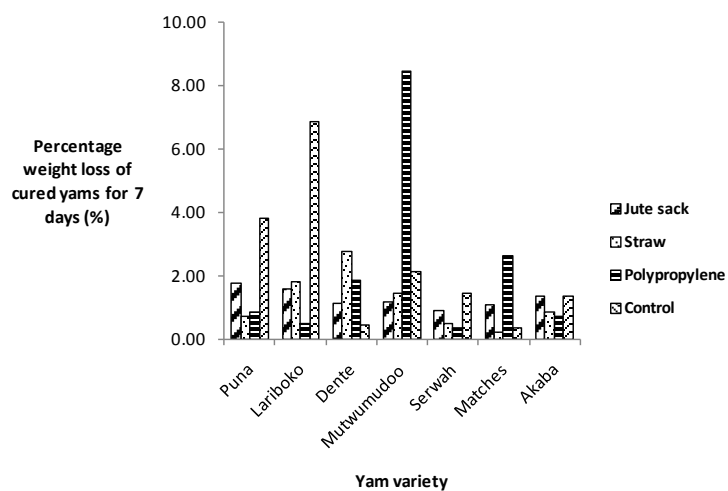


Figure 2. Percentage weight lost after 7 days of curing.

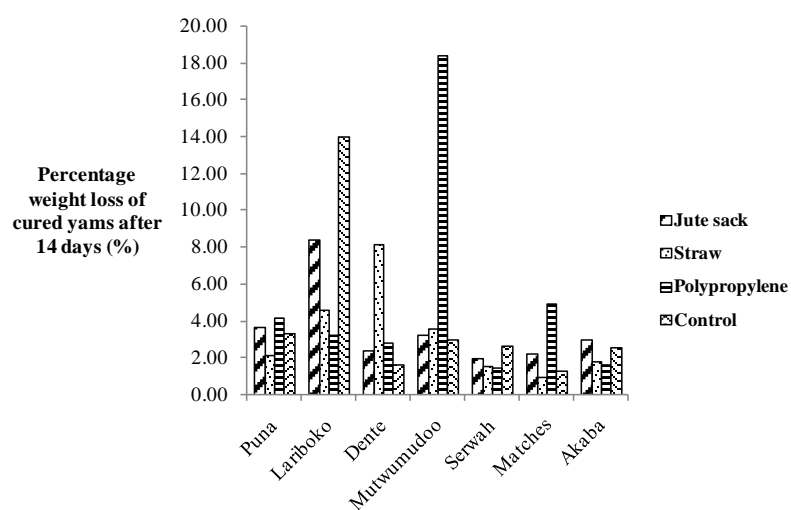


Figure 3. Percentage weight lost after 14 days of curing.

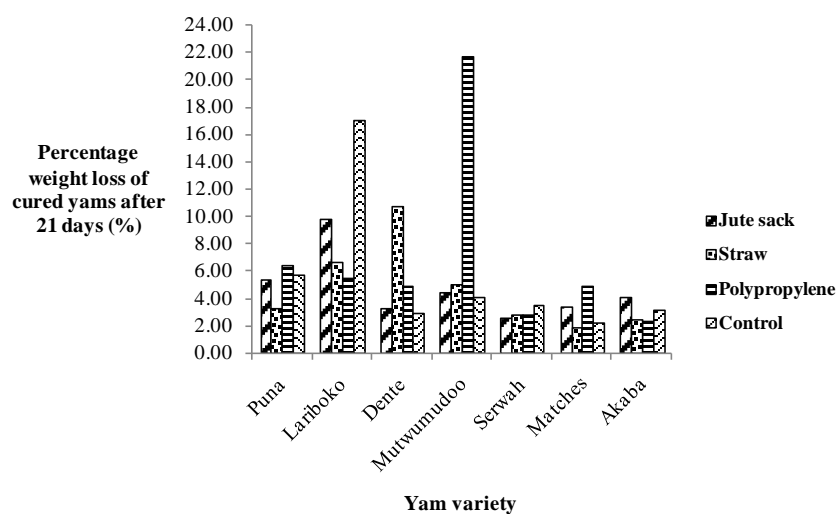


Figure 4. Weight lost during 21 days of curing.

the cured yam tubers is an indication that healing of wounds is related to a certain loss in tuber weight as reported by Bautista [16]. The loss in weight is influenced by the curing conditions implemented. In curing studies conducted on yams in a combination of straw and jute sheets showed weight losses of approximately 1% of the fresh weight of the tubers for 3 days duration [19]. Interestingly, when yam tubers are deeply injured they undergo a process of wound repair which is made up of migration of starch cells to the injured surface within 5 - 10 hours of injury. This is followed by the formation of a suberized layer beneath the cut surface after 2 - 3 days and the production of periderm (cork) after approximately 5 days. There is increased rate of respiration as well as increased hydrolysis of starch to sugars by invertase activity during the changes. Interestingly, studies by Jenkins [21] shows that respiratory losses are higher and greater under tropical temperatures. The increased rate of metabolic activity is maintained until healing is complete. However, wound healing processes do not occur when tubers are injured by surface abrasions or severe bruising. When such abrasions or superficial cuts occur on yams they undergo increased respiratory activity and weight loss until decay as they are exposed to prolong loss of moisture and an increased susceptibility to rot pathogens [22]. Other authors have described wound healing during curing as a process of lignification as cell walls below the wounded cell layers become thickened with lignin or suberin [23] [24].

Statistical analysis of the mean weight loss of the tubers at curing for the four treatments is presented in Tables 1-3. After 7 days of curing under the different conditions, mean weight loss of the seven yam varieties differed significantly ($p = 0.05$). Curing under jute sack, the mean weight loss ranged between 0.009 - 0.12 for *Mutwumudoo* and *Serwah* as the lowest and *Mutwumudoo* as the highest yam varieties. *Serwah* variety recorded the smallest mean weight loss during 7 days curing period under polypropylene sheet and control. However, other varieties behaved quite differently. While *Mutwumudoo* cured well under jute sack, it did not perform well under polypropylene. A similar trend was observed under straw, which shows that *Matches* performed well than the other varieties. Curing under polypropylene and control treatment shows *Mutwumudoo* losing weight more than the other varieties.

Similar trends were observed under the influence of curing treatment and duration of 14 and 21 days. After curing cumulatively for 14 and 21 days *Serwah*, *Matches* and *Akaba* cured appropriately under jute sack and straw than polypropylene and control treatments (Table 2, Table 3).

Table 1. Weight loss of yams after 7 days curing.

Yam variety	Jute sack	Polypropylene sheet	Straw	Control
<i>Pona</i>	0.018 ± 0.012a	0.008 ± 0.008a	0.007 ± 0.007a	0.038 ± 0.038a
<i>Lariboko</i>	0.016 ± 0.005a	0.005 ± 0.005a	0.018 ± 0.014a	0.069 ± 0.058a
<i>Dente</i>	0.011 ± 0.007a	0.019 ± 0.059a	0.027 ± 0.027a	0.004 ± 0.004a
<i>Mutwumudoo</i>	0.012 ± 0.001a	0.084 ± 0.084a	0.015 ± 0.015a	0.021 ± 0.012a
<i>Serwah</i>	0.009 ± 0.009a	0.003 ± 0.003a	0.005 ± 0.004a	0.014 ± 0.011a
<i>Matches</i>	0.011 ± 0.009a	0.026 ± 0.006a	0.002 ± 0.002a	0.003 ± 0.003a
<i>Akaba</i>	0.013 ± 0.010a	0.007 ± 0.007a	0.008 ± 0.008a	0.014 ± 0.014a

Means in column followed by the same letter are not significantly different ($p = 0.05$) from each other.

Table 2. Weight loss of yams after 14 days curing.

Yam variety	Jute sack	Polypropylene sheet	Straw	Control
<i>Pona</i>	0.037 ± 0.012 ^a	0.042 ± 0.028 ^a	0.021 ± 0.010 ^a	0.033 ± 0.019 ^a
<i>Lariboko</i>	0.084 ± 0.055 ^a	0.033 ± 0.017 ^a	0.047 ± 0.016 ^{ab}	0.139 ± 0.042 ^b
<i>Dente</i>	0.025 ± 0.008 ^a	0.029 ± 0.007 ^a	0.082 ± 0.030 ^b	0.017 ± 0.007 ^a
<i>Mutwumudoo</i>	0.032 ± 0.011 ^a	0.184 ± 0.059 ^b	0.037 ± 0.013 ^a	0.030 ± 0.009 ^a
<i>Serwah</i>	0.020 ± 0.011 ^a	0.015 ± 0.006 ^a	0.016 ± 0.007 ^a	0.027 ± 0.008 ^a
<i>Matches</i>	0.023 ± 0.007 ^a	0.049 ± 0.017 ^a	0.010 ± 0.005 ^a	0.013 ± 0.006 ^a
<i>Akaba</i>	0.030 ± 0.009 ^a	0.017 ± 0.006 ^a	0.018 ± 0.006 ^a	0.026 ± 0.008 ^a

Means in column followed by the same letter are not significantly different ($p = 0.05$) from each other.

3.2. Temperature and Relative Humidity

The temperature and humidity over 7, 14 and 21 days of curing is presented in Figures 5-7. Curing of yam tubers under the three different treatments showed temperature and humidity in the range of 27°C - 40°C and 87%

Table 3. Weight loss of yams after 21 days curing.

Yam variety	Jute sack	Polypropylene sheet	Straw	Control
<i>Pona</i>	0.054 ± 0.014 ^a	0.063 ± 0.027 ^a	0.033 ± 0.011 ^{ab}	0.057 ± 0.024 ^a
<i>Lariboko</i>	0.098 ± 0.042 ^a	0.054 ± 0.019 ^a	0.066 ± 0.018 ^{bc}	0.170 ± 0.036 ^b
<i>Dente</i>	0.033 ± 0.008 ^a	0.049 ± 0.016 ^a	0.107 ± 0.027 ^c	0.029 ± 0.010 ^a
<i>Mutwumudoo</i>	0.044 ± 0.011 ^a	0.216 ± 0.048 ^b	0.050 ± 0.013 ^{ab}	0.040 ± 0.010 ^a
<i>Serwah</i>	0.025 ± 0.006 ^a	0.028 ± 0.011 ^a	0.028 ± 0.009 ^{ab}	0.035 ± 0.008 ^a
<i>Matches</i>	0.033 ± 0.009 ^a	0.049 ± 0.012 ^a	0.018 ± 0.006 ^a	0.022 ± 0.007 ^a
<i>Akaba</i>	0.041 ± 0.010 ^a	0.024 ± 0.006 ^a	0.025 ± 0.006 ^{ab}	0.031 ± 0.007 ^a

Means in column followed by the same letter are not significantly different ($p = 0.05$) from each other.

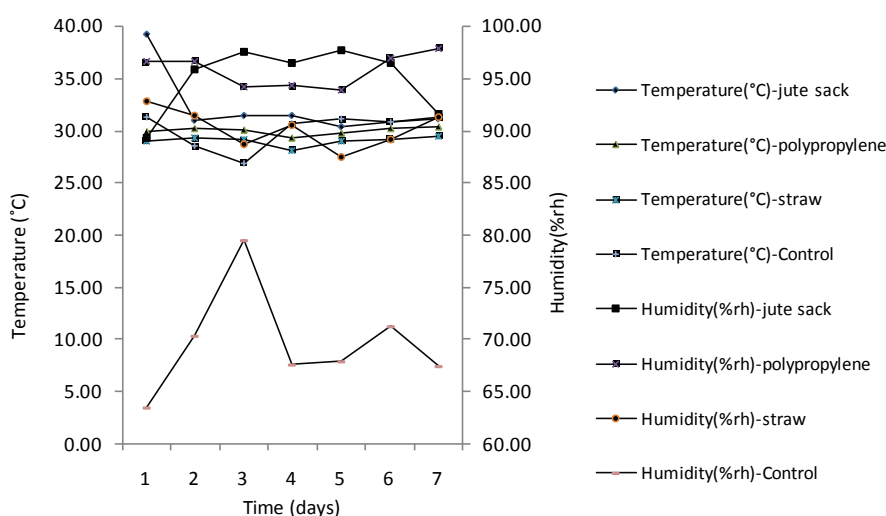


Figure 5. Temperature and humidity changes during the first 7 days.

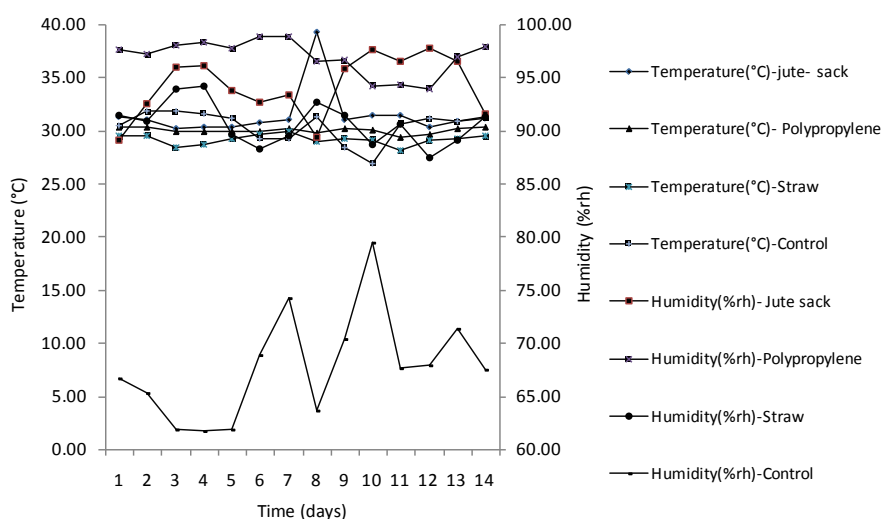


Figure 6. Temperature and humidity changes during 14 days of curing.

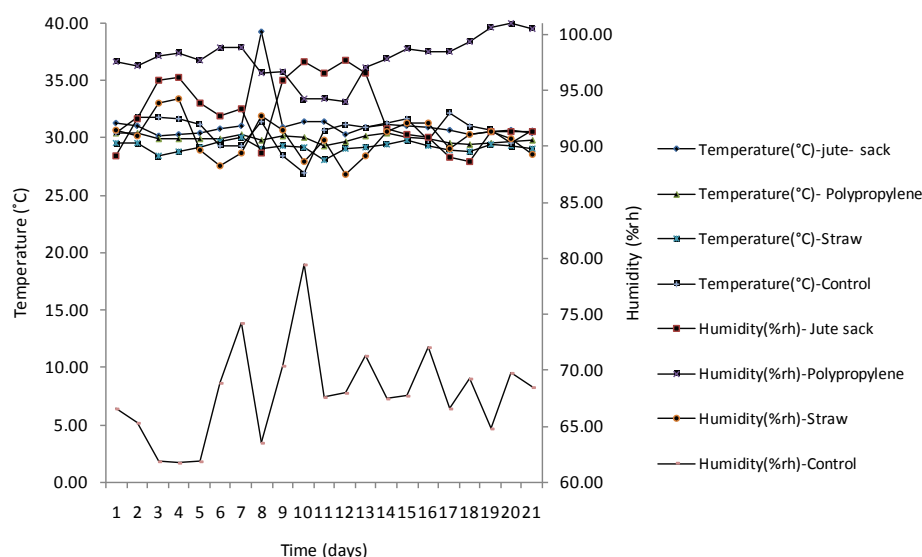


Figure 7. Temperature and humidity changes during 21 days of curing.

- 100% rh, respectively. However, the control treatment recorded lower humidity of 60% - 80% rh (Figures 5-7). These ranges are similar to 35°C - 40°C and 80% - 90% for temperature and humidity as reported by FAO (1990). In other studies the best temperature and humidity was 26°C and 92%, respectively for duration of 11 to 15 days in pit curing system [25]. These values are similar to that obtained in this study. In similar studies on curing of sweetpotatoes, the roots cure efficiently when roots were exposed to temperatures of 28°C - 30°C and relative humidity (RH) greater than 85% that aids the formation of a layer of cork cells around the roots [26]. In other studies at similar temperature and humidity, the percentage weight loss during storage of cured and uncured roots in the West Indies for 113 days was 17% and 43%, respectively [17].

Similar curing studies on sweetpotatoes were reported by Tortoe *et al.* [27], where the roots initially cured under temperature (30°C - 35°C) and humidity (90% - 95% rh) conditions for 7 and 14 days and subsequently stored in local (traditional), pit and clamp storage structures for 84 days. Earlier studies on sweet potatoes were reported by Rees *et al.* [28].

Climatic conditions have influences on curing as increase temperature and humidity stimulate the healing process. The healing process during curing causes migration of starch cells within 5 - 10 hours to the injured surface. Suberized layer forms beneath the cut surface after 2 - 3 days and there is production of periderm (cork) after approximately 5 days during healing. The increased structural changes results in high rate of metabolic activity which is maintained until healing is completed [21] [29] [30].

4. Conclusion

The process of curing is affected by the curing material, duration of curing, climatic conditions and the varieties of yams. The varieties of the yams behaved differently under the different treatments. However, yam variety *Serwah*, which is a *D. rotundata*, is the best bet yam variety to cure under jute sack for 7, 14 and 21 days of curing. However, 7 days curing was appropriate for yams. Additionally, the second best bet yam variety curing under straw was *Matches*, which is a *D. alata*. Curing processing is therefore appropriate for wounded yams to cure for storage.

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