A Method to Evaluate Building Performance in the Sustainable Food Processing Industry: Application to an Olive Oil Mill in Calabria

Francesco Barreca1,* Pasquale Praticò1

1 Università degli Studi Mediterranea di Reggio Calabria
* Correspondence: fbarreca@unirc.it; Tel.: +39 09651694215

Abstract: The sustainability of agri-food products is an increasingly pressing need. It is fundamental to consider the various needs related to the factors of production and to workers, which are different from those of products and plants, as well as new requirements, such as environmental hygiene, protection from pests, and perishability control. To that purpose, this work proposes a method for in-use performance assessment in food processing buildings. The method was applied to a traditional olive oil mill in Calabria. The building was investigated and a questionnaire was administered. An overall negative judgement value was recorded only for the oil storage area. The indoor thermal conditions of this area were monitored by a sensor network. The results obtained showed that the temperature in the oil storage area sometimes reached and exceeded 30 °C, while the optimal maximum temperature for the storage of extra-virgin olive oil should not go beyond 20 °C to preserve its organoleptic characteristics. To solve the problems detected, modelling and analyses were carried out with a dynamic thermal software programme. A few minor building interventions were proposed and the indoor thermal values obtained with the dynamic thermal simulation showed a clear improvement in the building behaviour in terms of protection from high temperatures, which were 5 °C lower than the current condition.

Keywords: sustainability; building performance evaluation; agriculture buildings; food processing buildings; olive oil mill; food safety

1. Introduction

The concept of building performance was first developed in Canada, in the mid-'40s, as a method that could be applied only in the early phase of design. In the following years, it was applied and adopted also by a few Public Institutions in the United States. It was only in the '70s that this methodological approach was given due attention by the scientific and research world. In those years, the International Council for Building Research Studies and Documentation (CIB) designated a specific working group, called W06, with the purpose of developing and codifying this method [1]. Thus, a method, which had been created for the performance assessment of single building components, was developed to be applied to the whole building. That was the birth of a new philosophy, which, over time, was adopted also in the technical regulatory field: building design had to follow performance, rather than prescriptive, indications. Designers started to care more about the result and the degree of service the building was able to assure than about the observation of constraints and prescriptions imposed by rules.

In a nutshell, the new methodological approach consists in matching the users’ needs with the performances the building can guarantee [2]. A crucial aspect for the application of the method is the identification of the users’ needs and their translation into technical performance requirements. This operation is not always easy and straightforward for several reasons, some of which derive from the different type of interest shown by the subjects involved in the utilization and management of buildings, whether they be investors, users, or administrative authorities. The knowledge of the needs of the various users is fundamental to implement, already in the pre-design phase or after the
occupancy of the building, all the technical building solutions that can meet them. Usually, the idea of building quality takes different meanings for designers and users, since they have different cultures, perspectives and experiences. In this sense, the in-use building performance assessment, the so-called Post Occupancy Evaluation (POE) [3] or, more generally, the Building Performance Evaluation (BPE), become of the utmost importance. These methods are based on the acquisition of the users’ needs when they carry out their routine activities inside the building so that they can be compared to the degree of service the building is able to guarantee. This analysis is crucial not only to implement possible building interventions aimed to improve the building performances, but also to give a feedback to designers looking for sustainability when conceiving new buildings.

The development of the POE derives from the primary need to check that the performances required from the building correspond to what it is actually able to assure. In particular, its main goals are to improve productivity inside the workspace minimizing the cost of use and increasing, at the same time, users’ satisfaction. Moreover, it is a tool for the management of and support to decision-making aimed at boosting investment profits and users’ wellbeing [4]. Therefore, the benefits of its application variously affect the different subjects involved in the building process. As to the final users, it entails the search for the best environmental working conditions; the verification of the actual knowledge of workplace control measures; and the verification of the adequacy of the building. As regards managers, it assures the verification of the knowledge of the building management operations; the identification of the areas that may show greater problems, so that specific control measures can be implemented; the improvement of productive efficiency; the decrease in operational and management costs; the possibility to make changes to meet the emerging market needs; the interaction with the final users to find and solve specific problems and to define priority investments concerning necessary improvements. Moreover, it allows showing the quality of management and the results attained. As far as designers are concerned, the POE provides feedback and the opportunity to solve problems, to learn useful lessons for future projects, to make small adjustments and to keep relationships with clients.

One of the greatest difficulties in applying this method lies in the way users translate their specific needs into technical building performance requirements. Users are not often able to express these needs through objective and measurable technical parameters and only give qualitative judgements. Therefore, these needs should be translated into performance requirements the building should meet. In particular, building performances can be classified into the following categories [1]:

- **functional performances**, which describe and assess the optimal conditions that ensure that processes and activities are carried out inside the building. Requirements concern the adequacy of space for its intended use, accessibility, adaptability to the varying needs of users, visitors, public community, etc.;
- **technical performances**, which describe the structural, physical and technical characteristics. Requirements concern resistance to load and fire, noise and vibration control, heat losses of the envelope, etc.;
- **economic performances**, which concern investment and costs. These requirements measure the effectiveness of the investment property in terms of return on investment and of its revaluation over time. These are the requirements demanded by entrepreneurs and owners. Cost requirements measure the costs incurred in terms of planning, building, use, maintenance, demolition and disposal of waste materials. The Life Cycle Costing (LCC) analysis is particularly useful for the assessment of these requirements;
- **environmental performances**, which describe and assess the building characteristics determining its environmental impact. Local and global effects on the environment are assessed. Special attention is paid to the use of renewable resources and to the optimization of energy consumption to improve the environmental performances of the building;
- **social performances**, which refer to the workers’ safety and to the occupants’ health and wellbeing;
• process performances, which concern the whole life cycle of the building. Such requirements
allow assessing some of the most important phases of the life of the building, from its
planning to its construction, management and decommissioning.

Furthermore, in order to be effectively assessed, all the performance requirements should have
the following characteristics [5]:
• being objective and quantifiable;
• being precise and clear;
• being operational;
• showing positive qualities;
• being used as benchmarks.

Starting from the ‘80s, in order to provide suitable standardized assessment tools, a few
methods and tools for building performance assessment have been developed and proposed. The
most common model, which was internationally standardized after various modifications and
validations (ISO TC59/SC14/WG10), was developed by the Canadian International Centre for
Facilities (ICF). It was the so-called ST&M (Serviceability Tools & Methods), which was adopted in
1996 by the American Society for Testing and Materials (ASTM) that introduced it in the American
National Standards (ANSI). The same method was then adopted in France by the Centre Scientifique
et Technique du Bâtiment [6]. Such a method includes the acquisition of the functional requirements
through the administration of multiple-choice questionnaires to the groups of users of the building.

Functional requirements are chosen for each analysed performance requirement on the basis of a
prefixed and ordered set. Moreover, users are asked to express themselves on the degree of
service the building is actually able to provide, always referring to a predefined and ordered set.

Finally, for each analysed functional requirement, the method directly compares the capacity of the
building to assure the performance and meet users’ needs. Though the method shows clear
advantages, such as the use of a user-friendly language that makes it easy to apply, and the
possibility to be modified, even if it is standardized, depending on the needs and on the fields of
application, it also shows some questionable aspects. Such aspects are related to the users’
qualitative, and not quantitative, definition of the level of functional performance of the perceived
building. If, on the one hand, this guarantees that the users can assess directly and immediately the
performances required, perceived and actually provided by the building, on the other hand, it
makes the method highly subjective. Furthermore, the building performance assessment should not
take into account only functionality but also other aspects and characteristics of the building that
involve a series of actors other than the users, e.g., entrepreneurs or investors, engineers, public
administrations, etc. Therefore, tools are needed to assess performance characteristics in an objective
and equal manner for all actors. It is necessary to measure the degree of service of a building as
objectively as possible using tools and procedures based on objective and measurable criteria.

Recently, the efforts of the scientific community have been focused exactly on that. Worth
mentioning is the approach including the assessment of two different series of “performance
indicators” [7]. Once they are identified, such indicators are distinguished into two different
typologies. The first typology includes all the indicators that can be measured relying on the current
scientific knowledge in the field of physiology and biophysics, e.g., those which allow assessing the
building performances in terms of energy, indoor lighting, thermal wellbeing and maintenance.

These indicators are referred to as “hard” because they derive from the objective and “hard”
knowledge of science. The other series of indicators refers to a so-called “soft” multidisciplinary
scientific branch, i.e., environmental psychology, which studies man’s behaviours and interaction in
relation to the confined environment he uses. Unlike the hard ones, these indicators are based on the
quantification of less objective factors, such as those concerning culture and human psychology.

“Hard” performance indicators are based on physical experiments and consolidated scientific
theories and a few are also included in the technical standards of some countries. These assessment
methods are able to measure and predict the level of building performance with remarkable
accuracy and can be generically applied to different buildings.
The sustainability of agri-food products is an increasingly pressing need. In its recent Implementation Action Plan, the European Technology Platform (ETP) “Food for Life”, created under the auspices of the Confederation of the Food and Drink Industries of the EU (CIIA) [8], has stated that the achievement of a sustainable food chain is crucial to the food sector and that the development of tools to define and identify the limit of sustainability should be one of the greatest future challenges of research and concern all the phases of the production chain. In this sense, the performances of agri-food buildings significantly affect the overall sustainability of the process. Therefore, it is essential to develop and provide agri-food buildings with specific models of performance assessment. However, the unique and complex nature of the sector adds certain difficulties to those typical of the methods developed for the traditional building sector. It is fundamental to consider the various needs related to the factors of production and to workers [9], which are different from those of products and plants, as well as new requirements, such as environmental hygiene, protection from pests [10], and perishability control [11]. These needs should be translated into specific performance requirements. To that purpose, this work proposes a model for the in-use performance assessment in the food processing industry.

2. Materials and Methods

The proposed method for the agri-food building performance assessment is composed of four phases (Figure 1): knowledge, investigation, diagnosis and action [12]. The phase of knowledge consists in acquiring the main production data. A checklist and simple interviews to entrepreneurs and to production and administrative managers will allow acquiring all the data useful to describe the production characteristics of the building, in particular, average data on production and waste. The data provided during the interviews should be preferably checked through appropriate official documents (invoices, bills, receipts, etc.) because, since interviewees are afraid of damaging the corporate image, they do not often highlight the problems of the production cycle. A further tool of investigation in this phase is a visit of the assessment team to the company during the main processing phases. Inspections should be reiterated in different times and, in particular, under different environmental conditions, since these affect indoor working conditions.

In the second phase, users’ satisfaction in relation to the different functional areas of the built environment is recorded and information and judgements on the capacity of the building to assure an optimal productive process are collected. The investigation is carried out by administering questionnaires which are suitably targeted to a homogeneous group of users. The users of the functional areas must be classified according to their activities and tasks, e.g. production employees, administrative personnel, occasional visitors, school groups, carriers, farmers, etc. Moreover, questionnaires should refer to the general information acquired in the previous phase; in particular, it is important to consider the company production potential, the number of workers, the complexity of its productive process, the markets of its products, and its quality certifications. The judgements asked for during the interviews should refer to certain specific building aspects and to others related to the context. Particularly, building aspects concern process performances, functional performances, and technical performances; those related to the context regard economic performances, environmental performances and social performances [13]. This phase of the method is extremely delicate since it is aimed at highlighting possible weaknesses of the built environment. Users’ judgements should be carefully analysed and assessed because, in general, human behaviour does not depend directly on the characteristics of the built space but is influenced by social, psychological and cultural factors. Furthermore, the environment itself is influenced by human activity [14]. A similar attention should be paid to the assessment of the judgements concerning the elements of the built environment that affect the quality of production. Environmental hygiene, protection from pests, ideal thermo-hygrometric and lighting conditions for the conservation of agri-food products are crucial to a high-quality production. In order to achieve production of excellence, a long and laborious process should be followed, where each aspect of production is carefully handled to keep quality standards high over time, also through process changes and innovations. The excellence of oil is not only about its organoleptic qualities and cannot be measured.
only through its compliance to the regulations establishing its characteristics. It is related to multiple productive, ethical, social, environmental, cultural, and historical factors [15]. Among all these factors, productive sustainability plays a fundamental role and is strongly influenced, in turn, by the built environment that hosts the productive process. Therefore, those who work in a company are often able to identify possible weaknesses of the productive conditions thanks to their personal experience and perception. Thus, questionnaires should be simple and able to acquire specific and objective data and judgements on the performances of the built environment. To that purpose, questionnaires should have the following characteristics:

- to be specialised on a type of users, *i.e.* the different type of activities carried out by each group of users should be taken into account
- to include a limited number of questions. Questionnaires should not take more than 10-15 minutes to be completed
- to contain direct and concise questions, so as to assure clear understanding of the questions and the reliability of the answers.

Once the knowledge procedure is completed, it is possible to start the next phase of the method, which consists in the analysis of the judgements on the performance of the building system and of the built environment. In this phase, the weaknesses emerged during the phase of investigation are highlighted. In particular, starting from the judgements expressed by the users and from direct observations, the elements of the built environment, which show a negative performance judgement and on which it is necessary to intervene to improve their performance efficiency, are pointed out. After finding weaknesses, it is necessary to conduct in-depth investigations by means of objective methods and instrumental diagnostic procedures that guarantee a precise and direct identification of their causes. Finally, based on the instrumental analyses and on the knowledge of the causes of the weaknesses detected, the last phase includes the design and the implementation of the most suitable interventions and technical solutions. However, the assessment process does not finish in this phase, since, in order to pursue productive excellence, it should be reiterated periodically to monitor and maintain the high performance standards of the built environment.
3. Results

3.1 The case study: a traditional olive oil mill in Calabria

Italy is the world’s second largest supplier of olive oil after Spain [16], with a 2015-2016 oil production of some 380,000 tonnes. The region Calabria, with its 44,000 tonnes [17], is the Italian second largest producer after the region Puglia and before Sicily [18], which records a production of about 169,000 tonnes and widespread olive groves [19]. These data account for the strategic importance of the oil sector for the whole agri-food economy of Calabria. Yet, the value of the average productivity of olive mills of the region is much lower. In fact, in Calabria, there are around 762 olive oil mills, while, in Puglia, they are 893 and record a productivity which is four times higher. This scenario highlights the extremely fragmented nature of the production and the need to upgrade the whole productive system. In addition, only 27 olive oil mills produce “Protected Denomination of Origin” (P.D.O.) and “Protected Geographic Indication” (P.G.I.) extra-virgin olive oil. This is still a very low value, above all if it is compared to other production areas, such as the region Tuscany, with its 303 mills, or Puglia with its 134 mills. In order to compete in increasingly demanding and globalized markets, Calabrian olive oil production must now step up and aim at a production of excellence. Among the factors contributing to a quality production are, undoubtedly, those related to the productive context and, in particular, those concerning the in-use performances and the sustainability of the production building.

The proposed model was applied to an olive oil mill that typically represents the productive situation in Calabria. The building is located in Lametia Terme, a town in the province of Catanzaro (38° 55’ 20.593” N 16° 19’ 27.082” E). It is part of a larger historic rural building complex (Figure 2)
that presumably dates back to 1780 and is one of the best preserved rural complexes in Calabria. The olive oil mill, which is still situated in the original building, has a modern continuous milling system. The extra-virgin olive oil it produces is extracted from olives of the *Carolea* cultivar, which are exclusively grown in the company’s olive grove and assure an annual production of some 50,000 l. Milling starts in the early weeks of October and continues until March, while the produced extra-virgin olive oil is kept in stainless steel tanks, which are placed in an area of the same mill, and then bottled during the year according to the market demand. With a view to assuring the excellence of the production, the whole production process is carefully checked by a quality manager and by a technical supervisor. Moreover, around 15 employees take part in the processing cycle with different tasks.

![Figure 2. 3D vision of the case study: a historic rural building complex in Calabria.](image)

### 3.2 Application of the method

The method proposed in this paper was adapted and applied to the above-mentioned olive oil mill. During the first phase, several visits were carried out in the company to acquire documents and information on the building, on its history, on the changes it had undergone over time, on maintenance interventions and on the characteristics of its products and their reference markets. The collected information and the visits allowed getting a first general knowledge of the company and of the building. The subsequent phase concerned the investigation of the problems pointed out by users. To that purpose, a questionnaire was administered to all employees, to the administrative personnel and to the process managers.

### 3.2.1 Description of the Questionnaire

The questionnaire was targeted to each category of users of the building: process operators (U₁), quality managers (U₂), sanitation operators (U₃), and visitors (U₄). Questions concerned the assessment of functional performances (FP), technical performances (TP), economic performances (EP), environmental performances (VP), social performances (SP) and process performances (PP). All performances were referred to the five functional areas into which
the building is divided, *i.e.*, area for the delivery of raw material (A1), pre-processing area (A2), processing area (A3), oil storage area (A4), service area (A5) (Figure 3).

**Figure 3.** Lay-out floor plan of the Olive Oil Mill. A1: area for the delivery of raw material; A2: pre-processing area; A3: processing area; A4: oil storage area; A5: service area.

Each performance was assessed based on the average value of the judgements users had given to the relevant criteria. The value of the judgement ranged from -3 to +3, where -3 referred to a completely negative judgement for that criterion, 0 corresponded to a sufficient value, +3 corresponded to the highest positive judgement for the examined criterion. The following criteria were identified for each performance:

**Functional Performances (FP):** adequate spaces, adequate accessibility, indoor environmental conditions, flexible spaces, easy sanitation.

**Technical Performances (TP):** conditions of load-bearing structures, state of conservation of building components, adequate fire protection systems, sound pressure levels, adequate thermal insulation.

**Economic Performances (EP):** operational cost evaluation, maintenance cost evaluation, efficiency evaluation, rate of obsolescence, constant productive quality.

**Environmental Performances (VP):** environmental impact of production waste, use of renewable energy sources, utilization of reusable materials, energy saving solutions, green solutions for sanitation.

**Social Performances (SP):** safety at work, thermal comfort, acoustic comfort, light comfort, hygiene.

**Process Performances (PP):** easy integration with plants, modularity of the building system, reusability of its components, reconversion of spaces, useful life.

Furthermore, Table 1 shows the categories of users of the different functional areas of the building.
Table 1. Final assessment per typology of user in relation to each functional area.

<table>
<thead>
<tr>
<th></th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional performances</strong></td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A4_ A5</td>
</tr>
<tr>
<td><strong>Technical performances</strong></td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Economic performances</strong></td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Environmental performances</strong></td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Social performances</strong></td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A2_ A3_ A4_ A5</td>
<td>A1_ A4_ A5</td>
</tr>
<tr>
<td><strong>Process performances</strong></td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
</tbody>
</table>

Questionnaires were administered to 15 process operators (U1), 2 quality managers and 1 company owner (U2), 5 sanitation operators (U3), and 5 visitors (U4). Finally, the performance values for each area were calculated as the average of the values of the judgements expressed by users for the single criteria (Table 2).

Table 2. Average of the values of the judgements on the performances per Functional Area

<table>
<thead>
<tr>
<th>Area</th>
<th>Performances</th>
<th>FP</th>
<th>TP</th>
<th>EP</th>
<th>VE</th>
<th>SP</th>
<th>PP</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>2.1 (±0.4)</td>
<td>1.8 (±0.3)</td>
<td>1.5 (±0.3)</td>
<td>2.4 (±0.3)</td>
<td>2.1 (±0.3)</td>
<td>1.5 (±0.3)</td>
<td>2.3 (±0.3)</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>1.5 (±0.3)</td>
<td>1.1 (±0.5)</td>
<td>1.8 (±0.4)</td>
<td>1.1 (±0.2)</td>
<td>2.0 (±0.5)</td>
<td>2.5 (±0.2)</td>
<td>2.0 (±0.2)</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>1.6 (±0.2)</td>
<td>1.2 (±0.3)</td>
<td>1.6 (±0.3)</td>
<td>1.8 (±0.3)</td>
<td>2.1 (±0.3)</td>
<td>1.5 (±0.3)</td>
<td>1.6 (±0.1)</td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>-1.6 (±0.2)</td>
<td>-1.4 (±0.3)</td>
<td>-1.3 (±0.3)</td>
<td>-1.1 (±0.3)</td>
<td>1.6 (±0.3)</td>
<td>-1.2 (±0.3)</td>
<td>-1.0 (±0.2)</td>
<td></td>
</tr>
<tr>
<td>A5</td>
<td>1.3 (±0.6)</td>
<td>1.4 (±0.4)</td>
<td>1.1 (±0.1)</td>
<td>1.5 (±0.4)</td>
<td>1.4 (±0.5)</td>
<td>1.8 (±0.6)</td>
<td>1.7 (±0.5)</td>
<td></td>
</tr>
</tbody>
</table>

The final results of the qualitative performance assessment of the functional areas showed an overall positive picture. An overall negative judgement value (-1) was recorded only for the area A4 (oil storage area), particularly for **Functional Performances** (-1.6), **Technical Performances** (-1.4), **Economic Performances** (-1.3), **Environmental Performances** (-1.1) and **Process Performances** (-1.2).

3.2.2 Instrumental assessment

A following interpretation of the judgements showed that the weakness found in the oil storage area was mainly due to the inadequacy of the thermal conditions highlighted by the users, since the storage temperature caused a variation in the quality of oil [20]. The next phase of the proposed method consisted in the diagnosis of the problem and, therefore, in the instrumental monitoring of the area A4 and, specifically, of its indoor thermal conditions, above all during summer, when temperatures reach their maximum seasonal values [21]. Thus, in order to detect the main indoor thermal parameters, a sensor network was designed, installed and connected with a datalogger to acquire and save values at a time interval of 15 minutes (Figure 4a). Monitoring mainly concerned the measurement of surface temperatures (T) and of the heat flows (F) passing through the walls of the storage area, of the indoor temperature (T_i), of the air temperature in the attic (T_{att}), and of the direct solar radiation on the external walls (P) (Figure 4b). In addition, a station for meteorological data was placed outside the building to measure the air temperature and humidity, and the diffuse, reflected and direct solar radiation (Figure 5).
Figure 4. Installed instrumental network. (a) oil storage area (b) network lay-out showing the type of thermal sensors installed and their position.

Figure 5. External climate network: (a) Meteorological station; (b) Sensors for the measurement of solar radiation and of the temperature of the external wall of the oil storage area.
The instrumental analysis was carried out from 19 July to 29 September 2016, a time interval generally including the hottest period of the year [22]. The particular configuration of the sensor network allowed analysing the main indoor microclimate characteristics of the area and to compare them to outdoor environmental measurements, with a view to verifying the real thermal conditions of oil storage and the level of heat protection guaranteed by the building envelope.

The results obtained (Figure 6) showed that, during the monitoring period, the temperature in the oil storage area sometimes reached and exceeded 30°C, a value far higher than the optimal maximum temperature for the storage of extra-virgin olive oil, which should not go beyond 20°C [23] to preserve its organoleptic characteristics.

The comparison with outdoor temperatures also showed that the building offered inadequate protection from high summer temperatures, which even exceed 35°C at certain times of the day.

3.2.3 Intervention plans

The last phase of the proposed method concerned the development of technical solutions to solve the problems detected in the previous phase. In particular, it was necessary to develop and propose building solutions and actions to lower indoor temperature. The utilization of DesignBuilder, a building energy simulation software programme based on EnergyPlus dynamic simulation engine (Figure 7), was particularly useful. Actually, the modelling and analysis carried out with that software programme allowed simulating and verifying, in real-time, the effectiveness of certain solutions. A few minor sustainable insulation building interventions were proposed, such as the installation of a sun screen on the external wall exposed to the south-west; the separation of the storage area from the processing area by means of an internal mobile partition wall [24]; an automatic forced ventilation system with a 7 vol/h air renewal; and the thermal insulation of the walls of the storage area with 7 cm-thick agglomerate cork boards (λ = 0.04 W·m⁻¹·K⁻¹) [25]. The final results of the thermal analysis of the building carried out with the software programme demonstrated the effectiveness of such interventions, since the indoor thermal values obtained with the dynamic thermal simulation showed a clear improvement in the building behaviour in terms of protection from high temperatures, which were 5°C lower than the current condition.

Figure 6. Outdoor and indoor temperature measured
4. Discussion

Building performance assessment is usually a particularly complex and time-consuming activity, above all if it is applied to production buildings, since the process generally interacts with the building and vice versa. This is all the more true for agri-food buildings, where entire phases of the process are strongly influenced by outdoor environmental conditions. Typical examples are cheese storage areas or cellars for wine ageing. Therefore, performances should be assessed by taking into account different needs and sometimes clashing objectives. For instance, floors should be easy to clean and, at the same time, they should be slip resistant [26][27]. If, on the one hand, the instrumental performance assessment could be the most accurate and objective method to assess the performances of the building and of its components, on the other hand, procedures are sometimes difficult or even practically unfeasible, not only for the time required but also for the inevitable interference with the delicate food productive process, which demands particular attention and sanitation precautions. In fact, the technicians taking measurements could contaminate food unless activities are temporarily suspended, which entails a loss of production. Therefore, such procedures should be limited as much as possible. In this sense, the proposed method allows detecting weaknesses and carrying out instrumental analysis only on their potential causes. It was demonstrated that the model could be applied to a real case and that it highlighted weaknesses which were then well investigated using tools and procedures for thermophysical measurements. This allowed not only confirming certain weaknesses of the building system but also acquiring data to propose improvement actions and evaluate their effectiveness with appropriate simulation models. Thus, the development of specific computer systems in performance and sustainability assessment proves to be a fundamental process to improve and accelerate the assessment process.

Further developments of this study could include the integration of the method with the Building Information Model (BIM), in order to best manage and control building performances during the life of the building itself. The control of agri-food building performances does not concern only the company, because it guarantees a cautious management of production costs, but also the whole community, because it assures the quality of products, food safety and a low environmental impact [28], i.e., it allows pursuing the global sustainability of quality food products.

Acknowledgments: The research was funded by the project PON03PE_00090_2, included in the MIUR-MiSE National Operational Programme for Research and Competitiveness (PON R&C) 2007-2013, and co-funded by the European Regional Development Fund (ERDF).
Author Contributions: Francesco Barreca developed the models and wrote the paper, Pasquale Praticò collaborated in developing the literature review, and data acquisition and analysis under supervision of Francesco Barreca.

Conflicts of Interest: The authors declare no conflict of interest.

References


17. Unaprol Filiera olivicola - analisi di scenario; Roma, 2016;


22. UNI 10349 Riscaldamento e raffrescamento degli edifici - Dati climatici 2016, 46.


