COLD CHAIN DATABASE

&

COLD CHAIN PREDICTOR SOFTWARE (v1.1)

USER INSTRUCTIONS

CONTENTS

1. INTRODUCTION

FRISBEE PROJECT

The **Frisbee Project** is a European Union funded 4-year Project (http://www.frisbee-project.eu). The objective of FRISBEE (Food Refrigeration Innovations for Safety, consumers' Benefit, Environmental impact and Energy optimisation along the cold chain in Europe) is to provide new tools, concepts and solutions for improving refrigeration technologies along the European food cold chain. At all stages the needs of consumer and European industry will be considered. The project will develop new innovative mathematical modelling tools that combine food quality and safety together with energy, environmental and economic aspects to predict and control food quality and safety in the cold chain.

COLD CHAIN DATABASE

Cold Chain Database has been developed by a systematic data collection for the purpose of identification and evaluation of the weak links in the cold chain for different types of chilled and frozen products. Data collection was achieved in the FRISBEE project framework within the Cold Chain Data Collection Platform (http://frisbee-wp2.chemeng.ntua.gr/). The Cold Chain Database (hosted in the link http://www.frisbee-project.eu/coldchaindb.html) was 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 time-Temperature 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.

COLD CHAIN PREDICTOR SOFTWARE

Cold Chain Predictor is a software tool designed by IRSTEA (National Research Institute of Science and Technology for Environment and Agriculture, former CEMAGREF) and NTUA (National Technical University of Athens) in the framework of FRISBEE project. The purpose of this tool is to reproduce a time/temperature history by simulating a cold chain. This tool is based on nearly 9000 time temperature profiles obtained for different food products along the European cold chain. The profiles have been contributed by FRISBEE consortium members, beneficiary members, industry and research institutes to the Cold Chain Database.

2. Cold Chain Database User Instructions

2.1 Introduction

Cold Chain Database was constructed in order to develop a user friendly on line platform where collected data from all cold chain stages can be retrievable and available to be used from candidate users (consortium members, beneficiary members, industry and research institutes). Furthermore, another Cold Chain Database application is the ability of building cold chain scenarios according to user defined successive steps of the food cold chain.

2.2 Levels of access to the Cold Chain Database

There are three levels of access to the Cold Chain Database depending on the number of cold chain data records the user can have access to (Table 1).

Table 1. Description of the three levels of access to the Cold Chain Database.

Access Level	Description	Cold chain data records	User Profile
1	Access to the Cold Chain Database Demo version	✓ 92 representative files of cold chain data (Distribution Warehouse for chilled processed, ready to eat milk products) ✓ Demo access to the "Build Cold Chain" appication	New Users or already signed Users of the Cold Chain Data Collection platform that haven't contributed any records (so far).
2	Access to the Cold Chain Database Demo version & user's contributed data.	✓ 92 represetnative files of cold chain data (Distribution Warehouse for chilled processed, ready to eat milk products) ✓ All data that the user has already contributed to the Cold Chain Data Collection platform. ✓ Demo access to the "Build Cold Chain" appication	Users-Contributors of the Cold Chain Data Collection platform http://frisbee-wp2.chemeng.ntua.gr/
3	Full access to the Cold Chain Database.	All files of cold chain data that have been collected. So far the Database comprises 9000 records (May 2013). The Database will be continuously updated.	▪ ***Consortium Members*** free access to see + licence for use + no transfer allowed + condition of mention of the co-owners ▪ ***Academic research use*** free access for research activity – activity exclusive of commercial or industrial use + no transfer allowed + condition of share of any derivation and mention of the co-owners ▪ ***Commercial or industrial use*** Licence for use (conditions to be settled between the co-owners)

2.3 Cold Chain Database

2.3.1 Enter the Cold Chain Database

In order to enter the Cold Chain Database web based platform the user should visit the following URL: http://www.frisbee-project.eu/coldchaindb.html

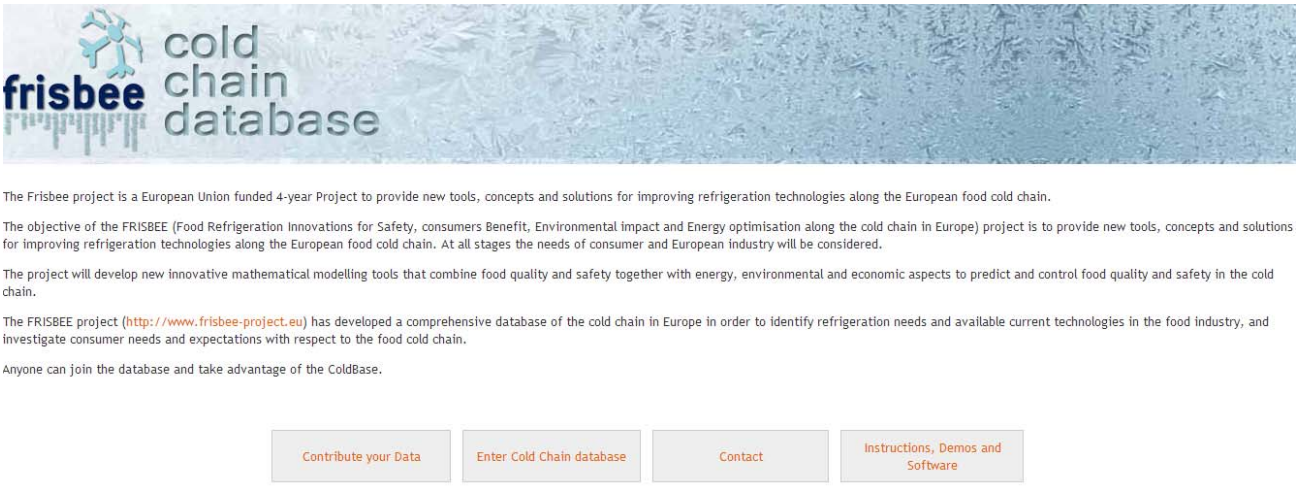


Figure 1. Introductory screen of the Cold Chain Database.

Click on the **Enter Cold Chain Database** button. This will lead you to the Login Window.

2.3.2 Login to the Cold Chain Database

- ***Cold Chain Data Collection Users***

  Use your Login details (username and password) that you have created for the Cold Chain Data Collection (http://frisbee-wp2.chemeng.ntua.gr/). If you do not remember your account details contact at frisbee@chemeng.ntua.gr for receiving your username and password.

- ***New Users***

  If you do not already have an account you can create a new one by pressing on the "**Create a new account**" field. You will be directly transferred to the Login screen (Figure 2).

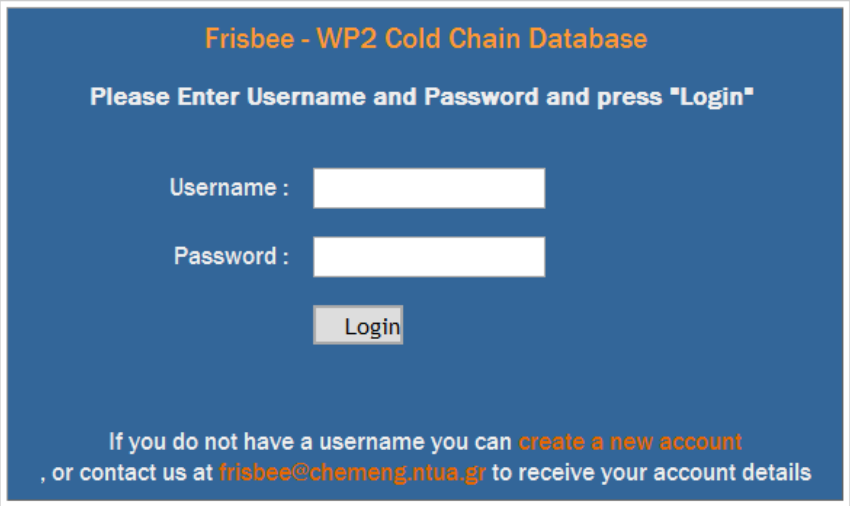


Figure 2. FRISBEE Cold Chain Database login window.

As soon as you create a login account you can enter the Cold Chain Database and use it according to the following instructions.

In the link http://www.frisbee-project.eu/coldchaindb.html, in the introductory screen use your login details in the field **Enter Cold Chain Database**

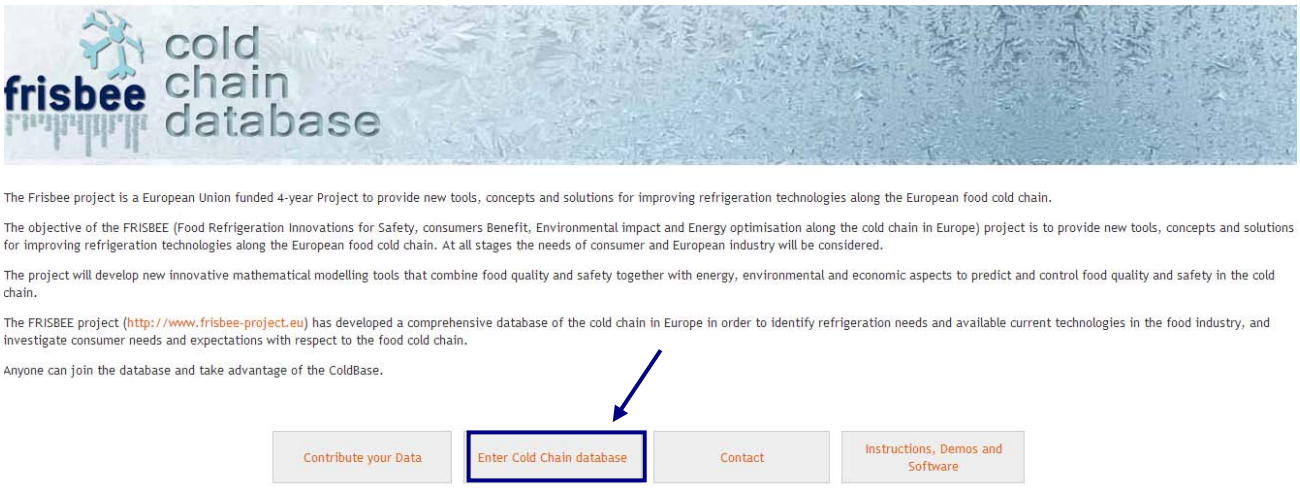


Figure 3. Introductory screen of the Cold Chain Database: Entering the Cold Chain Database

2.3.3 How to use the Cold Chain Database-Access Level 1 (Demo version)

2.3.3.1 Search within the database time-temperature profiles

In the Demo version of Cold Chain Database the user has access to 92 data records. The left pane of search criteria is actually inactive; the search criteria are already predetermined and are the following (see also Figure 4):

Stage/Step of cold chain: Distribution warehouse

Food storage temperature range: Chilled

Characterization of food: Processed ready to eat

Type of food: Milk and milk product

The user can also see the number of records matching those predetermined criteria and the corresponding descriptive statistics (mean, minimum and maximum temperature).

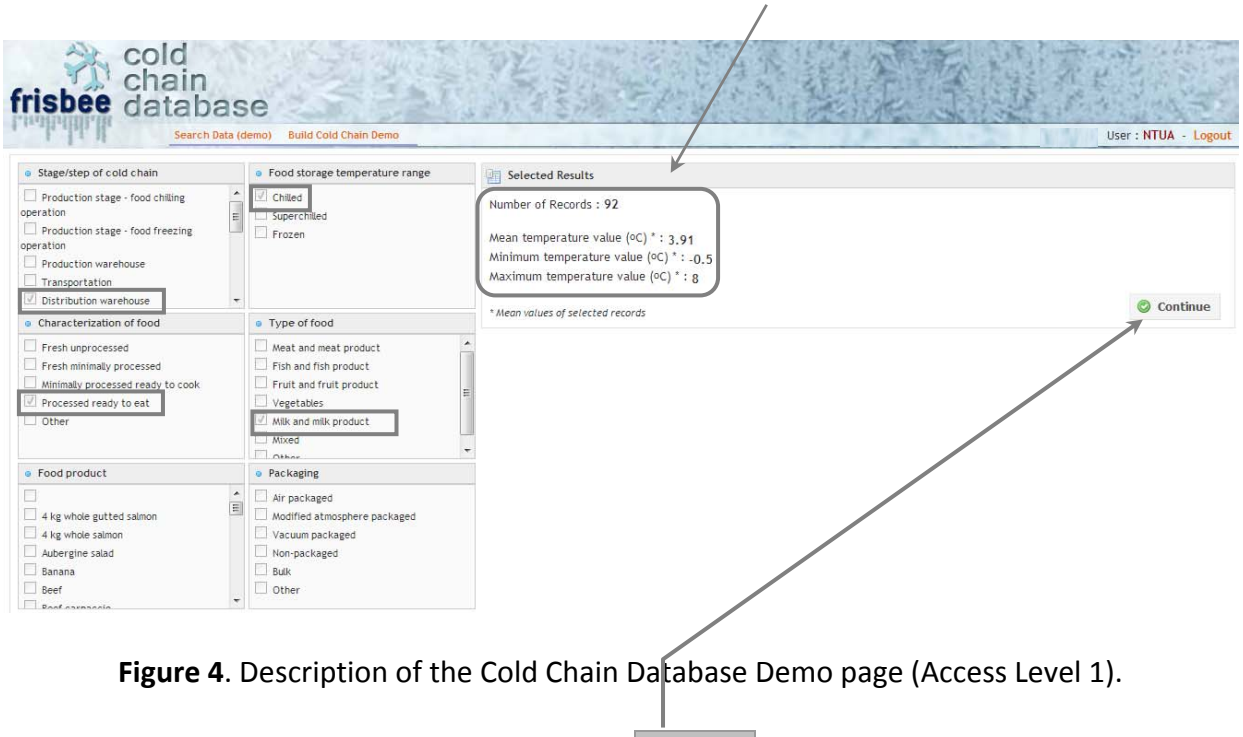


Figure 4. Description of the Cold Chain Database Demo page (Access Level 1).

In order to access the data records click on the Continue button and follow the instructions in **Section 2.3.4.1 Search within the database time-temperature profiles.**

2.3.3.2 Use the "Build Cold Chain" application

The "Build Cold Chain" application is embedded in the Cold Chain Database in order to serve as a toll to build "what if" scenario of the food cold chain. This tool enables the user to build a cold chain scenario consisting of different successive cold chain stages. As long as the user selects the successive cold chain stages, the application is retrieving all time-temperature profiles that exist in the database matching the specified cold chain scenario. The retrieved data are gathered in a .csv file (works in Excel, Microsoft) and can be further used by the Software: FRISBEE Cold Chain Predictor Software.

The Cold Chain Database-Access Level 1 users have limited access to the "Build Cold Chain" application. In order to upgrade their account and have full access to the "Build Cold Chain" application users need to join forces and contribute to the Cold Chain Database by uploading temperature data concerning any stage of the food cold chain. **As soon as you contribute data your account will be eligible to be upgraded!**

Instructions in using the "Build Cold Chain" application in conjuction with the Cold Chain Predictor Software can be found in **Section 3.3.1 FRISBEE CCP Software-Option 1: Build Representative Profile**

2.3.4 How to use the Cold Chain Database-Access Level 2

2.3.4.1 Search within the database time-temperature profiles

Users with an Access Level 2 can either search within all data contribute to the database or work with the their own (already) submitted data by clicking on the corresponding fields as illustrated in the following figure as Option 1 and 2, respectively.

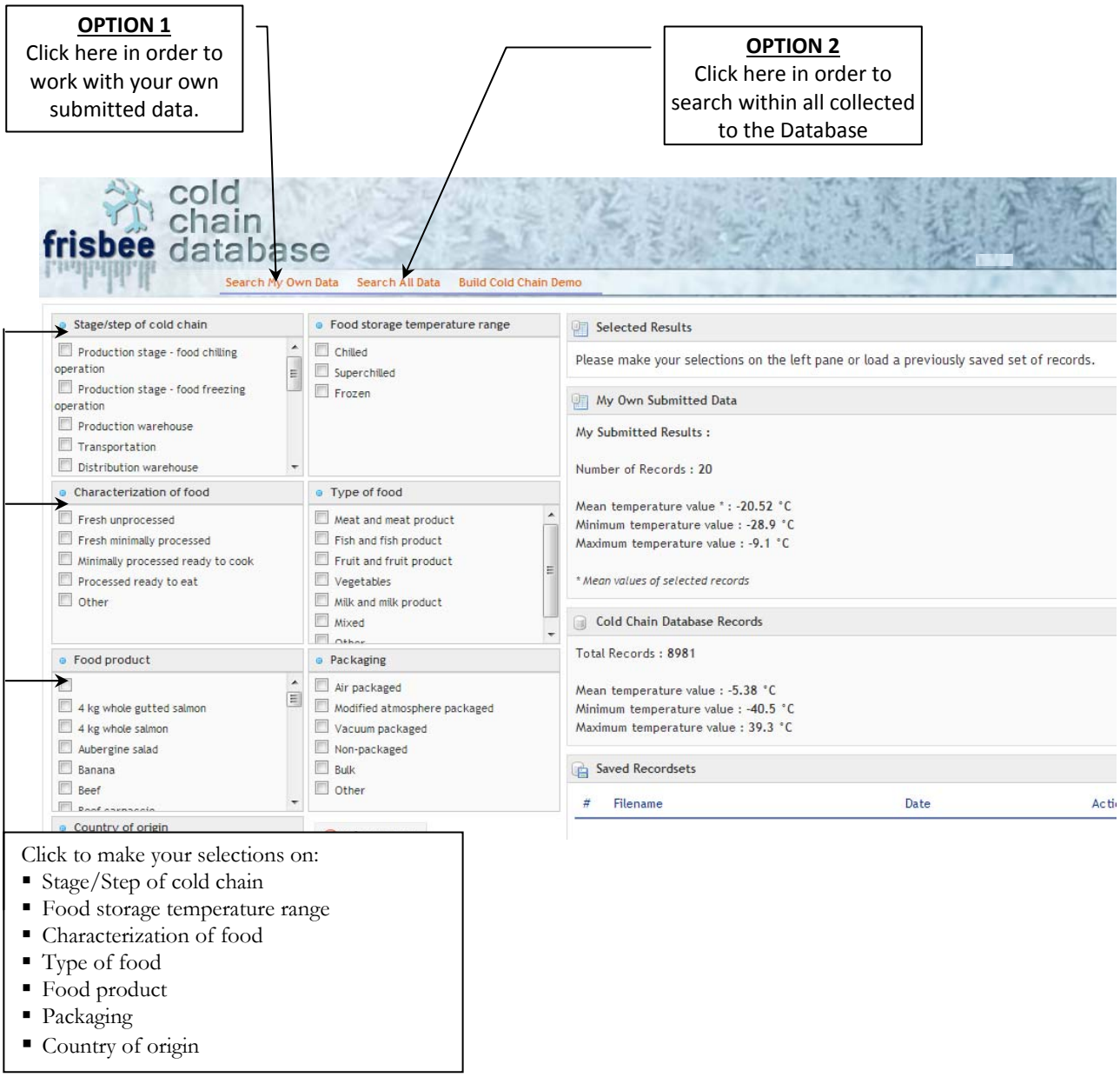


Figure 5. Description of the Cold Chain Database (Access Level 2).

IMPORTANT: Access Level 2 Users may search within all data BUT they can NOT download related information (raw data & metadata). This kind of data is accessible only to Access Level 3 Users (Full Access).

2.3.4.2 Use the "Build Cold Chain" application

The "Build Cold Chain" application is embedded in the Cold Chain Database in order to serve as a toll to build "what if" scenario of the food cold chain. This tool enables the user to build a cold chain scenario consisting of different successive cold chain stages. As long as the user selects the successive cold chain stages, the application is retrieving all time-temperature profiles that exist in the database matching the specified cold chain scenario. The retrieved data are gathered in a .csv file (Excel, Microsoft accessible) and can be further used by the Software: FRISBEE Cold Chain Predictor Software.

The Cold Chain Database-Access Level 2 users have limited access to the "Build Cold Chain" application. In order to upgrade their account and have full access to the "Build Cold Chain" application users need to join forces and contribute to the Cold Chain Database by uploading temperature data concerning any stage of the food cold chain. **As soon as you contribute data your account will be eligible to be upgraded!**

Instructions in using the "Build Cold Chain" application in conjuction with the Cold Chain Predictor Software can be found in **Section 3.3.1 FRISBEE_CCP Software-Option 1: Build Representative Profile**

2.3.5 How to use the Cold Chain Database-Access Level 3 (Full access)

2.3.5.1 Search within the database time-temperature profiles

Users with Access Level 3 have access to all contributed time-temperature profiles (raw data & metadata may be downloaded) and can set their search criteria by selecting from the left pane

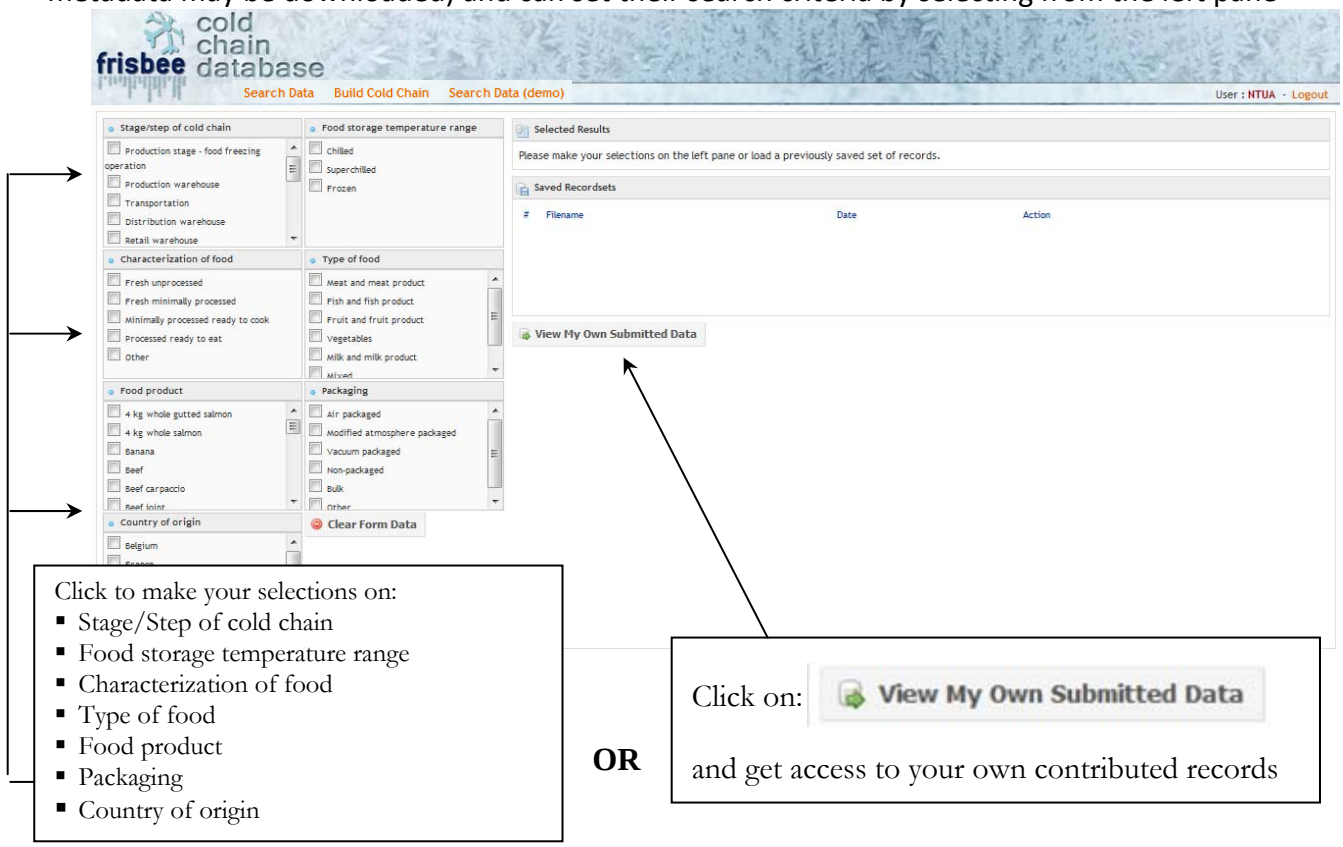


Figure 6. Description of the Cold Chain Database (Access Level 3-Full Access).

As soon as the user sets the search criteria the number of records matching these criteria and the corresponding descriptive temperature statistics (mean, minimum and maximum temperature values) are depicted.

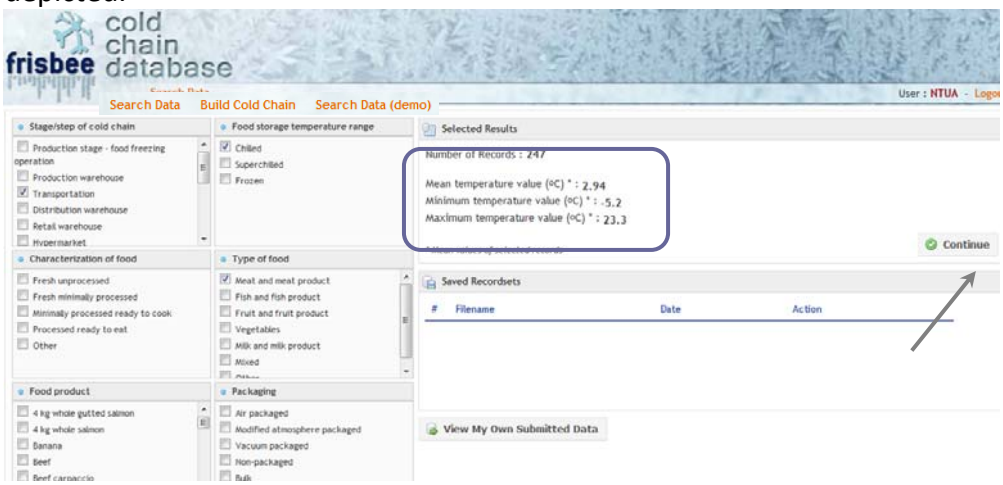


Figure 7. Description of the Cold Chain Database (Access Level 3-Full Access).

In order to access the data records in detail click on the Continue button.

On the left pane the user can see the list of records matching the selected search criteria. In order to see the data of a specific record click on the **record name (**e.g. 1581.1mins, 0.5 to 7.3 °C).

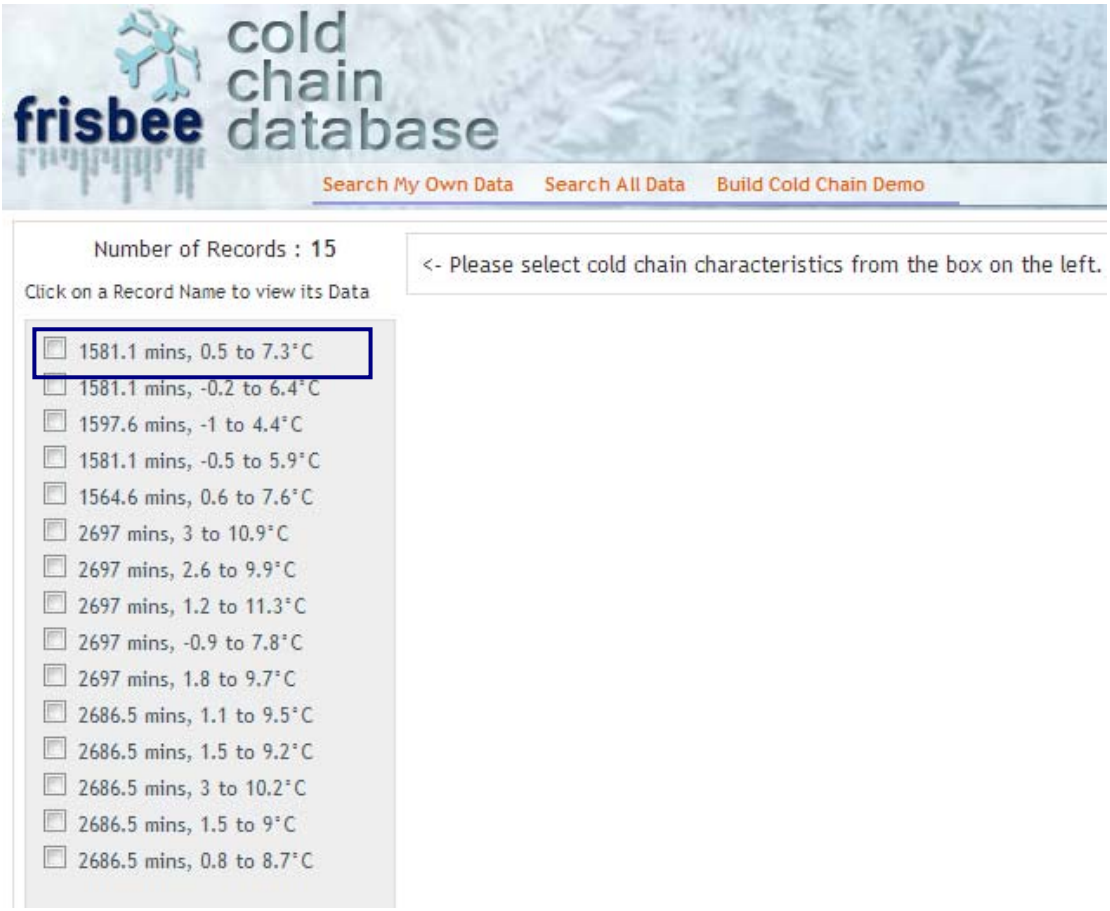
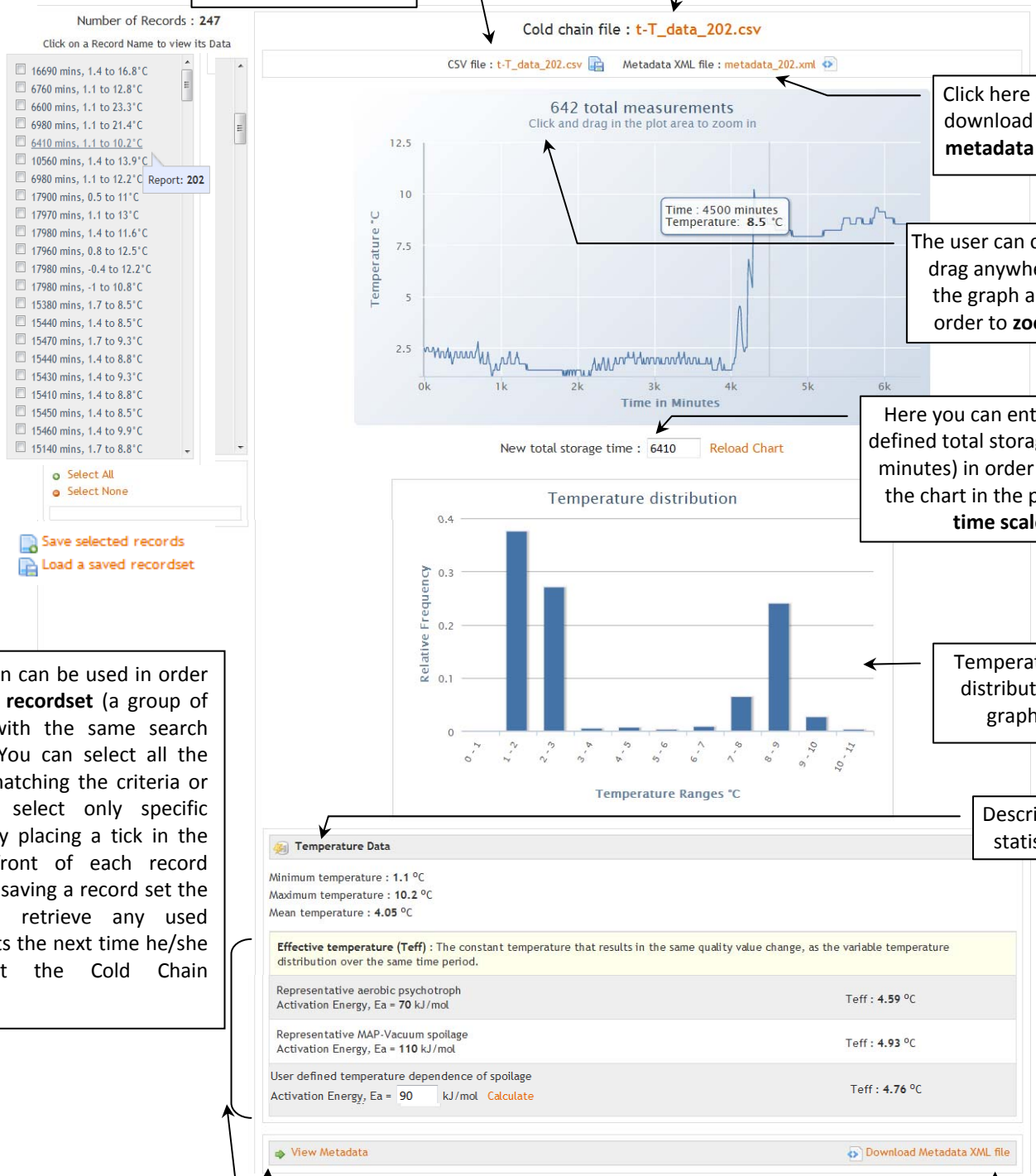


Figure 8. List of records corresponding to user 's search criteria.

As soon as the user clicks on a specific record name he/she gets access to all data (raw data and metadata) concerning the selected data record (See the following figure).


Click here and download the raw data (time and temperature)
Record name
(Corresponds to the filename given when the record was uploaded on the Cold Chain Data Collection)
Number of Records : 247
Click on a Record Name to view its Data
16690 mins, 1.4 to 16.8°C
6760 mins, 1.1 to 12.8°C
6600 mins, 1.1 to 23.3°C
6980 mins, 1.1 to 21.4°C
6410 mins, 1.1 to 10.2°C
10560 mins, 1.4 to 13.9°C
6980 mins, 1.1 to 12.2°C
Report: 202
17900 mins, 0.5 to 11°C
17970 mins, 1.1 to 13°C
17980 mins, 1.4 to 11.6°C
17960 mins, 0.8 to 12.5°C
17980 mins, -0.4 to 12.2°C
17980 mins, -1 to 10.8°C
15380 mins, 1.7 to 8.5°C
15440 mins, 1.4 to 8.5°C
15470 mins, 1.7 to 9.3°C
15440 mins, 1.4 to 8.8°C
15430 mins, 1.4 to 9.3°C
15410 mins, 1.4 to 8.8°C
15450 mins, 1.4 to 8.5°C
15460 mins, 1.4 to 9.9°C
15140 mins, 1.7 to 8.8°C
Select All
Select None
Save selected records
Load a saved recordset
Cold chain file : t-T_data_202.csv
CSV file : t-T_data_202.csv
Metadata XML file : metadata_202.xml
642 total measurements
Click and drag in the plot area to zoom in
Temperature °C
Time : 4500 minutes
Temperature: 8.5 °C
Time in Minutes
Click here and download the metadata file
The user can click and drag anywhere on the graph area in order to zoom in
New total storage time : 6410 Reload Chart
Here you can enter a user defined total storage time (in minutes) in order to reload the chart in the preferred time scale
Temperature distribution
Relative Frequency
Temperature Ranges °C
Temperature distribution graph
Descriptive statistics
Temperature Data
Minimum temperature : 1.1 °C
Maximum temperature : 10.2 °C
Mean temperature : 4.05 °C
Effective temperature (Teff) : The constant temperature that results in the same quality value change, as the variable temperature distribution over the same time period.
Representative aerobic psychotroph
Activation Energy, Ea = 70 kJ/mol
Teff : 4.59 °C
Representative MAP-Vacuum spoilage
Activation Energy, Ea = 110 kJ/mol
Teff : 4.93 °C
User defined temperature dependence of spoilage
Activation Energy, Ea = 90 kJ/mol Calculate
Teff : 4.76 °C
View Metadata
Download Metadata XML file
This option can be used in order to save a recordset (a group of records with the same search criteria). You can select all the records matching the criteria or you can select only specific records by placing a tick in the box in front of each record name. By saving a record set the user can retrieve any used record sets the next time he/she logins at the Cold Chain Database.
This field is used to calculate the effective temperature value of the specific time-temperature record.
The effective temperature can be calculated either based on predetermined activation energy values or by entering a user defined value.
Click here and view the metadata details
Click here to download the metadata file

2.3.5.2 Use the "Build Cold Chain" application

The "Build Cold Chain" application is embedded in the Cold Chain Database in order to serve as a toll to build "what if" scenario of the food cold chain. This tool enables the user to build a cold chain scenario consisting of different successive cold chain stages. As long as the user selects the successive cold chain stages, the application is retrieving all time-temperature profiles that exist in the database matching the specified cold chain scenario. The retrieved data are gathered in a .csv file (Excel, Microsoft accessible) and can be further used by the Software: FRISBEE Cold Chain Predictor Software.

The Cold Chain Database-Access Level 3 (Full Access) users have full access to the "Build Cold Chain" application.

Instructions in using the "Build Cold Chain" application in conjuction with the Cold Chain Predictor Software can be found in **Section 3.3.1 FRISBEE CCP Software-Option 1: Build Representative Profile**

COLD CHAIN PREDICTOR SOFTWARE v1.1

Cold Chain Predicting & Shelf Life Calculating Tool

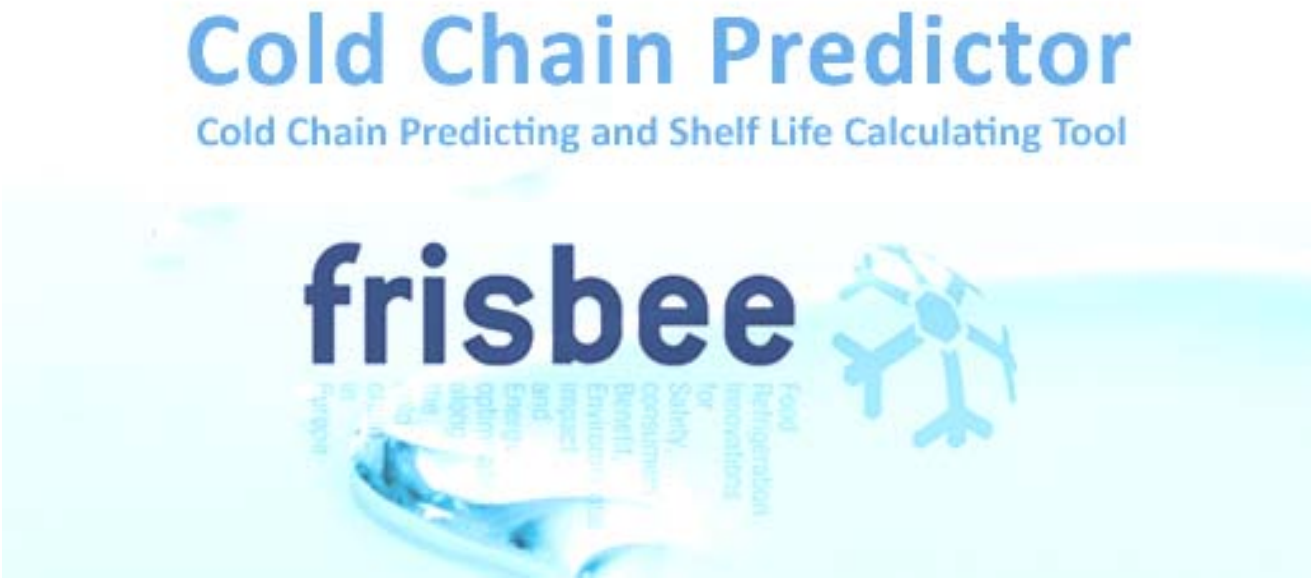
USER INSTRUCTIONS

DISCLAIMER

This tool was designed as a research and instructional tool for building a representative time-Temperature profile representing the cold chain of different food products and estimating their remaining shelf-life.

Although every care has been taken in the collection of the time-Temperature profiles and the food deterioration kinetic characteristics of the library, the final conditions of their use are outside the control of the ColdBase Partnership.

Expert interpretation is required and users must determine if they have the necessary skills for themselves. In case of doubt please consult an expert food technologist or contact at frisbee@chemeng.ntua.gr.



Cold Chain Predictor

Version 1.1
Release Date: August, 2012

3. Cold Chain Predictor Software

3.1 Software concept-Building Blocks

This tool was developed in order to:

a. Predict the time temperature profile of specific food products along the cold chain

b. Predict the product quality status, in terms of shelf life, at different stages of the cold chain

The two respective building blocks of the tool are (a) the time-temperature records consisting the cold chain database and (b) available quality and shelf life data (from peer reviewed articles in scientific journals).

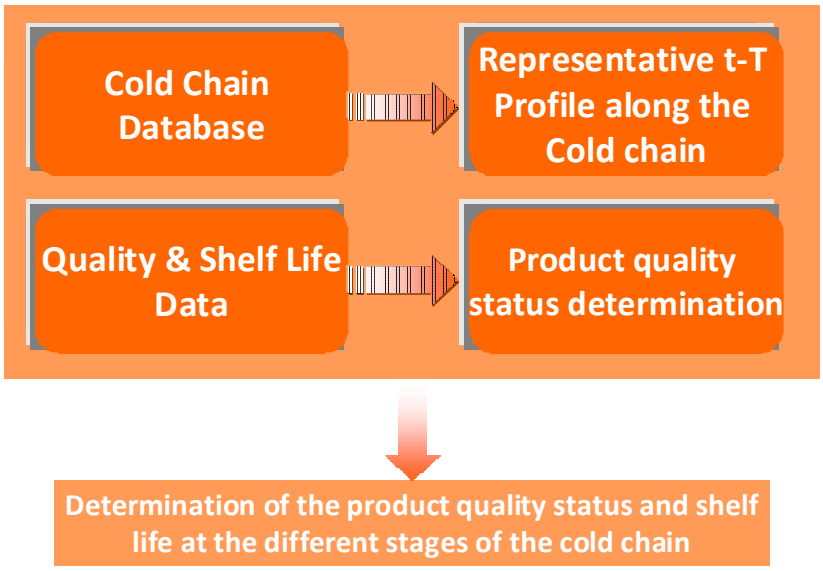


Figure 3.1. The building blocks of the tool developed to predict a representative time-temperature profile correlated to food quality.

The representative t-T profile along the cold chain (Figure 3.1) can be either a user own t-T profile or a t-T profile retrieved by the Cold Chain Database. Alternatively, the profiles collected in the Cold Chain Database can be used in order to build a representative profile according to user defined criteria. The procedure of building a user defined cold chain through the available on line platform of Cold Chain Database is thoroughly described in section: *3.3.1 FRISBEE CCP Software-Option 1: Build Representative Profile.*

3.2 Software requirements

The software is a stand alone executable program and there is no need of installing any additional software. In order to use the software the user should install the program using the setup file.

Anyone can have free access to the CCP software by applying in the following link http://frisbee-wp2.chemeng.ntua.gr/coldchaindb/?go=demo and selecting Download FRISBEE Cold Chain Predictor Software (Figure 3.2).

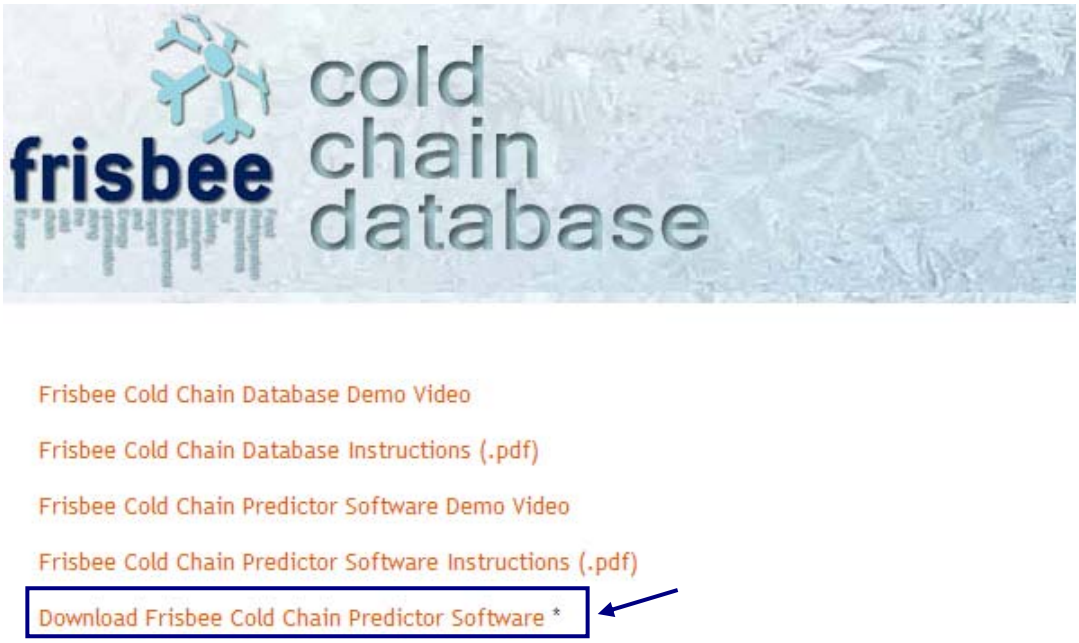


Figure 3.2 Applying for free access to the Cold Chain Predictor Softaware in http://frisbee-wp2.chemeng.ntua.gr/coldchaindb/?go=demo

After applying for the software, users will receive an e-mail with download instructions. The default destination directory of FRISBEE_CCP folder is in Program Files folder (Computer/WINDOWS(C:)/Program Files (x86)/FrisbeeCCP/). Once installed in the user's computer it can be used with a double click on the FRISBEE_CCP file (Figure 3.3a). Furthermore, users can find the files needed to run the cases studies described in the following instructions in the following directory: Documents/FRISBEE_CCP-Example Files (Figure 3.3b)

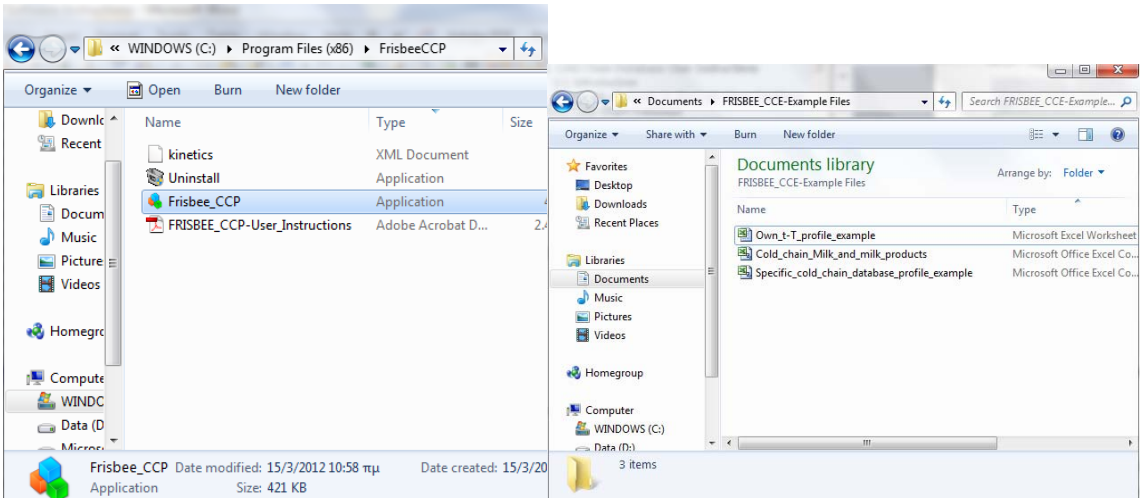


Figure 3.3 (a) FRISBEE_CCP software folder saved in user's PC and (b) FRISBEE_CCP-Example Files saved in user's PC.

3.3 Software description

The FRISBEE Cold Chain Predictor (FRISBEE_CCP) software has been developed to give the users 3 different options. The user can calculate the remaining shelf life of a specific food product at different stages of the cold chain corresponding to a specific time-temperature profile. The user can choose among the following options (Figure 3.4):

i. Build a representative profile
ii. Use your own t-T profile
iii. Use a specific profile from the Cold Chain Database

Figure 3.4. FRISBEE Cold Chain Predictor software introductory screen.

3.3.1 FRISBEE_CCP Software-Option 1: Build Representative Profile

In this option prior to the use of the software, the user should login to the FRISBEE Cold Chain Database (http://www.frisbee-project.eu/coldchaindb.html) and build a specific sequence of cold chain stages for specific food product. The FRISBEE_CCP Software option of building a representative profile is described in Figure 3.5. **Access to the online Cold Chain Database is a prerequisite for the use of this software option.**

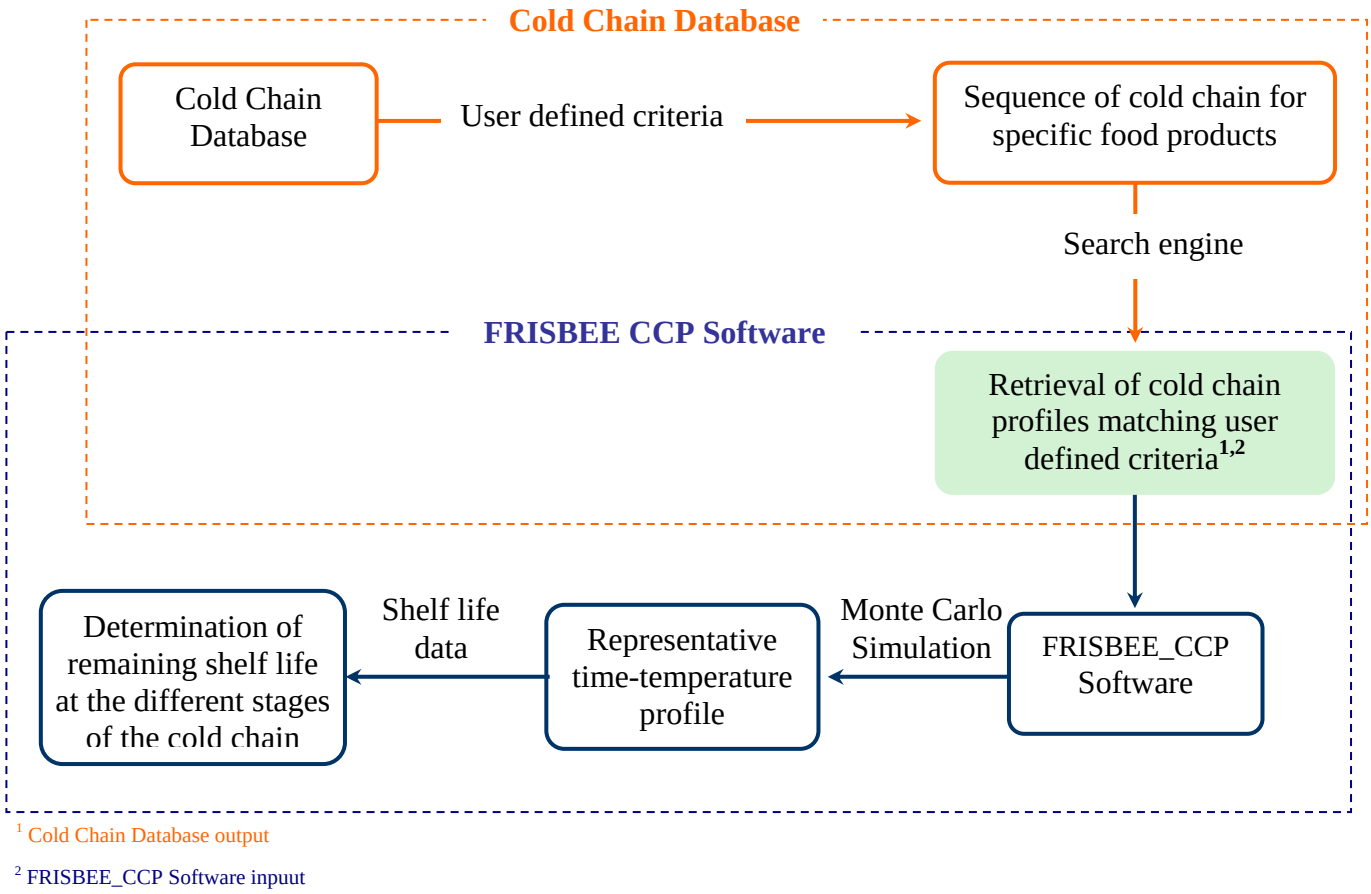


Figure 3.5 Illustration of FRISBEE_CCP Software-Option 1: Build Representative Profile

A detailed example of using the 1st option of FRISBEE_CCP Software is described in detail in the following pages. Milk and milk products are used as a case study of food products.

Step 1: Login to the Cold Chain Database

Visit the Cold Chain Database web site and enter your login details to enter the database following the instructions in sections: *2.3.1Enter the Cold Chain Database* and *2.3.2 Login to the Cold Chain Database*.

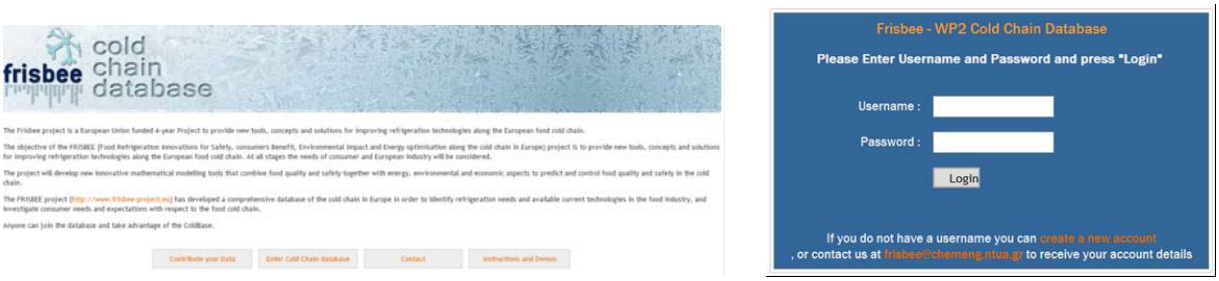


Figure 3.6 (a) Introductory screen of the Cold Chain Database and (b) Login window

Step 2: Enter the Build Cold Chain application

As soon as you login to the Cold Chain Database click on the Build Cold Chain Tab

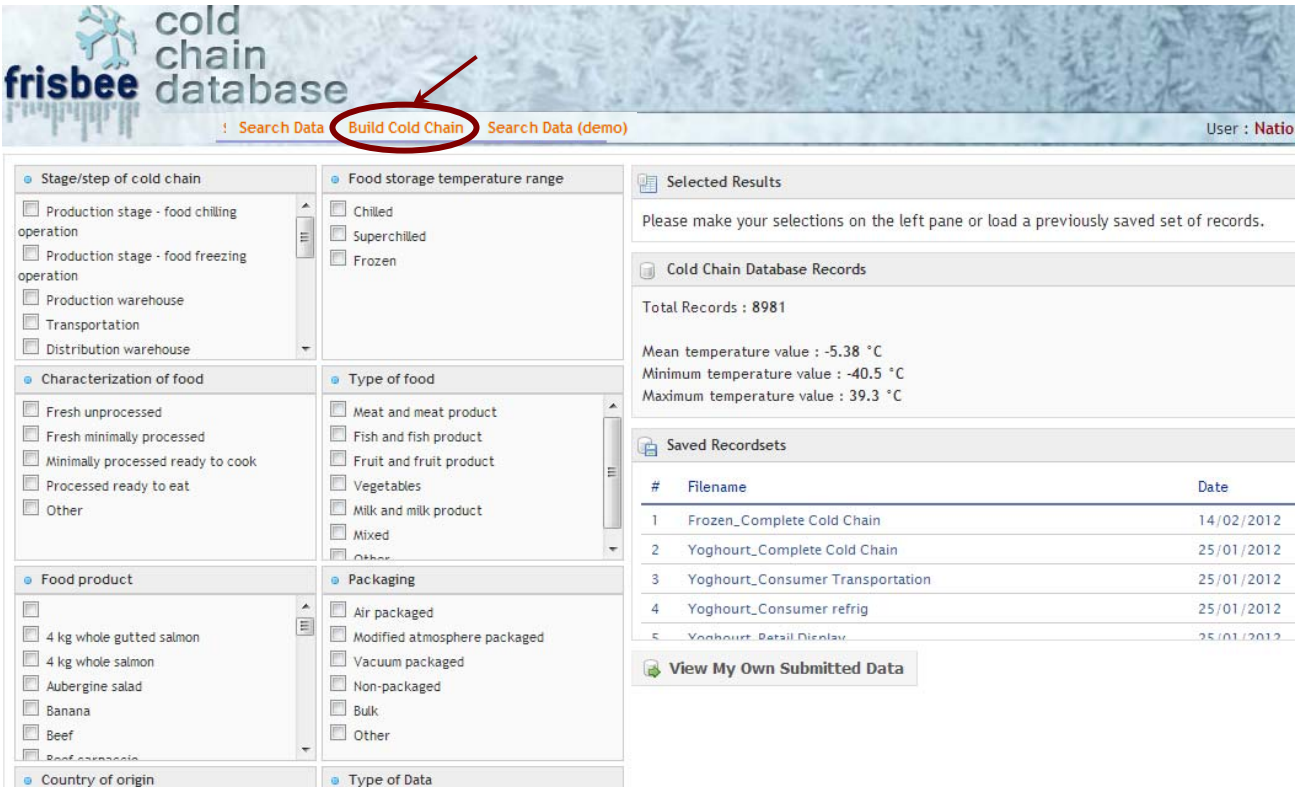


Figure 3.7 Cold Chain Database web site where the user can select the "Build Cold Chain" application.

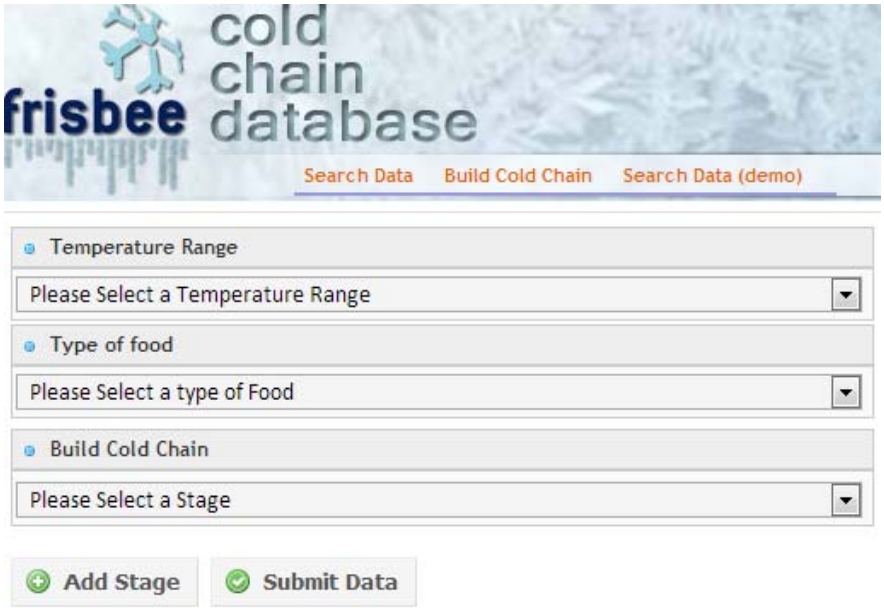


Figure 3.8. Build Cold Chain window.

Step 3: Build a cold chain for specific food products

In the Build Cold Chain window (Figure 3.8) the user can select the type of food and the cold chain stages from the corresponding drop down lists (Figures 3.9 a, b and c).

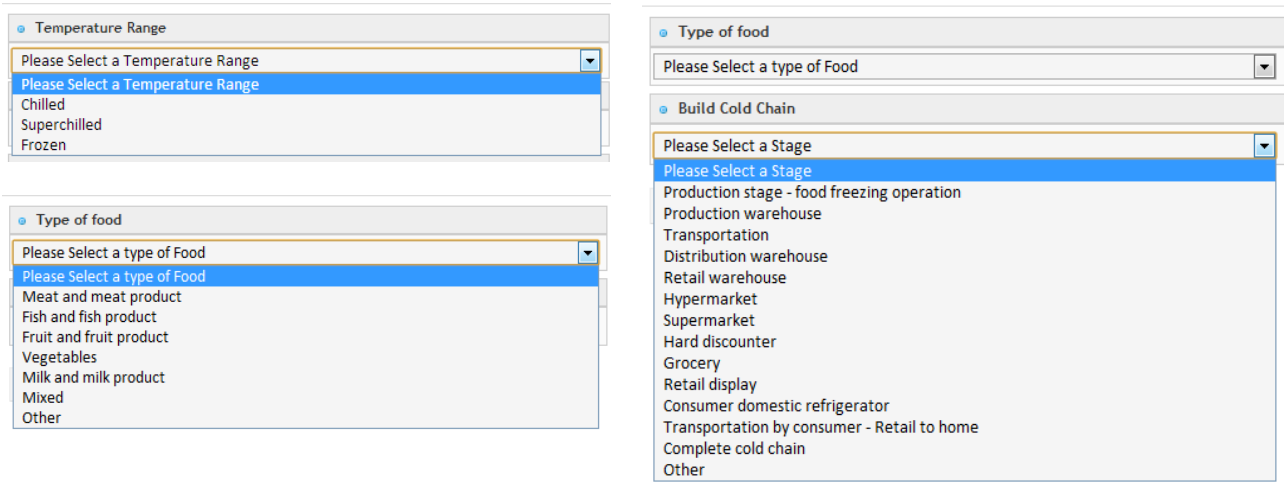


Figure 3.9 (a) Temperature range drop down list, **(b)** Type of food drop down list and **(c)** Cold chain stage drop down list.

The user can add as many stages as he/she wishes by clicking on the Add Stage tab. In this example milk and milk products was selected from the type of food drop down list. A complete

cold chain consisting of 9 succesive stages was used as a case study: Transportation ➡ Production Warehouse ➡ Transportation ➡ Distribution Warehouse ➡ Transportation ➡ Retail Warehouse ➡ Retail Display ➡ Transportation by consumer ➡ Consumer Domestic Refrigerator (Figure 3.10).

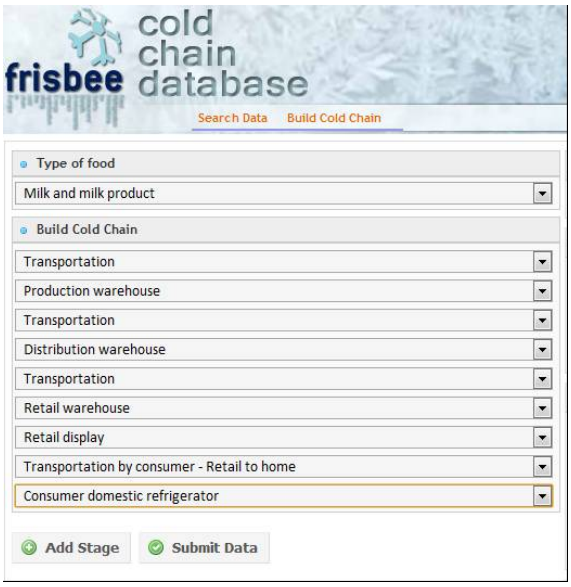


Figure 3.10 Building a cold chain for milk and milk products consisting of nine successive stages.

As soon as the user has completed the selection of food type and the cold chain stages he/she can proceed with a click on Submit Data the Submit Data tab. By clicking on the tab the user is informed of the number of records available at the cold chain database for each selected cold chain stage (Figure 3.11). In order to use the FRISBEE_CCP Software the user has to download the time-temperature data from all selected stages by clicking on the Download All Selected Stages tab.

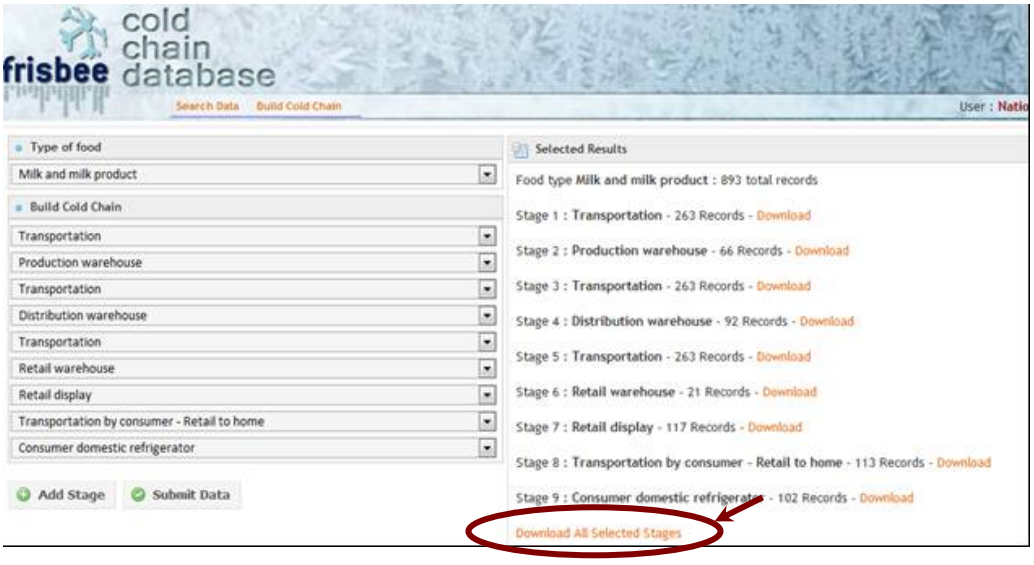


Figure 3.11 Results of cold chain stages number of records according to user defined criteria.

The dowloaded file is in csv format and it contains all necessary information to be used as the input file in the FRISBEE_CCP software. The specific file contains information regarding the effective temperature value and time for each time-temperature profile retrieved from the Cold Chain Database. The effective temperature is defined as the constant temperature that results in the same quality value as the variable temperature distribution over the same time period. The user can save this file in any destination directory in his/her PC and open it using the software, as it is described in the following step (Step 4: Use the CCP Software Option 1: Build Representative Profile).

Step 4: Use the FRISBEE_CCP Software Option 1: Build Representative Profile

The downloaded file (.csv format) from the Cold Chain Database website is used as the input at the FRISBEE_CCP Software. From the introductory screen the user should choose the **Build Representative Profile** tab.

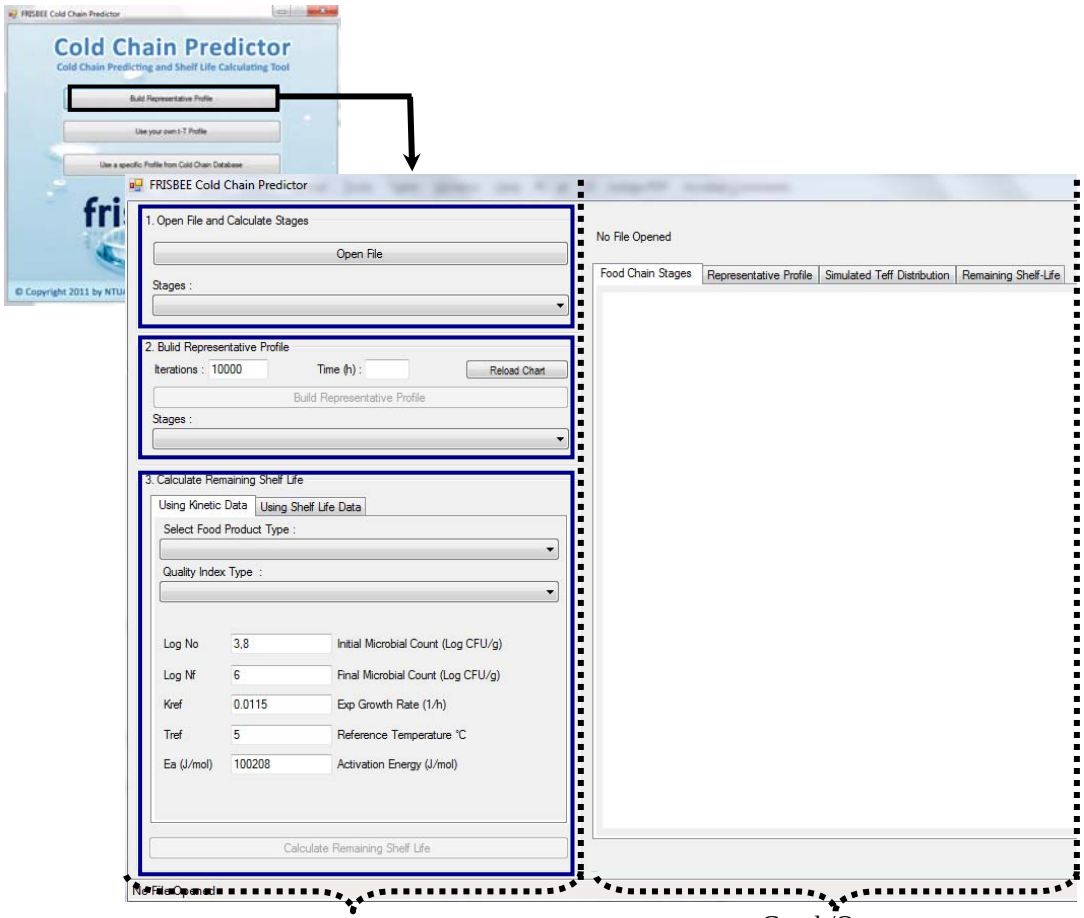


Figure 3.12 FRISBEE Cold Chain Predictor basic screen using the FRISBEE_CCP Software Option 1: Build Representative Profile.

The software screen consists of two basic windows; the input window and the graph/output window (Figure 3.12).

In the input window (on the left pane) the user can see three subwindows:

1. Open file and calculate stages

   In this section the user opens the csv file downloaded from the Cold Chain Database website. This file is the input required from the software.

2. Build representative profile

   In this section the user defines the desired number of Monte Carlo iterations in order to build the representative profile. The software runs Monte Carlo simulation using the time-temperature data that were retrieved from the Cold Chain Database.

3. Calculate remaining shelf life

   In this section the user can select from a drop down list the food product type he/she wishes to calculate the remaining shelf life for. When selecting a product from the drop down list the kinetic parameters are automatically depicted on the respective fields.

Step 4.1 Input csv file retrieved from the Cold Chain Database

At the software screen click on the tab Open File and open the csv file that was downloaded at the previous step. As soon as the user opens the corresponding .csv file, the list of cold chain stages are available in a dropdown list (Figure 3.13). By clicking on any stage (Figure 3.13), the corresponding distribution graph of (effective) temperature is depicted as shown in Figure 3.14 (a) and (b). The user can find the csv file (Cold chain_Milk and milk products. csv) concerning milk and milk products that was retrieved from the Cold Chain Database and it is used as a case study in this example in the following directory: Documents/FRISBEE_CCP-Example Files.

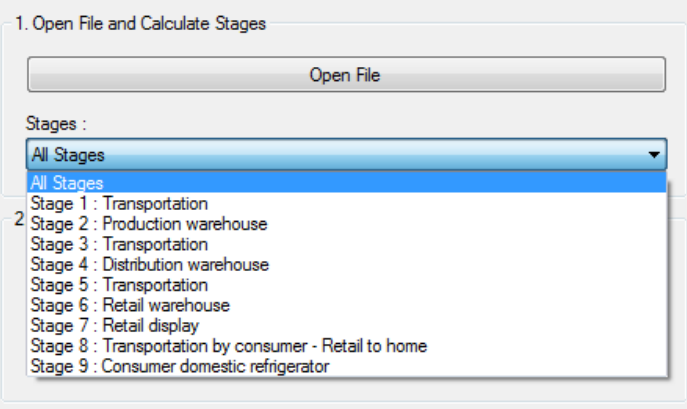


Figure 3.13 Dropdown list of cold chain stages for milk and milk products

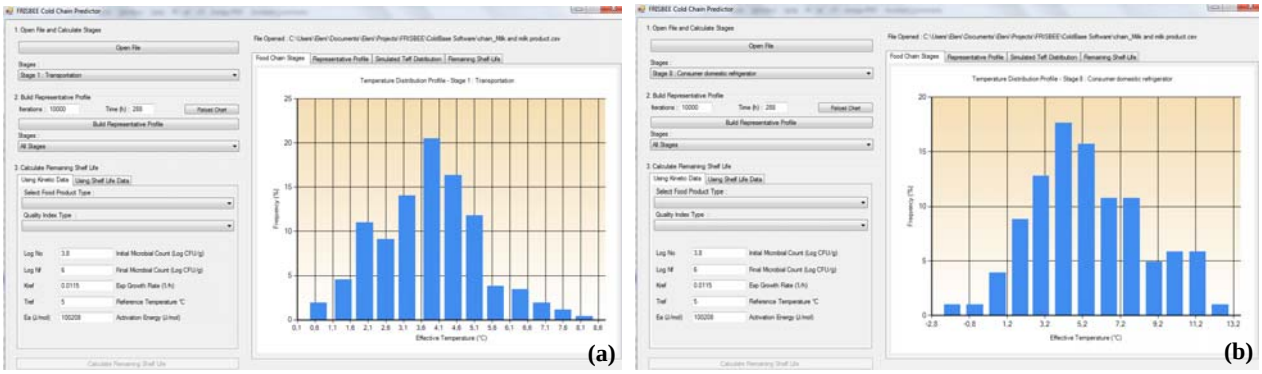


Figure 3.14 Distribution of (effective) temperature during the stage of (a) transportation and (b) of consumer domestic refrigeration storage for milk and milk products.

Step 4.2 Build representative profile

In the next step, the user can define the number of iterations for the Monte Carlo simulation in order to build the representative profile in the appropriate box (Figure 21, ①). Monte Carlo simulation (Metropolis & Ulam, 1949) is a very usefull technique to facilitate data from the Cold Chain Database. This numerical approach is based on the generation of hypothetical scenarios in terms of the temperature values reported during all the segments of the cold chain by substituting the entire range of values. The default (suggested) number of iterations is 10000. The Monte Carlo simulation is performed using the csv file retrieved from the online platform of the Cold Chain Database. The simulation generates a representative time-temperature profile where each cold chain stage is represented by an isothermal step. The temperature of this step (cold chain stage) represents the most probable effective temperature of the t-T profiles (pre-estimated for each profile when building the cold chain in the Cold Chain Database) for the specific stage of cold chain. The Standard Deviation –to represent the most propable range of deviation above and below the effective temperature- is also calculated and

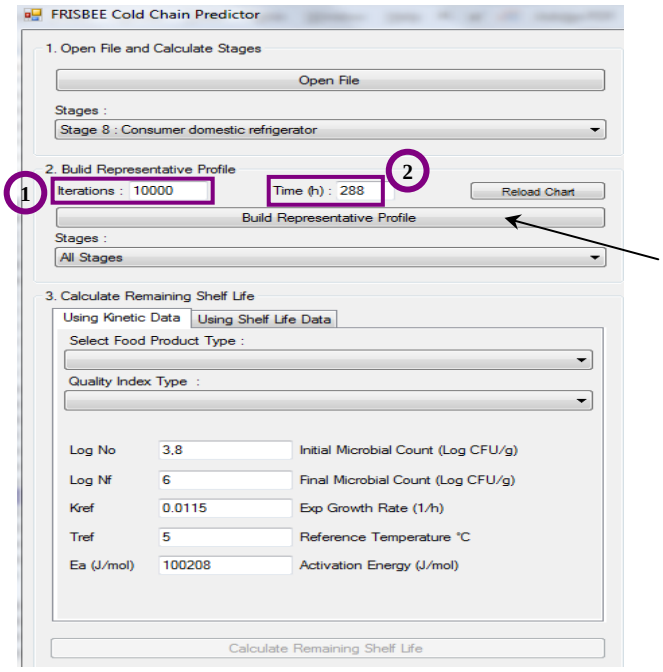


Figure 3.15 Setting the number of Monte Carlo number of iterations in order to build the representative time-temperature profile.

presented in the graph by the orange lines above and below the isothermal lines for each stage of the representative profile.

The duration of the step is also estimated applying Monte Carlo simulation, as the most probable duration for each cold chain step. The total duration of the representative profile can be redefined by the user when changing the value in the appropriate time box illustrated in Figure 3.15 ②. The duration of each stage of the profile is accordingly modified (proportional time modification for each stage).

The representative profile is built by clicking on the Build Representative Profile tab (Figure 3.15). Finally the 9 stage cold chain for milk and milk products is described by a representative time-temperature profile consisting of 9 isothermal steps (Figure 3.16).

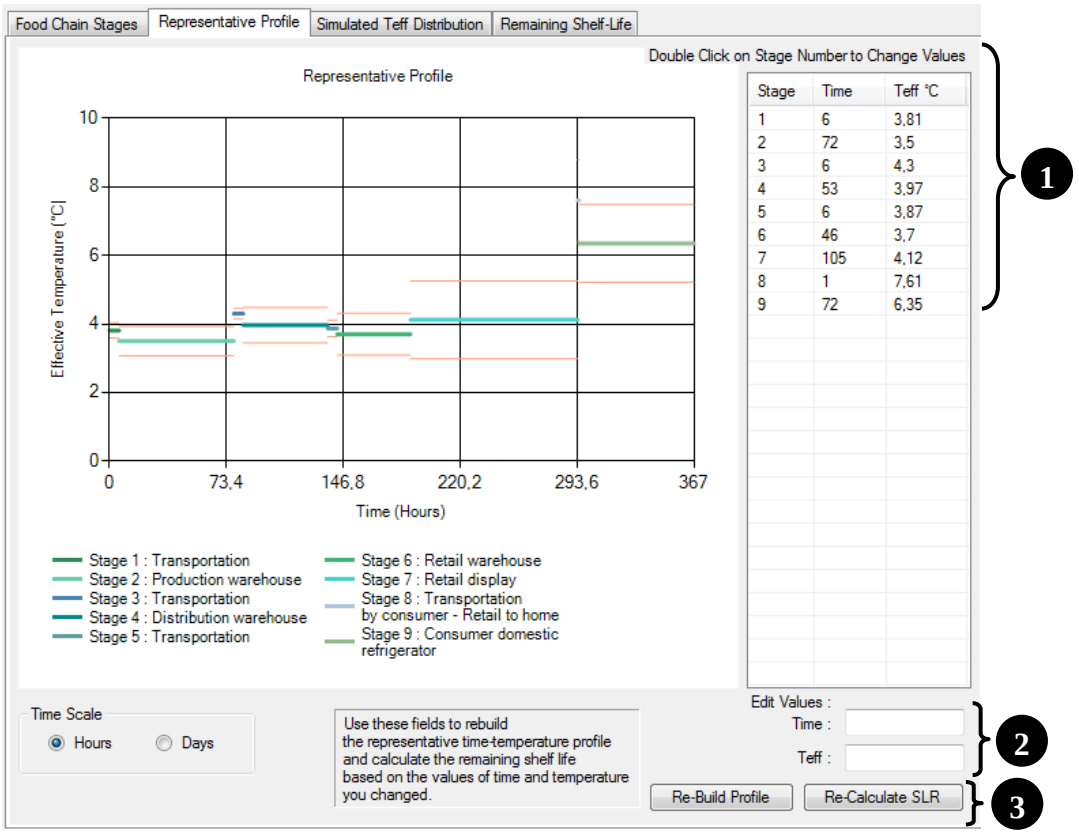


Figure 3.16 The representative time temperature profile generated by Monte Carlo simulation using the cold chain profiles for milk and milk products retrieved from the Cold Chain Database for nine successive cold chain stages.

The above profile representing the nine selected cold chain stages is obtained through the Monte Carlo simulation process on the relevant t-T files used directly from the Cold Chain Database. In this window the user has the ability of changing time and/or temperature values to any or all

stages according to his will. In order to change the time and/or temperature value in any step double click on the Stage number (❶) and enter the preferred values in the corresponding fields (❷). Finally click on the **Re-Build Profile** tab (❸). In order to calculate remaing shelf life of food product after the Re-Built Profile click on the **Re-Calculate SLR** tab (❸).

Step 4.3 Product quality status determination

After the representative profile has been build, the user can proceed to the third subwindow and determine the product quality status, in terms of shelf life, at the different stages of the cold chain. The quality status determination can be performed by using either **(a)** available kinetic data or **(b)** user 's own shelf life data (Figure 3.17).

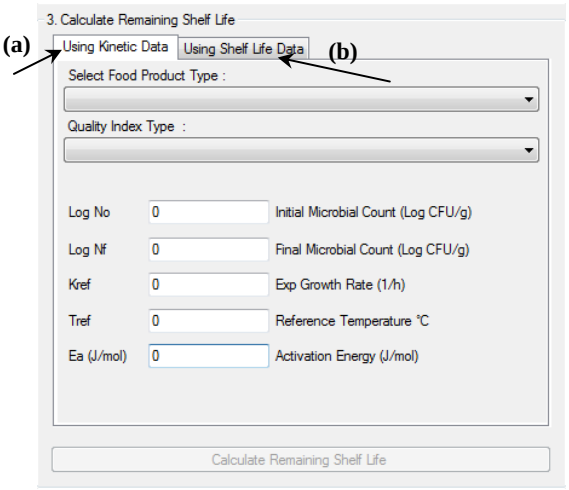


Figure 3.17 Calculate remaining shelf life window based on the representative time temperature profile.

(a) Using Kinetic Data

The user can select among different food product types that are available within the software. When selecting a food product, automatically the software recalls the kinetic characteristics of a typical quality index concerning the selected food product. The kinetic characteristics are retrieved from the corresponding kinetic models that have been published at peer reviewed scientific journals. Once the user selects the Food Product Type, the Quality Index Type is automatically filled in the next tab (Figure 3.18). In Table 3.1 the list of available food product types, the corresponding quality indices and the respective literature references are described. The kinetic characteristics used by the software are summarized in Table 3.1.

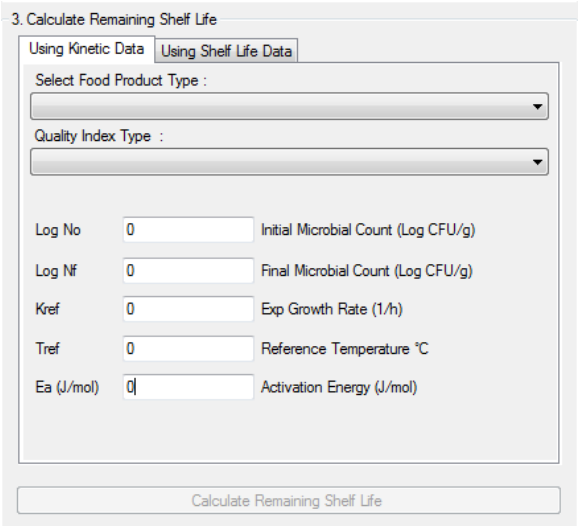


Figure 3.18. Calculate remaining shelf life window using kinetic data for specific quality index.

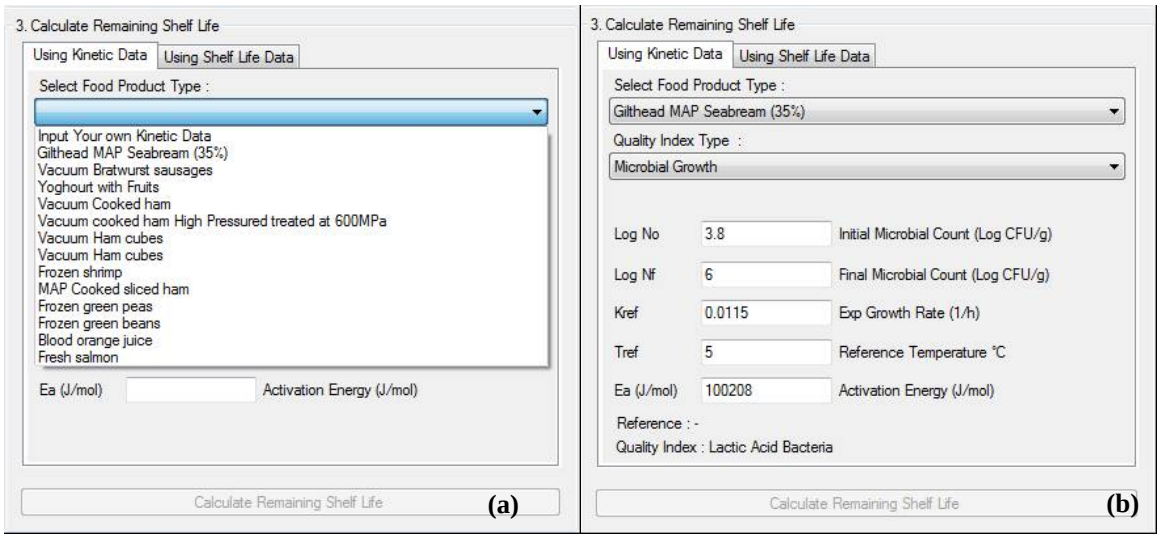


Figure 3.19 (a) Dropdown list of available food products' kinetic data and (b) Example of quality index kinetic parameters automatically filled in the window software.

Table 3.1 List of food product types, the corresponding quality indices and the respective literature references available within the FRISBEE_CCP software.

Food Product	Quality Index	Reference
Frozen shrimp	Total volatile basic nitrogen	*Tsironi et al., 2009.*
Yoghurt with fruits	Evident spoilage (sensory evaluated)	*Mataragas et al., 2011*
Vacuum cooked ham	Lactic acid bacteria	*Katsaros and Taoukis, 2008*
Vacuum bratwurst sausages	Lactic acid bacteria	*Karousi et al., 2006*
Vacuum cooked ham high pressure treated at 600 MPa	Lactic acid bacteria	*Katsaros and Taoukis, 2008*
Gilthead seabream fillets in modified atmosphere packaging	Lactic acid bacteria	*Tsironi et al., 2011*
Modified atmosphere-packed (MAP) cooked sliced ham	Lactic acid bacteria	*Kreyenschmidt et al., 2010*
Frozen green peas	Ascorbic acid	*Giannakourou et al., 2003*
Frozen green beans	Ascorbic acid	*Giannakourou et al., 2003*
Blood orange juice	Ascorbic acid	*Zanoni et al., 2005*
Fresh salmon	Microbial degradation	*Simpson et al., 2011*

Table 3.2 Kinetic characteristics used by the FRISBBE_CCP software code in order to determine product quality status in terms of remainng shelf life at the different cold chain stages.

Quality Index Type	Kinetic characteristic	Symbol	Measurement unit	Definition
Microbial growth (ie bacteria, yeasts)	Initial microbial count	Log N_o	Log(cfu/g)	Log of cell concentration at time of entering the cold chain
	Final microbial count	Log N_f	Log(cfu/g)	Log of acceptable cell concentration at the end of product shelf life
	Exponential growth rate constant	k_{ref}	(h^{-1})	Growth rate at the reference temperature
	Reference temperature	T_{ref}	(°C)	Temperature value characteristic of the range at which the food product is stored The remaining shelf life of the food product is estimated at T_{ref}
	Activation energy	E_a	(J/mol)	Parameter of the Arrhenius equation expressing the temperature dependence of the growth rate costant
Chemical Index (ie vitamin, enzyme, chemical compound)	Initial value	V_o	mg/ml or Units/ml or Percent	Concentration of a quality index (ie vitamin, enzyme, chemical compound) at the time of entering the cold chain
	Percent value	a	mg/ml *or* Units/ml *or* Percent	% of acceptable increase or loss of a specific quality index at the end of product shelf life
	Reaction rate constant	k_{ref}	(%/h^{-1})	Rate constant of increase or loss of the specific quality index at the reference temperature
	Reference temperature	T_{ref}	(°C)	Temperature value characteristic of the range at which the food product is stored The remaining shelf life of the food product is estimated at T_{ref}
	Activation energy	E_a	(J/mol)	Parameter of the Arrhenius equation expressing the temperature dependence of the rate costant of loss or formation of the chemical index
Sensory Index (ie aroma, taste, color)	Initial score	S_o	1 to 10 (10: Best score)	Score of a sensory index at the time of entering the cold chain
	Lower score	S_F	1 to 9 (1: Worst score)	Lower acceptable score of a sensory index corresponding to the end of product shelf life
	Sensory loss rate	k_{ref}	(score units/h^{-1})	Rate constant of sensory index decrease
	Reference temperature	T_{ref}	(°C)	Temperature value characteristic of the range at which the food product is stored The remaining shelf life of the food product is estimated at T_{ref}
	Activation energy	E_a	(J/mol)	Parameter of the Arrhenius equation expressing the temperature dependence of the rate costant of loss or formation of the chemical index

Based on the above kinetic characteristics the remaining shelf life of food product is calculated according to Equations 3.1-3.3, taking into account the three types of quality index; microbial growth, chemical index, sensory index (Labuza 1984).

- **Microbial Growth**

The remaining shelf life at different cold chain stages is calculated considering that microbial growth follows first order kinetics, using Equation 3:

$$SLR = \frac{\log N_F - \log N_o - k_{ref} \cdot \exp\left[-\frac{E_a}{R} \cdot \left(\frac{1}{(T_{eff} + 273{,}16)} - \frac{1}{(T_{ref} + 273{,}16)}\right)\right] \cdot t}{k_{ref}} \quad \text{(Eq.3.1)}$$

where, SLR: Shelf life remaining at reference temperature (h); $\log N_F$: Log of acceptable cell concentration at the end of product shelf life; $\log N_o$: Log of cell concentration at time of entering the cold chain; k_{ref}: Rate constant of sensory index decrease (h^{-1}); E_a: Activation energy (J/mol); R: Universal constant (8.314 J/mol·K); T_{eff}: Effective temperature of the cold chain stage (°C); T_{ref}: Reference temperature (°C); t: time spent at the cold chain (h).

- **Chemical Index**

The remaining shelf life at different cold chain stages is calculated considering that chemical index increase/loss follows first order kinetics, using Equation 4:

$$SLR = \frac{\ln\left(V_o \cdot \exp\left(-k_{ref} \cdot \exp\left(-\frac{E_a}{R} \cdot \left(\frac{1}{(T_{eff}+273.16)} - \frac{1}{(T_{ref} + 2763.16)}\right)\right) \cdot t\right)\right) - \ln\left(\frac{100 \pm a}{100} \cdot V_o\right)}{k_{ref}}$$

(Eq.3.2)

where, SLR: Shelf life remaining at reference temperature (h); V_o: Concentration of a quality index (ie vitamin, enzyme, chemical compound) at the time of entering the cold chain; a: % of acceptable increase or loss of a specific quality index at the end of product shelf life; k_{ref}: Rate constant of increase/loss of the specific quality index at the reference temperature (h^{-1}); E_a:

Activation energy, (J/mol); R: Universal constant, (8.314 J/mol·K); T_{eff}: Effective temperature of the cold chain stage (°C); T_{ref}: Reference temperature (°C) and t: time spent at the cold chain (h).

- **Sensory Index**

The remaining shelf life at different cold chain stages is calculated considering that sensory index loss follows zero order kinetics, using Equation 5:

$$SLR = \frac{S_o - k_{ref} \cdot \exp\left[-\frac{E_a}{R} \cdot \left(\frac{1}{T_{eff} + 273.16} - \frac{1}{T_{ref} + 273.16}\right)\right] \cdot t - S_F}{k_{ref}} \quad \text{(Eq.3.3)}$$

where, SLR: Shelf life remaining at reference temperature (h); S_o: Score of a sensory index at the time of entering the cold chain; S_F: Lower acceptable score of a sensory index corresponding to the end of product shelf life; k_{ref}: Rate constant of sensory index decrease (h^{-1}); E_a: Activation energy (J/mol); R: Universal constant (8.314 J/mol·K); T_{eff}: Effective temperature of the cold chain (°C); T_{ref}: Reference temperature (°C); t: time spent at the cold chain (h).

The remaining shelf life is calculated at the different cold chain stages by clicking on the Calculate Remaining Shelf Life tab. The remaining shelf life at each cold chain is represented by a bar chart on the Graph window (Figure 3.20). The standard deviation of the remaining shelf-life at each stage of the profile is also estimated and presented (the upper limit of the SLR is presented by the red circle on each bar and the lower limit by the orange square). The upper and lower limits of the SLR are estimated using the lower and upper values of the temperature standard deviation respectively.

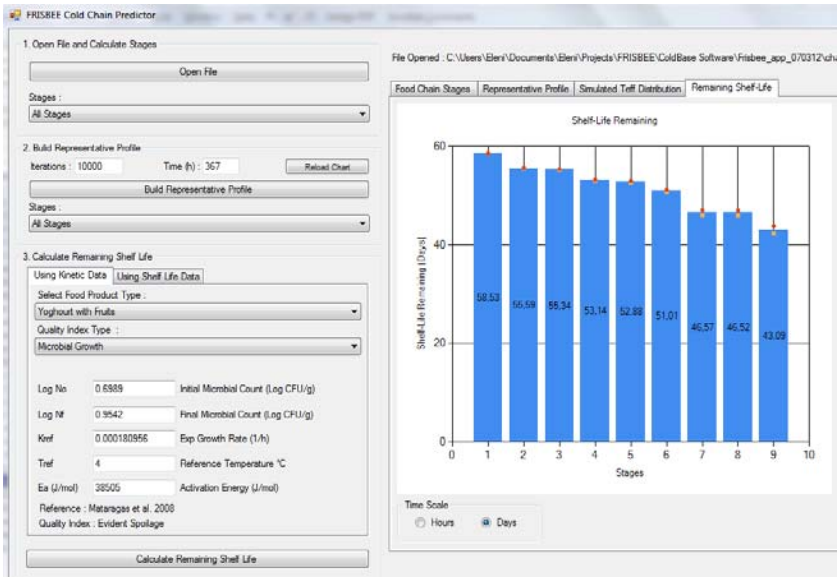


Figure 3.20 Calculated remaing shelf life of milk product (yoghurt with fruits) at each stage of the cold chain based on the built representative profile using kinetic data.

(b) Using Shelf Life Data

In case the user wants to use the software for his/her own specific product there is the option of using own shelf life data. The information required is the product shelf life at two different storage temperatures. A case study is thoroughly described for yoghurt with fruits.

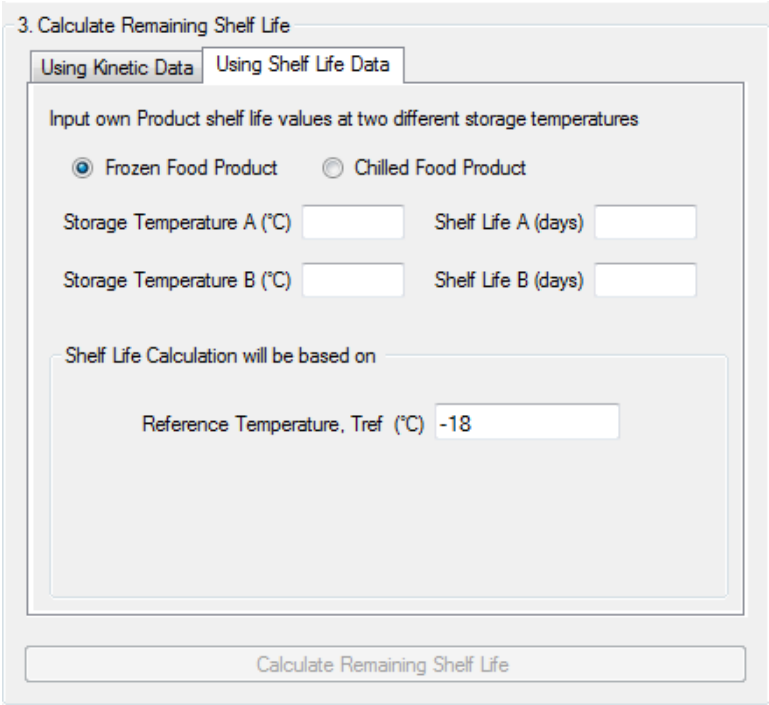
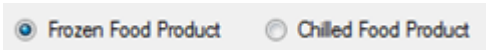


Figure 3.21 Calculate remaining shelf life window using shelf life data of user's own food product .

Assuming the yoghurt shelf life at storage temperature of 5 and 10°C to be equal to 55 and 41 days, respectively (Mataragas et al., 2011). The user should fill in this information in the respective boxes (Storage Temperature A, Storage Temperature B, Shelf Life A, Shelf Life B, illustrated in Figure 3.21). In addition, the user should give the information whether the food product is frozen or chilled with a click on the corresponding field: 

The calculation of remaining shelf life based on shelf life data is performed using Equation 3.4:

$$SLR = \exp\left[\frac{\ln(SL_B) - \ln(SL_A)}{\frac{1}{T_B + 273.16} - \frac{1}{T_A + 273.16}} \cdot \frac{1}{T_{ref} + 273.16}\right] \quad \text{(Eq.3.4)}$$

where, SLR: Shelf life remaining at reference temperature (days); SL_A: Shelf life (days) at storage temperature A (°C); SL_B: Shelf life (days) at storage temperature B; T_A: Storage temperature A (°C); T_B: Storage temperature B (°C) and $T_{ref:}$: Reference temperature (°C).

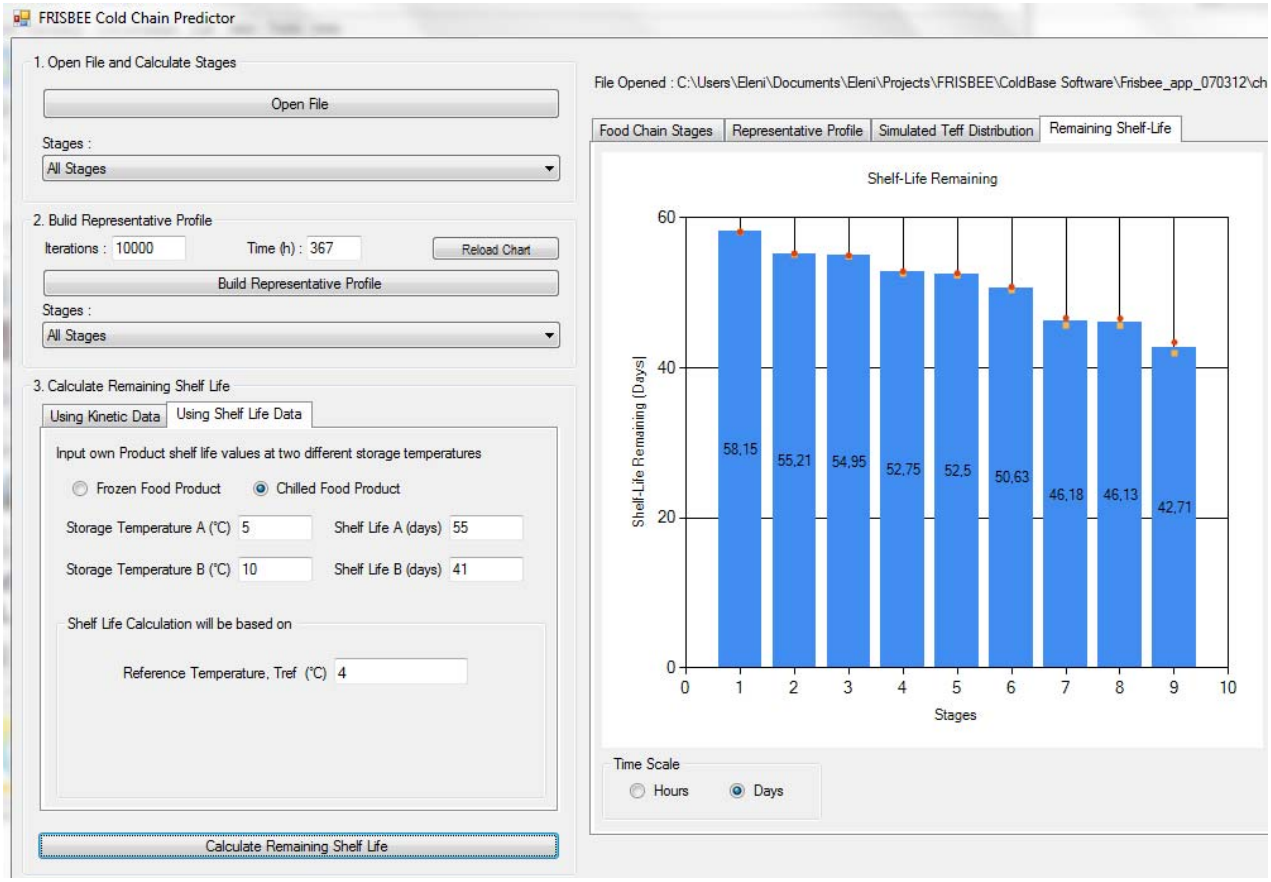


Figure 3.22 Calculated remaing shelf life of milk product (yoghurt with fruits) at each stage of the cold chain based on the built representative profile using shelf life data.

3.3.2 FRISBEE_CCP Software-Option 2: Use your own t-T profile

In this option the user can use own time temperature profile instead of building a representative time temperature profile from the Cold Chain Database. Prior to the use of the software the user should create a csv file (.csv) containing own time-temperature data. The file must be created according to the following instructions and using the template included in the FRISBEE_CCP-Example Files Folder installed in user's PC in the following directory: Documents/FRISBEE_CCP-Example Files:

a. In the first column (A) input the time data in minutes. The first time value should be entered at sell A1.
b. In the second column (B) input the temperature data in celcius degrees (°C). The fisrt temperature value should be entered at sell B1.
c. Save the file in your PC

An example of own time-temperature profile (Own t-T profile_example.xls) is included in the FRISBEE_CCP-Example Files Folder installed in user's PC in the following directory: Documents/FRISBEE_CCP-Example Files. In a following step the user should choose the **Use your own t-T Profile** tab in the software introductory screen (Figure 3.23).

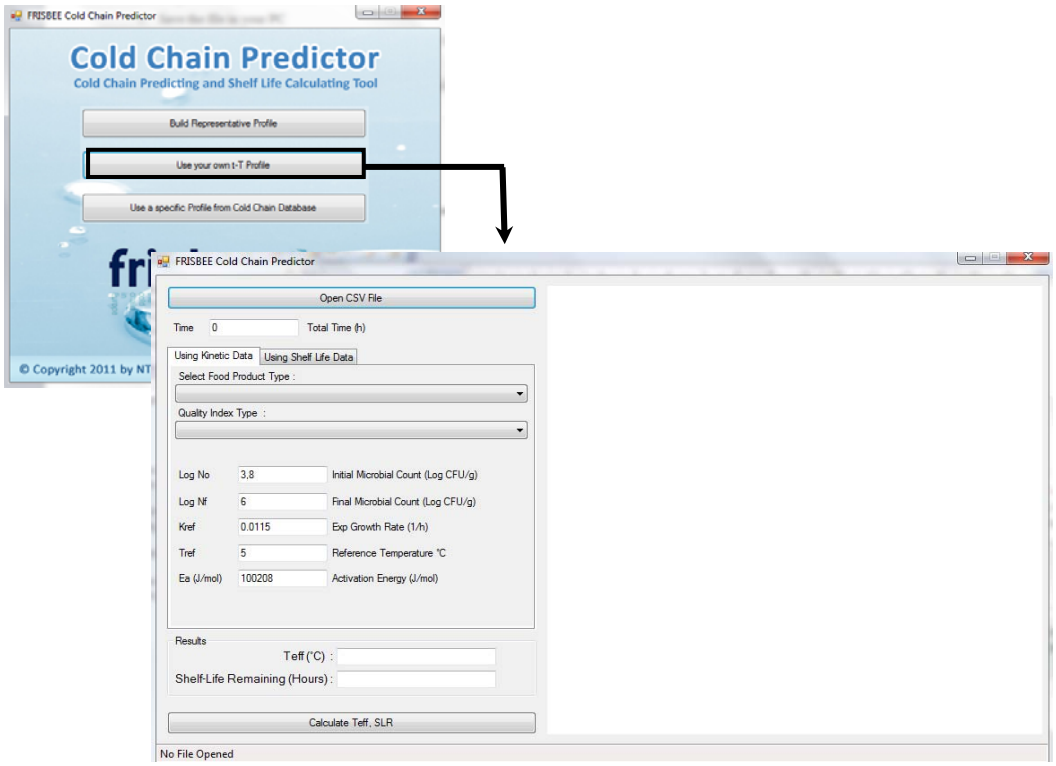


Figure 3.23 FRISBEE Cold Chain Predictor basic screen using the FRISBEE_CCP Software-Option 2: Use your own t-T profile.

At the software screen click on the Open CSV File tab and open the file created using own time-temperature data.

Finally, the quality status determination of a food product can be performed based on the specific own time-temeprature profile acccording to instructions given in section: ***Step 4.3 Product quality status determination***. This can be performed either by using **(a)** available kinetic data or **(b)** user 's own shelf life data.

3.3.3 FRISBEE_CCP Software-Option 3: Use a specific profile from the Cold Chain Database

In this option prior to the use of the software, the user should login to the FRISBEE Cold Chain Database (http://www.frisbee-project.eu/coldchaindb.html) and download a specific time-temperature. **Access to the online Cold Chain Database is a prerequisite for the use of this Software option**. Instructions to download a specific profile from the Cold Chain Database are thoroughly described in Section: 2.3 Cold Chain Database. An example of a specific Profile from Cold Chain Database (Specific cold chain database profile_example.xls) is included in the FRISBEE_CCP-Example Files Folder installed in user's PC in the following directory: Documents/FRISBEE_CCP-Example Files

In a following step the user should choose the **Use a specific Profile from Cold Chain Database** tab in the software introductory screen (Figure 3.24).

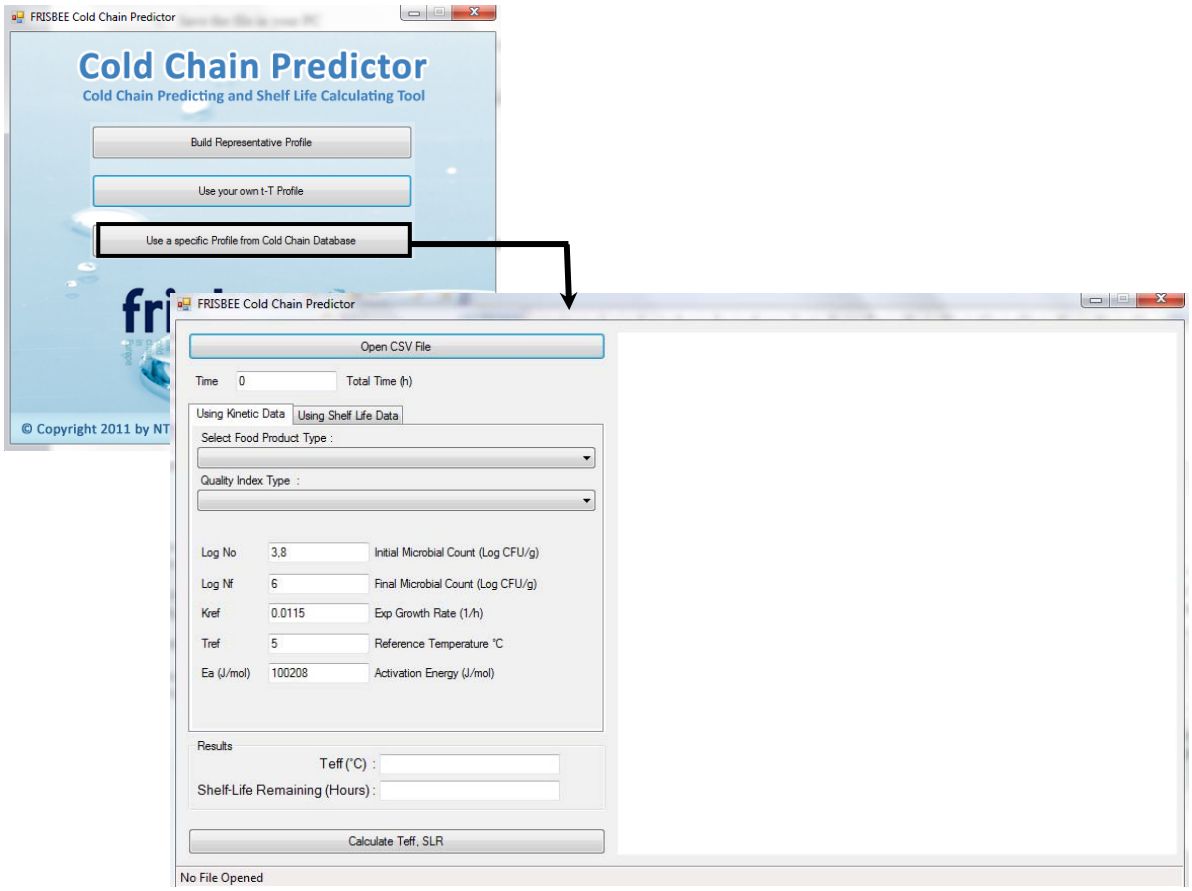
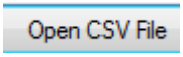


Figure 3.24 FRISBEE Cold Chain Predictor basic screen using the FRISBEE_CCP Software-Option 3: Use a specific profile from the Cold Chain Database.

At the software screen click on the 

tab and open the file downloaded from the Cold Chain Database.

Finally, the quality status determination of a food product can be performed based on the specific Cold Chain Database profile acccording to instructions given in section: ***Step 4.3 Product quality status determination***. This can be performed either by using **(a)** available kinetic data or **(b)** user 's own shelf life data.

4. References

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