# Underground Structures Used For Storage Of Perishable Food: State Of The Art

**Yeiner Pinilla, Leonel Gómez, Sandra Ospina**

**Abstract:** This paper presents the state of the art of underground structures that have been used for the storage of perishable foods throughout history around the world, their morphometry and the materials with whose they were built. In addition, the characteristics contributed by the soil for decrease the temperature inside these structures are reviewed. Subsequently, an analysis of the discoveries found in the investigation is carried out, in order to establish relationships between the variables that give structures the conditions necessary to store and conserve food for long periods of time. Finally, the results obtained show that the information provided by the underground structures analyzed is inconclusive, exposing the topics that are still unknown in the study of these underground spaces.

**Index Terms**: Underground Structures, Underground Storage, Food Conservation, Thermal Insulation, Soil, Materials, Temperature

## 1 INTRODUCTION

Considering that the underground structures have been used in different areas of the world, and for different uses, a bibliographic research was carried out to identify and analyze which characteristics from the point of view geometric model, geomechanical model and model or construction specifications will determine the operation of this type of structures to store highly perishable products such as fruit and vegetable products. The search was extensive and sufficient, covering different databases, trying to cover aspects such as the time in which findings on these types of structures were reported, the geographical location where they were located or are locate today, and the conditions mentioned regarding the intrinsic characteristics of these. Since its inception, humanity has sought ways to preserve its food in order to meet a basic and indispensable need such as feeding, which is vital for its subsistence. Because of this, man has used underground spaces for millennia, as a place to store food safely. People in ancient cultures understood that, in underground storage, stable temperatures in a sealed environment provide important advantages, such as reducing heating losses and reducing theft by insects, rodents, birds and other pests (Keller, 2012). As a measure of regulation of new storage systems for perishable foods, due to the problems generated during the post-harvest, different technologies of cooling and conservation of food have been implemented throughout the world, where soil characteristics are exploited to control the storage temperature, and due to the ease of construction of the different structures, excellent results have been obtained by improving production costs by reducing product losses (Roux, 2015).

- *Yeiner Pinilla is currently a member of the INDETEC research group, Civil Engineering Student, University of La Salle. Bogota, Colombia. E-mail: yeinerpinilla00@gmail.com*
- *Leonel Gómez is currently a member of the INDETEC research group, Civil Engineering Student, University of La Salle. Bogota, Colombia. E-mail: gomezlmc01@gmail.com*
- *Sandra Ospina is a Civil Engineer, Master's in engineering-Geotechnics, Full-time Professor at the University of La Salle, a member of the INDETEC research group and a PhD student in Agrosciences. Bogota, Colombia. E-mail: seospina@unisalle.edu.co*

In this research work, the underground structures used in the storage of perishable products are reviewed, through the different ages of history worldwide, the geometry of these underground spaces, the materials and implemented construction methods, and the characteristics of the soil on which the structure is built. For this, a search and selection of information was carried out by going to previous research, identifying that they contained the variables to be evaluated, with the aim of generating a systematic analysis of this type of infrastructure to establish their state of the art, finding which are the existing gaps in the knowledge of the subject investigated. One of the characteristics of interest in the bibliographic search carried out, is the capacity of the soil as a thermal insulator, identifying the efficiency in the decrease in temperature through it, this thermal variation depends on other factors such as solar radiation, internal temperature and external air, depth in soil mass, soil type, and physical and chemical characteristics of this (unit mass, relative density, moisture content, consistency limits, etc.) (I. Cañas, 2012), (F. Tinti, A. Barbaresi, S. Benni, D. Torreggiani, R. Bruno and P. Tassinari, 2014). Another of the relevant aspects in the conservation or isolation of the temperature, is the coating of the underground structure, the different building materials that make up the storage spaces can provide heat reduction. Uncoated rock structures have been built, in order to take advantage of the cooling and stability properties that the excavation material provides, because the rock mass, in addition to maintaining a low thermal conductivity, provides mechanical stability of the cavern ( B. Unver & C. Agan, 2003). However, the technological development of many countries enabled innovation in the use of raw materials, as in the case of the Netherlands where a company is dedicated to the construction of a modern storage system called "Groundfridge" and made of laminated polyester, its manufacturers emphasize that this is a lightweight material, with a long service life and resistant to soil conditions, tree roots or other plants (El Sol, 2016). The findings of this research allowed to establish the global distribution of underground structures around the world, what are the ranges of temperature deltas between the outside and interior of these environments, the materials and geometries used, and a compilation of the physical and chemical properties of the soils in which they have been built, allowing in the end to obtain a comparative matrix of all this information.

## 2 UNDERGROUND STORAGE STRUCTURES IN THE WORLD

The geographical distribution of the land allows us to find different climatic conditions around the world, composition of the earth's surface and diversity of cultures originated throughout the history of mankind, which have evolved by developing and applying new technologies for conservation and Food storage worldwide. In Europe, the cradle of great ancient civilizations, multiple finds of remains of underground spaces used centuries ago have been found as an efficient technique for storing their food. The Aegean civilization, during the Neolithic and the Bronze Age, developed underground storage techniques to cover the risk of drought, bad weather and poor harvests, therefore, these underground spaces located in the countries on the shore from the Aegean Sea (Greece, Italy, Serbia, Macedonia, Yemen, Tunisia), served the farmers of the time to store and conserve their grain and cereal crops for up to two years (Roux, 2015).

Other underground structures, have been built a few years ago, in China and the United States recently patented structures, which are designed to store perishable foods such as fruits and vegetables, as technological advances in these countries have allowed new models of underground infrastructure to be developed from the modern age that has the right conditions for the conservation of different types of food (Patent No. US4894928A, 1988), (Patent No. CN204081577U, 2014). For Latin America, a large number of underground storage structures were not found, however, in 2007, it was demonstrated that some pre-Hispanic cultures that settled to the west of Guanajuato state, in central Mexico, implemented the use of underground structures to store food. Underground deposits were registered where the remains found and morphological characteristics allowed to establish that they were structures built for the storage of food harvested at the time, mainly maize (S. Bortot, 2007). From the information collected throughout this research, eighty-four underground structures were found with their respective geographical location where they were built, and which are linked to the storage of various types of food. To facilitate the analysis, these foods are classified in vegetables, fruits, cereals, grains and wines, it should be noted that the storage of wines was taken into account in order to mention the underground cellars that were implemented in the Ribera del Duero in Spain, and that are directly related to the type of structures studied. In Figure 1, the geographical distribution of the structures found is shown, where it can be seen that the location center of each one indicates the time of the history in which it was built and its orbits represent the products that are stored there. In this figure, it is identified that the largest number of structures used for food storage are located in the countries of Europe, represented in 69% of the total number of structures found, on the other hand, in the continents of America and Asia this percentage is equivalent to 11%, while Africa only 5% of these structures are located. In addition, the implementation of these underground spaces for storing food was presented mostly, in regions near the earth's hemispheres, where climatic conditions are not optimal for the constant production and conservation of food, the existence of climatic seasons in the year generates very low temperature peaks during winter and too high in summer times. The location of the underground structures in a time interval of history, relates the social, technological, productive and economic conditions of the time, in this way it is understood because these underground structures were built in the different forms and materials that were found in the investigation, evidencing how societies were adapt to the context presented by the historical periods in which they are built, to meet the needs that drove the implementation of underground infrastructure as spaces for food storage (J. Miret, 2015).

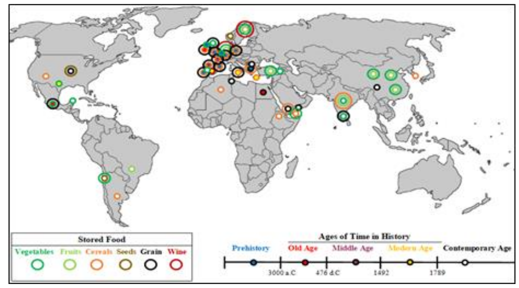


***Figure 1.*** *Geographic distribution of underground storage structures throughout history.*

## 3 STRUCTURE MORPHOMETRY

The geometry of the underground structures is directly related to the constructive skills that the men of the time had, the technical knowledge and the tools available to them. The human being has adapted to the places where he lives, giving him the best use of the soil and taking advantage of the characteristics of the place, depending on the topography present on the site and the mechanical conditions of the soil, the man could identify the most feasible geometry to build an underground structure that met all stability requirements. In the research several geometric shapes were found in the structures, a total seventy-five (75) structures contained information regarding the geometry presented by each of them. Some wineries had a peculiar shape and little used so it was necessary to group them in the category of "others", this category is composed of a cavern whose geometry is "M", another presented an elliptical section and an underground structure with form of "Well" (A O'dell, 1961). The other forms found in the investigation are presented in Figure 2, there they are classified into 6 large groups which in turn are composed of other more specific forms. In the group of spherical structures are also those shaped like pears and ovoids, in the conics we find pyramidal and truncated conical structures, in the group of hexahedrons are all those structures that resembled a cube and the cylindrical is a category composed of silos and structures built with circular bases.

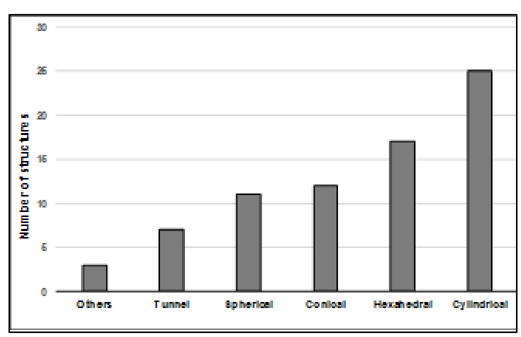


***Figure 2.*** *Geometric shapes presented by underground*

*storage structures.*

In the graph, it is clearly observed that the cylindrical shapes are the ones that have been most used when it comes to building underground storage structures, this form has great advantages over the others in the construction part since it provides more stability at the time of digging and there is greater control over volumetric dimensions. Hexahedra are also very employed, these provide ease in excavation during their construction and being a regular figure, their use is facilitated (Falkowitz, 2014). The conical and spherical geometries are very even, these differ significantly from cylindrical and hexahedrons, such a difference can be given by the complexity that occurs when it comes to building until obtaining the shape of those figures, the structures that presented Tunnel or cavern form were usually located in mountainous areas where it was more feasible to make the structure on the slope by decreasing the volume of excavation and taking advantage of the covering of the mountain (J. Miret, 2015).

## 4 STORAGE CAPACITY

The size of the structure is a factor that intervenes in the analysis of this research, since it involves the different dimensions applied in the construction of these underground spaces depending on the shape, use and storage capacity desired. In the previous paragraph it was shown the multiple ways in which some underground structures were built to store food, in terms of the length values found, these are dependent on the way the structure presents, that is, in the case of a hexahedral structure , the lengths that represent its size will be given by its height, length and width, if it is a cylindrical silo, its size will depend on the values of diameter and height, and so on for each of the shapes found. In order to typify the length parameters found, these will be represented through the volume of the structure, because it is very difficult to establish a size relationship when there are different values for each of the types of structures. The volume represents a cubic unit ($L^3$) defined as the extension in three dimensions of a region of space, in this case the underground space of each of the storage structures (C. Mosquera, 2019). The storage capacity will depend on the respective volume of the structure, since the amount of food that will be stored will be limited by the space with which the underground structures are counted inside. Normally, the dimensions of these storage spaces are not governed by the product stored inside, but depend on the hectares of land of the producer and their production (N. Alonso, F. Cantero, D. Lopez , E. Montes, G. Prats, S. Valenzuela & R. Jorner, 2012). In order to establish a relationship between the size of the structure and the storage capacity that it may contain, the length values identified in the investigation were collected, resulting in a total of thirty-two underground structures in which these parameters were presented , of these structures only for 16% was known its ability to store food. Once these values were identified, they were all taken to the same system of units, since these were different and varied depending on the country of origin of the structure. Due to the lack of information offered by the storage structures found, a Storage Factor (SF) was determined for the structures that recorded the two variables studied: volume and storage capacity. This factor was calculated by the following expression:

Where:
SF = Storage Factor
Ws = Weight Stored in Tons
Vs = Structure Volume in $m^3$

$$SF = \frac{Ws}{Vs} \quad (1)$$

After finding the S[...] d be calculated, the values found [...] ge unit value of the tons stored per unit volume was obtained for the other structures. Knowing the storage factor and the respective volume of each structure, it is possible to clear the stored weight (Ws) from equation (1):

$$Ws = Vs * SF \quad (2)$$

Complete the data of the analyzed structures, are expressed by means of a graph as shown in figure 3.

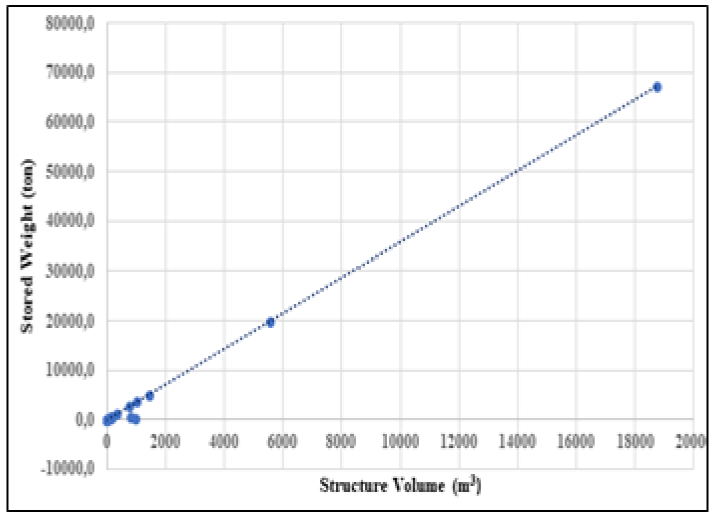


***Figure 3.*** *Graph representing the relationship between volume and storage capacity in tons of underground*

When observing the graph, a relationship between these two variables is evidenced, where it is appreciated that when the volume of the underground storage structure is greater, in turn, the weight of food that can be stored will be greater, existing between these a direct proportionality, where if there is a need to store large quantities of food, it will be necessary to build a large underground structure; or otherwise, build a large structure that represents a large volume, in order to store high amounts of food.

## 5 THE SOIL AS A THERMAL INSULATOR

In various investigations, it has been widely demonstrated that the soil, understanding the concept as particulate material or the rock mass, is a material that has adequate characteristics, when what is sought is to maintain a stable temperature within it. It has been determined that it has a potential for temperature stabilization, and the behavior in climatic zones of high environmental temperatures, where the soil with the depth increases its potential for temperature decrease, speaking of short digging depths (<10 m). The following Table presents the findings regarding the temperature information offered by some underground structures that have been used in food storage, showing the peak values presented outside

(Ambient Temperature) and indoors (Storage Temperature ) of the structure, relating in turn, the products that were stored in these temperature ranges.

**TABLE 1**
EXTERNAL AND INTERNAL TEMPERATURE INTERVALS IN THE DIFFERENT UNDERGROUND STORAGE STRUCTURES

| Location | Stored Food | Room Temperature (°C) | Storage Temperature (°C) | Reference |
|---|---|---|---|---|
| USA | Cereals and Grains | 1,7 / 37,8 | 10 / 15,6 | (Patent nº US5117593A, 1991) |
| China | Grains | -8 / 31 | 10 / 18 | (Patent nº CN203603558U, 2013) |
| China | Fruits and Vegetables | 0 | 11 / 14 | (Patent nº CN204081577U, 2014) |
| USA | Grains and Cereals | 27 | 10 | (Patent nº US4894928A, 1988) |
| Netherlands | Fruits, Vegetables, Cheese and Wine | -10 / 35 | 10 | (El Sol, 2016) |
| Norway | Seeds | -7 / 21 | -18 | (El País, 2008) |
| Sweden | Fruits, Vegetables and Wine | -6 / 22 | 8 / 12 | (Strigari, 2016) |
| Spain | Wine | 0 / 33 | 11 / 13 | (Bodega PeñaCoba, 2017) |
| Macedonia | Cereals and Grains | -4 /31 | 0 / 15 | (Roux, 2015) |
| Turkey | Citrus and Potatoes | 50 | 0 / 20 | (B. Unver & C. Agan, 2003) |
| South Korea | Fruits and Vegetables | -6 / 30 | 15 | (Park, Synn, Park & Kim, 1999) |
| Italy | Wine | 14,3 | 16,4 | (A. Barberesi, 2014) |

Numerous authors, in their investigations talk about the characteristics that the excavation material presents (soil or rock), and how the values that you present contribute to decrease the intensity of the thermal wave, when it is, it propagates through the different soil strata. Therefore, the properties of the land will condition the transfer of heat, achieving greater thermal stability at a given depth (I. Cañas, 2012). Table 2 shows the properties of soils that have most often allowed to establish a temperature reduction effect in the study of underground structures.

**TABLE 2**
PROPERTIES INVOLVED IN HEAT TRANSFER IN THE SOIL

| Property Evaluated | Reference |
|---|---|
| Soil moisture, Solar radiation, Ambient temperature, Relative humidity and Internal temperature | (Balghouthi, M., Kooli, S., Farhat, A., Daghari, H., & Belghith, A., 2005) (Hinzman, Goering, & Kane, 1998) |
| Humidity of soil | (Dong, J., Steele-Dunne, S. C., Ochsner, T. E., & van de Giesen, N., 2016) (Lu, Ren, Gong, & Horton, 2007) |
| Soil surface temperature | (Szabó, J., Kajtár, L., Nyers, J., & Bokor, B., 2016) |
| Physical properties: soil density, granulometry and organic content | (Suarez-Domínguez, Aranda-Jiménez, Palacio-Pérez, & Izquierdo-Kulich, 2014) (Fröb, 2011) |

The realization of experimental investigations in the field, allowed to demonstrate that the temperature of the soil in superficial and shallow areas, which are those of interest for underground structures, assumes optimum values for the conservation of some fruits and vegetables (temperatures from 12 ° C to 16 ° C), below 4.0 m deep. On the other hand, it was concluded that at depths less than 2.0 m, the behavior of temperatures is significantly influenced by external conditions of the place where the structure lies (F. Tinti, 2012)

## 6 THE USE OF MATERIALS IN THE UNDERGROUND STRUCTURES

As the human beings move forward, he develops new knowledge and at the same time, new techniques applied in everyday activities. For the construction of infrastructure works, man has made use of the materials available in his environment, taking advantage of the constructive characteristics that these present. In ancient times, the most commonly used materials for the construction of underground structures were those that could be obtained from nature in a simple way, such as clay, rocks, straw and wood, which did not require greater complexity for its application in construction processes , being thus, that the first constructions were elaborated from empirical knowledge (Roux, 2015). With the discovery of concrete and handling of steel, man began to implement these materials in the construction of structures, providing them with greater stability and increasing their durability (J. Miret, 2015). This research allowed to know the types of materials in which the different underground storage structures for food have been built. In the findings, forty-three structures were found that presented information regarding the materials with which they were constructed. After this review, the proportion in which each material was used for the construction of underground storage structures was identified, infrequent materials such as salt and ceramics were grouped into the category of “others”. These data were consolidated in the diagram shown below (See figure 4).

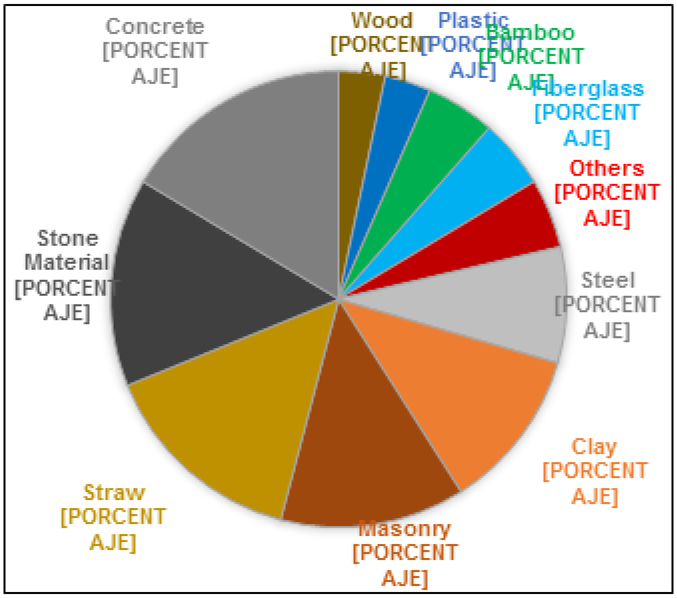


***Figure 4.*** *Materials used in the construction of underground storage structures.*

As shown in the diagram, the most frequent materials in the elaboration of underground storage spaces were clay, masonry, straw, rocks and concrete. Each of these materials provides favorable characteristics to the structures, for example, clay, being an easy material to obtain and handle, provides impermeability and serves as a sealant, preventing the entry of insects and rodents. On the other hand, masonry has been used in history to improve the performance of time in the execution of works and reduce construction costs. Some organic materials, including straw, which is a good thermal insulator, were used in underground food storage structures, to provide ventilation and serve as drainage (S. J. Kale 2016). It was evidenced that stone materials such as stones and rocks were used for the coating of structures, these materials could be obtained as a result of the excavation carried out for the elaboration of the structure or be brought from its surroundings. The rocks were used to take advantage of their thermal diffuse capacity while providing good support to the structure. Of the data found, concrete is the most used material throughout history for the construction of underground storage structures, this is because it has a large number of qualities required by these infrastructure works. The concrete has an excellent performance as a waterproof and thermal insulating material, being highly resistant to moisture and pest attack, it is also the material with the best structural resistance characteristics (Strigari, 2016).

## 7 CONCLUSIONS

At the end of this research and the respective analysis of the information found, it can be concluded that, the underground structures are used around the world to store food, because optimal temperature and humidity conditions are provided inside. In Figure (1), shows that in the equatorial area of the land there are no underground storage structures, this can be said because it is a region comprised of tropical countries that do not have climatic stations but they maintain temperatures slightly variable, with a diversity of thermal floors that allow the production of different types of fruit and vegetable products, the need to build underground structures where they could store their food for a long time never arose. The information obtained in this review did not allow establishing a relationship between the thermal storage conditions of the structures and the depth of excavation at which they were built. However, a profile of the depths implemented by some food storage structures in different countries is presented below (Figure 5).

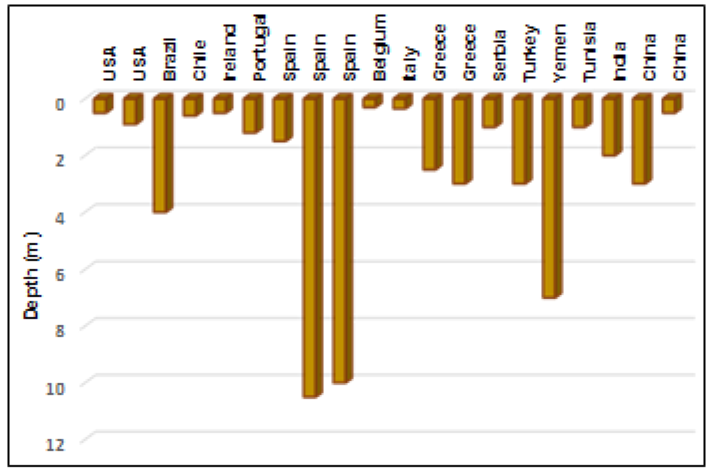


***Figure 5.*** *Depths implemented in the construction of underground storage structures.*

Throughout the research highlight the main characteristics that allow underground structures to obtain an adequate thermal environment for the conservation of some perishable foods. As for the structures that were found and studied in this work, there is no clarity as to whether the conditions required for food storage were provided by the coating material that was used in its construction, or by the material of food excavation (floor or rock) where it was built.

## 8 ACKNOWLEDGMENT

We would like to thank our degree project director and co-author Sandra Ospina Lozano, who was always a guide and support during the development of this research work.

## 9 REFERENCES


[1] Barbaresi, D. T. (2014). Thermal simulation of the underground cellar: definition of a method for modeling performance assessment based on experimental calibration. Energy and Buildings, 363 - 372.

[2] A.D. Stuckes, P. y. (1975). Thermal conductivity of solids. P. y. A.D. Stuckes, Thermal conductivity of solids (pages. 24 -28). London: Pion.

[3] Agan, C. (2011). Investigation into the usage of Sanliurfa limestones in Turkey as underground storage cavern about some engineering properties. International Journal of Physical Sciences, Volume 6, Issue 33, 7629-7637.

[4] Ali, Z., Yadad, A., Stobdan, T., & Singh, S. B. (2012). Traditional Methods for storage of vegetables in cold

arid region of Ladakh, India. Indian Journal of Traditional Knowledge, 351-353.
[5] Ali, Z., Yadad, A., Stobdan, T., & Singh, S. B. (2012). Traditional Methods for storage of vegetables in cold arid region of Ladakh, India. Indian Journal of Traditional Knowledge, 351-353.
[6] Alonso, N., Cantero, F. J., López, D., Montes, E., Prats, G., Lamas, S. V., & Jornet, R. (s.f.). Rubbish Ethnoarchaeology: Pit Storage and Reuse in the Ouarten Village of El Souidat. El Kef.
[7] Alves, A. B., & schmind, A. L. (2014). Cooling and heating potential of underground soil according to depth and soil surface treatment in the Brazilian climatic regions. ENERGY AND BUILDINGS, 41-50.
[8] Aulakh, J., & Regmi, A. (s.f.). POST-HARVEST FOOD LOSSES ESTIMATION- DEVELOPMENT OF CONSISTENT METHODOLOGY.
[9] Balghouthi, M., Kooli, S., Farhat, A., Daghari, H., & Belghith, A. (2005). Experimental investigation of thermal and moisture behaviors of wet and dry soils with buried capillary heating system. Solar energy, 79(6), 669-681.
[10] Bishop, W. M. (1988). United States Patent nº US4894928A.
[11] Boe, G. D., & Verhaeghe, F. (1997). Rural Settlentents in Medieval Europe. Medieval Europe Brugge, (pages. 14-250). Zellik.
[12] Boxall, P. S. (1984). POST HARVEST LOSS REDUCTION PROGRAMMES: A DECADE OF ACTIVITIES: - WHAT CONSEQUENCES? University of Greenwich, 4-13.
[13] Cañas, I., Cid-Falceto, J., & Mazarron, F. R. (2012). Underground cellars excavated on land: Characteristics of soils in the Ribera del Duero (Spain). Construction Reports.
[14] Carslaw, L. y. (1959). Conduction of Heat in Solids. L. y. Carslaw, Conduction of Heat in Solids (pages. 236-245). London: Oxford University Press.
[15] Cha, S. S., Lee, K. K., Bae, G. O., Lee, D. H., & Gatelier, N. (2007). Analysis of rock drainage and cooling experiments for underground cryogenic LNG storage. Engineering Geology, 93(3), 117-129.
[16] Choi, S. O., Park, H. D., Park, Y. J., Kim, H. Y., & Jang, a. H. (2000). Test Running of an Underground Food Storage Cavern in Korea. Tunneling and Underground Space Technology, 91-96.
[17] Dachy, T. (2014). Réflexions sur le stockage alimentaire en Égypte, de la Préhistoire aux premières dynasties. Archeo-Nil, Volume 24, 31-46.
[18] Devroey, J.-P. (s.f.). Cereals in the networks of large land ownership in the Carolingian era. Storage and distribution.
[19] Dong, J., Steele-Dunne, S. C., Ochsner, T. E., & van de Giesen, N. (2016). Estimating soil moisture and soil thermal and hydraulic properties by assimilating soil temperatures using a particle batch smoother. Advances in Water Resources, 91, 104-116.
[20] Embrapa. (1997). POST-HARVEST LOSS MANUAL IN FRUITS AND VEGETABLES. EMBRAPA/CTAA, 1-17.
[21] Food and Agriculture Organization (FAO). The State of the World's Agriculture and Food. Rome, 2012.
[22] Francesco Tinti, A. B. (2014). Experimental analysis of shallow underground temperature for the assessment of energy efficiency potential of underground wine cellars. Energy and Buildings, 451-460.
[23] Ghazali HUSSIN, R. A. (2015). Malaysia Patente nº WO2017116222A1.
[24] Glamheden, R., & Lindblom, U. (2002). Thermal and mechanical behavior of refrigerated cavernsin hard rock. Tunnelling and Underground Space Technology, 341-353.
[25] Gustafsson, B., & Strang, H.-E. (1982). United States Patent nº US4534144A.
[26] Habtegebriel, B. (2016). Postharvest Pest Management. Research, Education and Extension in Ethiopia: The situation and perspectives. Proceedings of the 22nd Annual Conference. Addis Abela, Ethiopia.
[27] Hansen., N. A. (1884). The development of green coal, particularly in England and its potential impact on Danish agriculture. Lecture in Dot Kgl. Lan Household Company, 150-191.
[28] Jiayin Zhu, L. R. (2020). Annual thermal performance analysis of underground cave dwellings based on climate responsive design. Renewable Energy, 1633-1643.
[29] Kale, S. J., Natch, P., Jalgaonkar, K. R., & Mahawar, M. K. (2016). Low Cost Storage Structures for Fruits and Vegetables Handling in Indian Conditions. Indian Horticulture Journal, 376.379.
[30] Keller, H. (2012). Underground storage of food items. En B. Singh, J. Zhao, & R. Goel, Underground infrastructures (pages. 69-87). India: BUTTERWORTH HEINEMANN.
[31] Koula DOUKANI1, S. T. (2013). Physical-chemical characterization of fermented wheat by Underground Storage (Matmora). Ecology-Environment Review.
[32] Kraemer, R., Plouff, A., & Veen, J. (s.f.). Design of a Small-Scale, Low-Cost Cold Storage System.
[33] Lenti István, B. F. (2008). HORSE BEANS (VICIA FABA L.) Protect. PLANT PROTECTION, 403-421.
[34] Liu, W. V., Apel, D. B., Bindiganavile, V. S., & Szymanski, J. K. (2016). Analytical and numerical modeling for the effects of thermal insulation in underground tunnels. International journal of mining science and technology, 26(2), 267-276.
[35] Lötscher, C. (2014). The Neolithic Silex mine "in Chalchofen" near Olten Canton Solothurn. Archaeology Switzerland, 26-33.
[36] Marchena, L. A. U., Parra, G. A. M., Quiroz, M. A. C., Henao, D. C., Zapata, P. A., Mira, L. L., ... & Gómez, B. D. (2011). Effect of bioactive compounds of some foods on health. Human Nutrition Outlook, 11(1), 27-38.
[37] Mestre, J. M. (2015). HOYOS, SILOS AND OTHER THINGS CATALOG OF EUROPEAN PREHISTORICAL STRUCTURES.
[38] Montero Calderón, M., & Cerdas-Araya, M. (2012). Postharvest physiology and storage. En M. Siddiq, Tropical and subtropical fruits - Postharvest, physiology, processing and packaging (pages. 17-34). Iowa, USA: Wiley-Blackwell.

[39] Moretti, C. L., Mattos, L. M., Calvo, A. G., & Sargent, S. A. (2010). Climate changes and potential impacts on postharvest quality of fruit and vegetable crops: A review. Food Research International, 1824-1832.
[40] Multon, J. L., & Sigaut, F. (s.f.). History and prospects of grain and seed storage and preservation technologies.
[41] Neely, G. I., & Bentley, M. R. (1914). Storage Structures and Home Storage of Vegetables and Fruits. Texas: College Agricola and Mechanic de Texas.
[42] Ö Aydan, P. N. (1997). Deformability dependent on the speed and resistance characteristics of the rocks. In t. Symp. on Geotechnical hard soils-soft rocks, Napoli, vol. 1, 403 - 411.
[43] O'dell, R. A. (1961). U. S. patentee nº US3092010A.
[44] PAGNO, R. S. (2009). EVALUATION OF THE ANTAGONISTIC POTENTIAL OF IsolateS OF Bacillus spp. IN THE CONTROL OF PHYTOPATHOGENIC FUNGI, CAUSING ROT IN THE POSTHARVEST PERIOD OF APPLE. CENTER OF AGRARIAN AND BIOLOGICAL SCIENCES BIOTECHNOLOGY INSTITUTE, 1-104.
[45] Reynolds, P. J. (s.f.). A GENERAL REPORT OF UNDERGROI.'ND GRAIN STORAGE EXPERIMENTS AT THE BUTSER ANCIENT FARM RESEARCH PROJECT.
[46] Roux, M. P. (2015). Harvesting, threshing, boasting, storage of cereals at protohistoric and ancient times in the Aegean world: History of techniques. Paris: University Paris I - Pantheon Sorbonne.
[47] S. Benni, D. T. (2013). Thermal performance assessment for energy-efficient design of farm wineries. Transactions of the ASABE, 1483-1491.
[48] Saikaew, S. T.-E. (2010). The Effect of Temperature and Storage Time on the Chemical and Physical Compositions Changes of KaenTaWan (Helianthus tuberosus L.) Tubers after Harvesting. Agricultural Sci. J., 249-252.
[49] Sharon, M. E., Abirami, C. K., & Alagusundaram, K. (2014). Grain storage administration in India. Postharvest Technology Magazine, 12-24.
[50] Shin, H.-S., & Park, E.-S. (2007). The Current Status of Underground Space Utilization in Korea. Underground Space: Expanding the Frontiers, 181-186.
[51] Silvia Angelone, T. G. (2006). Soil Permeability. Argentina: National University of Rosario.
[52] Szabó, J., Kajtár, L., Nyers, J., & Bokor, B. (2016). A new approach and results of wall and air temperature dynamic analysis in underground spaces. Energy, 106, 520-527.
[53] Tiernan, B. H. (1991). United States Patent nº 5,117,593.
[54] Tinti, F. (2012). The probabilistic characterization of the subsurface as a tool for optimizing the integrated design of geothermal systems. Bolonia: Universidad de Bolonia.
[55] TT Chow, H. L. (2011). Estimation of soil temperature profile in Hong Kong from climatic variables. Energy and Buildings, 3568 - 3575.
[56] U. S. DEPARTMENT OF AGRICULTURE. (1939). Home Storage of Vegetables and Fruits.
[57] Unver, B., & Agan, C. (2003). Application of heat transfer analysis for frozen food storage caverns. Tunnelling and Underground Space Technology, 7-17.
[58] Valéria, D. B. (1989). ASPECIFICITY OF GRAIN STORAGE IN VOJVODINA. Intermunicipal Monument Protection Institute, 24-39.
[59] Yang, T., Zhang, X., Zhou, B., & Zheng, M. (2013). Simulation and experimental validation of soil cool storage with seasonal natural energy. Energy and Buildings, 63, 98-107.
[60] Yenjai, P., Chaiear, N., Charerntanyarak, L., & Boonmme, M. (2012). Hazardous gases and oxygen depletion in a wet paddy pile: An experimental study in a simulating underground rice mill pit, Thailand. Industrial Health, 540-547.
[61] 刁小琴, 关. 海. (2013). China patent nº CN203087038U.
[62] 周 炼, 王. 日. (2010). China patent nº CN201649749U.
[63] 熊晓莉, 金. 崔. (2013). China patent nº CN203603558U.
[64] 王人庆. (2014). China patent nº CN204081577U.