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Full Length Research Paper

Engineering graphics applied to the study of old methods of olive oil production

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This original research paper undertakes a graphic engineering study of old pressing and milling systems which have been used in the production of olive oil over the last centuries, from a graphical and historical point of view, in the main areas of production, Mediterranean countries. The research is based on information found in historical documents, and has been completed by fieldwork carried out in Jaen, Cordoba and Malaga, which are the Spanish provinces with the highest olive oil production, and which are possibly the most important worldwide. The research consisted of finding the best-conserved examples of olive-producing equipment located in museums of culture and of olive oil. This work allowed the 3D modeling of these examples, which can lead to the desired scientific publication. Lastly, conclusions were obtained which show the reasons for the modifications in the design of this equipment in order to obtain a greater quantity of oil in the first pressing and therefore greater industrial performance of the operation.

Key words: olive oil, mills, presses, computer-aided design, industrial archaeology.

INTRODUCTION

Olive oil is a key element in the human diet, owing to its great benefit to health and its dietary worth. In 1988, there were in the world around 800 million olive trees, of which 750 million were located in countries around the Mediterranean, principally in Spain, Italy, Portugal, Turkey and Greece (Civantos López-Villalta et al., 1999). Within Spain, Jaén is the province with the highest production of olive oil, and is known as the 'world capital of olive oil'; it is the host to the biannual symposium EXPOLIVA (International Fair of Olive Oil and Allied Industries), which has been held since 1983 (http://www.expoliva.com/expoliva2011/default_en.aspx).

Olive oil mills and factories have used various different methods during their history in search of quantity, and later quality of their production, in the different stages of production from the arrival of the harvest at the mill to the sale of the oil. These stages of production are the control of the fruit upon its arrival, its cleaning, storage, and the extraction and storage of the oil.

The research presented here centered on the most technological aspect referring to the extraction of the oil, and specifically the older unconnected processes of milling and pressing of the olives; that is, first the olives were milled and then pressed. To this end, many references have been consulted which document the main examples of machinery and procedures used over time.

The objective of this study is to undertake a graphic engineering study of the models of mills and presses found over centuries in the principal olive oil producing countries of the Mediterranean, in order to document a heritage element which is in the process of disappearing. This is mainly due to the fact that these techniques have been superseded, and also to the poor state of conservation of these models and mills. Thus, all this equipment has been modeled in three dimensions, so that in the future their design parameters and operating codes can be obtained, as well as their possible study and optimization using computer-aided engineering.

In sum, this research has carried out the most complete graphic study of the common oil-producing equipment in

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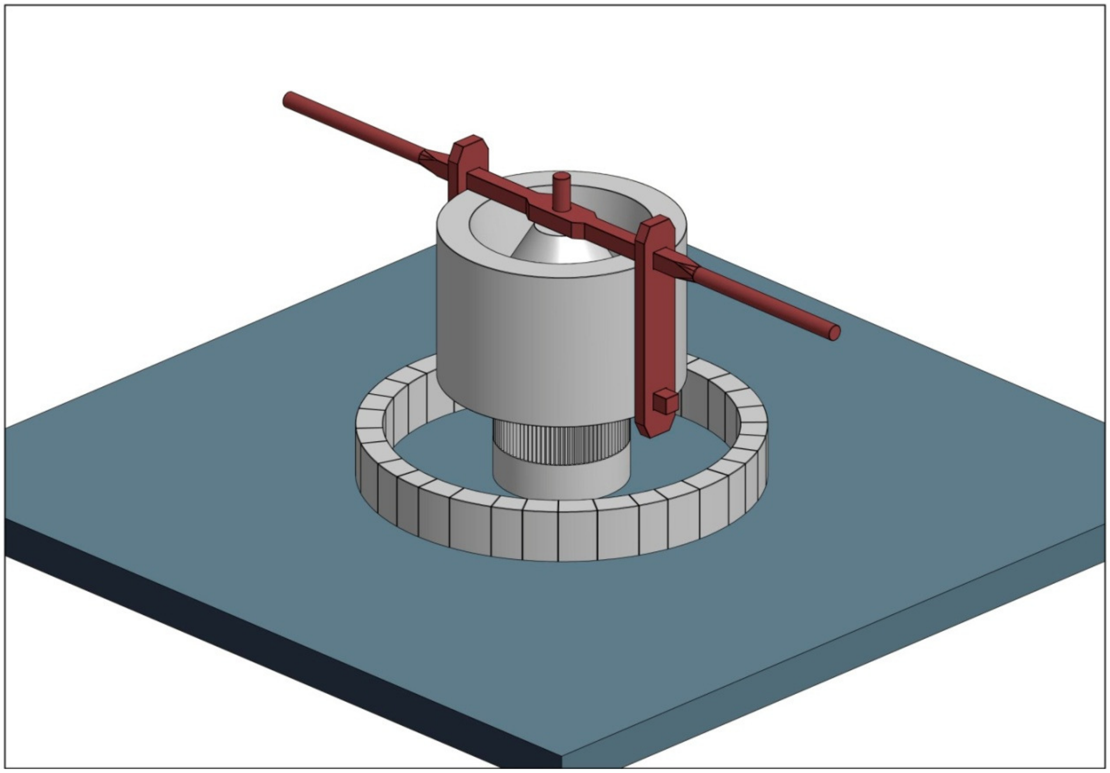

Figure 1. Galerie gouttière.

the countries of the Mediterranean basin over time, with the objective of making them known scientifically.

MATERIALS AND METHODS

In order to carry out the engineering graphics work, extensive bibliographic documentation has been used (Amouretti, 1992; Bulut, 2005; Drachmann, 1932; Frankel et al., 1994; Frezzotti et al., 1956; Gal and Frankel, 1993; Guillén, 1917; Manjarres, 1896; Milton, 2003; Noriega, 1903; Pequeño and Muñoz, 1879; Simari and Martinenghi, 1950; Soroa and Pineda, 1959; Stahl, 1977; White, 1975), which contain different graphic material, such as drawings, photographs or sketches. In many cases, the sources consulted are the only remaining information available for the modeling of the machinery, which has meant that proportionality rules have had to be used.

In addition, given the various museums and interpretation centres of olive oil culture in Andalusia, visits were made to the Museum of Olive Culture and Olive Oil in Puente del Obispo (Jaén), the Museum of the Hojiblanca Cooperative in Antequera (Málaga), and the Olive oil mill Núñez de Prado in Baena (Córdoba), which are the principal museums in Spain, and which are in a good state of conservation.

These visits permitted the completion of the fieldwork by photographs, sketches and videos, which have allowed perfect modeling of these mills and presses, and therefore a 3D model which is faithful reproduction of reality. This model can then be used to obtain a computer animation and can be studied from an engineering perspective.

The software used in the three-dimensional modeling of the mills and presses is Autodesk Inventor Professional 11™, which gives a 3D model which can be exported to other computer animation software such as Autodesk 3DSMax 2011™, in order to obtain a virtual recreation and at the same time to study the model using computer-aided engineering modules to discover the operation of the machinery in different task. This objective, by extension, will be the subject of a forthcoming study with an appropriate methodology (Montes et al., 1998; Rojas, 1997, 2005).

RESULTS

The existence of the principal machinery found is reflected in a magnificent historical book (Arambarri, 1992), which has served as the thread of this research, which has been completed by the other texts previously mentioned. This book shows that within milling systems, the first to appear was a friction mill known as Galerie Gouttière, which dates from the 3rd century B.C. (Figure 1). It consists of two stones which fit together, one fixed conical grooved stone with a cylindrical base and a central vertical shaft attached to the point, and the other in the form of a ring with a triangular section. This stone was fitted into a wooden framework formed by two vertical supports joined by a horizontal stone which in turn is crossed by the vertical shaft, so it turns around the bedstone; the milling of the olives is produced by friction. The olives were poured between the turning stone and the bedstone, starting the movement and the producing the friction.

Subsequently, another friction mill was produced in Greece. It is known as *Trapetum* and dates from the 2nd

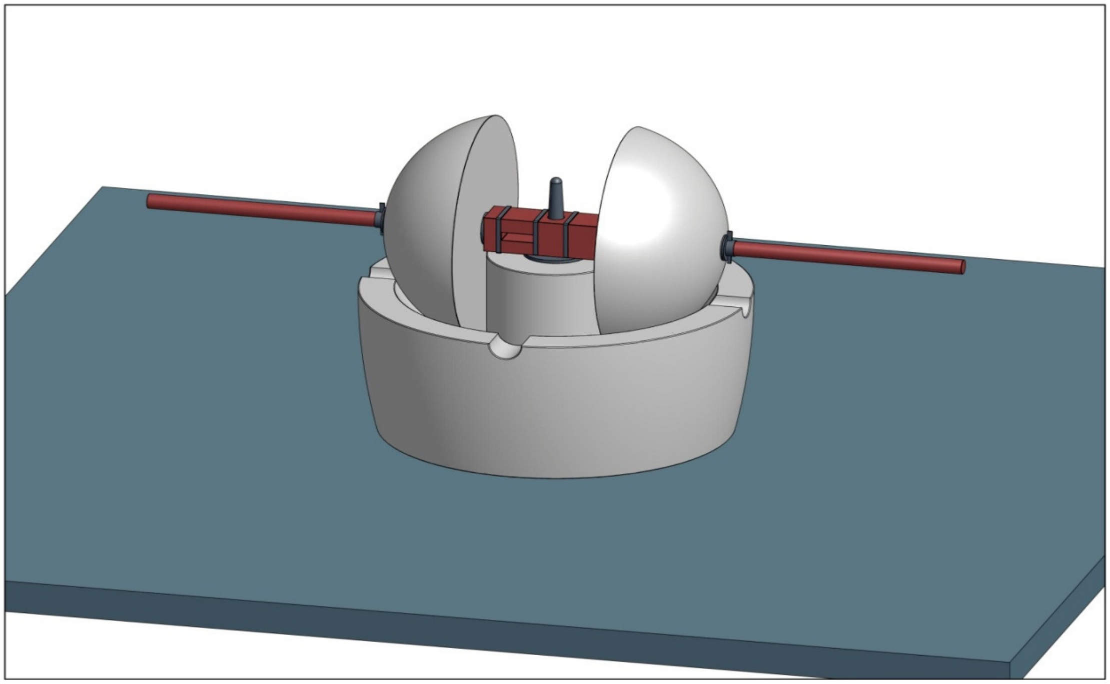

Figure 2. Trapetum.

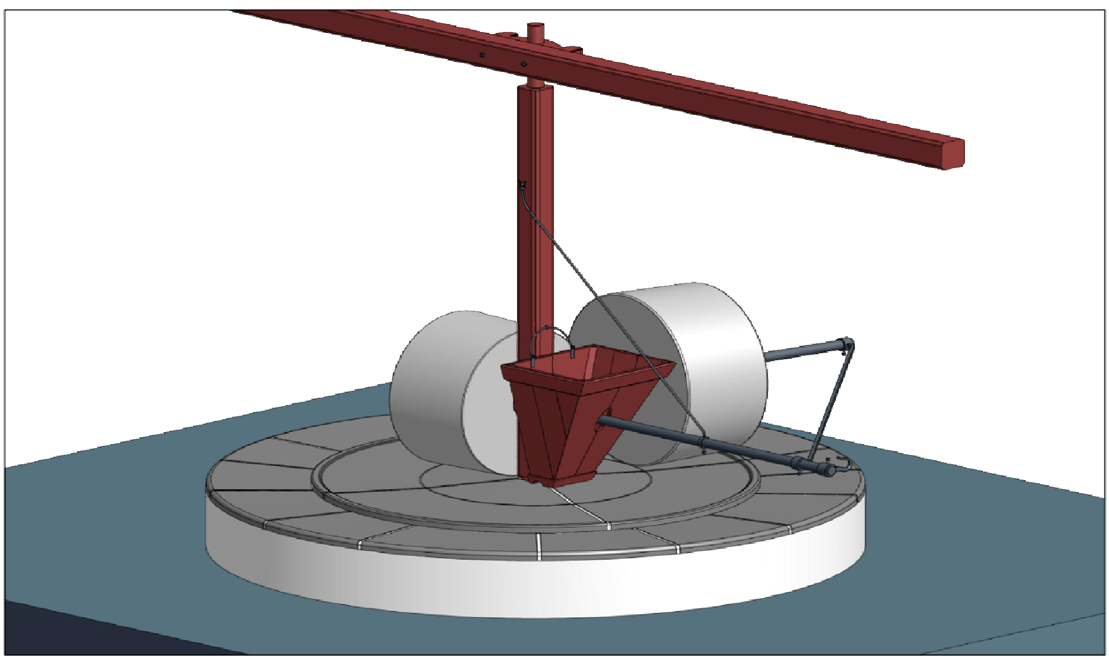

Figure 3. Mill with vertical cylindrical stones and hopper.

century B.C. (Figure 2). Its operation consisted in the movement of two mill stones (*orbes*) of volcanic rock, which turned around a mortar (*mortarium*), and which could be hung with a bigger or smaller suspension using a device.

The two mill stones were crossed by a lever and were moved by men from each end, allowing both translational and rotational movement. The olives were placed in the *mortarium*, and could be crushed to a greater or lesser degree depending on the separation of the milling stones.

Later the appearance of breaker mills was seen with vertical cylindrical stones (Figure 3) which were operated through the movement of two or more stones on a

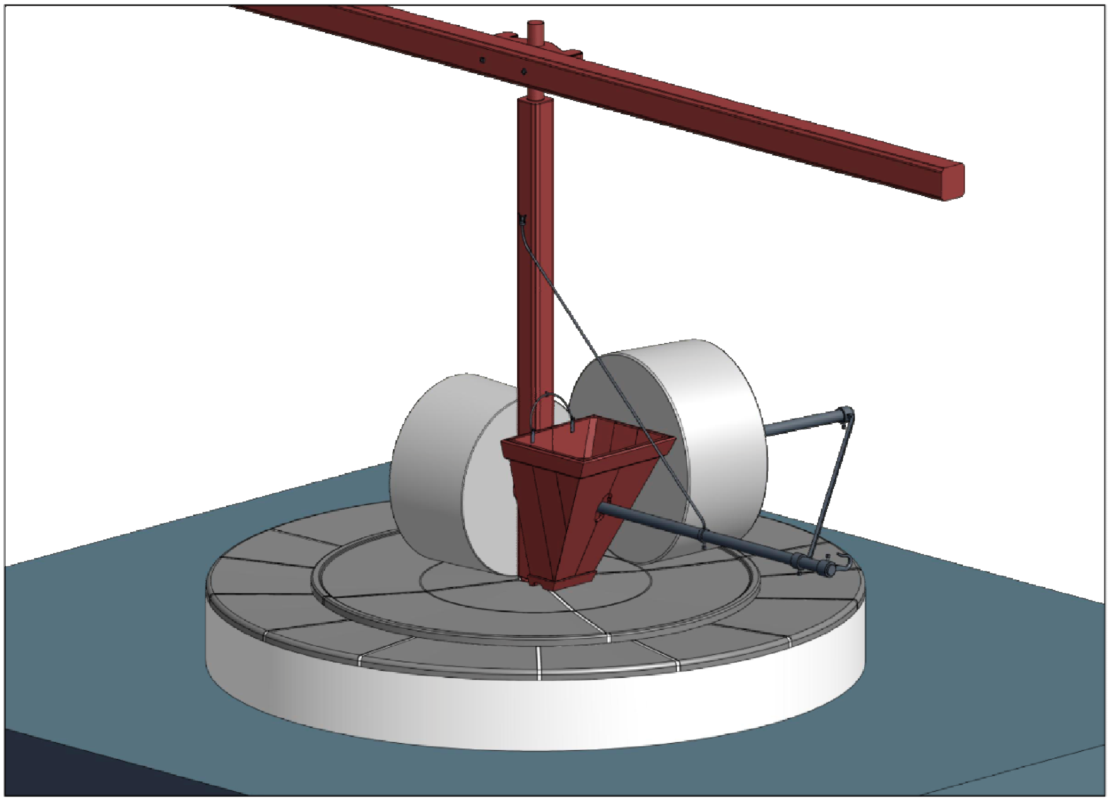

Figure 3. Mill with vertical cylindrical stones and hopper.

bedstone where the olives were milled, and the crushing surface depended on the thickness of the stones. This type of mill dates from the 1st century B.C. and has a circular basalt bedstone which is slightly sloped towards the centre and which is smooth or with radial grooves. These mills were sometimes accompanied by hoppers which fed the olives to the bedstone.

A later modification of these mills occurred with the modification of the stones from cylindrical to conical or truncated cone shaped, leading to the breaking mills with these forms of stones (Figure 4). These mills used up to four joined conical stones, and more modern version replaced stones with forged metal cones. The cone shape allowed for a larger milling surface and reduced resistance, which was considerable in vertical cylindrical mills. When a cone turns on a plane, the development of the cone's surface coincides with that of the circle, and there is therefore no slipping, and the resistance to the turn is determined by the friction between the rolling stone and the bedstone and its weight. This is why this type of mill has been the most widely used in olive oil production until the middle of the 20th century.

Among the more primitive procedures was the Greco-Roman press or wedge press (Figure 5), in which the olives were placed inside a sack situated in the lower part of the structure. The truncated pyramid shaped wedges were beaten, which in turn drove the boards that put pressure on the sack of olives. However, the industrial performance of the operation was negligible.

In order to optimize performance, the first known direct action press was design, the chapel or corner press (Figure 6). This was so called because they were used domestically and were commonly placed in the corner of the room. They worked by means of a manually operated wooden screw which made a wooden plate put pressure on the load of disks (filtration disks where the milled olives were placed, and piled one on top of the other), thus providing greater pressure than a wedge mill.

The lever and wheel press, the winch press, and the beam and hundredweight press are the three main examples of the second type of lever presses in which the resistance to be pressed (the filtration disks) is located between the point where the force is applied and the supporting point. This was a significant advance on previous presses such as the corner press or the wedge press, as there was a considerable manpower energy saving owing to the change in the physical operating principle. In the case of the lever and wheel press, also known as the 'Roman torcular' (Figure 7), which dates from the 2nd century A.D., it was operated via a winch that lowered the main lever using a pulley system to put pressure on the filtration disks.

In the case of the winch press (Figure 8), which dates from the 1st century A.D., the counterweight stone was

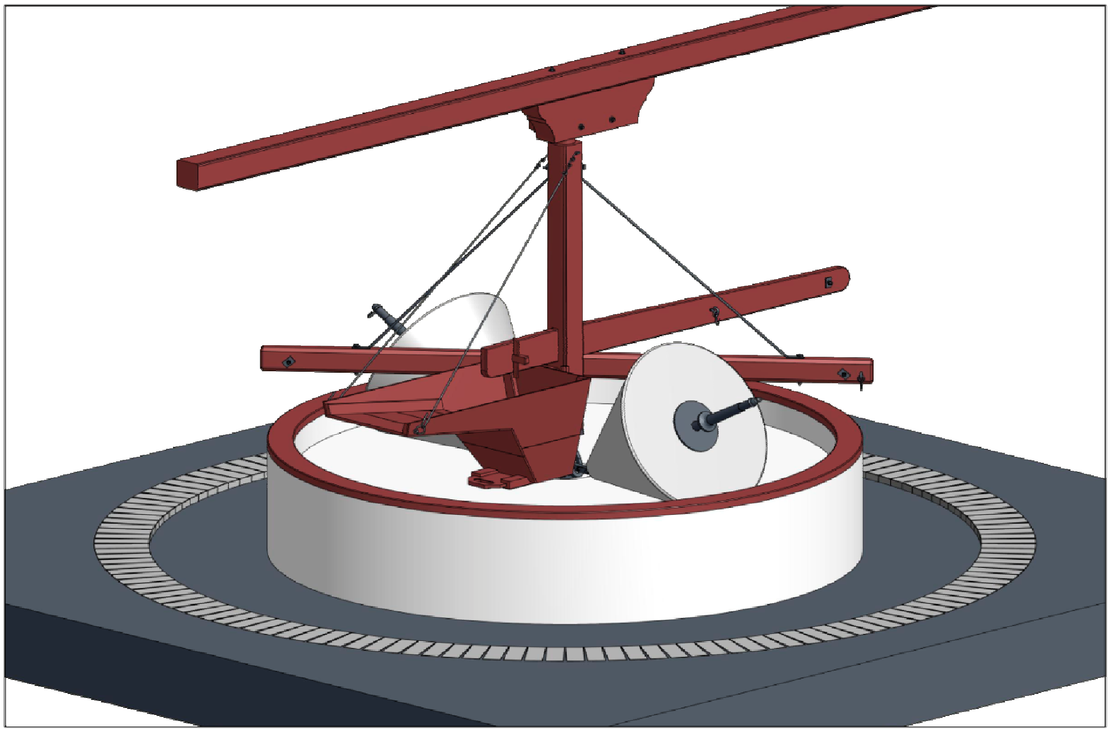

Figure 4. Truncated cone mill with hopper.

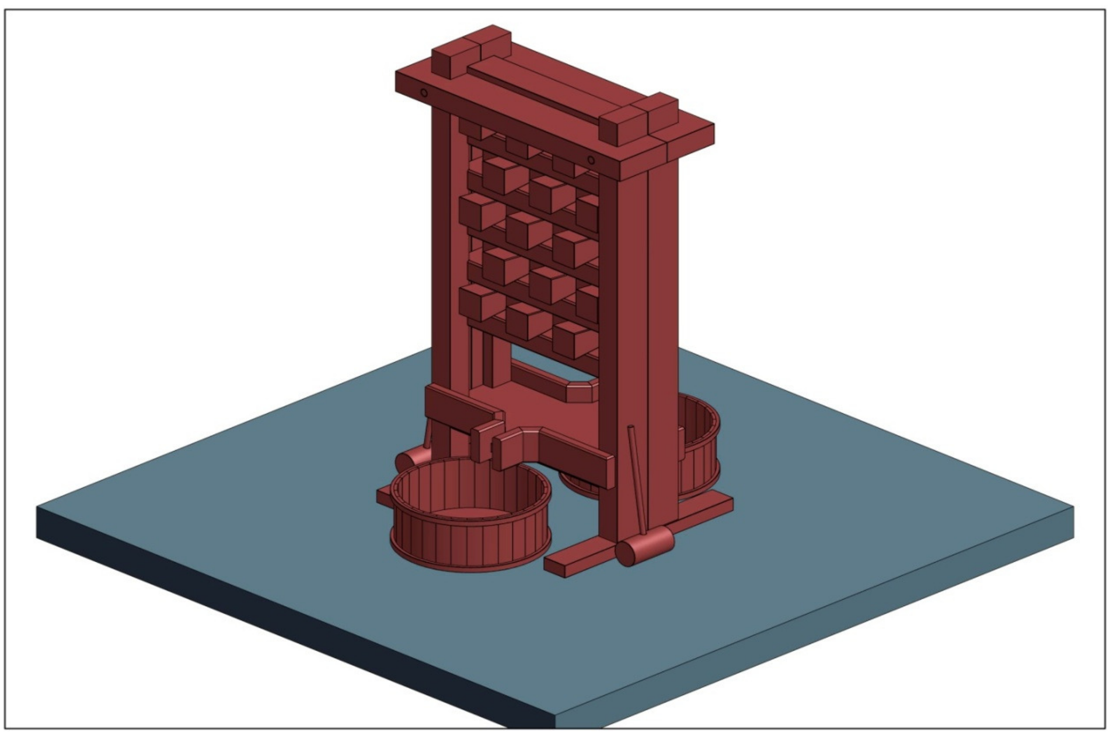

Figure 5. Greco-Roman or wedge press.

joined to the beam using ropes. There was a considerable difference in the floor level of the counterweight and the support of the main beam, in order to press the filtration disks the greatest extent possible.

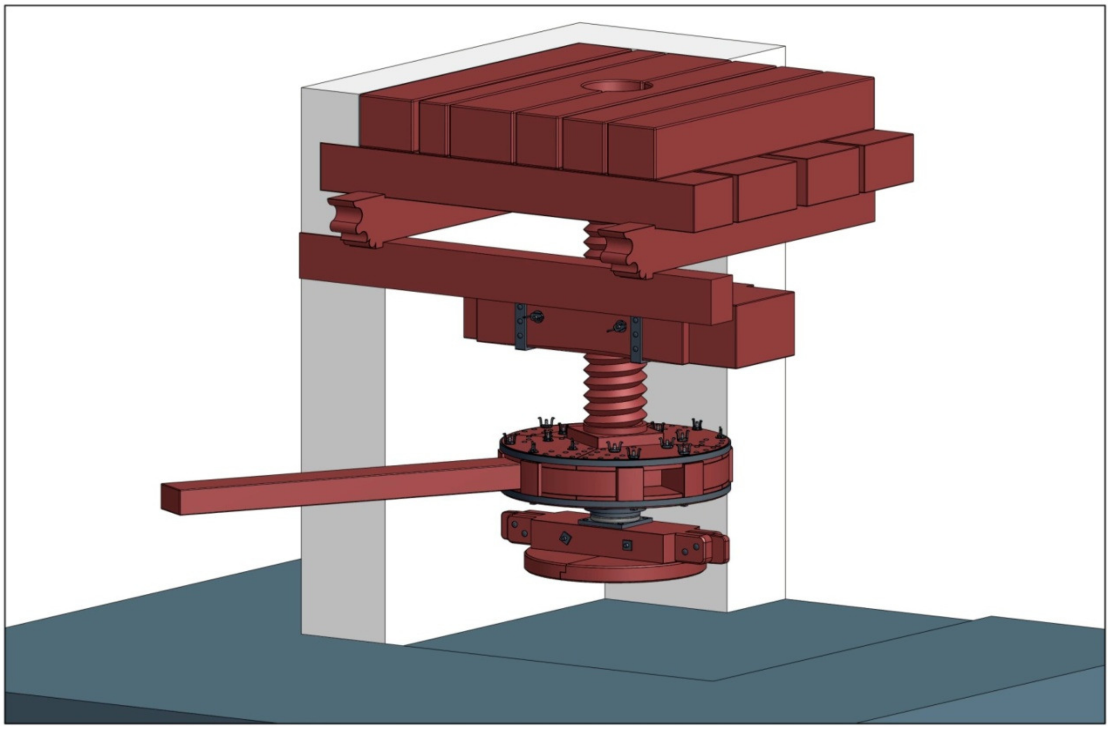

Figure 6. Chapel or corner press.

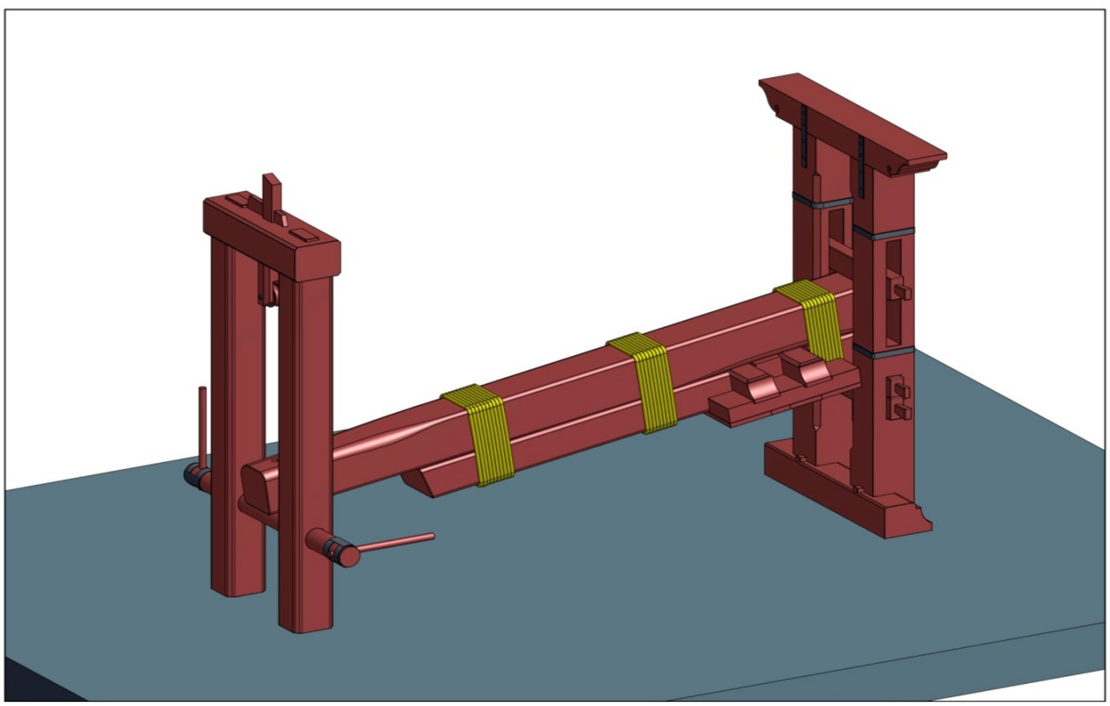

Figure 7. Lever and wheel press.

The beam and hundredweight press (Figure 9) considerably increased the length of its beam and played with the lever arms, the distances between the application point of the force and the support point, so that the pressure exerted was as high as possible. This press did not have a winch which operated the beam via a rope, but

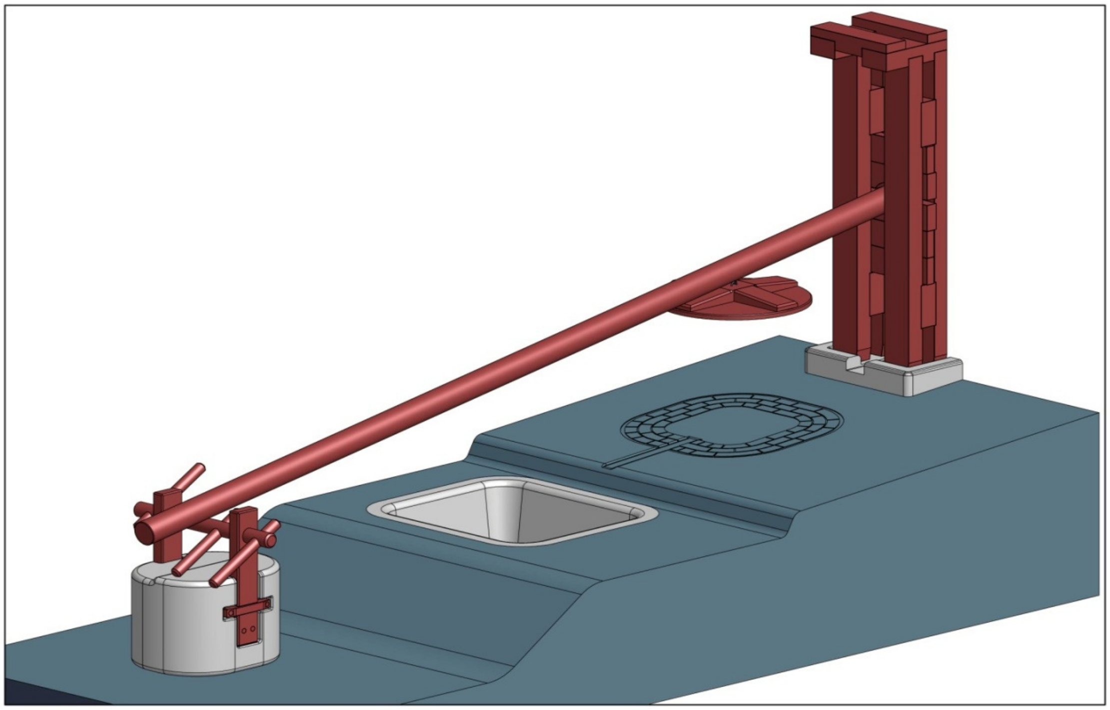

Figure 8. Winch press.

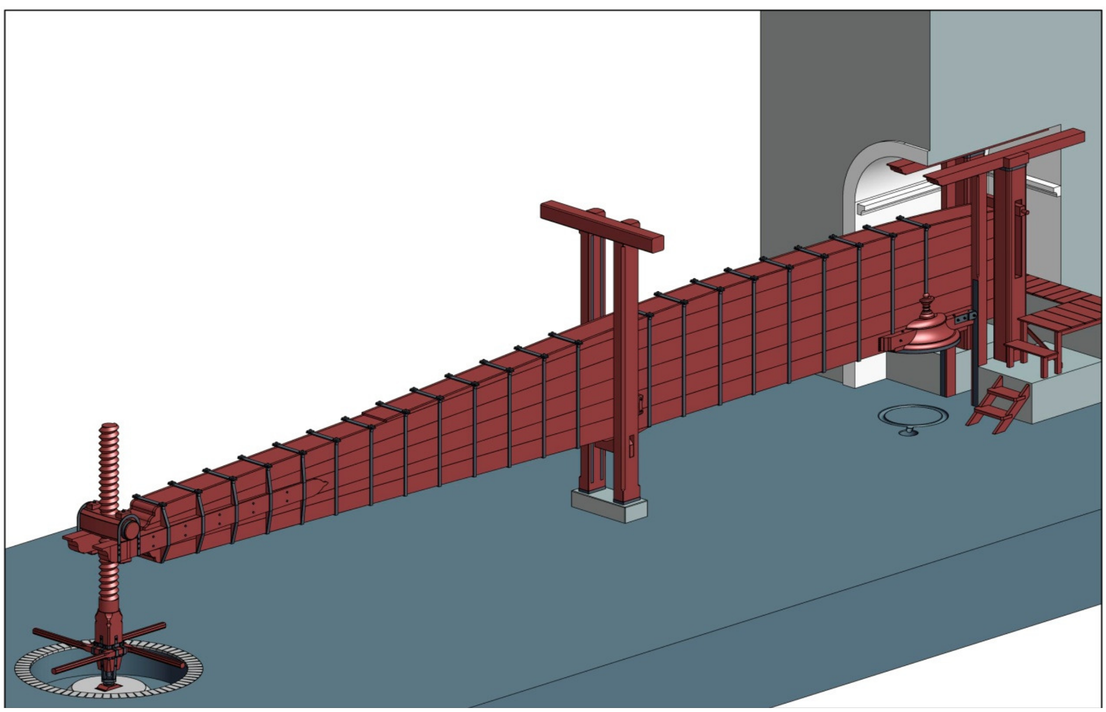

Figure 9. Beam and hundredweight press.

rather a wooden screw in the beam itself which permitted its movement. At first, the heavy counterweight stone was fixed to the floor (*beam and screw press*, 1st century B.C.); this meant that only the weight of the beam was applied to the filtration disks. Subsequently, the counterweight was freed, and as the screw was turned it rose from floor level;

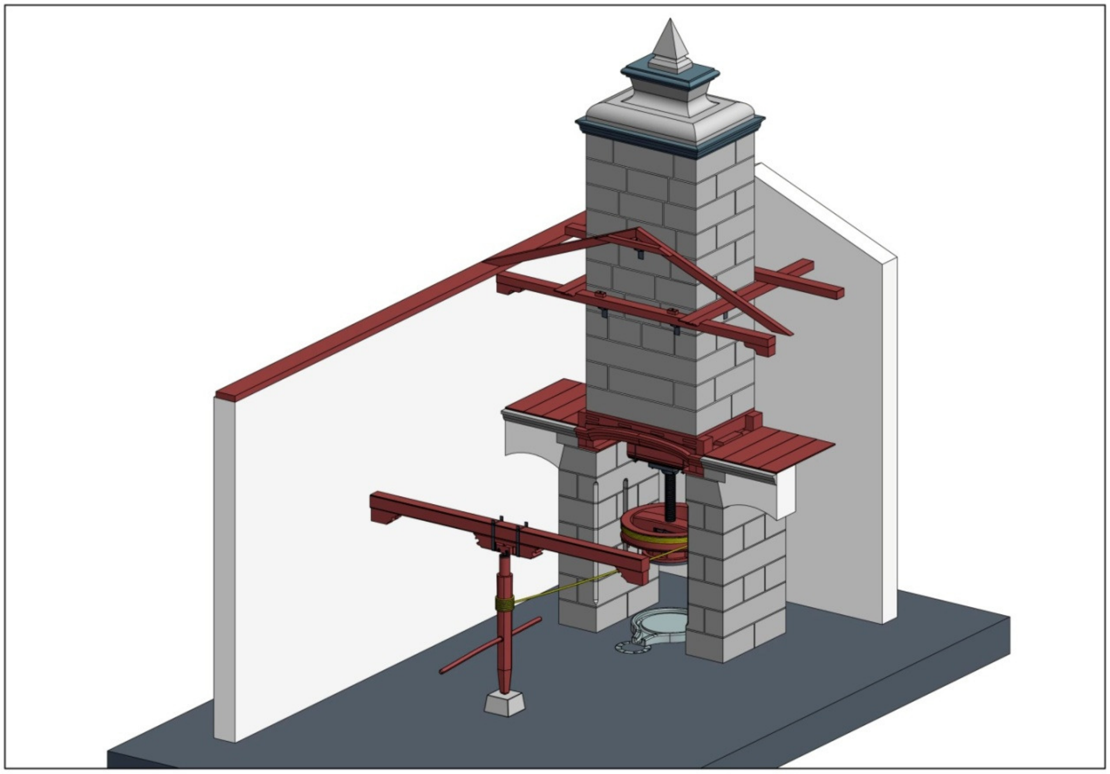

Figure 10. Tower press.

this meant that its weight was added to that of the beam, applying greater pressure and thereby obtaining a greater quantity of olive oil.

The tower press from the beginning of the 20th century (Figure 10) signified a change in operation, moving away from the lever principle to that of direct pressure; that is, dropping on to the filtration disks a mass of stone of various tens of tons, while taking care that the downward trajectory of this weight was as straight as possible. This meant that the weight was applied to the centre of the filtration disk, thereby exerting greater pressure, as the higher the mass, the greater the force and in turn the greater the pressure exerted. This modification was interesting from an engineering point of view, as friction was minimized, and new elements were introduced, such as bearings.

Hydraulic presses (Figure 11) entailed in the mid 20th century a substantial qualitative and quantitative improvement in obtaining a large amount of high quality olive oil, given the enormous pressure they exerted on the filtration disks. These presses were based on Pascal's principle and imagined by Joseph Bramah on 1796, and achieved very high pressure on the filtration disks with a system of pumps (on the left in the figure) which provided pressures of hundreds of atmospheres. The lower plate, on which the filtration disks were placed, was mobile and rose to press against the fixed upper plate. In addition, timing could be optimized, since as one load was pressed, another could be prepared, which was then moved into place on rails.

Worthy of special mention is the appearance in Spain in the first half of the 20th century of the first known semi-continuous system (Figure 12), which had a winch and linked by a chain the movement of the mill with the winch, and in turn with the press. Its principal objective was to reduce the time of the process and thereby increase the daily oil production.

DISCUSSION

This work has shown how the evolution in the design of new milling systems has always attempted to achieve a larger contact surface between the bedstone and the mill stone, in order to be able to mill a larger quantity of olives; for this reason, the number of mill stone and their size has increased. For example, the cylindrical mill stone of the Galerie Gouttière evolved into the Trapetum, with two millstones of semispherical geometry and two rotation axes, both man-operated. Later, mills were powered by animals, which led to the design of cylindrical and truncated cone mill stones which were bigger than their predecessors, with the incorporation of hoppers which regulated the supply of olives to the bedstone. The objective was to increase the quantity of olives pressed and therefore produce a greater amount of olive oil from the first pressing, which produced the highest quality oil.

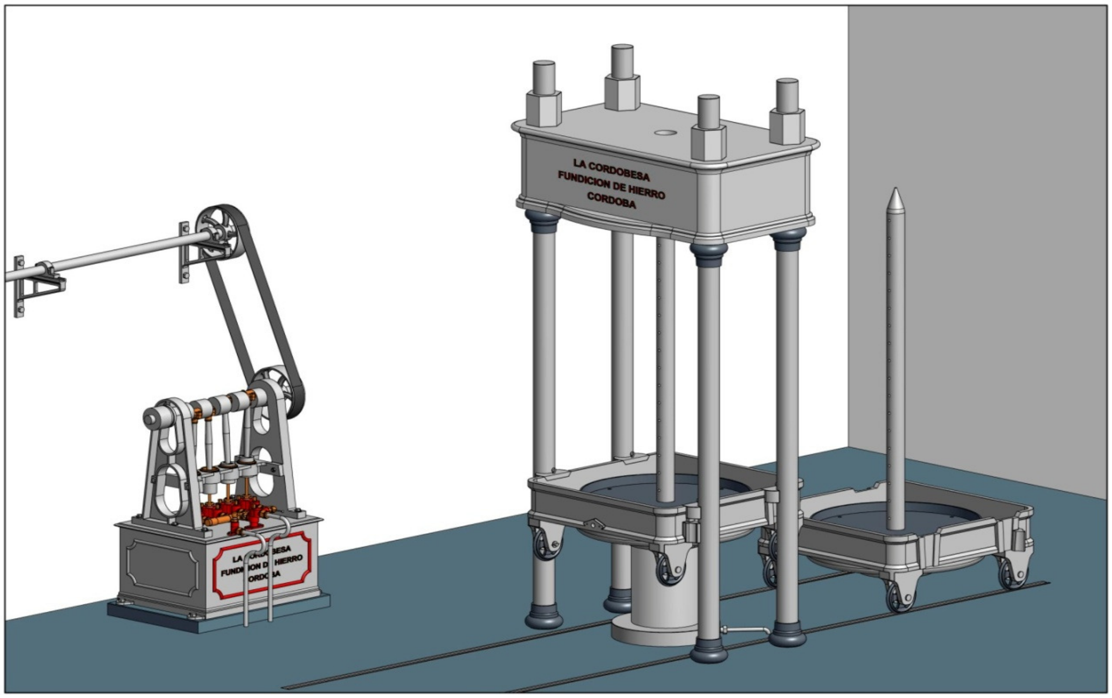

Figure 11. Hydraulic press.

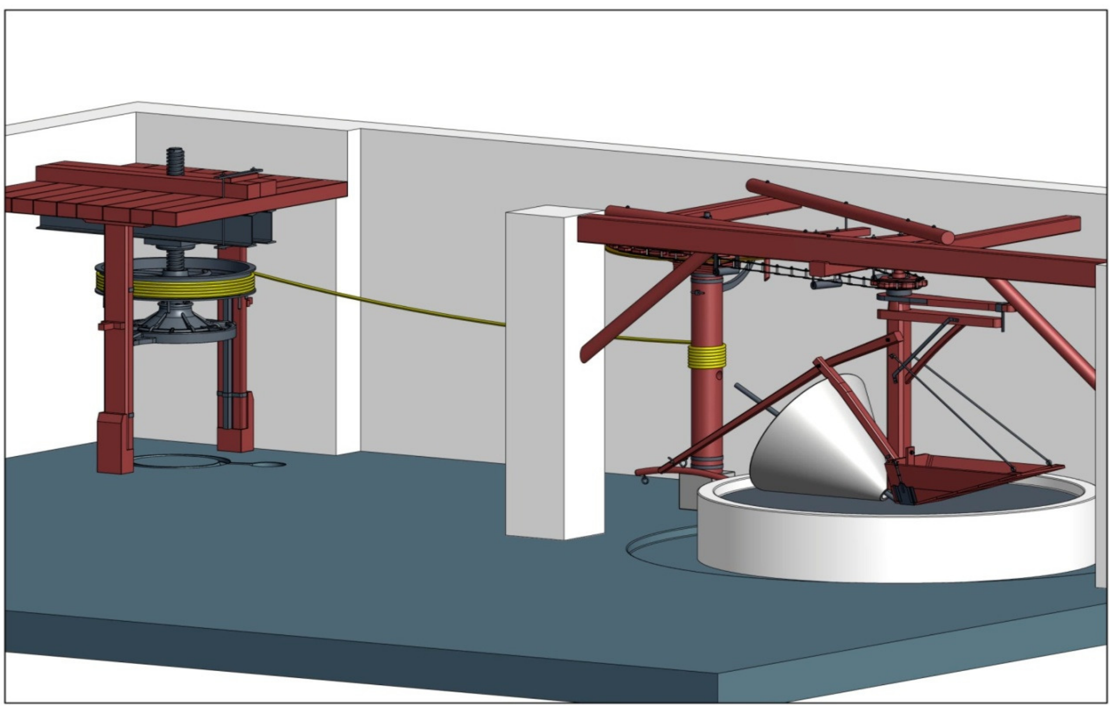

Figure 12. Semi-continuous milling and pressing system.

In terms of the pressing process, in the same way as for mills, the evolution in its design was brought about by geometric considerations and physical operating principles. For example, the evolution from the Greco-Roman press to the chapel press was based on the modification of the contact surface, moving from a surface which did not exert uniform pressure on a sack of olives to a wooden plate which did exert a uniform pressure on the filtration disks. Subsequent presses were based on a lever principle, in which the resistance (the filtration disks) was placed between the point of application of force and the support point; this was a more effective method than direct pressure. Examples of this are the lever and wheel press of Roman times; the winch press from the 1st century A.D., and subsequently the beam and hundred weight press. However, although direct pressure was less effective than lever pressure, the more modern tower press has been widely used for much time, owing to the enormous stone mass which dropped on the filtration disks, and to other improvements introduced such as bearings and guides to reduce friction and to ensure that pressure is distributed evenly.

Lastly, it is worth noting that of all the old pressing methods, hydraulic presses stand out because of the huge pressure exerted on the filtration disks, based on Pascal's principle.

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