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Shelf-life Determination of Dried Onion (*Allium cepa)* and Tomato (*Lycopersicon esculentum*) Products

Hailemariam Tekie Mahari[1], Jemal Nurhusen Mohamed[2]

1. Department of Food Science and Post-Harvest Technology, Mekelle University, Mekelle, Tigray, Ethiopia
2. Department of Dryland Crop and Horticultural Sciences, Mekelle University, Mekelle, Tigray, Ethiopia
E-mail: hailet2012@gmail.com; jemdej2013@gmail.com

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Abstract: The role of nutrient-rich vegetables in promoting good health has resulted in an increase in their demand over the past decade, but they are highly seasonal, causing lower prices and heavy losses at peak season. The objective of the study was to determine the shelf life of dried onion and tomato products. The study was conducted in Mekelle University’s food science and post-harvest technology laboratory. Four treatments (sun, shade, solar, and oven drying methods) were used to dry onion and tomato products, and shelf life was determined using CRD at a 5% level of significance. Data such as microbial counts, time and temperature of drying, moisture content, rehydration ratio, and sensory characteristics were recorded and analyzed using analysis of variance. The highest microbial load obtained was for shade-dried onion (6.06 $\log_{10}$cfu/g) and sun-dried tomato (5.83 $\log_{10}$ cfu/g). For dried onion, significant differences were observed among the driers on the microbial population of coliform ($p<0.05$) and total bacterial count ($p<0.01$) but not on yeast and mold count. The maximum rehydration was achieved in the oven-dried products (3.64) followed by solar drying (3.28). Dried onion and tomato remained organoleptically acceptable, except for sun-dried tomatoes for color and appearance (4.75) and aroma (4.75) in the first month of storage. The oven-drying method was the best method of dehydration of freshly dried onions and tomatoes. Further research should be carried out to determine the effect of drying on the extended storage time of the dried products.
Keywords: Driers; Onion; Shelf-life; Tomato.

1. Introduction

Several studies in the past and present have established that micronutrient deficiency is a major public health problem in Ethiopia, as elsewhere in developing countries [1]. Although several factors are known to precipitate micronutrient deficiency, most often in synergy, inadequate consumption of the nutrient appears to outweigh all. Limited availability of nutritious foods, economic constraints, lack of knowledge and information, and other related factors are critical issues that limit people’s access to quality foods [2].

In theory, the agricultural sector could help address inadequate access to micronutrient-rich foods by contributing to income generation for at-risk groups and by making nutritious foods more accessible [3]. Though agricultural production and consumption by producer households is the primary focus, the links between what is produced on the farm, the consumer, and the income received by the producer do not stop at the farm gate. Far from it: food is stored, distributed, processed, retailed, prepared, and consumed in a range of ways that affect the access, acceptability, and nutritional quality of food for the consumer [4]. As a result, retaining more of the food that is already grown would make a significant contribution to agriculture and nutrition goals [5]. This is particularly important for nutritionally vulnerable groups such as children under five, who have a very small window of time before reductions in quantity and quality of food can cause severe and often irreversible health and cognitive impacts. Seasonal food shortages can also have lifelong consequences if experienced during the critical window of 9 to 24 months [6].

The importance of fresh fruits and vegetables as a rich source of nutrients and their role in promoting good health has resulted in an increase in their demand over the past decade [7]. Fruits and vegetables bring us vitamins, minerals, and fiber; some energy; and phytochemicals, or secondary plant products, which are potentially beneficial for our health. Epidemiological studies have shown that high intakes of fruits and vegetables are associated with a lower risk of chronic diseases, particularly cardiovascular disease [8], type 2 diabetes [9], and certain cancers [10].

Onions (*Allium cepa*) and tomatoes (*Solanum lycopersicum*) are among the most widely cultivated and consumed vegetables in Ethiopia [11, 12]. They play a crucial role in Ethiopian cuisine, serving as essential ingredients in various traditional dishes. These crops are also rich sources of essential micronutrients, including vitamins, minerals, and antioxidants, which contribute to improved health and nutrition [13, 14]. Onions are rich in vitamin C, B-complex vitamins, and flavonoids, which have antioxidant and anti-inflammatory properties [15]. Tomatoes provide a significant source of vitamin C, potassium, and lycopene, a powerful antioxidant linked to reduced risks of chronic diseases [13]. However, despite their high production and demand, a significant proportion of onions and tomatoes are lost due to post-harvest spoilage [16,17]. These losses not only reduce food availability but also result in economic losses for farmers and traders. Tomatoes and onions are highly seasonal and available in plenty at particular times of the year. In the peak season, the selling price decreases, and this can lead to heavy losses by the grower [18]. Also, due to the abundant supply during the season, a glut in the market may result in the spoilage of large quantities. In Ethiopia, post-harvest losses of perishable crops like onions and tomatoes can reach up to 30-50% due to poor handling, lack of storage infrastructure, and market inefficiencies [16].

Refrigeration and controlled atmosphere storage have been used to preserve tomatoes and onions [19]. However, this method is very expensive and extremely electricity-dependent, so people in the countryside could not have access to preserve these vegetables. Hence, drying, which decreases the water content of the raw product to the level that minimizes its biochemical, chemical, and microbiological deterioration, is one of the oldest methods of food preservation and represents a very important process in the food industry [20]. It can remove water to the level at which microbial spoilage and deterioration reactions are greatly minimized [21]. But processing and storage conditions, including high temperature, light, and oxygen exposure, may affect the nutritional and sensory quality of final products [22-24]. Studies revealed a considerable decrease in ascorbic acid content of tomatoes by length of storage, temperature, and initial nutrient concentration [24-26]. Hence, implementing effective preservation techniques is needed to retain the nutritional value of onions and tomatoes for longer periods, ensuring year-round availability and food security; improving market stability and increasing farmers' income; helping ensure consistent food supply; supporting environmental conservation; and promoting sustainable agricultural practices [27, 28]. Therefore, the objective of the study was to determine the shelf life of dried onion and tomato products using different drying methods to contribute towards reducing micronutrient deficiencies through reducing the problem of seasonality.

2. Materials and methods

2.1 Description of the study area

The experiment was conducted in Mekelle University, Food Science and Post-Harvest Technology Department Laboratory. Mekelle University is located at 13º28 'N and 39º29'E. The altitude ranges from 2150 to 2250 m.a.s.l. The agro-climatic zone of the region is characterized by a mean rainfall of 680 mm. The mean annual temperature is 17ºC. The maximum speed recorded in November and December is 11 km/h [29].

2.2 Experimental design

Four treatments (sun-drying, shade-drying, solar-drying, and oven-drying methods) were used to dry onion and tomato products. The treatments were replicated three times, and shelf life was determined using a completely randomized design (CRD) at a 5% level of significance.

2.3 Raw material collection and dried sample preparation

Row onion and tomatoes were purchased from the local farmers the day before sample preparation and stored at room temperature. The fresh and intact onion and tomatoes were washed with running tap water and cut into pieces of uniform size using a sharp stainless-steel knife. The cutting material and utensils were also cleaned properly with tap water.

The samples were divided into two groups; each group weighed 1000 g. The initial mass of the sample cubes was measured using a balance (0.1 g precision). The sliced samples were subjected to the different dryers immediately after cutting. The temperature of drying chambers was recorded with a thermometer at different intervals. The drying time for the dried samples was determined by finger-feel, which is common practice in the rural community except for the oven-drying method. For the oven drying, the time of drying was predetermined based on the required moisture content of the specific products for storage. After drying, the samples were stored in a plastic cup.

2.4 Data collection and statistical analysis

In this experiment, data such as microbial counts (coliform count, total bacterial count, yeast and mold count), time and temperature of drying, moisture content, rehydration ratio, and sensory characteristics of the products were recorded at different storage times.

2.5 Microbial analysis

A portion of the processed cubes (10 g) was taken aseptically from each package and transferred into an alcohol-sterilized mortar and pestle. The sample was ground with 90 ml of distilled water in a laminar flow chamber, and this was transferred into a sterile conical flask for proper shaking. Samples were further diluted 10-fold by serial dilution technique up to five dilutions, and 1 ml of an aliquot of each dilution was placed into sterilized Petri dishes in duplicate with the help of sterilized pipettes. About 15 to 20 ml of sterilized medium, Plate Count Agar (PCA) for total bacterial count, MacConkey Sorbitol Agar for coliform count and Potato Dextrose Agar for yeast and mold count, was poured and mixed by gently swirling with the sample in the plate. Plates were closed with covers and kept for about 30 minutes to solidify the medium. Plates were incubated for 48 hours at 37ºC for coliform and total plate counts, and 72 hours at 25ºC for yeast and mold counts. Colonies were counted, and the results were expressed as cfu.g^{-1} of sample, and then these were converted into log values for statistical analysis. Analyses were carried out during the two-month storage period.

2.6 Determination of moisture content

Moisture content of the raw and dried slices was determined by the gravimetric method. At regular time intervals during the drying process, samples were taken out and dried for 8 hours at 105°C until constant weight. Weighing was performed on a digital balance, and then moisture content was calculated. Moisture content was expressed in wet matter (g per 100 g fresh matter, %).

2.7 Rehydration ratio (reconstitution ratio)

Rehydration ratio was determined according to the official method of AOAC [30]. Six beakers of 200 ml capacity each were taken, and 150 ml of water and 5 g of dried sample of each treatment were poured into each beaker and kept for 50 minutes for pre-soaking.

The samples were transferred to another six beakers with 150 ml of boiling water. The liquid portion was drained off, and solid contents were transferred to other beakers, each of which was fitted with a funnel and filter paper separately. The excess water was removed by keeping them for a few minutes till droplets stopped through the funnel. The rehydrated materials were removed from the funnel, and the weights were taken individually, and finally the rehydration ratio was calculated using

$$\text{Rehydration ratio} = W_2/W_1$$

where: W_2 = weight of drained material, g; W_1 = weight of dried material, g.

2.8 Sensory quality

Sensory evaluation of onion and tomato samples was carried out by using a 9-point hedonic scale. A test panel made up of six semi-trained persons evaluated the sensorial quality of samples during the storage time. The sensory attributes consisted of color & appearance, aroma, and overall acceptability (average of scores of all parameters) and were scored using a scale of 1 to 9 (1 = dislike extremely and 9 = like extremely). A score of 5 was considered the limit of acceptance. A scoresheet with its instructions was provided to the panelists.

2.9 Statistical analysis

Analysis of Variance (ANOVA) was used in the interpretation of the analysis results. The significance levels of the different treatments were determined at $p<0.05$.

3. Results

The performance of the different drying methods was determined to ascertain the best possible drying method on the quality of dried onion and tomato products.

3.1 Drying time, moisture content, and drying temperature of the products

The time required for drying onion and tomato for obtaining the final dried products, the initial and final moisture content of the products under different drying methods, and the drying temperatures for the driers are presented in Table 1. The time taken for drying onions was one, seven, five-, and five-days using oven, shade, solar, and sun drying methods, respectively. For tomatoes, it was two and six days by oven and sun-drying methods. As it was not possible to dry tomato products using shade and solar drying, there was no result found for these two methods. The initial moisture content of fresh onion and tomato was determined by the oven drying method. The mean value of the moisture contents of fresh onion and tomato was found to be 87.1% (wb) and 94.57% (wb) respectively. The moisture content was also determined for the dried products and the results obtained from oven, shade, solar, and sun drying methods were 2, 16, 12, and 10%, respectively, for dried onions. Similarly, for tomato-dried products, the moisture content, which was initially 94.57%, was reduced to a moisture content of 10% each using oven and sun-drying methods. The temperature measured in each of the dryers was 70ºc, 18-21ºC, 57-65ºc, and 25-28ºC in the oven, shade, solar, and sun dryers, respectively.

Table 1. Effect of driers on drying time and final moisture content of onion and tomato

Treatment	**Onion**			**Tomato**			**Drying temperature**
	Drying time (days)	**Moisture content (%)**		**Drying time (days)**	**Moisture content (%)**		
		Fresh	**Dried**		**Fresh**	**Dried**	
Oven drying	One	87.10%	2	Two	94.57	10	70⁰C
Shade drying	Seven		16	NA		NA	18-21ºC
Solar drying	Five		12	NA		NA	57-65⁰C (noon)
Sun drying	Five		10	Six		10	25-28ºC

**NA – not applicable*

3.2 Microbiological quality

The microbial population of fresh, dried, and stored products was evaluated for coliform count, total bacterial count, and yeast and mold count.

The results in Table 2 and Table 3 revealed that the initial microbial count of coliform, total bacterial count, and yeast and mold count was 2.03, 2.51, and 2.01 log_{10}cfu/g for onion dried products and 1.54, 3.65, and 2.38 log_{10}cfu/g for tomato dried products, respectively. During storage, the coliform count increased progressively up to one month for onion and tomato treated with all the driers except sun drying, which decreased from 2.62 to 2.35 log10 cfu/g (onion) and from 5.83 to 3.0 log10 cfu/g (tomato). In the second month, the coliform count declined except for solar and sun drying of onions. For yeast and mold count, the trend was opposite to that of coliform count for dried onion. The highest microbial load obtained was for shade-dried onion (6.06 log_{10} cfu/g) and in the case of tomato, it was sun-dried that revealed higher microbial counts (5.83 log_{10} cfu/g). For dried onion, significant differences were observed among the driers on the microbial population of coliform ($p<0.05$) and total bacterial count ($p<0.01$) but not on yeast and mold count. But there was no significant effect of oven and sun drying on the microbial count of dried tomato products. On the other hand, there were no significant differences among all the dryers in the storage microbial quality of onion and tomato dried products with regard to coliform, total bacterial count, and yeast and mold count at $p<0.05$. In some of the dried products, it was observed that the microbial counts were above the required quality for vegetable consumption (5.0 log10 cfu/g or 10^5 cfu/g).

Table 2. Effect of driers on microbial quality of onion

Treatment	Coliform count (log10cfu/g)				Total bacterial count (log10cfu/g)				Yeast and mold count (log10cfu/g)			
	Fresh	Dried	M1	M 2	Fresh	Dried	M1	M2	Fresh	Dried	M1	M2
Oven drying	2.03	1.98	4.42	3.3	2.51	5.18	6	F	2.01	2.41	3.76	3.81
Shade drying		5.19	5.63	4.45		6.06	2.9	F		4.47	5.53	3.64
Solar drying		3.79	5.12	5.64		4.8	3.11	F		2.62	4.63	3.94
Sun drying		2.62	2.35	4.83		4.28	5.51	F		3.6	2.62	3.78

**F – Petri plate full of colonies*

Table 3. Effect of driers on microbial quality of tomato

Treatment	Coliform count (log10cfu/g)				Total bacterial count (log10cfu/g)				Yeast and mold count (log10cfu/g)			
	Fresh	Dried	M1	M2	Fresh	Dried	M1	M2	Fresh	Dried	M1	M2
Oven drying	1.54	2.56	3.46	2.48	3.65	4.26	4.08	F	2.38	4.5	3.76	3.87
Sun drying		5.83	3	1.9		4.92	4.13	F		5.3	3.97	3.38

**F – Petri plate full of colonies*

3.3 Rehydration ratio

The rehydration characteristics of onion and tomato products dried using different drying methods are illustrated in Figures 1 and 2, respectively. The table showed that the maximum rehydration was achieved in the oven-dried products (3.64), followed by dried products treated with solar drying (3.28) in the first month of storage for onions. The rehydration ratio of shade- and sun-dried onion was 3.07 and 3.22, respectively. The rehydration ratio for oven- and sun-dried tomato products in the first month of storage was 4.0 and 4.14. In all the treatments, the rehydration ratio declined during storage, except for sun-dried tomatoes. Though there were differences in the mean rehydration ratio of the products, there were no significant differences among the treatments with regard to the rehydration ratio at $p<0.05$ during two months of storage.

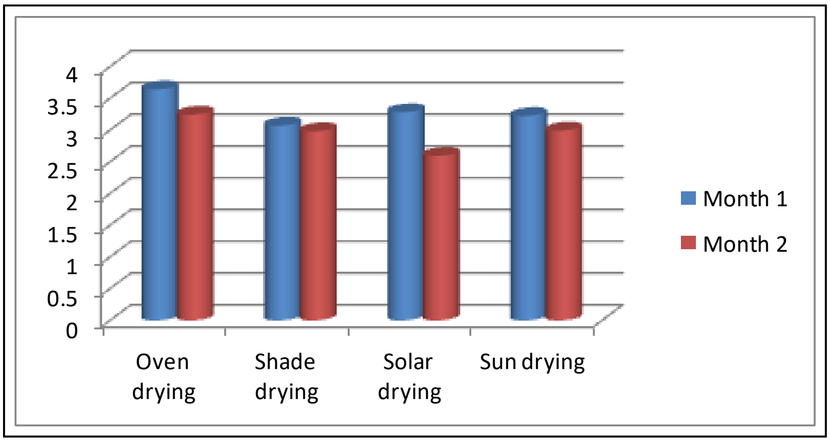

Figure 1. Rehydration ratio of dried onion during storage

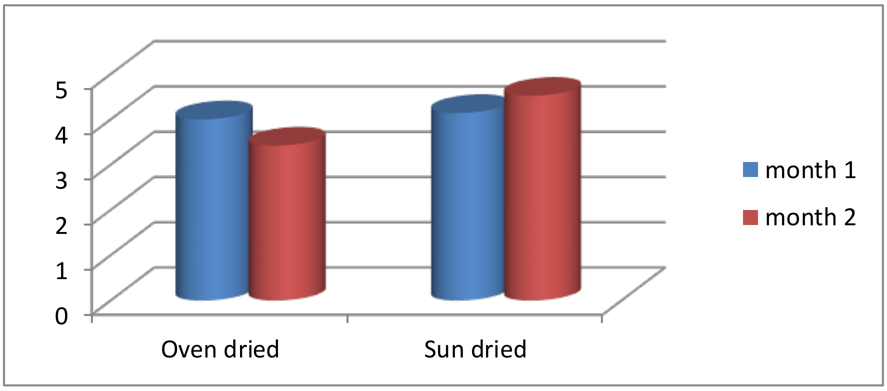

Figure 2. Rehydration ratio of dried tomato during storage

3.4 Sensory quality

The results in Table 4 showed the color and appearance, aroma, and overall acceptability of dried onion and tomato products during storage. In the present investigation, irrespective of treatments applied, dried onion and tomato remained organoleptically acceptable except for tomato treated with sun drying for color and appearance (score of 4.75) and aroma (score of 4.75) in the first month of storage. The maximum overall acceptability was obtained from oven-dried onion (7.67) and tomato (6.67) during the second month of storage. The minimum overall acceptability was obtained from sun-dried onion products (5.0) and tomato products (5.5) in the first month of storage, which slightly increased in the second month of storage with a score of 6.0 and 6.33 for onion and tomato, respectively.

4. Discussions

There has been an increased microbial count for the dried products during storage. This might be due to increased moisture content, which would be a suitable condition for the growth of microbes, as it was manifested by cell wall degradation (reduced rehydration ratio). Similar research conducted by Guadalupe and Diane [31] showed that after 3 months of sun-dried tomato storage at 25 °C, moisture content increased slightly from 14% to about 17% for all samples. Though oven drying was carried out at higher temperatures than other drying processes, there were high loads of microorganisms. The increased microbial load could also be due to contamination at different levels of the drying process, such as washing, cutting, displaying the cut pieces for drying, and packaging, as long as the processes were carried out using local practices. Brocklehurst *et al*. [32] and Dijk *et al*. [33] have also suggested that the large numbers of lactic acid bacteria and fungi present on fresh-cut products indicate likely contamination from processing, such as cutting.

Table 4. Sensory characteristic of dried onion and tomato during storage

Onion	Color and appearance		Aroma		Overall acceptability	
Treatment	Month 1	Month 2	Month 1	Month 2	Month 1	Month 2
Oven drying	6.25	7.33	7.25	6.5	6.75	7.67
Shade drying	7.5	7.33	6.5	5.5	6.75	6.33
Solar drying	6.75	7.33	5.5	6.0	6.0	7.0
Sun drying	4.75	5.67	5.0	6.0	5.0	6.0
Tomato						
Oven dried	5.75	6.67	7.0	7.5	6.5	6.67
Sun dried	5.5	5.67	4.75	7.0	5.5	6.33

It was also clear that when products are dried without additional treatments (physical and chemical) to extend the shelf life like that of industrially produced products, there would be microbial loads (coliform, total bacteria, and yeast and molds) detected though the products are dried. In an experiment conducted by Abraham and Tahiru [34], room-dried moringa leaves relatively had high counts of total viable cells (6.45 log10cfu/g); coliforms (6.18); molds and yeasts (3.46); *E. coli* (1.58) and *Pseudomonas* spp. (3.32) compared to samples dried by mechanical or solar methods. In the experiment, solar-dried moringa leaves had improved microbiological quality compared to mechanically or room-dried leaves, but it was the gamma irradiation that significantly improved the microbiological quality of dried moringa leaves. Another experiment conducted by Guadalupe and Diane [31] indicated that pre-drying treatments have been found to improve the quality of stored sun-dried tomatoes. Research conducted by Idah and Aderibigbe [35] on dried tomatoes stored in high-density polythene film, however, showed that the microbial counts reduced tremendously during three months of storage, and it was noted that the decline of the load could be due to the exhaustion of the nutrients on which these microbes thrive.

Though it is believed that dried products do not contain microorganisms, different research activities revealed higher microbial levels. For example, Hell *et al*. [37] investigated the presence of microflora and mycotoxin contamination in a selection of dried vegetables, tomatoes included. In tomatoes with a moisture content of 10.2 %, they detected growth of *Aspergillus niger*, *Aspergillus flavus* and *Fusarium verticillioides*, but no aflatoxin was found. Another researcher, Misra [38,39], found *A. flavus* among others that grew at both 20 and 30 °C and with RH between 60 and 80% in dried spices. The higher microbial counts in shade drying could be due to the lower drying temperature. In an experiment conducted by Martinov *et al.* [36], it was noted that convective drying at temperatures below 45°C results in a higher microbial count.

Rehydration characteristics of the dried products were used as a quality index by different researchers [40-42] who indicated the physical and chemical changes that occurred during the drying and reported that the changes were influenced by processing conditions, sample compositions, sample preparation, and the extent of structural and chemical disruptions induced by drying. In the present study, the higher rehydration ratio could be related to a higher drying temperature in producing a lower final moisture content of dried products. A significantly increased rehydration ratio was reported by Agunbiade *et al.* [43] by soaking dehydrated chips of banana in boiling water. Funebo and Ohlsson [44,45] also reported that the rehydration ratio of apples and mushrooms dried at lower temperatures was lesser as compared to the higher temperatures. The researchers pointed out that the lower rehydration values are evidence for product shrinkage caused by prolonged drying resulting in irreversible physicochemical changes. Similar results were also reported by Sandhu and Parhawk [46] and Nimmol *et al*. [47] in banana slices and Devahastin *et al*. [48] in carrot dried products. But there was a contradictory result in the case of sweet potato drying.

Oven drying was the fastest method applied in achieving a significant reduction of moisture content as compared to other methods. This might be the reason for the higher rehydration ratio. In a study by Vishwanathan et al. [49], it was reported that the rapid heating with IR and quicker diffusion of water vapor within the sample might be facilitating the material to retain its porous structure, thereby increasing its ability to absorb a higher amount of water during rehydration.

Irrespective of drying treatments applied, dried onion and tomato products remained organoleptically acceptable during storage based on the overall acceptability. This could be due to the reason that the growth of microorganisms is not at the maximum level, though there were higher loads, and also due to lower cellular failure, as indicated by a higher rehydration ratio. Jokić *et al.* [50] reported that convective drying of asparagus resulted in the smallest color change of the fresh material, whereby drying at 60°C presented the optimum.

5. Conclusion and Recommendations

It can be concluded that the oven drying method was the best method of dehydration of freshly dried onion and tomato. But sun drying is preferred because there is no significant difference between oven and sun drying during storage, and also because of its cheap processing. Local processing may contaminate the products, but drying limits the high growth of microorganisms. So, by reducing the moisture content of onion and tomato using driers, the shelf life of the products can be extended. But solar and shade drying methods could not effectively dehydrate tomato slices and were unable to achieve tomato products for storage.

Further research should be conducted on the pretreatment of dried samples of onion and tomato to extend the shelf life; otherwise, drying alone may not be enough for safe consumption, as some of the dried products were found to contain microorganisms beyond the limited level. Research should also be carried out on the effect of drying on onion and tomato products for an extended period of time (more than two months).

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