The Potato Storage in The Volcanic Tuff Storages in Turkey

Turgut Öztürk
University of Ondokuz Mayis, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, 55139 Atakum - Samsun, Turkey

Abstract: The quality of potato, and its storage life, is reduced by the loss of moisture, decay and physiological breakdown. These deteriorations are directly related to storage temperature, relative humidity, air circulation and gas composition. Potatoes being a living organism require an effective management for storage. Many studies have been carried to investigate the suitability of various storage systems for safe storage of potatoes. In this study, the knowledge about volcanic tuff storages used in potato storage in Niğde and Nevşehir regions in Turkey, does not have an example in the world has been given. These storages have not any cooling and heating equipment. Hence, potato storage in these warehouses brings an important cost advantage for companies. In Turkey, many commercial companies wishing to benefit from this cost advantage prefer to volcanic tuff storages for the storage of potatoes. There are over two thousand volcanic tuff storage formed for this purpose in the region.
Key words: Potato, Storage, Volcanic Tuff

Türkiye'de Volkanik Tüf Kaya Depolarda Patates Depolaması

Özet: Patatesin kalitesi ve depolama ömrü; yumru nem kaybı, çürüme ve fizyolojik bozulmayla azalmaktadır. Bu bozulmalar doğrudan doğruya depo sıcaklığı, bağıl nemi, havalandırma ve gaz kompozisyonuyla ilişkilidir. Patates canlı bir organizma olduğu için depolamada etkin bir yönetim ister. Patatesin güvenli bir şekilde depolanabilmesi için uygun depolama sistemlerini saptamak amacıyla birçok çalışma yürütülmüştür. Bu çalışmada Türkiye'de Niğde ve Nevşehir yörelerinde patates depolamak amacıyla kullanılan ve dünyada bir örneği daha olmayan volkanik tüf kaya depolama sistemi hakkında bilgi verilmiştir. Bu depolar herhangi bir soğutma veya ısıtma donanımına sahip değildir. Bundan dolayı bu depolarda patates depolama firmalar için büyük bir maliyet avantajı sağlamaktadır. Türkiye'de birçok ticari firma bu fiyat avantajından faydalanmak amacıyla patates depolamasında volkanik tüf kaya depoları tercih etmektedir. Bu amaçla bölgede depo olarak kullanılmak amacıyla iki binin üzerinde volkanik tüf kaya depo bulunmaktadır.
Anahtar kelimeler: Patates, Depolama, Volkanik Tüf

1. Introduction

The common potato (*Solanum tuberosum*) is one of around 150 tuber-bearing species of the genus *Solanum* (family *Solanaceae*). The potatoes cultivated in South America as early as 1800 years ago probably consisted of a mixture of varieties; in the same area today, as many as 60 varieties may be distinguished in a single village market (Ooster ,1999).

The potato (*Solanum tuberosum L.*) is the most important food crop in the world after wheat, rice and maize. China is the biggest producer potatoes (approx. 65 million tones). The other important countries in the potato cultivation are Russia (32 million tones), India (24 million tones), U.SA (21 million tones) and Ukrainian (16 million tones) respectively (FAOSTAT, 2010). In the year 2008, the world's potato production is 322.412.701 tones, also Turkey's potato production is 4 246 207 tones (FAOSTAT, 2010).

Potatoes are consumed in different forms such as cooked, roasted, french-fried, chipped etc. Cooking often reduces mineral and vitamin constituents. If potato flour is mixed with bread flour 3-5% ratio, bread taste enhances and staling delays. Besides, potato starch is widely used in making salami and sausages. (Arıoğlu, 2000; Eltawil et al., 2006).

Potatoes are rich in carbohydrate and provide significant quantities of proteins, minerals (iron), vitamins (B complex and vitamin C) and dietary fiber and antioxidants (Tarn et al., 2006). The quality of potatoes is dynamic and continues to change as a result of physiological activity owning to accumulation of reducing sugars and depletion of starch. Therefore, sugar and starch are the main components affected by post-harvest metabolism in potato tubers (Nourian et al., 2003). Recently, the concept of potato starch has sparked new interest in the bioavailability of potato starch and its use as a source dietary fiber, particularly in adults (Sajilata et al.,2006).The beneficial physiological effects of potato starch include prevention of colon cancer, hypoglycemic effects providing improved metabolic control in type II diabetes, as a prebiotic, reduction of gall stone formation, hypocholesterolemic effects, inhibition of fat accumulation, and absorption of minerals (Leeman et al., 2005).

Potato is a seasonal crop. There is but one potato crop per year in temperate climates. Storage is necessary for a continuous supply to the market of fresh potatoes. This means that part of the crop must be stored during 8 to 10 months. The demands for steady supply of potatoes increased ever since potato has been used for industrial processing. Storage of potato has therefore become an essential part of the potato industry. Potato is a perishable but storable crop. Storability of potato, however, can be affected by weather conditions during growth and at harvest time. Given favorable conditions, quality potato can be stored well during extended periods of time (Rastovski, 1988).

The potato is a semi-perishable commodity. In Turkey, the potato is harvested at the end of summer. The purpose of storage is to maintain tubers in their most edible and marketable condition and to provide a uniform flow of tubers to market and processing plants throughout the year. In this study, the knowledge about volcanic tuff storages used for potato storage in Niğde and Nevşehir regions in Turkey, does not have an example in the world has been given.

2. Storage of Potato

Potato can be stored in any farm building. Storage of potato can be bulk storage, storage in crates, and storage in sacks. Potato warehouses must be properly insulated to keep stored potatoes healthy. It is recommended that enough insulation be installed to achieve a minimum thermal resistance ($*R_{SI}$) of 6.1 (**R). This is equivalent to 10 inches (250 mm) fiberglass or 6 inches (150 mm) of polyurethane insulation. In addition, ventilation is the most important factor for maintaining desired temperature, relative humidity, and air quality in the storage. The warehouses can be mechanically ventilated or naturally ventilated. Bulk storage can be vertically or horizontally ventilated. The design of ventilation system in the potato storages structure is similar to the ventilating systems of other farm structures (Ooster, 1999 ; Small and Pahl, 2009).

Potatoes are stored successfully when the storage environment conditions are set to match the requirements of the crop and the purpose for which it is stored. Ideally, potatoes are harvested when the pulp temperatures are around 15°C. A continuous supply of air, at a slow rate, will help equilibrate the pile temperature reducing the chances of temperature differential in different areas of the pile. The relative humidity should be maintained at 90-95%. Once the storage is filled to capacity the temperature of the pile is maintained at 10-12°C for two weeks to cure the potatoes. This would include the time for bringing the pulp temperature to 10-12°C. Once the curing is complete the pile temperature is cooled to the holding conditions. The holding temperature is determined by the end use of the potatoes (Shetty, 2010).

During storage, weight and quality loss should be minimized. Storage losses are determined mainly by potato condition, storage conditions, and duration of the storage period. Weight losses are caused by;

-Respiration,

- Evaporation of inter- or intracellular moisture from the potato,

$$*R_{SI}\left(\frac{m^2.^0C}{W}\right), \quad **R\left(\frac{h.ft^2.^0F}{Btu}\right)$$

-Sprouting,

- Storage diseases.

Four variables to determine storage losses are the potato variety, pre-storage conditions, storage conditions and storage duration. It must be realized that storage losses cannot be avoided even by optimal storage.The approximately values of storability of potatoes at different temperatures was shown in Table 1 and ideal storage temperature for potato as per different uses was shown in Table 2.

Critical for good storage environment are successful management of temperature, relative humidity, CO_2 level of the store and air change system. Daily monitoring of these factors is crucial for maintaining good quality. The temperature within the storage facility and the outside ambient air can be measured with a simple minimum and maximum thermometer situated away from external influences, particularly direct sunlight. Relative humidity should be monitored by using a wet and dry bulb thermometer in a sling or battery–operated psychrometer. Portable CO_2 meters are useful tools when monitoring potato storages. (Booth and Shaw, 1987; Kleinkopf, 1995).

Numerous factors affect potato quality and many them relate to the chemical composition of tuber which is influenced by the environment during storage. The extent of biochemical changes occurring in tubers during storage. Post-harvest quality losses in stored potatoes can also occur through both physiological and disease related processes. Two of the most important physiological processes affecting potato storage and market quality (Salunkhe et al., 1989).

Climatic factors, but particularly temperature, influence both the choice of storage systems and the details of store design. Good storage should prevent excessive loss of moisture, development of rots, and excessive sprout growth. It should also prevent accumulation of high concentration sugars in potatoes, which results in dark-coloured processed products. Temperature, humidity, CO_2 and air movement are the most important factors during storage (Robert, 1988).

Systems used for potato storage all over the world are characterized in Fig. 1. As can be seen in Fig.1, the potatoes can be stored in different systems. This study focused on storage systems of potatoes in volcanic tuff storages. The volcanic tuff storages used for long-term storage of potato are located in Niğde - Nevşehir regions in Turkey.

Table1. Storability of potatoes at different temperatures (Eltawil et al., 2006).

Average storage temperature, °C	Storability, months
5	6
10	3-4
15	2-3
20	2-3
25	2
30	1

Table 2. Recommended storage temperature for potatoes for different usage (Ooster, 1999).

Potato Destination	Storage temperature, °C
Seed potatoes	2-4
Consumer potatoes	4-5
French fry dried products	5-8
Chip industry	7-10
Starch and derivatives	6

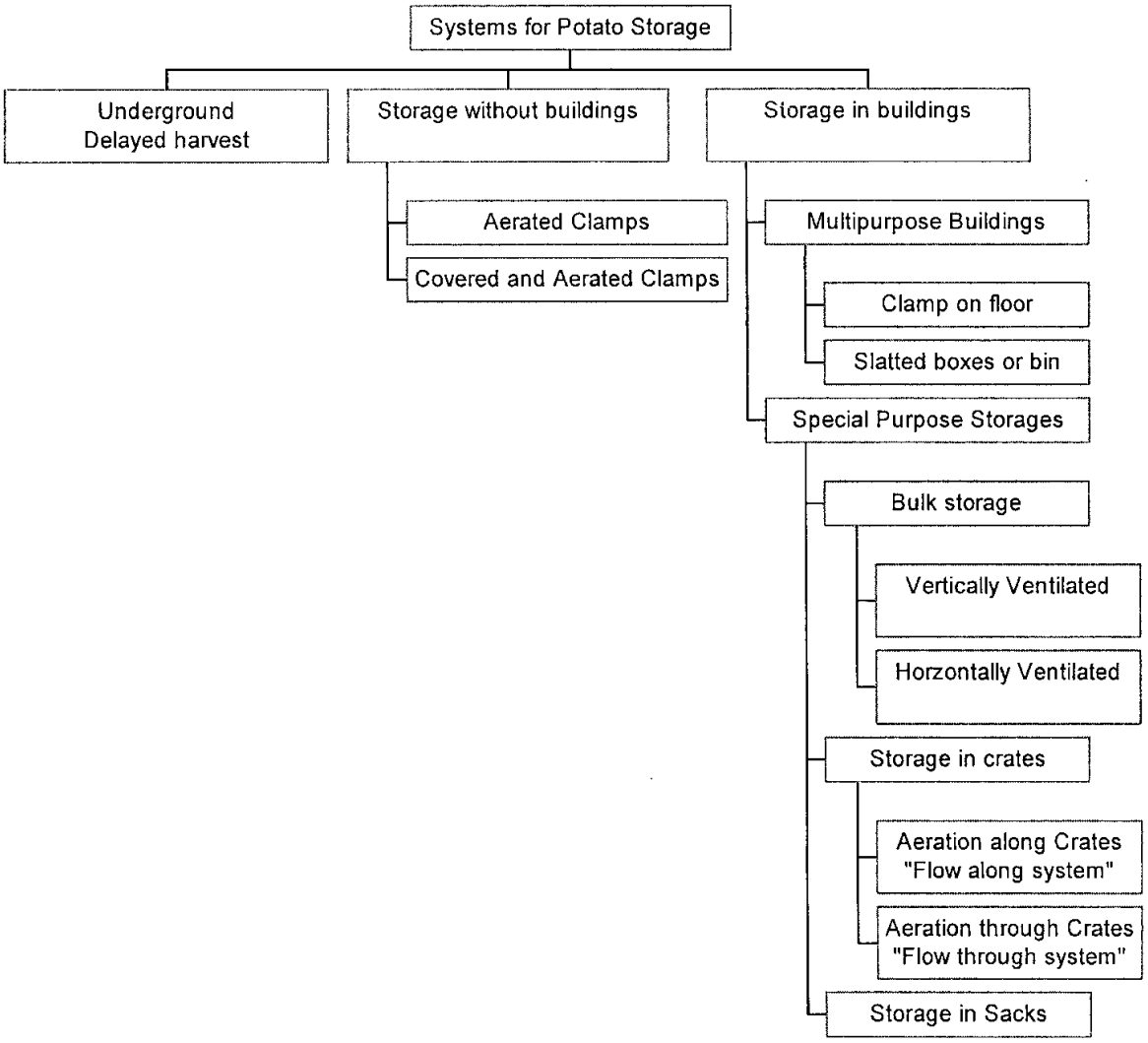

Figure1. The storage systems for potatoes (Ooster, 1999).

3. Volcanic Tuff Storages

Fifty percent of potatoes (approx.2.5 million ton) produced in Turkey are stored in the volcanic tuff storages in Niğde-Nevşehir region. The volcanic tuff storages used for potato storage in the region are formed by Tunnel Boring Machine (Fig. 2).Volcanic tuff in the area around Niğde-Nevşehir in Turkey consists of glassy particles of variable silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) content. The abundant phase is silica (69 %). The bulk density of volcanic tuff is 702 kg/m^3 .The proportion of bulk water absorption in volcanic tuff ranges between 30.4 and 44.75%. These rocks in the region formed as a result of suddenly cooling and suddenly leave of the gases during volcanic activities. According to the Mohs scale, the hardness of volcanic tuff is 6.5-8.0. The pores aren't usually interconnected. The porosity is 44-52% (Bekar et al., 2006; Stück et al., 2008). Hence, the thermal conductivity of volcanic tuff in the region is very low. It is preferred for the potato storage (Fig .3). Volcanic rocks have been drilled in the form of a long corridor. There are many partitions in the form of lodge and in length 10 to 200 meters on the corridor. These partitions are connected to alley corridor (Fig 4).

Figure 2. Tunnel boring machine (TBM)

Figure 3. The exterior view of volcanic tuff storages

Figure 4. The hallway

The partitions are average 5m in width, 7 m in height and L or U cross section. In this context, 10-15 trucks could drive on the hallway for enter-exit at the same time (Fig. 5). The cross -section of chambers are vary according to the storage capacity. In the ceiling of chambers are natural ventilation chimneys. These chimneys are opened to exterior environment (Fig. 6).

Figure 5. The truck on hallway

The volcanic rocks can be easily dilled by Tunnel Boring Machine (TBM). When the volcanic tuff that contain excessive moisture contact with air is becoming harder. While the volcanic tuff moisture out, the evaporation has occurred. Depending on evaporation, the ambient temperature in the storage falls. In this context, although the outside temperature at the storage season is kept at 35 ^{0}C, temperature in the storages is between 0 and 5 ^{0}C.The average storage period for potatoes stored in the volcanic tuff storages is eight months. These storages have not any cooling and heating equipment. Hence, potato storage in these warehouses brings an important cost advantage for companies. Many commercial firms wishing to benefit from this cost advantage prefer to volcanic tuff storages for the storage of potatoes. There are over two thousand volcanic tuff storages formed for this purpose in the region. In the volcanic tuff storages, onion and citrus fruits brought from other regions as well as potato produced in this region are also stored. Some commercial firms can store over sixty thousand tones potato in this rock stores. Potatoes are placed in the volcanic tuff storages from October to November, kept on hold until the end of May after 7-8 months storage (Fig. 7). At the end of storage period, the storage walls are washed with pressure water. In addition to this, fumigation is done against disease and pests (Fig. 8).

a) Storage entry

b) Panoramic view from the natural ventilation chimneys

Figure 6. Volcanic tuff storages

Figure 7. Taking of potatoes to the volcanic tuff storages

Figure 8. Cleaning in the storages

References

Arıoğlu, H., 2000. Starch and sugar crops. Çukurova University, Agriculture Faculty, General Publication No:188, Textbooks Publication No: A-57, Adana. (in Turkish).

Bekar, M., Sapcı, N. and Gündüz, L., 2006. The use of volcanic tuffs from Aksaray region as plaster material. IVth National crushed stone symposium, 2-4 December, 2006,İstanbul.

Booth, R. H. and Shaw, R. L., 1987. Principles of potato storage. International Potato Centre, Lima, 105p.

Eltawil, M. A, Samuel, D.V.K. and Singhal, O. P., 2006. Potato storage technology and store design aspects. *Agricultural Engineering International: the CIGR Ejournal*. Invited Overview, April, .No. 11. Vol. VIII.

FAOSTAT,2010. World crop production statistics. Available < http://faostat.fao.org>.

Kleinkopf, G. E., 1995. Early season storage. *American Potato Journal*,(72),pp. 449-462.

Leeman, A. M., Barström, L.M. and Björk, I.M., 2005. In vitro availability of starch in heat-treated potatoes as related to genotype, weight and storage time. *Journal of Sci. Food Agric*.,(85),pp.751-756.

Nourian, F., Ramaswany, H.S. and Kushalappa, A. C., 2003**.** Kinetic changes in cooking quality of potatoes stored at different temperatures. *Journal of Food Engineering* (60), pp. 257-266.

Ooster A., 1999. Storage of Potatoes. CIGR Handbook of Agricultural Engineering, Volume IV, Agro-Processing Engineering Edited by CIGR–The International Commission of Agricultural Engineering, Volume Editor:F. W. Bakker-Arkema, The American Society of Agricultural Engineers, U.S.A.

Rastovski, A., 1988. Agrometeorology of the Potato Crop. *In*: Rastovski, A, Stigter, C.J.; Rijks, D.A (eds.) Storage of Potato in Temperate Climates. Stigter, C.J.; Rijks, D.A. Acta Horticulturae 214, Special issue co-published by ISHS and WMO (1988) 201 pp. Wageningen, Netherlands.

Robert H. B., 1988. Agrometeorology of the Potato Crop. *In*: Robert H. B., Stigter, C.J.; Rijks, D.A (eds.) Agrometeorology and Potato Storage in third World Countries. Acta Horticulturae 214, Special issue co-published by ISHS and WMO (1988) 201 pp. Wageningen.

Sajilata, M. G., Singhal, R. S. and Kulkarni P.K., 2006. Resistant starch –a review, *Comprehensive Reviews in Food Science and Food Safety* 5 (2006), pp. 1–17.

Salunkhe, D. K., Desai, B.B. and Chavan, J.K., 1989. Pototes.In:.Michhael Eskin (eds.).Quality and preservation of vegetables,pp.1-52,CRC Press INC:, Florida.

Shetty, K. K., 2010. Potato storage management for disease control. Potato Storage Research, University of Idaho, 3806 North 3600 East Kimberly, ID 83341.

Small, D. and Pahl, K., 2009. Potato Storage Management - Storage Structures and Ventilation, Agriculture and Rural Development, Government of Alberta.

Stück, H., Forgo, L. Z., Rüdrich J., Siegesmund, S. and Török, A., 2008. The behavior of consolidated volcanic tuffs: weathering mechanisms under simulated laboratory conditions. *Environmental Geology*, (56), pp. 699–713

Tarn, T. R., Tai, G. C. C. and Liu, Q., 2006. Quality improvement. In:J.Gopal, S. M. Paul Khurana /Eds.),Handbook of potato production, improvement and postharvest management, pp. 147-178.Food Products Press, New York.