Architecture for Fermentation and vice versa

arquitectura
fermentación
bioclimática
enfriamiento pasivo
cambio climático

architecture
fermentation
bioclimatic
passive cooling
climate change

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Una revisión de las estrategias de enfriamiento pasivo que pueden compartir para combatir el aumento de temperaturas a causa del cambio climático usando las casas matanceras del cerdo Ibérico como modelo hipotético donde ambas disciplinas convergen.

El cambio climático y el consiguiente aumento de las temperaturas son evidentes, y se necesitan soluciones que respeten el medio ambiente, la sociedad y la economía. La población humana se ha elevado hasta un punto en el que esas soluciones fueron diseñadas para colocar al ser humano en primera posición. Una demostración de este hecho se encuentra en los diseños de nuestras propias viviendas, que han sido mejoradas por donaciones de conocimientos procedentes de muchas otras disciplinas, entre ellas, la arquitectura. Varias técnicas de enfriamiento pasiva provienen de esta disciplina y podrían ayudar a enriquecer el portfolio de algunas otras que se verán afectadas por el mismo problema de aumento de temperaturas. La fermentación es una técnica ancestral que ha evolucionado hasta nuestros días y supone aproximadamente 1/3 de nuestra diversidad culinaria. La fermentación, al igual que la arquitectura, se basa en el diseño de entornos semi-aislados que facilitan cierto tipo de vida: microscópica, macroscópica o ambas. Asumiendo que el aumento de las temperaturas afecta a la estabilidad de la vida, tanto la arquitectura como la fermentación se ven comprometidos por dicho fenómeno y el cruce de técnicas de enfriamiento pasivo de forma multi, inter e incluso transdisciplinar puede ofrecer nuevas soluciones para ambas y muchas otras disciplinas. Para ello esta revisión propone como modelo hipotético de experimentación a las casas matanceras productoras de jamón ibérico, un espacio concebido para albergar tanto la vida humana como la microbiana y que por lo tanto también se verá afectada por el aumento de temperaturas. Se proponen por tanto futuros estudios que pongan a prueba las hipótesis planteadas en esta revisión.

A review of the passive-cooling strategies they may share to combat the rising temperatures due to climate change using Iberian pork slaughterhouse as a hypothetical model where both disciplines converge.

Climate change and consequent rising temperatures are evident, and solutions that respect the environment, society and economy are needed. The human population has increased to a point in which these solutions have been designed to put humans first. A demonstration of this fact lies in our own house designs, which have been improved by knowledge from many disciplines, including architecture. Several passive-cooling techniques have come from this discipline and might help others that will be affected by the rise in temperatures. Fermentation is an ancient technique that has evolved and now accounts for approximately 1/3 of our culinary diversity. Fermentation, like architecture, relies on the design of semi-isolated environments that facilitate a certain kind of life form: microscopic, macroscopic or both. Assuming that the rising temperatures affect the stability of life forms, the same rising-temperature challenge is shared by both architecture and fermentation; the cross-contamination of passive cooling techniques in a multi, inter and even transdisciplinary way, might create new solutions for both of these and many other disciplines. To this end, this review proposes a hypothetical experimental model, the Iberian pork slaughterhouse, a space that hosts both human and microbial life, and which will therefore also be affected by the increase in temperature. Future studies are therefore proposed to test the hypotheses put forward in this review.

In the transition from the 20th to the 21st century, global climate change has become more evident. During this transition humans have not only accelerated that change, but also become more aware of the resulting impact (Viola, 2020) at all levels, not only environmental but also social and economic. Improvements in communication and technology have increased the dissemination of knowledge, and the number of disciplines has increased, which have tended towards specialization, and investigating elementary particles trying to explain even "nothingness" (Genz, 2009). However, this very verticalization of knowledge has led to the loss of an overview of what surrounds us. Disciplinary specialization has been a consequence of the increase in quality and quantity of knowledge and, viewed in this light, one cannot say that it is a disadvantage. However, such specialization has created significant barriers that restrict permeability and blurring between disciplines (Hansson, 2008; Bechtel, 2013; Mestre and others, 2022). Disciplinary rigidity and lack of symbiosis in knowledge (not mutualism) are evident, not only at an academic level, but also at a professional level (Mestre and others, 2022). The separation between departments in buildings is a physical barrier that encourages the adaptation and isolated evolution of knowledge, just as living beings became bio-diversified with the separation of the continent Pangea (Blockstein, 1992).

Space can contain things and in order to contain, physical barriers must be erected, totally or partially isolating that space. This statement could be applied to a variety of disciplines, but architecture is certainly one in which humans have spent time figuring out how to get a perfect "isolated" —i.e. comfortable— space. Comfort is important, especially when it is related to our own species. However, there are still disciplines that rule life conditions through the management of space and its physical barriers. Microbiology is one of these; the management of micro-life depends directly on knowledge of space-control. This last discipline and the knowledge of space becomes even more interesting when humans are added to the equation, in what is known as the practice of fermentation. Within the variety of forms adopted by gastronomic science, fermentation is a technique that has evolved through history, absorbing the knowledge of human experiences. This fact is crucial; it was executed as an act of faith in its origins, when the lack of knowledge in microbiology and the biochemical processes were evident, although not limiting. Fermentations applied to gastronomy have gone from being a science to do science, culture, and economy. To do so, it has required knowledge, methods, techniques, and instrumentation from other disciplines (Battcock, 1998). This review aims to reflect on the interaction of disciplines that are apparently unrelated to each other, using Iberian pork slaughterhouses as a hypothetical model of the integration of passive cooling strategies. It is proposed that the contamination of fermentative techniques and spaces through architecture - and vice versa – are a form of biomimicry that generate results more adapted to the environment, economy and social functioning, in relation to the challenge of climate change and higher temperatures.

1.1. WHAT IS FERMENTING AND WHAT DOES IT MEAN FOR HUMANS?

Defined by biochemistry as a catabolic process of incomplete oxidation that does not require oxygen and whose product is an organic product obtained through the action of a ferment (Battcock, 1998). Fermentation in relation to our species goes further, as Francesc Xavier Medina affirms (Director of the UNESCO Cathedra in Food, Culture and Development; n.p.), One third of what we eat has been fermented at some point of its production. The action of micro-organisms is not and has not always been so evident in the products we consume, yet it still endures as a technique, culture, science, economy and trans-species society in today's world (Katz, 2020). The value that this transformation technique brings to the raw materials we consume is the reason why this technique has been with us for more than 7000 years (Babylon, now Iraq; Battcock, 1998) During all this time, and until the appearance of the microscope in 1590 (Ball, 1966; Lera, García, 2015), we were unaware of the micro-world around us, nor of the powerful transformation capacity that we were about to discover. This occurred from an act of faith in a transformation method used consciously in the biofuel, pharmaceutical and, of course, agri-food and catering industries (Grismer, Shepherd, 1998; Pretorius and others, 2003; Todaro, Vogel, 2014). In short, and in this context, fermentation can be redefined as the management of micro-organisms by humans in order to direct the metabolism of the former towards a specific transformation of the original substrates, obtaining as a final product this substrate in simpler parts and with added value at the organoleptic level (flavors, aromas, textures...), health (better assimilation, probiotics), environmental (sustainable), economic (with medium/high value in society in most cases, long conservation, production of materials and methods) and social (with strong roots in cultures, food identity).

The use of fire itself was considered the first technology and with the passage of time humans managed to "standardize" and replicate it. Its ability to transform due to the transmission of heat was understood, and consequently, it dozens of ways to recreate and use it were invented; wood stoves, gas, electricity, microwaves, pyrolytic ovens, steam, convection, glass-ceramic, induction etc. (Clark, Harris, 1985; Gowlett, 2016; James and others, 2019). Nothing less has been done with fermentation; it was learned how to replicate those conditions in which the results were approximately the same, and with the advance in knowledge, even standardization was reached. The instrumentation and methodology used today for fermentation in the food industry have come to create their own market niche at the domestic level. From small to large scale, it is possible to acquire DIY production packs of the most popular fermented products: kimchi, sauerkraut, pickles, kombucha, vinegar, kefir, beer, bread and even wine, molds and cheeses...

Fermentation, as with fire, has also added value beyond the kitchen, in the pharmaceutical industry or in the production of biofuels. (Grismer, Shepherd, 1998; Pretorius and others, 2003; Todaro, Vogel, 2014). In these technologies, the tools used nowadays remain a hybrid between advanced technology and artisanal practices, that is to say, even if wireless, phone-controlled, steam, wide-range temperature ovens have been invented, traditional wood ovens remain functional and useful within human culture.

1.2. THE FUTURE OF FERMENTATIONS IN A WARMER WORLD

Fermentation is a tool for change, one more variable in the complex equation that aims to both buffer and adapt to climate change. Using the knowledge that fermentation represents one third of culinary diversity, the evolution of this technique and its adaptability to new conditions might ensure a solution for an important variable of the equation. From all of the consequences of climate change, rising temperature has been chosen in this review as the common challenge for both architecture and fermentation (Parra Marcos, 2020; Martin Miguelez, 2021). Both humans and micro-organisms (Ayaviri Nina, Vallejos Mamani, 2014; Cruz, 2016) will experience its consequences, humans in any case are made of the second ones, which leads to a series of hypotheses that must be answered: Will humans' home be adapted to the future rising temperature? And how is it intended to do this for micro-organisms' "home"? Do these questions lead to the creation of a new discipline, architecture of fermentations perhaps, the incubator of our probiotics?

Throughout history, fermentation has colonised most of the planet, from warmer to colder regions, and the versatility and diversity of materials and methods that humans have developed for this purpose, matches fermentation itself. Fermentation has a lot to learn from itself, by only cross contaminating different cultures traditions and innovations. Nevertheless, these learning processes still could be enriched by a cooperative effort with disciplines such as architecture. Fermentation, by definition is linked to humans with the benefits it brings, and this technology shows it to be a promising self-production, conservation and flavor developer in the present and close future. Therefore, fermentation is becoming and will continue becoming a part of human's living architecture and probably each discipline will evolve within their own academic field. Instead, this paper reflects on how both disciplines might work symbiotically, at first by simply mixing temperature buffering techniques (passive cooling technology) from each one before proposing hypothetical case studies in which further interactions will be exposed.

1.3. ARCHITECTURE AND CLIMATE CHANGE

Both architecture and fermentation share the same challenge and architecture has been studying bioclimatic strategies that might fit "fermentation architecture" for some time. It is obvious that there is an issue of scale to be solved if we talk about the house of micro-organisms at the level of amphorae, jars, chambers, tanks, etc. But if we talk about cellars, attics, caves, drying sheds or industrial processing halls, that scale is not simply a question to be explored, but rather a copy-cut from one discipline to another.

However, this reflection wants to avoid the unidirectional copy-cuts between disciplines to make rather the bidirectionality of knowledge-transfer, a vehicle that potentially generates a third knowledge not intrinsic to each of the disciplines separately; that is to say, it is not only the fermentations that learn from architecture, but vice versa. Different studies and experiments were reviewed, from the scientific literature and other forms, such as those from ancestral innovations that became tradition to reinvented tradition that turns back into innovation and opens new future horizons.

2. ARCHITECTURE AND FERMENTATION

Architecture and Fermentation, from the technical point of view, seem to be disconnected and to have nothing in common. Despite this, human architecture and fermentation both share same goal. Both disciplines aim to host living beings and/or biological processes within the spaces they create. These spaces are intended to establish specific “indoor” conditions that benefits the living beings they contain (Fig. 1).

Benefitting a specific kind of life also means partially or selectively isolate those spaces from the “outdoor”, that is to say, both keeping a specific range of “indoor” temperature, humidity, aeration, light exposure, as well as avoiding “undesirable kinds” of life apart from the “indoor” spaces. In the case of human architecture: insects, pathogens, rats, allergen, etc.; in the case of fermentation: pathogens, dust, spores, etc.

To summarize what has been said, fermentation and human architecture shares the same aims and enemies, therefore, both disciplines must evolve, dream and fight back enemies in cooperation.

Let’s consider a wall and an amphora as two representative elements of the “skin” of our two disciplines to be studied, two elements that in both cases perform the function of partial isolation, the container that host a content.

Whether for fermentations or in our own homes, the goal is to protect a 3D space from the rest of the environment, not only from its conditions and meteorological effects, but also to create a specific environment that favors the development of life, that of micro-organisms or humans, whether to standardize the production of a wine or improve the comfort of our homes.

Surely there are areas in the globe where the rising temperature must be regulated in such a way that its final value coincides with the optimal temperature for the standardization of a wine, for example, and the perceived comfort in a home and yet, probably, the strategies used, and the energy resources are different for the same objective.

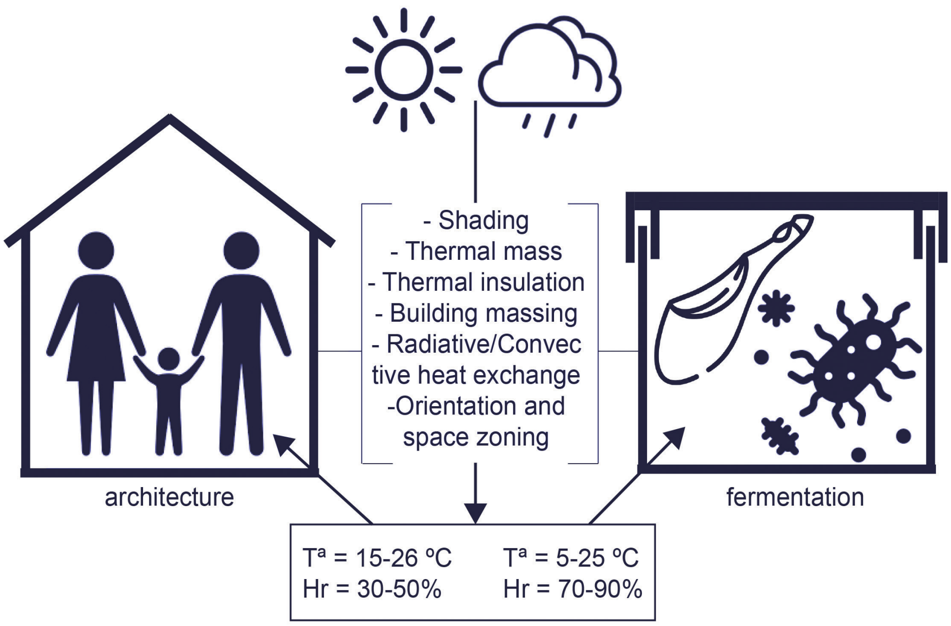

Fig. 1 – Common passive cooling strategies between architecture and fermentation to reach specific “indoor. conditions(n.p.).

3. ARCHITECTURE AND TRADITIONAL FERMENTATION METHODS

The past is and always will be a source of inspiration and learning, especially in those times and cultures in which necessity made from creativity a versatile problem-solver, adapted to the surrounding environment and resources. Architecture and the world of fermentation embrace this fact to such an extent that, if we want to look to the future, we must look at the sustainability of these disciplines in the past, learn from them, reconsider the knowledge of the present, and try to predict a hybrid application that adapts to different future scenarios. Bioclimatology has served and continues to serve as a link between both disciplines. Defined as an interdisciplinary scientific field that studies the interactions between the biosphere and the Earth’s atmosphere, on a time scale of seasons or longer, it is the ecological science that studies the reciprocity between climate and the distribution of living beings on Earth (Bugenings, 2022). Even if this field has been already well studied, the potential it hides and how it can help architecture and fermentations is key to how we might adapt to the coming rising temperatures by using the lowest amount of energy.

There are many examples in which architecture has been crucial to the production of some of humans’ most popular ferments worldwide. The wine cellars or the old Iberian ham slaughterhouses represent structures designed specifically for the transformation processes they host, in particular to create humidity and temperature conditions under a certain control. Two examples in which the definition of amphora or wall becomes one: a wine cellar can be seen as a large building with large walls that contains indoor small buildings with smaller walls or as a very large amphora that contains other smaller amphorae inside (Terrados-Cepeda, 2015). In both cases the contents are always semi-isolated and under optimal humidity and temperature

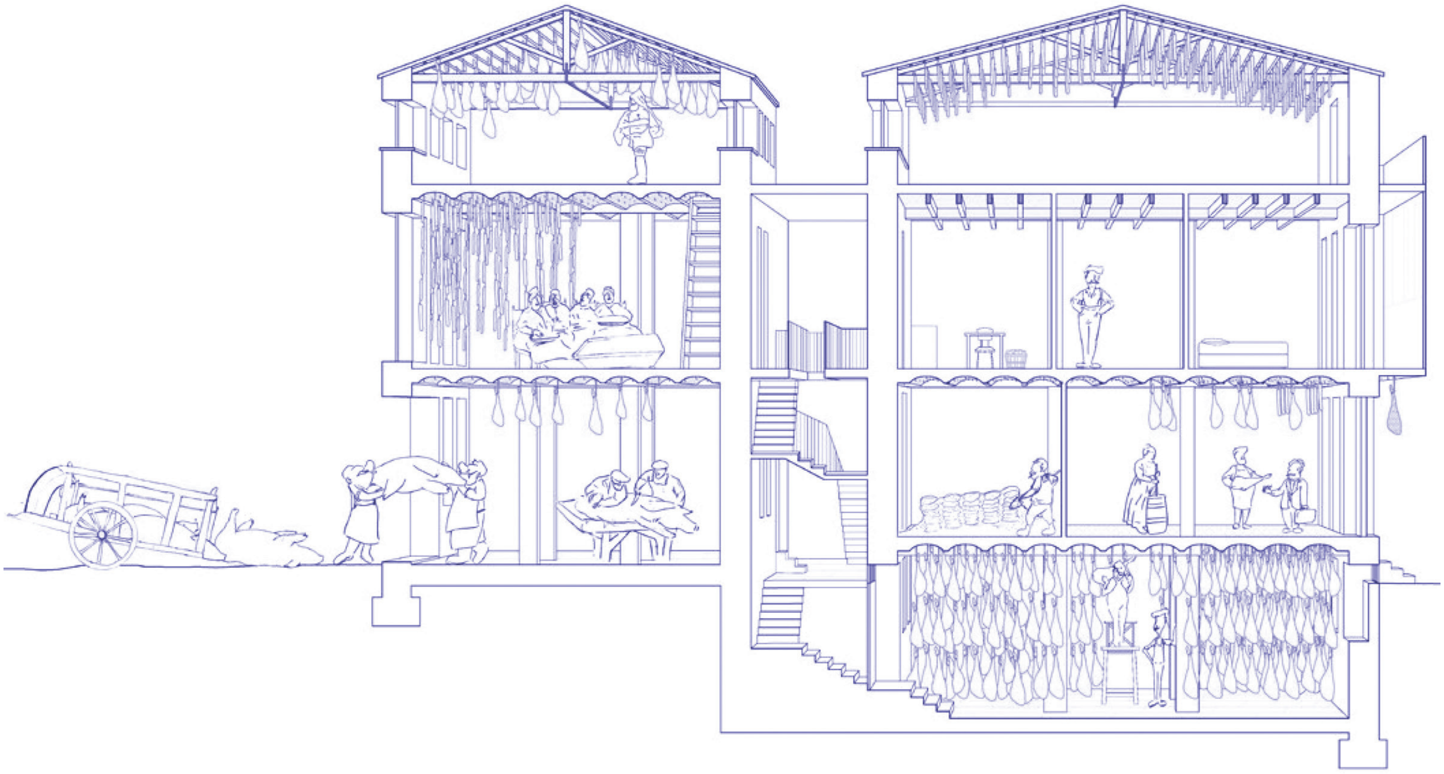

Fig. 2 – Schematic representation of a traditional Iberian pork slaughterhouse in Spain: a. ground floor, b. 1st floor, c. 2nd floor or “sobrado”, d. cellar (Parra Marcos, 2020).

parameters for the proliferation of the type of life it contains, sometimes optimal for all these types of life at the same time.

From the beginning, the houses of Iberian ham (slaughterhouses), wine cellars, cider, breweries, cheese factories, vinegar factories, bakeries... took into account factors such as altitude, latitude, climatological phenomena, orientation and solar incidence, construction material, etc., factors that were managed by the principles of bioclimatology to such success at the technical level that even today we are still learning from it (Fathy, 1986). Even when the scientific-technical knowledge of the fermentation process was not the most advanced, certain parameters were considered that had to be controlled to maintain a certain standardization of the expected result. These are examples in which architecture offers solutions to a fermentative process. However, history has been using multidisciplinary collaborations, where two or more disciplines put themselves at the service of another discipline, but each of these disciplines continued to act under the framework of its own academic field, maintaining the original methods and conceptions of the academic field to which they belong (Hedegaard, 2019; Nicolescu, 2012). To face future challenges, such as temperature increase, we need new solutions that go beyond the frameworks of each of the disciplines separately.

Continuing with the Iberian ham slaughterhouses as an example, it can be found that several methods and techniques have been used to better control temperature and, above all, aeration, and humidity. This type of construction was called a “house”, a space that by its very definition was not only intended to produce ham, but also to host the lives of the owners of the activity, what we might call home. A home designed to keep both humans and a fermentation process stable. These slaughterhouses were divided into 4 floors: the ground floor, with thick walls, destined to the reception of customers and sales in the front part, and to the reception of pigs and primary processing in the back part; 1st floor, with lighter and narrower adobe walls, destined for housing and accompanied by a drying room; 2nd floor, called the “sobrado”, an open space under the wooden ceiling, used for drying and preserving hams; and last but not least, the cellar where a cooler and more controlled space was created for curing the hams for years (Parra Marcos, 2020). The vertical distribution (Fig. 2) of the structure itself shows the versatility in the use of spaces depending on their ventilation, orientation and exposure to light and therefore heat radiation. In addition, narrow windows can be seen in the facade and at street level that allowed the passage of air controlled by two adjustable dampers. All these techniques used are especially appropriate for by the climate of the area; in fact, they make this structure a bioclimatic architecture that passively takes advantage of the environment and climatic conditions to generate the desired environmental indoor conditions while consuming the minimum amount of energy (Mekhilef and others, 2012; Bugenings, 2022).

These design details endure to this day and have become part of our repertoire of traditions.

Traditions are successful innovations for a specific time and place, i.e., adapted innovations. If our climate changes, then the innovations of the past would become unsuccessful for traditions today, i.e., not adapted. One more reason to keep learning from solutions in different times and specific places. Vernacular architecture shows more methods of temperature damping and temperature lowering using passive strategies, with minimal or no energy involvement (Fathy, 1986; Cañas, Martı́n, 2004).

For humans it has been always easier to create heat rather than coolth, fire facilitated this fact. However, that is not the only reason; cooling means lowering particles movement and, to do so, energy involvement is needed.

Therefore, the main way to passive cooling a specific space is to avoid the source of heat, that is to say, release or exchange heat through the walls or amphoras; or simply get isolated from heat.

Heat Dissipation

The first strategy is called, heat dissipation and it can be achieved by different ways. Evaporative heat exchange or evaporative cooling takes advantage of the heat exchange between air and water. This heat exchange can be direct or indirect depending on the water contact with air. The main difference is that in the direct way the air has received a mass contribution in the form of water vapor, which increases the relative humidity of the inner space in which is conducted.

Evaporative cooling has left several examples that might involve both disciplines under study. It is a strategy that involves the use of water to a lesser or greater extent. Depending on whether it is a direct or indirect system, the volume of water required can be recirculated, or alternatively allowing to control the exploitation of water resources of the areas where they are to be applied (Palomar Aguilar, 2017). An amphora by itself is a good example of small and big scale evaporative cooling, the porosity of the clay used in their construction increases the surface of contacts consequently easing the heat exchange at the same time as it acts as a isolator.

Muscata, an example from the Middle East, it consists of a porous ceramic container, arranged in a window and protected from solar radiation by eaves and lattices. The evaporation of the water contained inside cools the air. The entry of this air is both through the window behind the vessel and the lattice that could be arranged in the wall at the bottom, while the exit is by thermal stratification at the upper end. is an example in which architecture and fermentation tools gathers in the same space; the difference with the slaughterhouses is that a non-fermentation process is hosted within. (Fig. 3; Palomar Aguilar, 2017).

It is inevitable to think that these jars or amphorae could not contain wine, vinegar, soy sauce, mead or even sauerkraut... However, the first drawback that would be encountered is the fermentation smell getting into the rooms. However, the basis of this review is that it would be

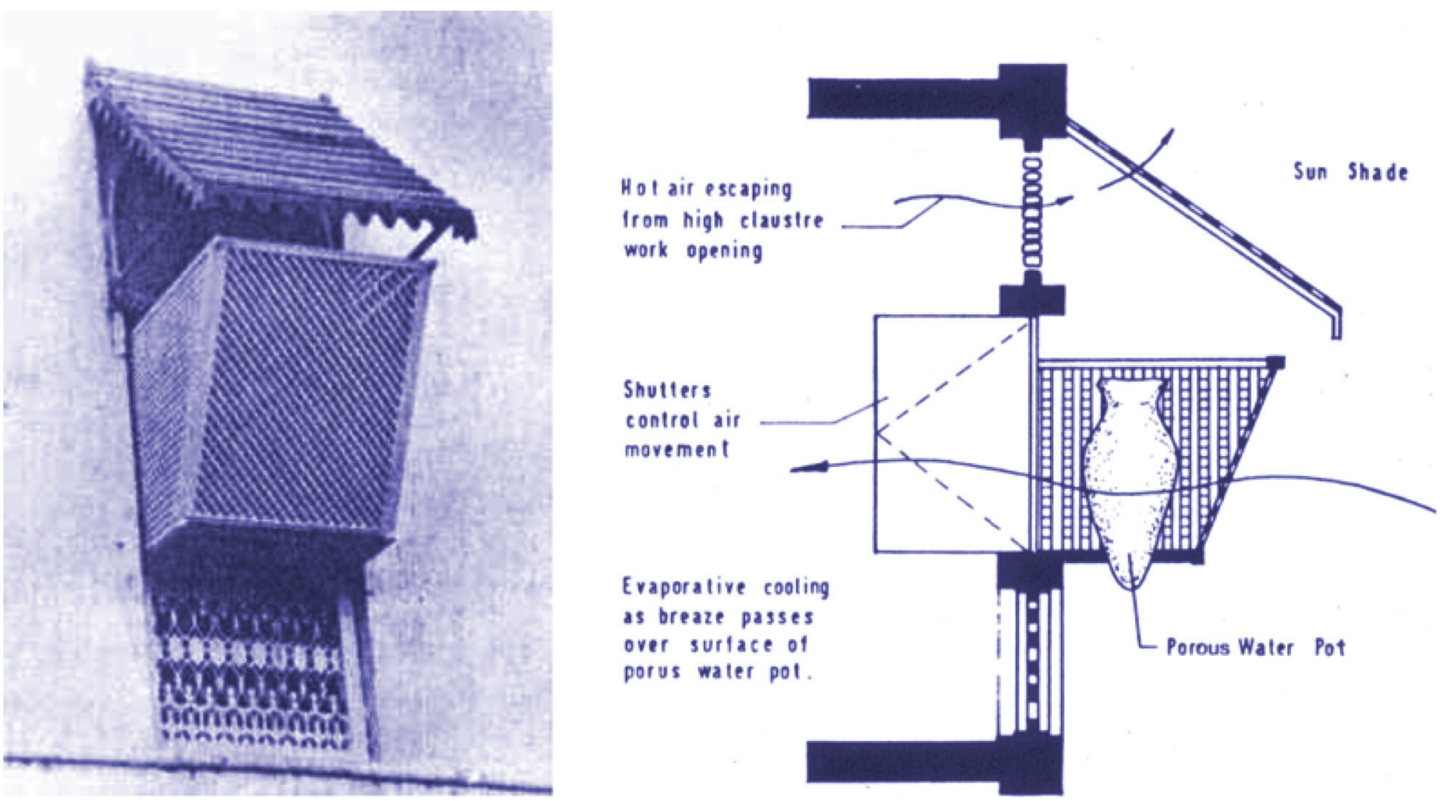

Fig. 3 – Muscata (Schiano-Phan, 2004).

vague to think that the innovation lies in replacing water with wine and that this would lead us to success. Once again there is a solution from other regions of the world called "Pot-in-pot", which is used mainly in Africa for food preservation. It consists of two concentric ceramic containers between which a sand filling is placed and moistened. The evaporation of the outer layer keeps the contents fresh. We can already intuit that in the Muscata system, we could replace the jar by a "pot-in-pot" amphora system and in the space between we would place water instead of wet sand, thus increasing the expiration effect by the pot's porosity. Thus making a stable temperature, both inside the room of the house and inside the amphora where our fermented food would be kept. (Fig. 4; Palomar Aguilar, 2017).

There would be more problems to solve: the porosity of the inner vessel should be minimal or nil, since the fermented liquid inside could pass to the interface where the water is located and begin to smell. To solve this problem, the innermost part of the vessel could be varnished, blocking the pores to isolate the fermenting liquid from the interface. In fact, Lee Kwang in 2006, evaluated the quality of Korean soy sauce in Korean earthenware (onggi) with different glazes - outside only, inside and outside, no glaze. Both glazed Korean "amphorae" resulted in sauces with higher levels of glutamic acid, enzyme activity and total acidity, i.e., better sauce quality (Lee, 2006).

Malqaf or Wind Towers is another example of architecture that uses an amphora as a passive cooler. The level of sophistication of long-established wind towers continues to be a model and inspiration.

These tall towers were intended to capture the breezes and introduce air movement inside the rooms of the lower part of the building. They originated in 2000 BC in the Qajar era (1781-1925) and were combined with the passive cooling technique we have seen at Muscata (Fig. 4). That is, they place an amphora inside the tower to further cool the breeze thus providing direct evaporative cooling (Fig. 5; Palomar Aguilar, 2017). Inevitable again, not to think of placing wine inside and applying the pot-in-pot system mentioned above. Perhaps the accessibility to the amphora is not adequate and it was not intended to be, but let's not forget that we are reflecting on techniques of the past and molding them with a single objective, to combat rising temperatures.

Both wind towers and muscata might be applied to slaughterhouses in order to lower the indoor temperature in the near future. Fig. 6 shows a schematic representation of how techniques used in a muscata and malqaf might be part of an evaporative cooling system in an Iberian pork slaughterhouse Assuming that stairs must be placed externally or internally in this hypothetical representation, the malqaf system or wind tower (e. Fig. 6) occupies that space with the aim of conducting cooled and wet air in the left side of the ground floor used for reception and primary processing of the pigs (left a. Fig. 6) and especially to the -1 floor (d. Fig. 6) where the coolest temperature must be enhanced for the curing process in combination with higher humidity, Fig. 1. In addition, two muscata systems(f. Fig. 6) have been placed on the first floor (b. in Fig. 6); in this way both rooms dedicated to human living and sausage preparation can be passively cooled, depending on wind direction of course. (Parra Marcos, 2020). The 2nd floor is for the first drying stages where higher temperatures are required, hence no passive cooling strategies have been added. Nevertheless, at the present time and in the near future, external temperatures might become so high that this floor might require similar solutions (Martin Miguelez, 2021).

Aside from evaporative cooling, there are some other passive cooling strategies that fit both disciplines under study. In both walls and amphoras the chosen

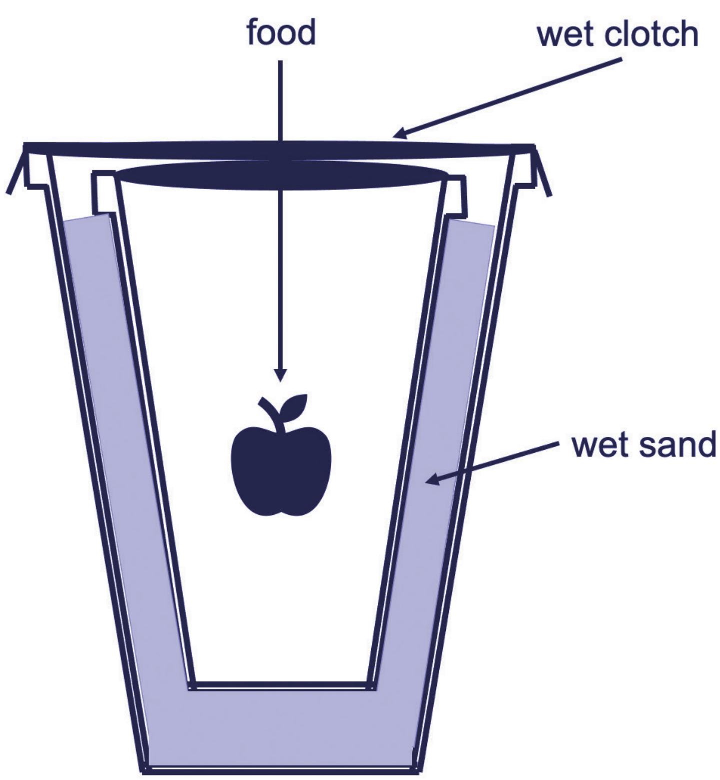

Fig. 4 – "Pot in Pot" (n.p.).

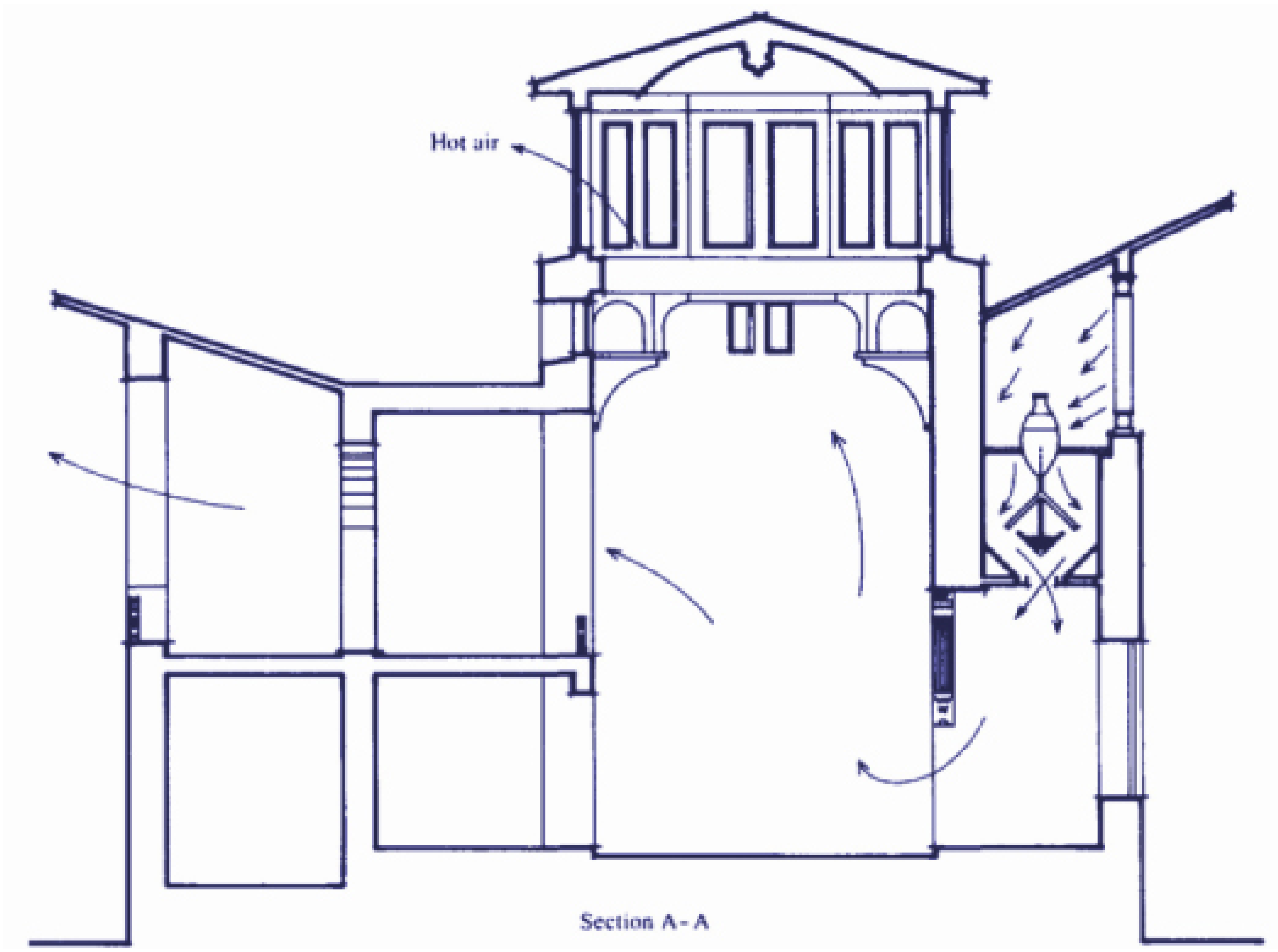

Fig. 5 – Malqaf with ceramic amphorae and humidified deflectors (Palomar Aguilar, 2017).

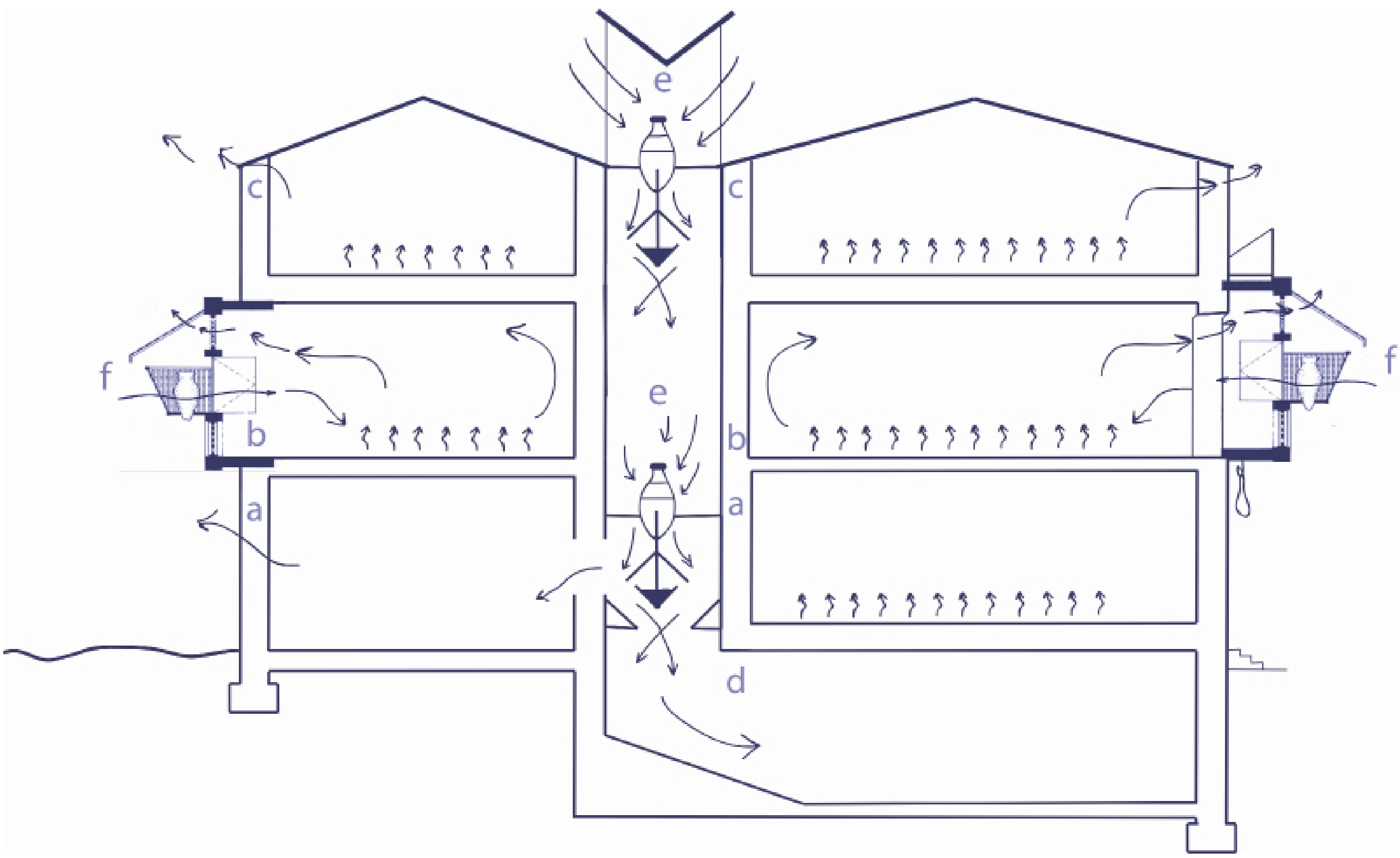

Fig. 6 – Schematic representation of hypothetical implementations of Malqaf with amphora as evaporative cooling (e) and muscata (f) at the balconies (n.p.).

material used to partially isolate the inner space is crucial for this same purpose and therefore also for better heat exchange. This is the case of Thermal Mass, which is mainly influenced by the nature (heat storage and transfer) and density of the material chosen. Another strategy that also aids with heat dissipation is the massing of the building, including its aspect ratio and compactness. This is one of the reasons why slaughterhouses have always been built upwards to reduce exposure to solar radiation.

The nature of the building material can also influence other strategies such as radiative and convective heat exchange, which take advantage of differences in daytime and nighttime temperatures or the air flow within the inner space, a natural ventilation technique.

Heat Exclusion

Solar radiation is one of the main sources of heat that needs to be addressed due to climate change. Heat exclusion is a complementary form of passive cooling that focuses on isolation against solar radiation. Shading methods have been used for this purpose, especially by designing different building geometries, interaction with vegetation or simply specific shading devices (Manzano-Agugliaro, 2015). Orientation and space zoning such as sun angles, local wind directions and seasonal and diurnal temperatures are key to optimizing orientation. Orientation is one of the most studied parameters; it can reduce the need for conventional heating or cooling and enhance the performance of other passive strategies. Space zoning, on the other hand, can influence both energy consumption and the quality of the indoor environment (Manzano-Agugliaro, 2015; Bugenings, 2022).

The use of these strategies alone or in combination have proved capable of reducing the internal temperature of buildings even in environments where the ambient temperature is very high (Manzano-Agugliaro, 2015; Terrados-Cepeda, 2015). As explained, each strategy offers a bioclimatic adaptation with greater or lesser results depending on the specific climate conditions of the specific area of the world (Jain, 2006; Kamal, 2012). Focusing again on the example of the second floor of the slaughterhouse (c. in Fig. 6), most of the heat exclusion strategies might be applied to the walls in order to buffer the increasing temperatures without necessarily cooling them down as certain heat and air flow is required by these drying rooms.

4. PRESENT AND FUTURE LINES

Examples from the past have been mentioned that continue to be of great use today. The simple cross-combination of techniques applied to the case study of the slaughterhouses shows the innovative potential of these ancient strategies in the present day. Several research studies are currently being conducted to combat rising temperatures in the present and future. The development of new technologies in combination with the passive cooling strategies mentioned above opens a new spectrum of solutions that will enable environments to be created that are adapted to specific ranges of humidity and temperature, even in places that will become even hotter (Kamal, 2012).

We can see how the wind towers of 2000 BC have undergone an evolution towards greater efficiency. In Fig. 7 we see how new materials have been selected in the walls of the tower (thermal mass and thermal insulation) depending on the level. These new materials are also intended to be vapor-resistant, preventing unwanted mold growth. The amphora used in the muscata has been replaced by perforated pipes and a pond at the base (direct evaporative cooling) and new layers have been added as the air descends. All this leads to greater efficiency in cooling the descending air column and better filtering of possible particles, insects or dirt (Kamal, 2012).

The improvement in the wind towers shows a convergence of multidisciplinary knowledge that goes further than the slaughterhouses did. Nonetheless, the replacement of the muscata system with perforated pipes and the consequent introduction of a water sump might bring problems related to the relative humidity inside. In this regard, it is proposed to use indirect evaporative systems such as the ancient muscata in combination with the new improvements. Fig. 8 below shows a breakdown of these improvements within the hypothetical model of an Iberian pork slaughterhouse. Compared to the hypothetical improved ancient slaughterhouse in Fig. 6, this new model decentralizes the central location of the wind towers and distributes the functions of the different layers in Fig. 7 all around the building, based on a profound understanding of the temperature and relative humidity required by both humans and the microorganisms involved in producing cured ham.

Starting from the upper part of the tower (head of wind tower in Fig. 8), all wind directions (Parra Marcos, 2020) flow in through a wire mesh, preventing birds and insects from entering. Once inside the tower head, the air descends to the second floor where it meets the first amphora (Fig. 8) or "pot-in-pot" system.

As it comes into contact with the water-filled (or other liquid such wine, perhaps) amphora, its temperature also descends, making it heavier and helping it to flow down to the following floors. No connections with the second floor (or "sobrado") were strategized due to the higher temperature and dryness required for the process of drying sausage and Iberian ham. Instead, heat exclusion strategies were applied to maintain indoor temperatures or simply release heat automatically if temperatures rise above 35ºC and 30% Hr. To achieve this, automated breathing-holes have been hypothesized connected to sensors that output to the breathing-holes in the event that the temperature and relative humidity rise above the pre-established range. Furthermore, north-oriented rooftops (since the slaughterhouses are located in the northern hemisphere, sunlight impacts especially from the south, east and west; Valladares-Rendon and others, 2017) made from high heat transfer materials and covered with a garden, avoid perpendicular solar radiation and isolate the indoor space from a minimum heat adsorption in its surface.

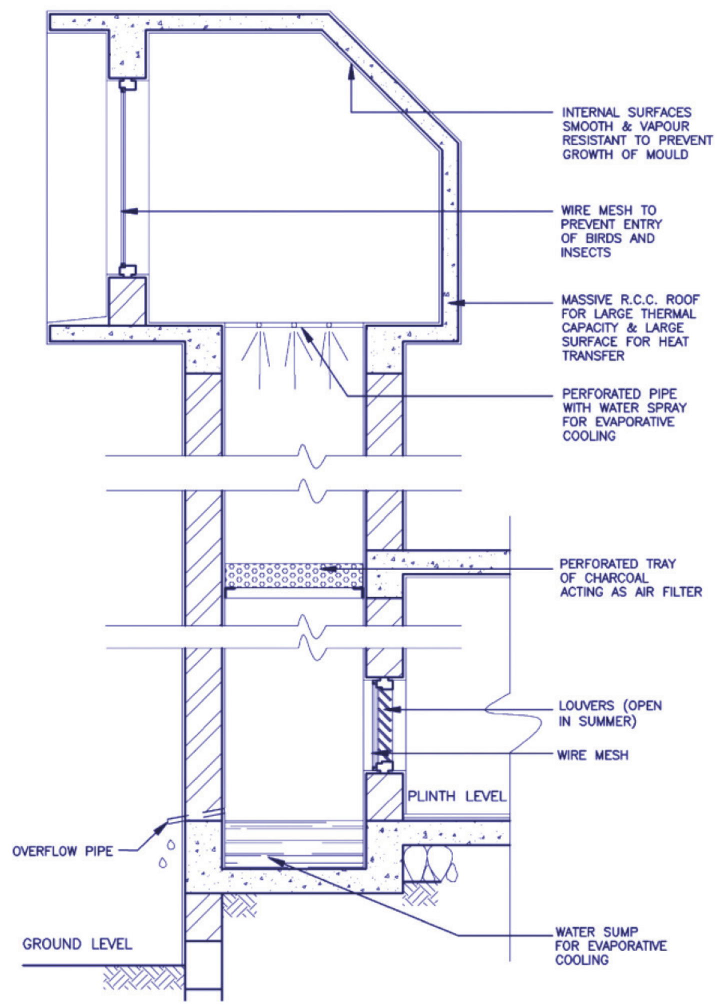

Fig. 7 – Section showing detail of a wind tower (Kamal, 2012).

Continuing to the first floor and past the amphora porosity, 2 ultraviolet lights have been fitted for water vapor sterilization. Perforated charcoal trays used in Fig. 7 are placed right after the UV lights for further filtration of any unwanted water droplets that might carry solids or pollution. Focusing on the safety protocol for pathogens, in microbiology and fermentation, the recent use of biosensors (input) and bioreactors together with new automated cooling systems, ohmic heating and Moderate electric field (MEF), etc., allow microorganisms to be controlled to extents that were not possible 50 years ago. Many of the direct evaporative cooling systems we have seen so far have certain drawbacks related to the growth of unwanted molds or microscopic algae, including the proliferation of Legionella. Legionella is a genus of bacteria with 48 species and 78 serogroups, most of which are associated with human diseases. The kind most often found in patients is L. pneumophila. There are protocols for preventing these pathogens; however, the incorporation of further biosensors, application of technologies such as ohmic heating for sterilization and the use of other non-pathogenic microorganisms that would serve as competition might serve as alternative solutions with a more microbiological and therefore effective approach.

Specifically, ohmic heating is described as being the process of passing an electric current through materials for heating purposes (Gavahian et al., 2020; Gavahian & Farahnaky, 2018; Knirsch et al., 2010). Initially applied to microorganisms, this type of technology was devised as a possible method of sterilization, because when set to high frequencies, it raises the temperature to levels that prevent life. However, (Gavahian, M., & Tiwari, B. K. (2020). Unlike traditional heating methods which usually rely on thermal conduction- and convection-based modes of heat transfer (as we saw in some of the passive strategies), ohmic heating relies on the direct generation of heat in the volume of the product, i.e., volumetric heating. This would therefore provide us with an alternative to microbial control in walls and amphorae in the slaughterhouse model. In Fig. 8, Ohmic heating devices are located at the output of the rooftop garden water tanks. A biosensor inside the water tanks has been fitted to detect the presence of certain pathogens such as Legionella. The biosensor outputs a signal to the ohmic heating device which aggressively and instantly sterilizes the water just before it reaches the amphoras.

The purpose of this system is to occasionally refill the amphoras

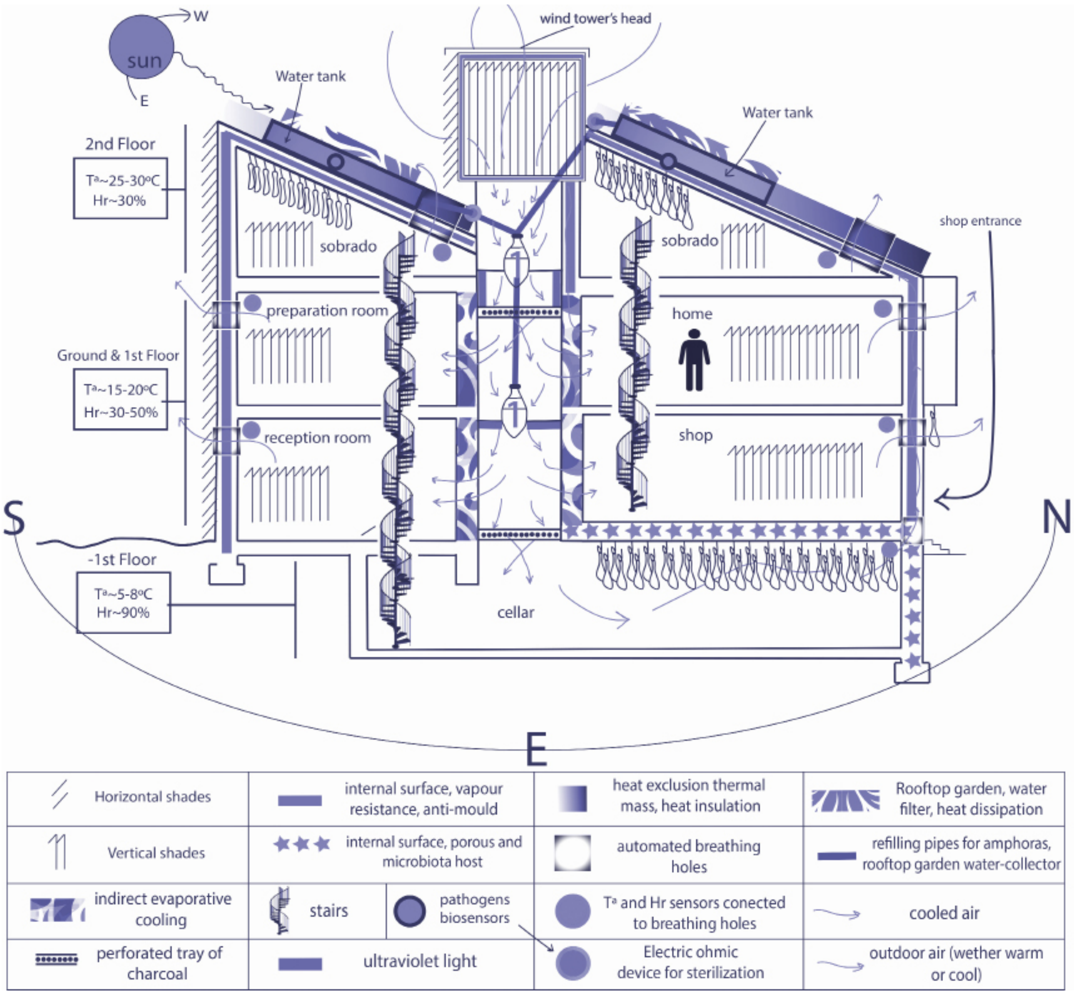

Fig. 8 – Schematic representation of a hypothetical Iberian pork slaughterhouse model which includes the passive cooling strategies explained in this review, both traditional and more innovative ones. 1. Amphoras. (n.p.).

by re-using surplus water from plant absorption that accumulates in the water tanks. In summary, there are 5 levels of protection against pathogens and pollution: the water tank biosensor, ohmic heat sterilization, ultraviolet lights, a perforated charcoal tray and the amphora microfiltration itself. At this point the clean and cooled air flows into both the first and ground floors through an indirect passive evaporative cooling wall. Passive evaporative cooling walls (PECWs) such the one shown in Fig. 9 use water capillarity to direct soaking vertical ceramic tubes. They are highly efficient and also create forms of shading that aid in dissipating solar radiation (He, Hoyano, 2010; Palomar Aguilar, 2017). In the slaughterhouse model the walls are internal, making the shading properties ineffective, even though indirect evaporative systems are more suitable for preventing over-humidification inside the first and ground floor, intended both for the manipulation of raw produce and for human dwelling.

PECW is a prototype, another idea within a whole spectrum of new projects that can and must enrich models such as that of the slaughterhouse. The inclusion of 3D printing technology in this prototype brings tailored and precise target solutions adaptable to any circumstances. There are works currently underway in which microorganisms have helped in the design and improvement of such strategies. Šál, J., & Nováková, P. in 2018 studied the benefits of increasing brick porosity by using fermented waste from biogas production. This study not only results in bricks that could fulfill the function of cool bricks but also offers an alternative use for the waste generated by this industry and all this through the indirect use of microbial fermentation. The study proposes the use of these bricks in the industry itself, since their ability to retain pollutants has been demonstrated, a feature that makes this solution even more interesting for extrapolation to buildings near factories, highways or even the agri-food industry close to cities. Bricks for passive cooling purposes might use microbiology not only for its functional properties but for its spontaneous design. Fractal proportions (Rajković, 2019) bio-mimic a porous, homogeneous design that could not only provide an evaporative cooling function but also shading. At present, several attempts at 3D-design are underway using mold mycelium as a skeleton (Attias, 2020), which might be suitable for use in the slaughterhouse model.

At this point and due to its weight, the air also continues to descend to the last and

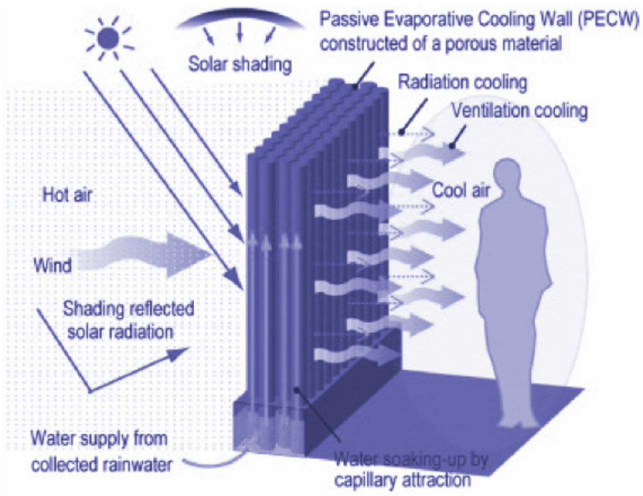

Fig. 9 – Prototype of PECW (He, Hoyano, 2010).

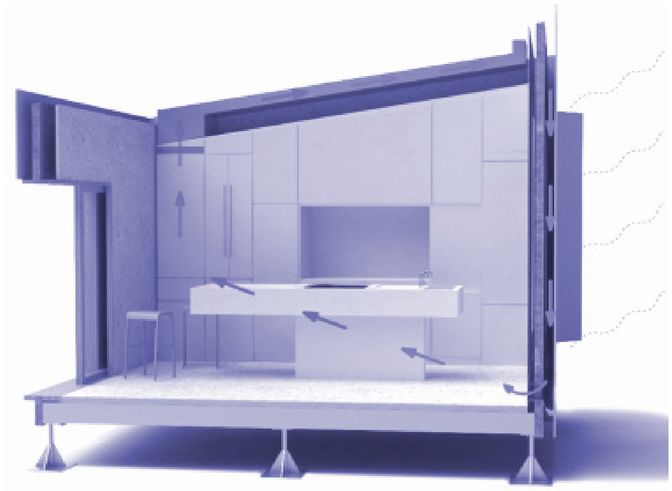

Fig. 10 – Top left: "botijo" effect, (Terrados-Cepeda and others, 2015).

probably most valuable room in the slaughterhouse, the cellar. As described at the beginning, it is here that the Iberian hams are stored and cured for up to 6 years, and the temperature and relative humidity conditions must be controlled. After all the layers of protection through the wind tower, the fresh air flows through a subsequent charcoal trail and enters the cellar, not only lowering the temperature, but more importantly, keeping it low (5-8ºC). The underground area is itself well insulated, and therefore, 90% Hr is achieved by accumulation and regulated by automated breathing holes. If the Hr becomes too high, the breathing holes open and allow the warm air to flow up, past the roof, where it is sterilized by the ohmic device and back down into the PECW, as seen in Fig. 8. This last is called the "botijo" (or "jug") effect, a reference to the passive cooling properties of the ceramic jug that can be applied to the walls of the house (Fig. 10; Terrados-Cepeda and others, 2015).

Finally, it should be mentioned that the main "sobrado" floors of the wind tower head are coated by an internal surface, resistant to vapor and mold growth due to the activities within these rooms. In contrast, in the cellar, porous traditional walls have been conserved, in this way the spontaneous or inoculated microbiota can be preserved over the years and continue to give the final Iberian ham product its special profile.

CONCLUSIONS

The combination of all these ideas might bring spaces with selective permeability to the type of life we want to promote, add value to the final products and increase indoor comfort. All this, knowing that we can detect (biosensors) and monitor (digital recording) the process while we fight against rising temperatures, combat climate change and consume as little energy as possible, especially non-renewable energy... While bioclimatic, biomimicry and architecture have been extensively studied over recent years, this review nonetheless casts light on these fields by adding complexity to the fermentation process. The application of climate-friendly architectural solutions in spaces where fermentation and habitation are combined, automatically involves infinite and versatile techniques operating in the opposite direction to normal, that is to say, from fermentation to architecture.

The interaction of Architecture and Fermentation is only one example of the infinite disciplines that might be married for a single purpose. The Iberian pork slaughterhouse is a model that shows the hypothetical interactions between disciplines with the aim of maintaining different life forms, buffering temperature rises due to climate change and using sustainable strategies.

However, further research must be carried out in order to test this model and understand whether the selected strategies, their interaction and the way they are applied are suitable for the activities hosted by this kind of space. With the common purpose of reducing climate change and its consequences, rethinking beyond the usual academic actors and introducing social relationships (Haribabu, 2010; Mestre and others, 2022), a closer transdisciplinary approach might introduce new knowledge that will help to understand a bit more how our planet works and how we can improve the ways in which we affect its stability.

Science often seeks measurable proof. The slaughterhouse model is a representation intended to seek hypotheses that will need to be tested and must be replicable. Coming from the past, slaughterhouses represent well-consolidated and successful structures that have seen almost no changes throughout their history. The main question for these conclusions might therefore be: "Why change something that already works?". Even aside from the climate change argument, the purpose of this review is to encourage creativity and a re-examination of things that we tend to believe have "already been solved".

Science could tell us a lot about the technicalities that already operate within a traditional slaughterhouse, and also the technicalities that do not work within the proposed slaughterhouse model. Yet science is not the only field that can contribute to this purpose and there is no reason why we should not revisit the successes of the past.

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