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Full Length Research

Effect of storage conditions on physico-chemical and sensory acceptability of sweet potato in Gamo Zone, Southern Ethiopia

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ABSTRACT: The effect of different storage conditions (pit, sack, wooden box and clump) on the physico-chemical and sensory acceptability of sweet potatoes was conducted. Sweet potatoes were stored in the four storage conditions and untreated sweet potatoes (control) were used for this study. In four storage conditions, 10 kg of freshly harvested sweet potatoes were stored until the end of four storage months. Per cent of weight loss, sprouting, and spoilage of sweet potatoes data were collected from storage conditions in monthly intervals. All samples were analyzed for physic-chemical properties at Hawassa University, Food Chemistry and Food Microbiology Laboratory, and sensory acceptability was evaluated by using untrained 45 panellists at the end of the storage period. Completely Randomized Design (CRD) was used for storage conditions with three replication. The mean scores of appearance, taste, flavour, smell, and texture of sweet potato in storage conditions at the end of four months and untreated sweet potatoes had not shown significant difference except for overall acceptability of sweet potato. The mean scores of moisture and protein of sweet potato samples had not shown significant ($p<0.05$) differences in all storage conditions and untreated sweet potatoes. The pit storage scored the highest mean of moisture (71.30), ash (1.53), protein (6.73), fat (4.66) and fiber (1.76) than other storage conditions but less than untreated sweet potato except for fiber content of pit storage. The least mean per cent of weight loss (26.45), sprouting (9.72), and spoilage (2.87) of sweet potato was recorded at pit storage than in other storage conditions at the end of the fourth month. It was concluded that pit is storage preferable to other storage conditions based on weight loss, sprouting, spoilage, better physic-chemical and sensory acceptability, and recommended to farmers for storing sweet potatoes. Further study will be needed on the microbial quality of sweet potatoes in different storage conditions during storage periods.

Keywords: Physic-chemical properties, sensory acceptability, storage conditions, sweet potato.

INTRODUCTION

Sweet potato (*Ipomoea batatas L.*) is among the most important root and tuber crops. It also ranked as the 3rd largest cultivated root crop (7.9 million ha) after potato and cassava worldwide (FAO, 2015; Markos and Loha, 2016). The plant is now widely grown as an important staple food in a number of African countries including Burundi, Rwanda, Uganda and Nigeria among others (Awojobi, 2004). Sweet potato is one of the five most important crops in 40 developing countries besides rice, wheat, maize and cassava (Elameen *et al.,* 2008). It stands third in production and area coverage next to Enset and Irish potato in Ethiopia while it ranks second in the southern region of Ethiopia after Enset. The crop has good adaptive ability due to the short growth cycle and ability to survive in diverse agro-ecologies, marginal lands and water stress soils (Markos and Loha, 2016; Chagonda *et al.,* 2014). Sweet potato belongs to the class of foods that basically provides energy in the human diet in form of carbohydrates. According to Olokesusi (2004), root and tubers refer to any grown plant that stores edible material in the roots, corms or tubers. Although, the leaves are edible, the starchy tuberous roots are by far the most important product (Bidzakin *et al.,* 2014).

During storage of sweet potatoes, the roots are very perishable because they contain high moisture content (60-75%) hence low mechanical strength as well as high susceptibility to microbial decay. They have a high respiratory rate and high environmental temperature which softens the textures and make them susceptible to damage. Postharvest quality deterioration emanates from respiration, weight loss, microbial attack, weevil damage and sprouting. Respiration and sprouting result in the loss of the nutritive value of organs (Munish *et al.,* 2006). Sprouting in particular leads to weight loss, reduction of nutritional, processing and marketable quality of roots (Delaplace *et al.,* 2008). Therefore, the shelf life of sweet potatoes varies from few days or months depending on the storage conditions.

Various traditional methods of sweet potato storage such as heap storage, in-ground storage, platform and pit storage methods have been practised in Nigeria and across African countries by farmers but the most common traditional method is pit storage. Pit storage can generally be considered to be cheap for rural communities since it requires minimal materials. According to Yakubu (2005), the pit storage method appeared to be the best traditional method because deteriorations such as sprouting moisture loss and pathological losses were minimal compared to other storage methods.

The study conducted in Boreda woreda, Gamo zone in southern Ethiopia is with the problems of sweet potato deterioration due to the less access to optimum storage. The less access of storage exposes sweet potatoes to sprouting, weight loss, decaying, and loss of nutritional composition and sensory quality. Therefore, this study was conducted to evaluate the effect of storage types (sack, pit, clump and wooden box) on physic-chemical and sensory acceptability of sweet potatoes in case of Gamo zone, southern Ethiopia.

MATERIALS AND METHODS

Description of study area and source of materials

The study was conducted at Hambise Kebele Farm Training Center, Boreda woreda, Gamo Zone, Southern Ethiopia. Freshly harvested *Kulfo* variety sweet potato tubers were obtained from Arba Minch Agricultural Research Center. After being properly transported to the Center, it was stored in each storage condition.

Treatments used for the study

Sack, wooden box, clump and pit storage conditions and sweet potato before storage (control) were used for the study. All treatments were used to store sweet potato until the end of four (1st, 2nd, 3rd and 4th) months.

Experimental design

Completely Randomized Design (CRD) was used for storage conditions with three replication.

Weight loss, sprouting and spoilage of sweet potato

Percentage of weight loss, sprouting percentage and spoilage percentage of sweet potato were measured from each storage condition at 1st, 2nd, 3rd and 4th months storage period.

Physico-chemical properties of sweet potato

The moisture, ash, fat and protein contents of sweet potatoes were done based on AOAC (2005). The crude fiber content of the sweet potatoes was determined by using the official method of AOAC (2000). Based on the procedure, moisture, crude protein, fat, ash, and crude fiber content of samples were analyzed after the 4th month of storage. All laboratory work was done at the Food Chemistry and Food Microbiology Laboratory, Hawassa College of Agriculture, Hawassa University.

Moisture content

Pre-washed, cleaned and dried crucible was weighed. About 2 g of sweet potato sample were weighed, and added weighed sample into a pre-weighed cleaned crucible. The crucible was uncovered and placed in a well-ventilated oven crucible and maintained at 103±2°C. After 16 hours, the crucible was replaced and transferred to desiccator at room temperature to cool for 5 minutes and quickly weighed the dried sample with crucible. The loss in weight represented percent moisture content as follows:

$$\text{Moisture content}(\%) = \frac{(W1+W2)-(W3+W1)}{W2} \times 100$$

W1 = Weight of crucible, W2 = weight of the sample before drying, and W3 = weight of the sample after drying

Ash content

Crucible was washed and dried in an air-hot oven, cooled in a desiccator and weighed (W1). About 2 grams of dried sweet potato (W2) was weighed into the empty porcelain crucible previously ignited over a hot plate in the fume cupboard to char organic matter. The crucible was placed in a muffle furnace maintained at a temperature of 600^0C for 6 hours, transferred to a desiccator, cooled and reweighed immediately (W3).

$$\text{Ash Content}(\%) = \frac{\text{W3} - \text{W1}}{\text{W2}} \text{ x } 100$$

Where, W1 = Weight of crucible, W2 = Weight of sample, and W3 = Weight of crucible + Ash

Fat content

Soxhlet system HT2 method was followed. 2 g of sweet potato sample was weighed, and loaded in thimble and plugged with cotton wool. The thimble was dried and inserted into the Soxhlet HT. Extraction beakers were dried and weighed and 25 ml of the solvent was added into each beaker. The beaker was inserted into the Soxhlet HT. The extraction beakers were dried and weighed with boiling chips. 25 ml of the solvent was added to the solvent in each beaker. The breaker was inserted into the Soxhlet HT and extracted for 15 minutes in boiling position and for 30 minutes in “rinsing position”. The solvent was evaporated; the breakers were released and dried at 100°C for 30 minutes. The beaker with fat was cooled in a desiccator and reweighed.

$$\text{Fat Content}(\%) = \frac{\text{W3} - \text{W1}}{\text{W2}} \text{ x } 100$$

Where: W3 = weight of beaker + weight of fat, W2 = Weight of sample, and W1 = weight of beaker.

Protein content

The protein content of the samples was determined using the micro Kjeldahl method of AOAC (2005). **Digestion:** About 1 g of each sample was weighed into a 100 ml micro-Kjeldahl digestion flask. About 1 g of copper sulphate and 10 g of sodium sulphate was added to the flask and thoroughly shaken and placed on the digestion rack in an inclined position. The sample in the flask was digested by heating in a flame chamber until frothing ceased. The temperature was increased and allowed to boil for about one hour until the colour changed to bluish green. The clear digested sample was allowed to cool. **Distillation:** Some distilled water was added to the digested sample with a wash bottle to 100 ml in a 100 ml volume metric flask. A 10 ml of the digest was pipette and transferred into a micro-Kjeldahl distillation flask followed by the addition of 60 ml of 60% sodium hydroxide (NaOH) solution. The flask was immediately fixed to the splash head of the distillation apparatus. A 4% boric acid was added into a 100 ml receiving conical flask, and 2 drops of methyl red indicator were added, in such a way that the outlet of the adopter of the delivery tube was extended under the surface of the boric acid solution. The mixture was heated to liberate ammonia into the receiving conical flask containing 100 ml boric acid and the indicator until yellowish-green colour distillate was obtained. **Titration:** The distillate was titrated with 0.1N hydrochloric acid (HCl) until the end point of pink colournnnnn was obtained. The percentage (%) protein was calculated as:

$$\text{Protein content}(\%) = \frac{\text{Tx } 0.0014 \text{ x } 6.25}{\text{Weight of sample}} \text{ x } 100$$

Where, 6.25 = protein conversion factor, 0.0014 = correction factor of the acid, and T = titre value of the sample.

Fiber content

The fiber content of the sweet potato samples was determined by using the official method of AOAC (2000). **Digestion**: Total sample (W1) was placed into a 600 ml beaker; 200 ml of 1.25% sulphuric acid was added and boiled gently for 30 minutes while a watch glass was placed over the mouth of the beaker. The level of the sample solution was kept constant by using hot distilled water during boiling. After exactly 30 minutes of heating, 20 ml of 20% KOH was added and boiled gently for further 30 minutes with occasional stirring. **Filtration:** The bottom of a sintered glass crucible was covered with 10 mm sand layer and wet with distilled water. The solution was then poured into a sintered glass crucible, and filtered with the aid of a vacuum pump. The wall of the beaker was rinsed with hot distilled water several times. The washing was transferred into the crucible and filtered. **Washing:** The residue in the crucible was washed with hot distilled water and filtered twice. Again, the residue was washed with 1% H2SO4, filtered, and again washed with hot distilled water, filtered and finally washed with 1% KOH, and filtered. At this level also, the residue was washed with hot distilled water, filtered and again washed with 1% H_2SO_4, and filtered. Finally, the residue was washed with water-free acetone. **Drying and combustion:** The crucible with the content was dried in a drying oven for 2 hours at 130°C, cooled for 30 minutes in a desiccator and then weighed (W2). The crucible was then transferred into a muffle furnace, and heating was continued for 30 minutes at 550°C. The crucible was cooled in a desiccator and then the crucible was weighed with the content (W3). The crude fiber was determined by the formula below:

$$\text{Fiber content}(\%) = \frac{\text{W2} - \text{W3}}{\text{W1}} \text{ x } 100$$

Where, W1 = weight of the sample, W2 = weight of crucible with the sample after oven drying and W3 = weight of the crucible with the sample after ash.

Sensory acceptability of sweet potato

Sensory acceptability was evaluated on cooked sweet potatoes from each storage type at the end of 4th month by using untrained 45 farmers. Prior to the sensory evaluation, well-cooked sweet potato samples from each storage type were individually coded and served to the panelists on plastic plates. Clean water was provided to the judges to rinse their mouths in-between testing of the sweet potato samples to avoid the residual effect. The judges were instructed to evaluate and score the sweet potato samples based on the degree of likeness and acceptance by using a five-point hedonic scale with 1, 2, 3, 4 and 5 representing very dislike, dislike, neither dislike nor like, like and very-like, respectively.

Data analysis

Physi-chemical properties, sensory acceptability, percentage of weight loss, sprouting percentage and spoilage percentage data of various storage conditions of sweet potatoes were subjected to analysis of variances (ANOVA) and analyzed by using SAS software version 9.2. The least significant differences (LSD) between means were attained at ($p<0.05$) and the results were expressed as mean separation.

RESULTS AND DISCUSSION

Weight loss of sweet potato

The results of weight loss of sweet potatoes stored for four months in different storage conditions are shown in Table 1. The mean score range for weight loss of sweet potato at the sack, wooden box, clump storage and pit storage after one month (1st month) was 6.12 to 14.59. The pit storage of sweet potatoes had shown the lowest mean score of weight loss (6.12). This is due to the high ability of temperature control of pit storage, as a result, low respiration rate and low moisture loss of sweet potato. The wooden box storage had shown the highest mean score (14.59) of weight loss among other storage types after one month duration. The mean per cent of weight loss of sweet potato in suck and wooden box storage had not shown significant ($p< 0.05$) differences, and also mean per cent of weight loss of sweet potato in clump and pit storage had not shown significant ($p< 0.05$) different at one month period. The mean per cent of weight loss of sweet potato in the sack, wood box, clump storage and pit storage had not shown a significant ($p< 0.05$) difference at two months period. The pit storage of sweet potatoes had shown the lowest mean score of weight loss (19.98) while wooden box had shown the highest mean score (25.83) among other storage conditions at two months period. During the three months storage times, there were no significant differences in potato weight loss in all types of storage.

The mean score range for weight loss per cent of sweet potato at different storage types after four months were 26.45 to 48.34. The pit storage of sweet potatoes had shown the lowest per cent of weight loss (26.45) among other storage types until four month storage periods which agreed with the findings of Dandago and Gungula (2011) who evaluated the effect of various storage methods on the quality and nutritional composition. Sack storage had shown the highest mean score (48.34) among other storage types after four months period. In the current study, the weight loss of sweet potatoes under different storage conditions increased with the storage period. This agreed with Dandago and Gungula (2011) who evaluated the effect of various storage methods on the quality and nutritional composition.

Sprouting of sweet potato

The means of per cent sprouting of sweet potatoes stored for four months in different storage conditions are presented in Table 2. Sweet potato stored in pit storage had the lowest mean per cent of sprouting while suck storage had the highest mean per cent of sprouting during 1st month of storage time. During the 1st month, there were no significant ($p< 0.05$) differences in sprouting in all storage types.

Sweet potato stored in pit storage had the lowest mean per cent of sprouting while suck storage had the highest per cent of sprouting during the 2nd storage month. During the 2nd month, sweet potato had not shown significant ($p< 0.05$) differences in sprouting in all storage conditions except the mean per cent of sprouting in pit storage. Sweet potato stored in pit storage had the lowest mean per cent sprouting while clump storage had the highest per cent of sprouting during the 3rd storage month. During the 3rd storage month, sweet potatoes had not shown significant differences in sprouting in the sack, wooden box, and clump storage but had shown significant differences in sprouting in pit storage. Whereas, 4th month storage showed no significant ($p< 0.05$) difference in sprouting in all storage conditions.

Spoilage of sweet potato

The means of per cent spoilage of sweet potatoes stored for four months in different storage types were presented in Table 3. Sweet potato stored in pit storage had the lowest mean per cent of spoilage while wooden box storage had the highest per cent of spoilage during the 1st storage month. During the 1st month, sweet potato had not shown significant ($p<0.05$) differences in all storage conditions except the mean per cent of spoilage in pit

Table 1. Result of weight loss of sweet potato during different storage conditions and storage months.

Treatments	Storage months			
	1st	2nd	3rd	4th
Sack storage	14.58[a]	24.17[a]	30.83[a]	48.34[a]
Wooden box storage	14.59[a]	25.83[a]	26.22[ab]	38.05[ab]
Clump storage	9.72[b]	25.27[a]	27.50[ab]	39.72[ab]
Pit storage	6.12[b]	19.98[a]	21.67[b]	26.45[b]
LSD(P<0.05)	4.09	13.9	7.88	16.03
CV (%)	19.31	31	15.76	22.33

Table 2. Result of sweet potato sprouting during different storage conditions and storage months.

Treatments	Storage months			
	1st	2nd	3rd	4th
Sack storage	4.86[a]	15.83a	17.22[a]	15.27[a]
Wooden box storage	5.41[a]	14.99[a]	16.39[a]	14.72[a]
Clump storage	4.58[a]	18.61[a]	20.00[a]	13.56[a]
Pit storage	3.19[a]	3.39[b]	7.54[b]	9.72[a]
LSD(P<0.05)	2.50	5.38	5.74	7.83

Table 3. Result of sweet potato spoilage during different storage conditions and storage months.

Treatments	Storage months			
	1st	2nd	3rd	4th
Wooden box	3.35[a]	3.61[a]	7.83[a]	10.16[a]
Clump storage	3.34[a]	3.72[a]	6.6[b]	10.50[a]
Pit storage	1.16[b]	1.80[b]	2.85[c]	2.87[b]
Sack storage	3.15[a]	3.32[ab]	7.51[a]	10.15[a]
LSD(P<0.05)	0.94	1.71	0.64	3.41

storage. Sweet potato stored in pit storage had the lowest mean per cent while wooden box storage had the highest mean per cent of spoilage during the 2nd storage month. During the 2nd month, sweet potato had not shown significant differences in spoilage in the wooden box, clump and sack storage, and also had not shown significant differences in spoilage in pit and sack storage.

During the 3rd month, sweet potatoes had shown significant ($p<0.05$) differences in spoilage in all storage conditions but had not shown significant differences in spoilage in the wooden box, and sack storage. Whereas, 4th month storage had not shown a significant difference in sweet potato spoilage in all storage conditions except the pit storage. Generally, the per cent of sweet potato spoilage increased with increased storage time. This agreed with the findings of Dandago and Gungula (2011) who evaluated the effect of various storage methods on the quality and nutritional composition.

Sensory acceptability of sweet potato

The results of sensory acceptability of sweet potatoes stored for four months in different storage types were presented in Table 4. The mean scores of sensory acceptability (appearance, taste, flavour, smell and texture) of sweet potato samples before storage (control), sack, wooden box, clump and pit storages had not shown significant ($p<0.05$) difference except for overall acceptability of sweet potato after four months storage times. Sweet potato before storage had the highest mean score of overall acceptability while the wooden box was the lowest mean score after the end of the four months storage time. Overall acceptability of sweet potato had not shown significant ($p<0.05$) difference in before storage, sack, clump and pit storages after the end of four months storage times. In addition, the overall acceptability of sweet potatoes had not shown any significant difference

Table 4. Sensory acceptability of sweet potato at different storage conditions after the end of four months.

Treatments	Sensory Acceptability					
	Color	Taste	Flavor	Smell	Texture	Overall acceptability
Sweet potato before storage	4.75[a]	4.78[a]	4.72[a]	4.74[a]	4.69[a]	4.70[a]
Sack storage	4.17[a]	4.34[a]	3.68[a]	4.35[a]	4.33[a]	4.00[ab]
Wooden box	4.33[a]	4.67[a]	4.33[a]	4.67[a]	3.67[a]	3.67[b]
Clump storage	4.35[a]	4.69[a]	4.67[a]	4.69[a]	4.00[a]	4.33[ab]
Pit storage	4.67[a]	4.33[a]	4.39[a]	4.33[a]	4.67[a]	4.68[a]
LSD(p<0.05)	0.98	1.08	1.44	1.09	1.33	0.94

Table 5. Result of the nutritional composition of sweet potato at different storage conditions after the end of four months.

Treatments	Nutritional composition				
	Moisture	Ash	Protein	Fat	Fiber
Sweet potato before storage	74.58[a]	1.75[a]	6.92[a]	4.69[a]	0.99[c]
Sack storage	70.82[b]	1.35[a]	6.04[a]	4.27[ab]	1.36[b]
Wooden box storage	70.23[c]	1.20[a]	6.37[a]	4.35[ab]	1.38[b]
Clump storage	70.87[b]	1.29[a]	6.64[a]	4.24[b]	1.34[b]
Pit storage	71.30[b]	1.53[a]	6.73[a]	4.66[a]	1.76[a]
LSD(P<0.05)	0.53	0.35	0.98	0.41	0.34

($p<0.05$) in the sack, wooden box and clump storage after the end of four months of storage.

Nutritional composition of sweet potato

The results of nutritional compositions of sweet potatoes stored for four months in different storage types were presented in Table 5. The moisture content of sack, pit, and clump storage of sweet potato did not show any significant ($p<0.05$) difference in mean scores. The highest moisture content was recorded in sweet potatoes before storage and the lowest was recorded in wooden box storage. The decreased value of moisture content of sweet potato in wooden box storage agreed with the findings of Dandago and Gungula (2011) who evaluated the effect of various storage methods on the quality and nutritional composition. The ash content of sweet potato had not shown significant differences in all storage conditions. The ash content of sweet potato was gradually decreased with increased storage periods; this was due to the loss of mineral content due to storage temperature. Sweet potato before storage had the highest mean score of ash while the wooden box had the lowest mean score of ash among other storage conditions.

The mean score of the protein content of sweet potato had not shown significant differences in all storage types. The decrease in protein content from 6.92 in fresh roots to 6.04, 6.37,6.64 and 6.73 in the sack, wooden box, clump and pit storage, respectively could be attributed to the findings of Ray and Ravi (2005) who reported that careless post-harvest handling often leads to losses in quality and quantity of protein in extreme temperature conditions as in Yola. The protein contents of sweet potato decreased as the storage period increased, this was agreed with Dandago and Gungula (2011) evaluated the effect of various storage methods on the quality and nutritional composition. The fat content of sweet potato had not shown significance ($p<0.05$) differences in before storage, sacks, wooden box, and pit storage, and had not shown significance ($p<0.05$) differences in the sack, wooden box, and clump storage. Whereas, the mean score of fiber content of sweet potato had not shown any significant ($p<0.05$) difference in the sack, wooden box, and clump storage of sweet potato. The sweet potatoes before storage had the least mean score of fiber content while pit storage had the highest.

Conclusions and Recommendations

Based on the results (findings) of this study, pit storage was better for storing sweet potatoes than sack, clump and wooden box storage in terms of reducing weight loss, sprouting, and spoilage of sweet potatoes during storage months. Increasing order of sweet potato weight loss values in the pit, wooden box, clump, and sack storage was recorded during the 4th storage month. Increasing order of sweet potato sprouting values in the pit, clump, wooden box, and sack storage was recorded during the

4th storage month. Increasing order of sweet potato spoilage per cent in the pit, sack, wooden box, and clump storage was recorded during the 4th storage month.

Pit storage sweet potato was more preferred in terms of overall acceptability and nutritional composition than sack, clump, and wooden box storage after the end of four months of storage time. Therefore, pit storage could be recommended to farmers for storing sweet potatoes. Further study will be needed on the microbial quality of sweet potatoes in different storage types during storage periods.

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COMPETING INTEREST

The authors declare no competing interest in this research work that could bias the collection, analysis and publishing of this paper.

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