COLD CHAIN EVALUATION AND MANAGEMENT USING FRISBEE PROJECT PREDICTION TOOLS

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INTRODUCTION

The main shelf-life determining post-processing parameter in the cold chain of chilled and frozen food products is temperature (Evans, 1992; James and Evans, 1992 a,b ; Giannakourou and Taoukis, 2003). 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 (Giannakourou 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 processed and packed under Good Manufacturing Practices and Good Hygiene Practices (Tijkens et al., 2001). Since in practice significant deviations from specified conditions often occur, 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). The development of a Cold Chain Database web-based tool could significantly contribute to the determination of the weak links of the cold chain for a significant number of food products. Stage and product specific t-T information can be used for the quantitative description of cold chains within the FRISBEE project. The contributed data of the cold chain will allow simulation of realistic cold chain scenarios based on actual cold chain data and can lead to corrective actions aimed to optimizing efficiency and commercial shelf-life.

MATERIALS AND METHODS

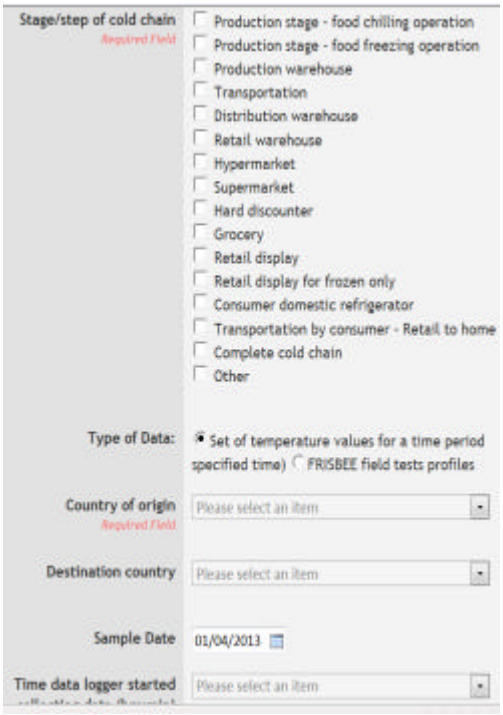
A systematic data collection for identification and evaluation of the weak links of the cold chain for different types of chilled and frozen products was performed. Within European FRISBEE project (Food Refrigeration Innovations for Safety, consumers Benefit, Environmental impact and Energy optimisation along the cold chain in Europe), a web-based platform (hosted in the link **http://www.frisbee-project.eu/coldchaindb.html**) has been built for t-T data collection, maximizing

information retrieval with user friendliness. Priority was/is the collection of as much data as possible. However, the data collection process should maximize information retrieval combined with user friendliness. A menu driven web-based questionnaire accompanies or incorporates the basic information that in all cases has the form of t-T data. Additionally, some basic information apart from t-T profile should be specified to the extent it is available by the data provider such as the type of food product, the packaging, the recommended storage conditions, the stage (step) of the cold chain, geographical and seasonal information, information concerning the storage and distribution equipment, specifications of data collecting equipment, the position of the data collecting equipment and the format the contributed data should have. The processing of these data addresses the needs of the FRISBEE project and the needs of the users. Therefore, the web-based database provides information (output) useful and usable for the users (including data providers and ultimately European researchers, regulators, industry and even the consumer). In the developed Cold Chain Database, all contributed t-T profiles were organized. In this platform, all t-T files were correlated to the meta-data of the original contributed t-T profile. The web-based platform was developed in order to organize input and provide easy and systematic access the contributed information. Application of an effective tool as a reliable predictive system of the shelf life of the product at any point of its marketing route would benefit food industries and retailers. The FRISBEE Cold Chain Predictor (FRISBEE_CCP) software was developed to give the users the ability to calculate the remaining shelf life of a specific food product at different stages of the cold chain corresponding to a representative t-T profile built from a sequence of cold chain stages.

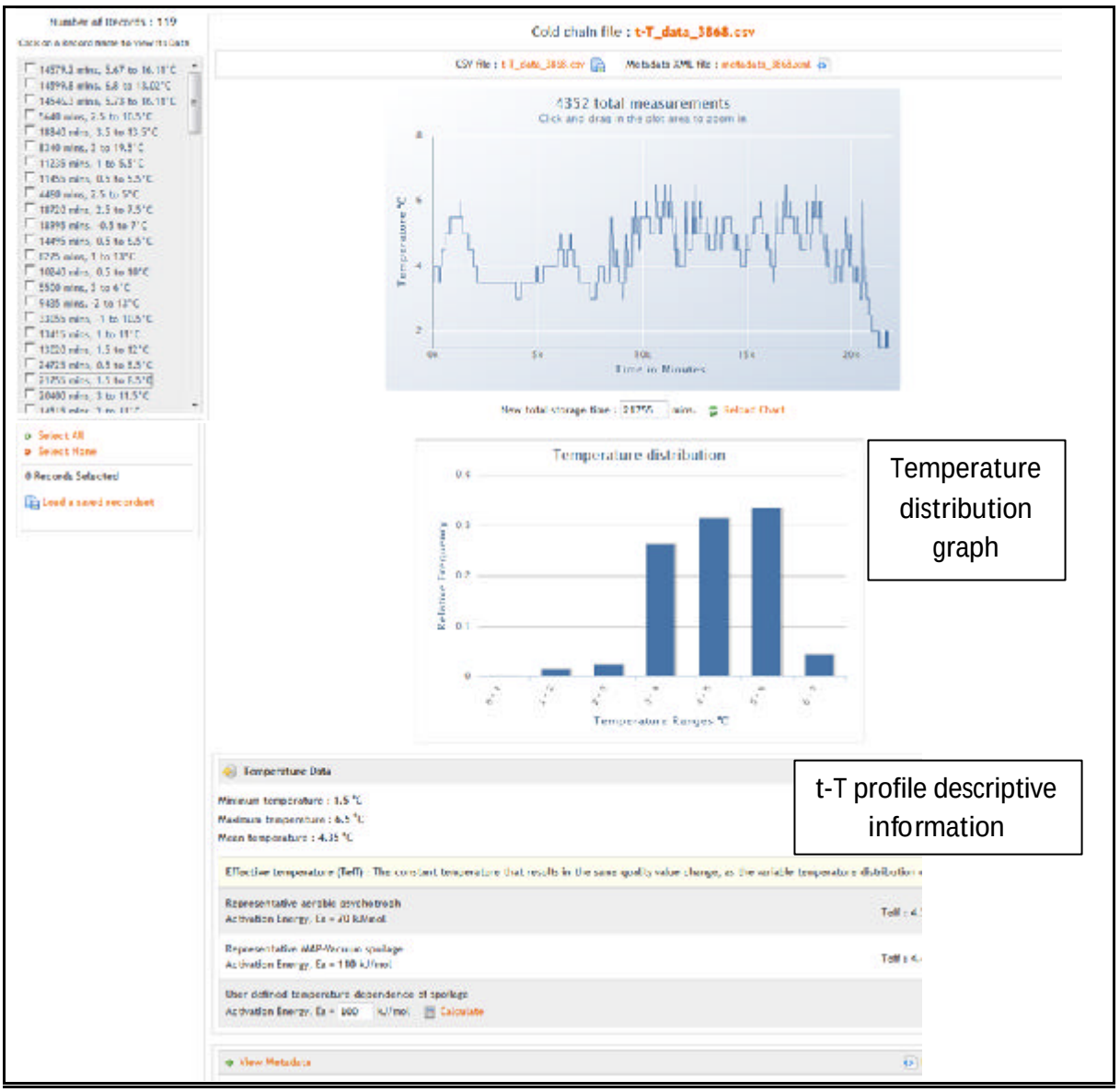
RESULTS

Cold Chain Data Collection Platform

In the Data Collection platform (Picture 1), data from industry, cold chain parties (distributors, retailers) and consumer surveys, including all stages of the cold chain (from production to consumption) are continuously collected. All contributors have privileged access to this database (by login and password) and the access to the database is secured. This platform consists of a menu driven web-based software retrieving information to accompany the contributed food product t-T data. During on-line data submission, it may be mentioned whether the data are confidential or not. Any input will be valuable in building a comprehensive and extensive database which will serve as a valuable tool to people and organizations that have contributed and are involved in the Cold Chain as researchers or industrial players. All received data were further processed in such a way that the output of the web-based database includes (Picture 2) the Actual t-T profiles, mean, min and max value of temperature for the whole t-T profile and the Effective temperature of the t-T profile: the constant temperature that results in the same quality value as the variable temperature distribution over the same time period.



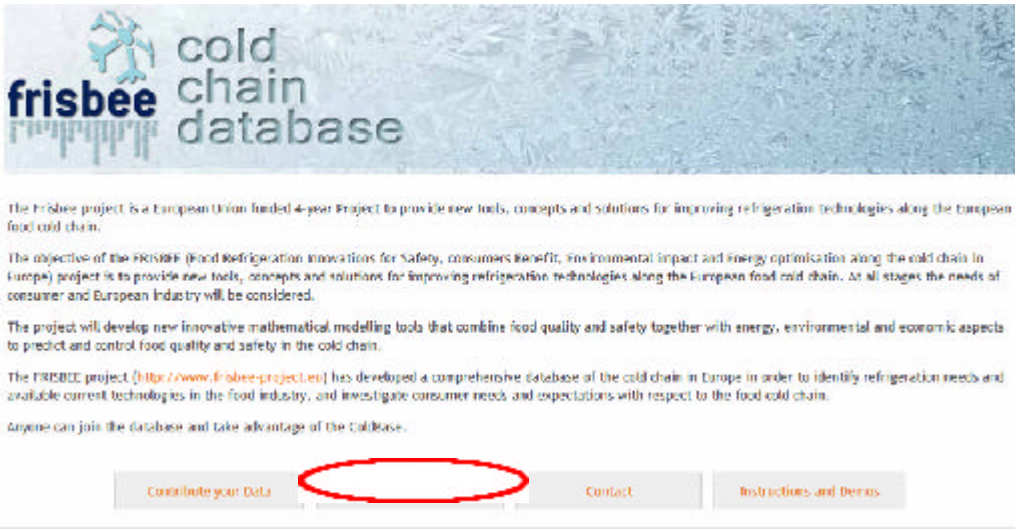
Picture 1. FRISBEE Cold Chain Data Collection Platform



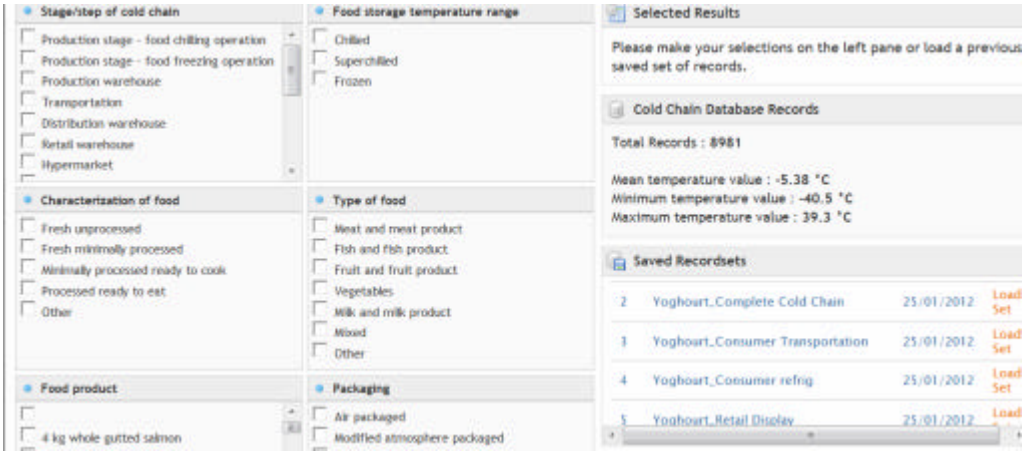
Picture 2. Description of the Cold Chain Data Collection Platform output

Cold Chain Database

Cold Chain Database (hosted in the link **http://www.frisbee-project.eu/coldchaindb.html**) (Picture 3) has been constructed in order to develop a user friendly on line platform where collected data from all cold chain stages (Data collected in the Cold Chain Data Collection Platform) can be retrievable and available to be used from candidate users (consortium members, beneficiary members, industry and research institutes). One is able to retrieve t-T profiles of specific products along the cold chain using search criteria such as Stage/step of the cold chain, Food storage temperature range, Characterization of food, Food product etc. Up to now the Cold Chain Database consists of approximately 9000 t-T profiles and is being continuously updated with new data uploaded from an expanding network of contributors. In this database, the user can build a specific sequence of cold chain stages for specific food product based on user defined search criteria (Picture 4).



Picture 3. Cold Chain Database web site (**http://www.frisbee-project.eu/coldchaindb.html**)



Picture 4. Cold Chain Database web site where the user can select the "Build Cold Chain" application.

Cold Chain Predictor Software

Cold Chain Predictor (v1.1) is a software tool designed in the framework of FRISBEE project. The purpose of this tool is to simulate a cold chain by building a t-T history from the contributed profiles. This tool is based on nearly 9000 t-T profiles obtained for different food products along the European cold chain. The FRISBEE Cold Chain Predictor (FRISBEE_CCP), software developed within FRISBEE objectives, allows the user to estimate the distribution graph of (effective) temperature for a specific stage of a

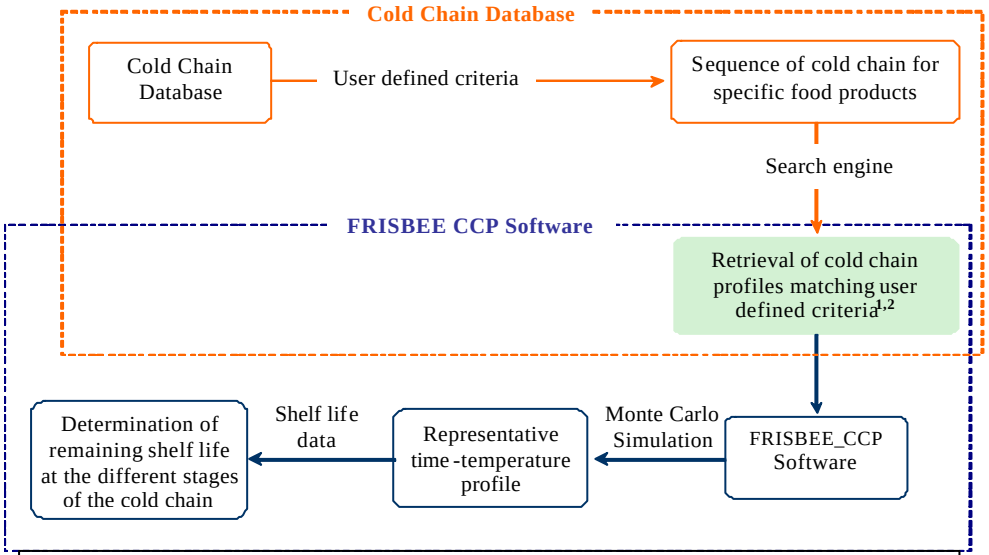
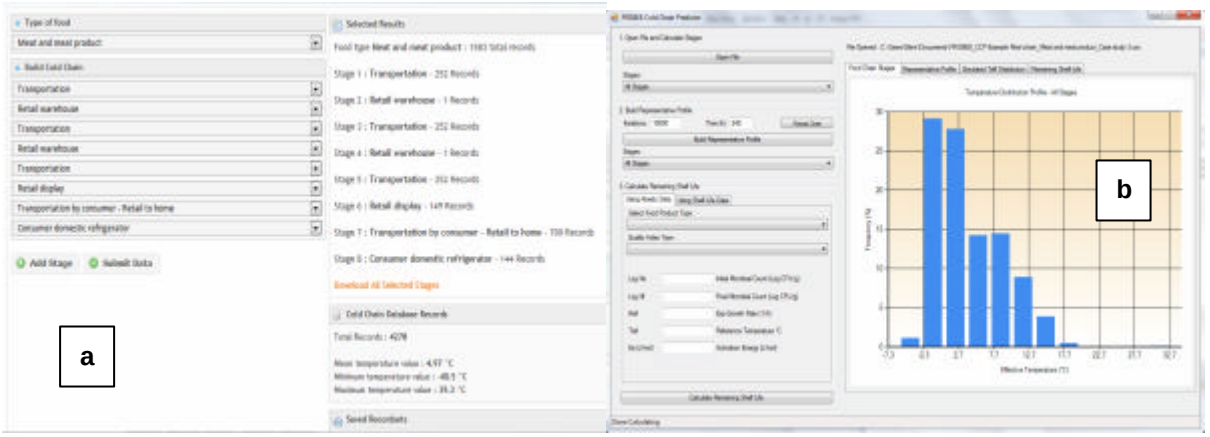
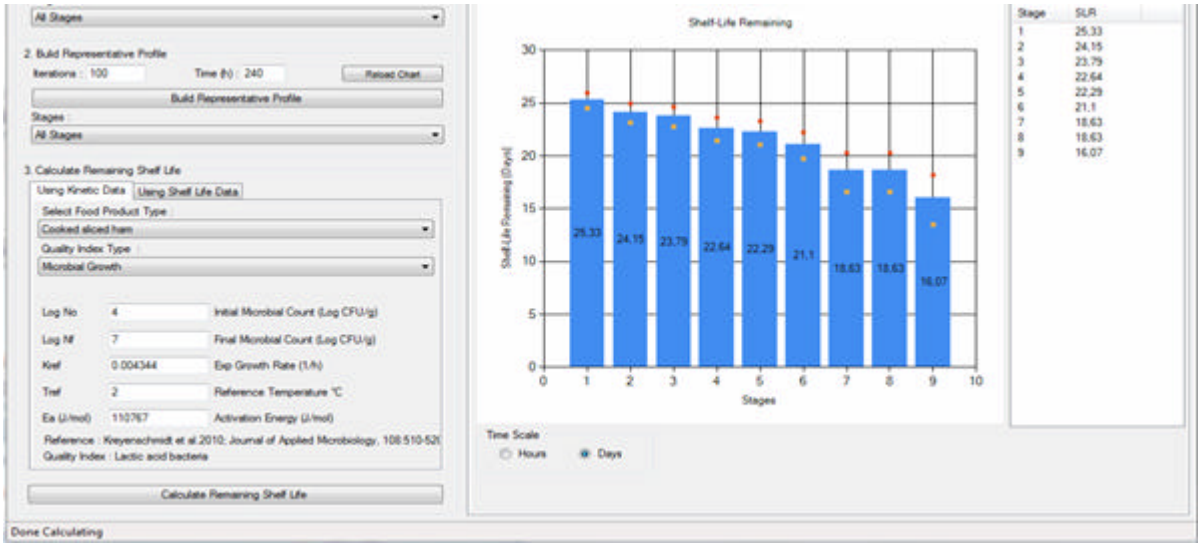


Figure 1. Illustration of FRISBEE_CCP Software - Building of Representative Profile

selected food product (Picture 5) and to calculate the remaining shelf life of the food product at different stages of the cold chain (Picture 6), if quality decay data are known (Figure 1).



Picture 5. (a) Build of a sequence of cold chain stages for meat products and **(b)** determination of the representative profile and temperature distribution for all stages (example).



Picture 6. Calculated remaining shelf life of meat product at each stage of the cold chain based on a built representative profile using kinetic data (example).

Cold Chain Management

The main objectives the FRISBEE project may be summarized in Figure 2. A Cold Chain Data Collection Platform was developed to collect t-T profiles. The generated and continuously enriched Cold Chain Database allows for collected data retrieval based on user defined search criteria. Using multiple real data from the database realistic representative sequences of user defined cold chain stages may be built. The FRISBE Cold Chain Predictor (FRISBEE CCP) software was designed to reproduce by Monte Carlo simulation the most likely time/temperature distribution for each defined stage of the cold chain and to estimate for a selected food product, going through the cold chain, the remaining shelf-life after each individual stage. Overall useful information from the Cold Chain Database may be retrieved and used to run realistic scenaria for the behaviour of food products along the cold chain avoiding costly and time-consuming field tests. The FRISBEE CCP offers thus the potential to effectively manage and improve cold chain weak links using appropriate shelf-life decision systems leading to an optimized handling of products in terms of both safety and quality. Using this tool, one can efficiently manage the food cold chain and undertake corrective actions at predetermined important stages of the cold chain. This could result in significant increase of the remaining shelf-life at the end of the cold chain.

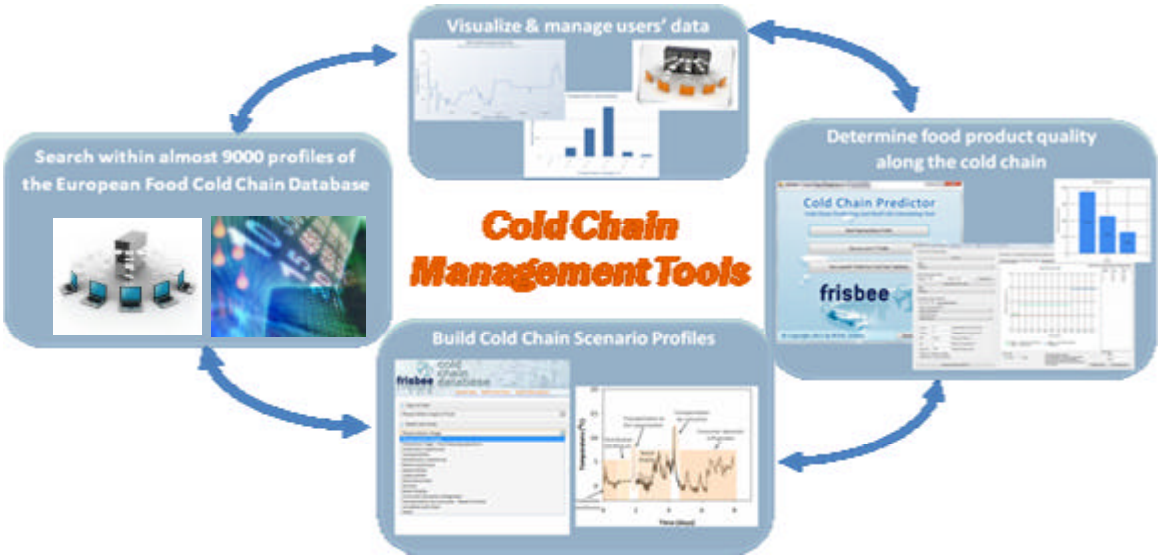


Figure 2. Summarized FRISBEE objectives for the Cold Chain Management

Conclusions

Development and application of the European cold chain database as a tool for food products cold chain management has been described. The aim is the estimation of the remaining shelf-life of food products after each stage of the cold chain, based on a large number of t-T profiles available in the database and retrievable based on user defined criteria. Simulations of alternative distribution scenarios based on real cold chain data can be executed based on which corrective actions could be applied on the important stages for maximizing remaining shelf-life.

ACKNOWLEDGEMENT

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