A novel method for improving the vacuum cooling of cooked meats

Final Report Summary - COOL-MEAT (A novel method for improving the vacuum cooling of cooked meats)

Irrespective of the preparation methods and cooking procedures, rapid cooling of meat after cooking is vital for microbiological safety as well as for keeping sensory and nutritional quality. Many European governments set strict guidelines, which stipulate that cooked meat joints for delicatessen, catering and industrial use must be cooled within tight time limits post-cooking.

Conventional cooling by air blast, cold room or even by immersion in liquid is unlikely to achieve recommended cooling rates, especially when dealing with large meat joints. Currently, the most effective technique, vacuum cooling, leads to considerable weight loss and due to high moisture loss meats are slightly less tender, drier and darker. A novel combined cook-cool technique known as immersion vacuum cooling (IVC) has recently been researched, whereby the vacuum cooling of cooked meat together with some of its cooking solution was explored for its potential use for rapid cooling of water-cooked meat joints. Based on this past research, the COOLMEAT project aimed to develop and implement an immersion vacuum cooling technology for reducing the cooling times of cooked meats and the energy...
consumption of the cooling process, as well as to reduce the loss of meat tenderness and juiciness that is normally associated with vacuum cooling.

The laboratory trials and recently the validation of the technology in DMRI and in the industry, tested the applicability of the immersion vacuum cooling (IVC) technology to two different products, 'morcilla' and hams, which were chosen to study within the consortium at the beginning of the project.

In terms of the cooling time, results with hams, both at laboratory and prototype scale, showed that although cooling times for IVC were higher than vacuum cooling as expected, they were approximately 40 - 50 % shorter than air blast, which is the usual cooling method used in industry for this type of products. Furthermore, the weight loss of immersion vacuum cooled hams was about 4 to 5 %, while for vacuum cooled samples weight loss ranged from 10 to 12 %. Thus, cool loss is remarkably lower than for vacuum cooling, and certainly still lower than for air blast (about 6 %). Tests with 'morcillas' or products alike were performed only at laboratory scale, though experiments are currently being undertaken in DAZA facilities, where COOLMEAT is installed. Reductions in the cooling time of approximately 70 % were obtained when 'morcillas' were immersion vacuum cooled and compared to the traditional method used in end-user SME DAZA.

Trials with meat were also carried out to document the cooling effect of the COOLMEAT technology in relation to food safety and eating quality of the cooled meat. Overall, it could be concluded that the immersion vacuum cooling technology is indeed a time reducing cooling method. Hams injected with Clostridium perfringens (pathogenic bacterium) were cooled efficiently and no growth of C. perfringens spores was detected. In the shelf-life study it was shown that the shelf life of IVC cooled products is comparable to the shelf life of sliced meat products. Concerns have been addressed to the possibility of reduced eating quality of immersion vacuum cooled hams especially due to a decrease in juiciness. However, this was not observed during the current trials. Comparing texture attributes rated by a trained panel, hams cooled in the IVC and hams cooled in air were equally juicy and tender. Finally, the measurements of vitamin B preservation showed that some vitamin B is degraded and thereby lost during cooking, but the decrease in vitamin B concentration is not related to the cooling method.

Intense discussions and reviews of all technical parameters of the COOLMEAT system led to focus during the project on two aspects, namely, the immersion operation during immersion vacuum cooling as it is one innovative aspect of the project; and the automation of the whole process, since market research indicated that the vacuum coolers commercially available are limited in controlling automatically the vacuum pressure reduction, which is the most important factor to consider since the cooling process is controlled by the evaporation of water. The COOLMEAT IVC prototype is implemented with a precise control of the pressure reduction, characteristic that will differentiate COOLMEAT with respect to vacuum coolers commercially available.

The COOLMEAT technology could indeed demonstrate the feasibility of reducing cooling times while keeping the safety and quality of the cooked products.

Project context and objectives:
In order to minimise the growth of pathogens in the cooked meat industry, strict EU guidelines demand that cooked meat joints including ham, turkey, chicken, pork and beef need to be cooled within tight time limits post cooking, whereby meat joints should not exceed 2.5 kg and 100 mm in thickness and should be chilled from 74 to 10 ºC within 2.5 h after being removed from the cooking process. Irrespective of the preparation methods and cooking procedures employed, rapid cooling of meat after cooking is vital for microbiological safety as well as for keeping sensory and nutritional quality.

Conventional cooling methods such as air blast, cold room and immersion cooling depend on heat conduction to cool the inside of the joints, but the relatively low thermal conductivity of meat coupled with the necessity to maintain a temperature of the cooling fluid above 2 ºC (to avoid surface freezing) makes it difficult to increase the rate of cooling significantly.

Vacuum cooling is a rapid evaporative cooling technique for moist and porous products that offers many advantages over conventional cooling methods, such as short processing time, extension of product shelf life and improvement of product quality, safety and nutritional content. However, despite these advantages, weight loss during vacuum cooling is high (around 11 - 12 %), which is almost double or more of conventional cooling loss. Due to the high moisture loss, vacuum cooked meats are slightly less tender, drier and darker. Significant research effort has been dedicated at trying to compensate water loss during vacuum cooling. For example, manipulation of brine injection levels has been demonstrated as an efficient and effective method that improves not only product yield but also quality. This, however, remains a partial solution because brine injection or increasing injection levels may not be applicable to all possible meat products. Methods such as pre-wetting the product or the installation of water sprayers inside the vacuum cooler also show promise, and could offer a more practical and universal method. However, product safety concerns still need to be addressed, thereby limiting the acceptability of such techniques.

A novel combined cook-cool technique known as IVC has recently been researched, whereby the vacuum cooling of cooked meat together with some of its cooking solution was explored for its potential use for rapid cooling of water-cooked meat joints. Reduced yield losses and improved quality for cooked pork ham have been reported.

In this context, the overall goal of the COOLMEAT project was to build on a new and emerging body of research in the field of IVC technology, and to apply it at industrial level by developing a novel rapid cooling technology for meat processors that will reduce meat cooling times up to 50 % compared to conventional cooling methods. The COOLMEAT system is thus based on conventional vacuum cooling technology that is readily available, which was adapted to monitor and carefully control the rapid cooling of hot cooked meats while immersed in a surrounding solution.

First, the participating SMEs, as well as a representative sample of European meat processors were consulted and results used to determine their needs and specifications and define the industrial specifications for the COOLMEAT prototype. This bottom-up approach ensured that the prototype which would be tested and validated in a real industrial environment, would meet not only the technological requirements of industry, but socio-economic requirements as well.

Second, laboratory research was conducted with two products selected by the consortium (hams and
Second, laboratory research was conducted with two products selected by the consortium (hams and 'morcillas') in order to validate the immersion vacuum cooling technology for the fast chilling of these products. During these studies, different IVC parameters such as rate and mode of vacuum pressure reduction, effects of cooling regime, immersion level, cooling liquid initial temperature, cooling loads, etc. were critically evaluated. The results generated a set of optimum process and equipment parameters that fed into the design and building of the COOLMEAT system. Additionally, a food quality analysis was successfully carried out and the necessary parameters for WP5 (Microbial risk assessment and meat quality evaluation of the IVC prototype) lab trials were identified.

Then, an associated objective was perform trials with meat in order to document the cooling effect of the COOLMEAT technology in relation to food safety and eating quality of the cooled meat. These trials consisted in a microbial risk assessment using challenge test methodology with the pathogenic bacterium Clostridium perfringens; a sensory profiling of meat cooled in the IVC prototype in order to evaluate especially juiciness of the meat; a shelf life analysis; a nutritional evaluation regarding the content of vitamin B in pork hams cooled using the prototype; and the identification of points of critical control including cleaning.

Finally, the project aimed to design and build a pre-industrial prototype of the COOLMEAT system keeping with the previously defined specifications outlined and based on the laboratory set up. The aim was to deliver a COOLMEAT system that is a time reducing cooling method that ensures no growth of pathogens, cost-effective, delivers consistent product quality, capable of being easily and readily integrated into meat processing plants and of minimal environment impact. Then this prototype can be installed, tested and validated in a real industrial environment in the facilities of the end-users in the consortium.

A further goal was to carry out demonstration activities proving the viability of the COOLMEAT system and outline its potential economic and environmental advantages.

The overriding goal of this project was to ensure that the precompetitive COOLMEAT prototype would fulfil the threshold requirements of the industry to ensure its further development post-project into a fully industrial system that would be taken to market, where its beneficial impact could be felt at European level. This was also empowered by the realisation of dissemination activities throughout the project and the concern related to exploitation strategy.

Project results:

The COOLMEAT project delivered a versatile, adjustable, scalable prototype system allowing to control and measure a number of parameters of interest and flexible enough for application on many different kinds of food products, which will render it highly competitive. At the end of the project, the precompetitive COOLMEAT technology can be defined as an affordable IVC technology, which improves the vacuum cooling process while safeguarding the quality and safety of the meat products. The system has been delivered to precompetitive prototype stage.

Several unique selling points (USPs) of the COOLMEAT system have been established in comparison with cooling systems in use in the meat industry. These USPs are of paramount importance in assisting to
with cooling systems in use in the meat industry. These USPs are of paramount importance in assisting to push the results to the market, as well as in stimulating demand in the marketplace.

The main S&T elements of foreground consist in:

- A reduced cooling time in conjunction with energy savings as result of lower process times - this is a strong selling point for COOLMEAT. In terms of the cooling time, results with hams, both at laboratory and prototype scale, showed that although cooling times for IVC were higher than vacuum cooling as expected, they were approximately 40 - 50 % shorter than air blast, which is the usual cooling method used in industry for this type of products. Tests with ‘morcillas’ or products alike were performed only at laboratory scale, though experiments are currently being undertaken in DAZA facilities. Reductions in the cooling time of approximately 70 % were obtained at laboratory level when 'morcillas' were immersion vacuum cooled and compared to the traditional method used in end-user SME DAZA.
- The COOLMEAT technology reduces the weight loss of vacuum cooling technology by at least 50 %. The weight loss of immersion vacuum cooled hams is about 4 to 5 %, while for vacuum cooled samples weight loss ranges from 10 to 12 %. Thus, cool loss is remarkably lower than for vacuum cooling, and certainly still lower than for air blast (about 6 %).
- COOLMEAT technology is a safe time reducing cooling method that ensures no growth of pathogenic microorganisms (e.g. C. Perfringens). No growth of C. Perfringens was observed in hams with and without nitrite addition during cooling in the IVC prototype. Results showed that the fast cooling with the COOLMEAT IVC technology improves the safety of large pieces of meat with low amounts of preservatives added.
- Product quality of the cooked-cooled meat product is also an additional strong selling point for COOLMEAT. The overall results showed no significant differences between ham samples immersion vacuum cooled and samples cooled in a chilling room (air) for any of the texture attributes studied (e.g. firmness, juiciness, tenderness, stringy, crumble, chewing time). In addition, and with respect to the vitamin content, thiamine in particular, no difference was observed between the two cooling methods used. Thus, with COOLMEAT is possible to obtain a product of comparable quality properties to those cooled by the traditional method (air blast).
- Preliminary tests in industry with sausage type products cooled with the COOLMEAT technology are very promising so far, and SME partner DAZA is very satisfied and motivated by the work carried out and the results obtained up to now.
- The COOLMEAT IVC prototype is implemented with a precise control of the pressure reduction, so to avoid sudden and uncontrolled boiling and reduce the free space on top of the solution containing the cooked meat product to be cooled. This characteristic will differentiate the COOLMEAT system with respect to vacuum coolers commercially available, which lack this type of control. In addition, the location of the condenser inside the vacuum chamber is another special feature, since in many of the commercial vacuum coolers evaporation and condensations occur in different places, which is a concept adopted from freeze-dryers where this is justified to avoid back contamination.
- COOLMEAT is an affordable technology that allows simple installation and integration into existing meat plants as it was demonstrated during its installation in DAZA premises. This feature would aid a successful marketing strategy of COOLMEAT.
- Cost efficiency and price - The COOLMEAT system would be marketable at a cost in the region of EUR 27 500 - 30 000. There is no equivalent equipment available in the market, but an approximate estimation could be done if the basic structure is a simple commercial available unit, a vacuum cooler, to which it is...
could be done if the basic structure is a simple commercial available unit, a vacuum cooler, to which it is added the control system and complementary accessories to be operated as immersion vacuum cooler. For example, the cost of a simple vacuum cooler, that is, without agitation system, container for loading the food, and other accessories, with a volume capacity of 0.6 m³, which can only cool down to 3 °C is around EUR 18 000 - 22 300, FOB price (Table 3 of D1.1 'Industrial specifications'). This compares very favourable for the COOLMEAT IVC prototype, which has a volume capacity three times bigger, more powerful refrigeration capacity, agitation system, food container and loading facilities, and mainly, control of the pressure reduction (manual and automatic).

Potential impact:

The food industry is the main industrial sector within the EU-27. In particular, the processed meat market in Western Europe is worth EUR 117.3 billion, some 10.6 % of the overall food and drink market of EUR 1111 billion (European Commission, Enterprise and Industry, 2011). More than 800 companies are involved in this market across Europe, employing hundreds of thousands of people and contributing to the economy and rural sustainability of European regions. It is thus an SME intensive sector. Within the food industry, the meat industry is the main industrial sector in countries like Spain, generating around 20 % of the product sales and 23 % of total employment (Food for Thought, 2009).

There are numerous socio-economic impacts that will be derived from the results of this COOLMEAT research project. A clear vision about these impacts is important since they provide a core message for dissemination activities to industry, the general public, governments and policy makers.

Results of COOLMEAT showed great promise for delivering a leap in competitiveness and productivity for meat processing SMEs, European manufacturers and suppliers of cooling equipment. The meat producers will be in a position to respond to growing consumer demand for high quality cooked meat products and meals including these products. This presents a great contribution to safeguarding and creating employment as well as increasing transnational technological cooperation in the EU.

These positive aspects are backed up by the willingness of meat processors to invest in such a new technology and improvements and the level of investment they might be willing to consider (D1.1 Section 4.1.2). The COOLMEAT system would be marketable at a cost in the region of EUR 27 500 30 000. There is no equivalent equipment available in the market, but an approximate estimation could be done if the basic structure is a simple commercial available unit, a vacuum cooler, to which it is added the control system and complementary accessories to be operated as immersion vacuum cooler. For example, the cost of a simple vacuum cooler, that is, without agitation system, container for loading the food, and other accessories, with a volume capacity of 0.6 m³, which can only cool down to 3 °C is around EUR 18 000 - 22 300, FOB price. This compares very favourable for the COOLMEAT IVC prototype, which has a volume capacity three times bigger, more powerful refrigeration capacity, agitation system, food container and loading facilities, and mainly, control of the pressure reduction (manual and automatic).

COOLMEAT is easy to implement and to operate. From the online survey, onsite visits and in-depth consultations, it was found that in terms of integrating a system into their existing plants, meat processor would require a system that is easy to implement, easy to operate, and ideally would need to function seamlessly with their existing process and plant.
Seamlessly with their existing process and plant.

The contribution to improving European standards and compliance with EU guidelines will improve the quality of life, health and safety of European citizens as well as provide a high food protection. Furthermore, by virtue of their technological features, the COOLMEAT system could improve working conditions by moving away from time consuming cooling techniques. There are also environmental benefits associated with the COOLMEAT system, in relation to the context of the precise monitoring of the process, whereby energy consumption can be reduced or optimised.

Main dissemination and exploitation activities

The technical benefits of the COOLMEAT technology for the meat industry, by achieving improvements of the cooling rate (reduction in the cooling time) while safeguarding the quality and safety of the meat products, have served as basis for the dissemination and exploitation activities. As previously mentioned, COOLMEAT is expected to have significant impact on the meat industry, which is demanding of such improvements to fulfil strict EU guidelines that stipulate that cooked meat joints for delicatessen, catering and industrial use must be cooled within tight time limits post-cooking.

A great importance was given to the management of the intellectual properties rights generated and in agreement of the dissemination of non-confidential information throughout the project. A patent review was carried out and concluded that COOLMEAT does not infringe upon existing protected IP. In addition, the project developed significant know-how in terms of process conditions that can be exploitable by the SMEs.

Just at the end of the project, and after assessing the results obtained with the COOLMEAT technology, the SMEs could have a clear understanding of the foreground of the project, and enabled them to evaluate IPR issues and business plan.

End-users SMEs like Stephens and McCarren, which were interested in the cooling of ham products, and despite the very good results obtained in terms of cooling time reductions, considered as disadvantage the facts that the meat is not wrapped, and also the handling of water. On the other hand, DAZA was very motivated and interested in continue to validating the COOLMEAT technology, based on the very promising results obtained at lab scale. From the discussions as well as the expressed interests of the SMEs, the SMEs generally agreed to install the COOLMEAT IVC prototype in DAZA premises and furthermore, to transfer their ownership of the foreground to DAZA so they can use and exploit the foreground.

At the moment, DAZA is carrying out post-project development work and will continue to validate the COOLMEAT technology with their whole range of products, and evaluate then the several options for bringing the technology to the market.

Finally, successful dissemination activities have been carried out on the results and principles of the COOLMEAT technology through the project website and number of other activities raising the awareness of COOLMEAT both in industry and in the public domain and generating positive feedback. The results obtained in the COOLMEAT project have been promoted in an active dissemination strategy covering a
obtained in the COOLMEAT project have been promoted in an active dissemination strategy covering a broad range of media. The quantitative and qualitative indicators that were considered and the outcome at the end of the project are presented in D8.4 Final Plan for Use and Dissemination of the Foreground.

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