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FIELD TEST MONITORING OF THE FOOD COLD CHAIN IN EUROPEAN MARKETS

E. Gogou^{a*}, E. Derens^b, G. Alvarez^b and P. Taoukis^a

^a *National Technical University of Athens, School of Chemical Engineering, Laboratory of Food Chemistry and Technology, Iroon Polytechniou 5, 15780 Athens, Greece, fax: +302107723163, e-mail:*

egogou@chemeng.ntua.gr

^b *National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), Antony, France*

ABSTRACT

Monitoring the cold chain can serve as a tool to evaluate the food supply chain and estimate the quality of food products at different stages of the cold chain based on realistic scenarios. The objective of this work was to conduct two focused field tests in Greece and France for selected chilled meat products. According to the field test design miniature electronic data loggers were incorporated in 580 food products in total at the production line and entered the typical cold chain from production to consumer domestic refrigerator. The retrieved field test data loggers were used to assess temperature throughout the cold chain stages. The results of the specific study can be used in order to evaluate the real cold chain of chilled meat products in Europe. The retrieved temperature profiles have been used to expand the publically available Cold Chain Database (www.frisbee-project.eu/coldchaindb).

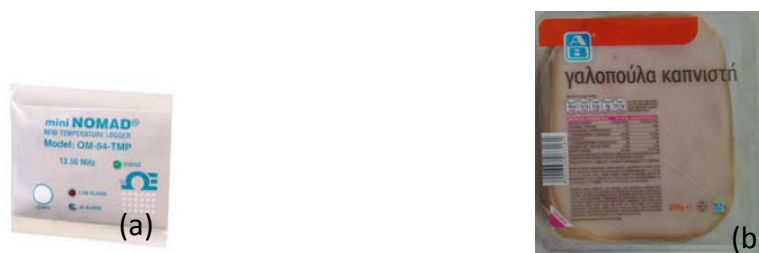
1. INTRODUCTION

The main shelf-life determining post-processing parameter in the cold chain of chilled and frozen food products is temperature (Evans, 1992; Giannakourou and Taoukis, 2002). A modern quality and safety assurance system should rely on prevention through monitoring, recording and controlling of critical parameters during the entire product's life cycle that includes the post-processing phase and extends to the time of use by the final consumer (Evans et al., 1991; Giannakourou et al., 2001; Dubelaar et al., 2001; Giannakourou and Taoukis 2002; Kennedy et al., 2005; Koutsoumanis et al., 2002; Koutsoumanis et al., 2005). Increasing attention should be focused on the role and the logistics of transport, storage and handling, and the benefits of taking a supply chain perspective are being appreciated and pursued. Temperature conditions in the chilled distribution chain (Broekmeulen, 2001) determine the risk potential, the shelf life and final quality of chilled products. Significant deviations from specified conditions may potentially occur; thus temperature variability has to be taken into account for cold chain control and any logistics management system that aims on product quality optimization at the consumer's end (Likar and Jevsnik. 2006; Giannakourou and Taoukis, 2002).

2. MATERIALS & METHODS

2.1 Field test conducted in Greece

The field test in Greece was conducted in collaboration with a Greek meat producer and one of the biggest retailers in Greece. The field test was performed by inserting data loggers inside the food packages invisible to people involved in the supply chain and the consumers. The selected food product was vacuum packed smoked turkey slices with a shelf life of 2 months. According to the field test design, miniature electronic data loggers (miniNOMAD, OM-84-TMP, Omega Engineering Inc., Stamford, USA) were incorporated inside packages of vacuum packed smoked turkey slices (Picture 1) at the production stage. The field test in Greece was conducted in two timeframes with the goal to screen temperature conditions in the food supply chain in two different seasons throughout the year. The first field test was conducted in June-July (2012) and the second one in October-November (2012).



Picture 1. (a) Data logger inserted in the food package in order to record time-temperature data of the cold chain and (b) vacuum packed smoked turkey slices package used in the field test conducted in Greece.

The specific meat products have a double package. An outside plastic transparent container within which the slices are placed vacuum packed (skin packed) in a second film. The packs containing the logger did not differ from the regular products and were picked randomly by the consumers. The food packages containing the data loggers also contained a notice card informing the consumers about the conducted study and asking them to return the data logger they discovered at the point of purchase. The selected food products were distributed to 24 retail stores all over Greece. The loggers were returned by the consumers to the customer service at the point of purchase. Consumers returning the logger were awarded with a free product like the one they purchased and contained the logger.

Food products containing the data loggers entered the typical retailer's supply chain. The retailer's supply chain consists of two distribution warehouses located in two different cities, serving as distribution centres for the supermarket stores located in the south and north part of Greece, respectively. Products containing the data loggers were distributed in 12 cities (including 2 islands) in 24 supermarket stores in total.

2.2 Field test conducted in France

The field test in France was conducted in collaboration with a French distributor who collaborated with one of his own ham manufacturers. The field test was performed by placing data loggers between two batches of 4 slices of ham and invisible to the people involved in the supply chain and to the consumers. The selected food product was modified atmosphere packaged (MAP) cooked ham slices. According to the field design, miniature electronic data loggers (miniNOMAD, OM-84-TMP, Omega Engineering Inc., Stamford, USA) were incorporated between packages of MAP cooked ham slices (Picture 2) at the production stage. The field test was conducted in the time period of November-December (2012).



Picture 2. (a) Data logger inserted in the food package in order to record time-temperature data of the cold chain and (b) MAP cooked ham slices package used in the field test conducted in France.

The field test was designed and conducted successfully with 223 data loggers inserted in 223 2-pack cooked ham during the production line (Picture 2). The food packages containing the data loggers also contained a notice card informing the consumers about the conducted study and asking them to mail back the data logger. Consumers returning the logger are awarded a voucher of 5 Euros.

Food products containing the data loggers entered the typical retailer's supply chain. The retailer's supply chain consists of two different alternative supply chains depending on the type/size of the retail outlet; products are promoted either to hypermarket stores or supermarket stores. Products promoted to hypermarket stores were distributed via the hypermarket distribution platform while products promoted to supermarkets were directed to the supermarket distribution platform. Products containing the data loggers were distributed in 24 supermarket/hypermarket stores in total.

The data loggers recorded temperature with a frequency of 10 min and were calibrated at three reference temperatures; 0 ,10 and 20°C, prior to use.

3. RESULTS & DISCUSSION

The return rate for the field test conducted in Greece was approximately 40%. The collected data were further analyzed in order to distinguish the cold chain stages and assess the temperature range recorded at the different steps of fresh meat products distribution. All time-temperature data from the received loggers were further used to perform a statistical analysis. Through the statistical analysis the distribution curves of temperature throughout all the cold chain stages were constructed.

The retrieved data loggers were used to download the time-temperature data collected during the field tests. In Figure 1 representative time-temperature profile of the complete cold chain in Greece is depicted. All retrieved time-temperature profiles were further analyzed along with available retailer's logistic information in order to distinguish the different successive cold chain stages. The cold chain consisted of the following 8 stages:

1. Production
2. Transportation to the distribution centre
3. Distribution centre
4. Transportation to the supermarket
5. Supermarket warehouse
6. Supermarket display
7. Transportation by the consumer
8. Consumer domestic refrigerator

The successive cold chains as distinguished for one typical retrieved time-temperature profile are depicted in Figure 1.

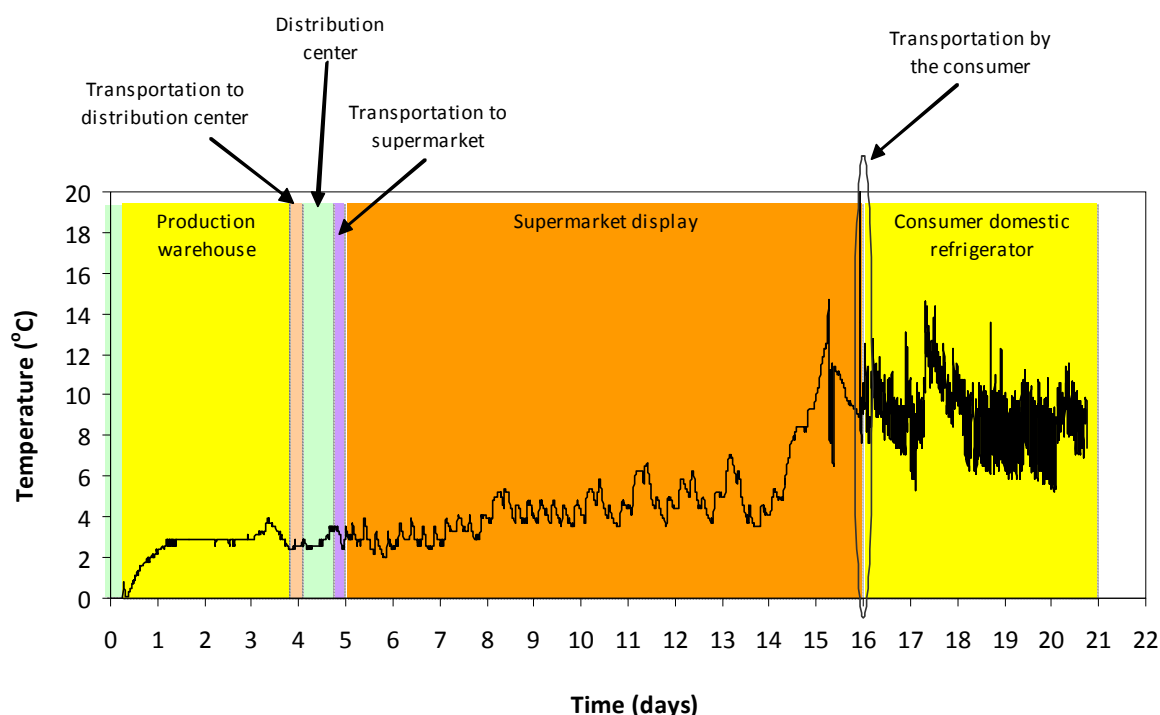


Figure 1. Typical retrieved time-temperature profile consisted of 8 successive steps of the cold chain in Greece of vacuum packed smoked turkey slices products.

As expected some fluctuations were observed throughout the cold chain stages, however differences between the different cold chain stages were also observed. Temperature data recorded during the stage of transporting the food products from the production site to the distribution centre was quite consistent with temperatures ranging mainly from 2 to 5°C. On the other hand temperatures recorded during the transportation stage from the distribution warehouse to supermarket stores showed greater variability with

broader temperature fluctuations. Although, temperatures reaching even 8°C were observed these conditions were rather short in duration. The variability in the recorded temperature profiles between different destinations can be mainly attributed to different transporting tracks used and different duration of transport. Food products containing the data loggers were mainly stored either at chilled vertical open front display cabinets or chilled horizontal serve-over open display cabinets as depicted, respectively. Table 1 summarizes the mean temperature and duration time in the complete cold chain and in the different steps based on all temperature data recorded during the field test conducted in Greece.

Table 1. Mean temperature of the temperature profiles retrieved within field test in Greece.

Cold chain stage	Mean temperature (°C)	Duration (days)
Production/Production warehouse	3.4±0.4	2.7
Transportation	3.9±1.2	0.4
Distribution warehouse	3.8±1.5	1.9
Supermarket	4.0±2.7	22.4
Transportation by the consumer	9.8±3.1	0.02 (48 min)
Domestic refrigerator	6.8±2.3	16

A typical time-temperature profile retrieved from the field test conducted in France is presented in Figure 2. The different cold chain steps that were recognized were:

1. Production
2. Refrigerated transport
3. Logistic platform storage
4. Transportation retail store cold room
5. Cold room in the retail store
6. Refrigerated display cabinet
7. Transportation by the consumer
8. Consumer domestic refrigerator

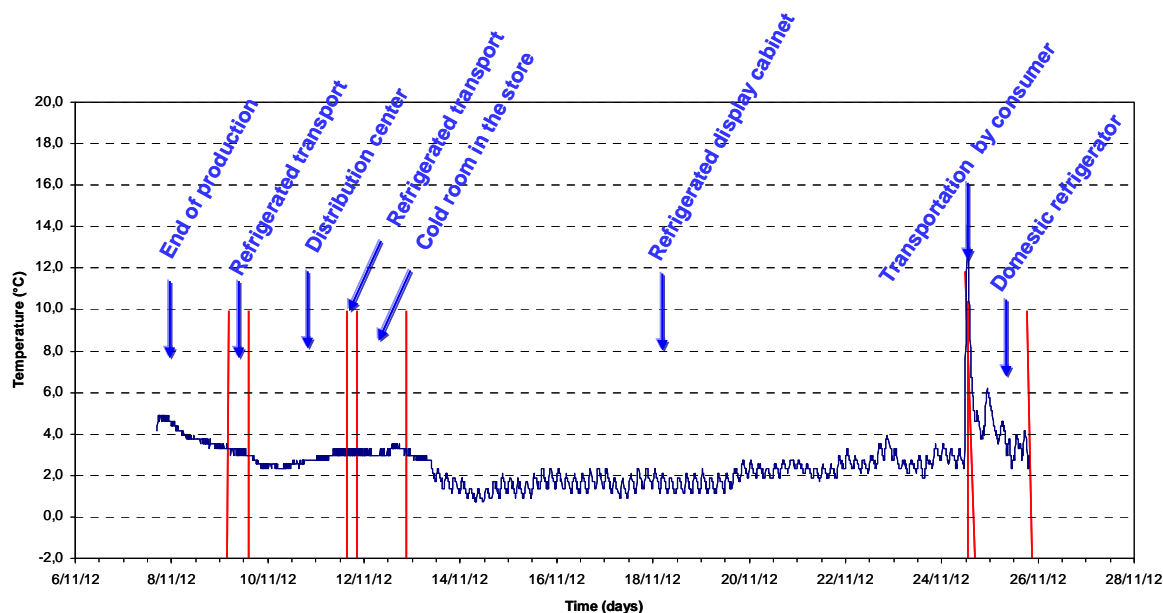


Figure 2. Example of time-temperature profile obtained for a product and interpretation of various steps of the cold chain in France.

It must be pointed out that 89.1% of the retrieved data loggers have gone through hypermarkets, 8.9% through supermarkets and one through internet purchase (its logistic system is different; it doesn't pass by a conventional store, but a distribution specialist in online retailing).

The mean product temperature from production until consumption was calculated for each collected time-temperature profile depicted in Table 2. It can be seen that the mean value is 3.8°C, with a minimum of 1.2°C to a maximum of 9.6°C. 58% of products were kept at a temperature at or below 4°C throughout the complete cold chain.

Table 2. Mean temperature of the temperature profiles retrieved within FRISBEE field test in France.

Cold chain stage	Mean temperature (°C)	Duration (days)
Entire cold chain	3,8 ± 1,3	14
Refrigerated transport	2,4 ± 0,7	0.3
Distribution centre	2,5 ± 0,6	2.1
Cold room in store	2,6 ± 0,9	1.3
Refrigerated display cabinets	2,8 ± 1,2	3.6
Transportation by consumer	6,5 ± 2,8	0.05 (1.2 hours)
Domestic refrigerator	6,3 ± 2,2	6.3

Regulatory services during their checks often take a margin of $\pm 2^{\circ}\text{C}$ that forms a "safety interval", taking into account the measurement uncertainties. Based on this concept and based on our observations, only 4% of the mean temperatures are upper 6°C (Figure 3), which means that only 4% of the products have been kept under abusive temperature conditions.

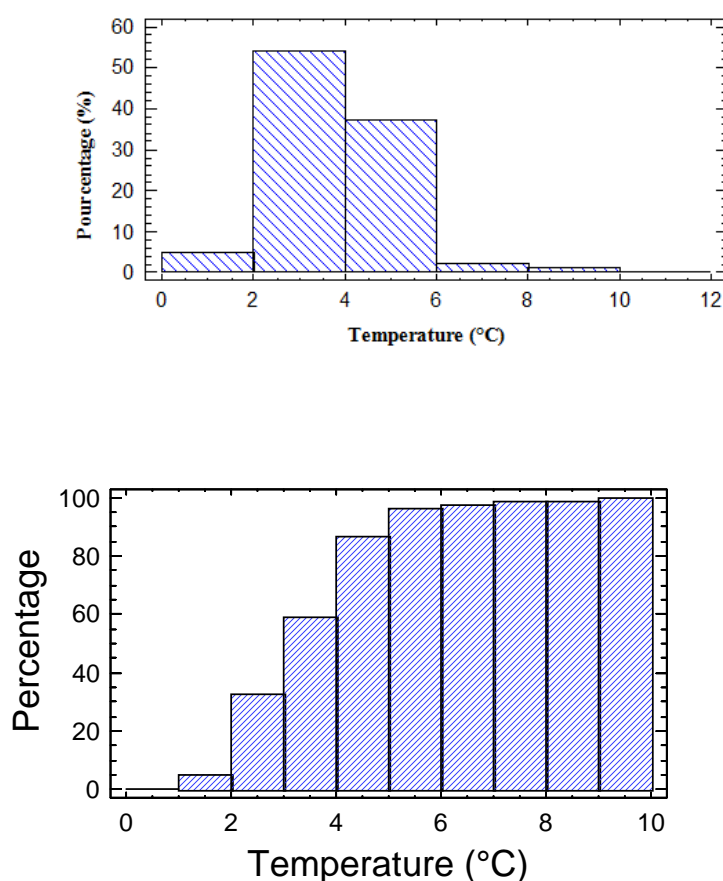


Figure 3. Distribution of mean temperatures recorded taking into account the complete cold chain in France.

All time-temperature profiles retrieved from the two field tests; in Greece and in France have been uploaded to the Cold Chain Database. The Cold Chain Database has been developed in the framework of FRISBEE Project and is publically available in the link: www.frisbee-project.eu/coldchaindb.

4. CONCLUSION

The overall results of the conducted field tests in Greece and France can serve as reference cold chain conditions for chilled meat products in Europe. According to the recorded temperature profiles the mean temperature of the complete cold chain of meat products in Europe is ranging between 3.5 and 5°C. Sharp fluctuations of temperature reaching even 10°C were only observed at the stage of transportation by the consumers. Although these fluctuations reached quite abusive temperatures the duration was rather small ranging from a few minutes to maximum 1.2 hours. Another, very important conclusion is that the weakest link in the cold chain is actually the final stage of domestic storage.

5. ACKNOWLEDGEMENTS

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