COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Alert to Temperature Abuse of UGR-A's

Final Technical Report STP#3009

Results and Accomplishments (June 2010 – December 2012)

Report No: FTR 304

CDRL Sequence: A003

April 2013

CORANET CONTRACT #: SP4701-08-D-0004

Sponsored by:
DEFENSE LOGISTICS AGENCY
8725 John J. Kingman Rd.
Fort Belvoir, VA 22060-6221

Contractor:
Food Innovation Center - North
The School of Environmental and Biological Sciences
Rutgers, The State University of New Jersey
New Brunswick, New Jersey 08903

Principal Investigators:
Henderikus B Bruins
Dr Mukund Karwe
Dr Donald Schaffner

TEL: 732-445-6130
FAX: 732-445-6145

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **01 APR 2013**	2. REPORT TYPE **Final Technical Report**	3. DATES COVERED **01-06-2010 to 01-12-2012**

4. TITLE AND SUBTITLE **Alert to Temperature Abuse of Unitized Group Rations - A (UGR-A) STP # 3009**	5a. CONTRACT NUMBER **SP4701-08-D-0004**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER **Mantech (PE# 0708011S)**
6. AUTHOR(S) **Henderikus Bruins; Mukund Karwe; Donald Schafner; Susan Harrington; Bob Trottier**	5d. PROJECT NUMBER **CORANET STP # 3009**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER **A003**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Rutgers, The State University of New Jersey,Food Innovation Center - North,School of Enviromental and Biological Sciences,New Brunswick,NJ,08903**	8. PERFORMING ORGANIZATION REPORT NUMBER **FTR 304**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **Defense Logistics Agency, 8725 John J. Kingman Rd, Fort Belvoir, VA, 22060-6221**	10. SPONSOR/MONITOR’S ACRONYM(S) **J335 DLA R&D**
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Unitized Group Ration ? A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. These rations are assembled in CONUS and shipped around the world for use in field feeding by deployed units. The frozen box containing perishable foods is stored at 0 F and must have 9 months remaining shelf life for OCONUS deliveries. Food safety and quality of frozen products is largely dependent on maintaining the proper temperature during transportation, storage, and thawing/tempering. Understanding the potential for temperature abuse of food is an important element in designing effective food safety controls. New technology can assist the food industry and risk assessors in evaluating the temperature-related risk profile of perishable food products. The data can enable the industry to maximize product quality, while minimizing the food safety risk caused by potential temperature abuse that occurs after a product leaves a food manufacturing facility. This project studied quality deterioration at various storage temperature and time periods well beyond what can be expected during the normal life cycle of the product. Both sensory and analytical data indicate that quality deterioration to the point that the product has reached the end of its shelf life is very unlikely to occur. It is more likely that the product will go through defrost cycles that would either cause textural changes in the product or in the worst case, cause microbial growth resulting in safety concerns. Mathematical heat transfer models were developed for the various UGR-A rations. Based on these models we evaluated various case studies with temperature upsets to predict when a microbial safety concern would develop if a UGR-A case is exposed to 35 F environmental temperature for 11 hrs or more. Similar, it expected that a microbial safety concern would develop after 195 hrs if a fully loaded, well insulated freezer would suddenly fail (compressor failure). Because quality deterioration and microbial growth have distinct separate kinetic reaction constants, typical TTI?s used for refrigerated product that were developed for microbial growth, might not work in frozen environments as they would react too quickly and indicate end of shelf life well before the actual end shelf life of the product has been reached. There are two solutions that were contemplated. The first solution would be to work with TTI?s that have a trigger temperature, below which they would not react. The second solution would be to develop a TTI that compromises between the quality deterioration and the microbial growth kinetics. Both solutions are feasible and best solution would come down to implementation cost and ease of use.

15. SUBJECT TERMS

Ration, UGR-A, Frozen, Shelf life, TTI

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**210**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
April 2013	Final	June 2010 - December 2012

4. TITLE AND SUBTITLE
Alert to Temperature Abuse of Unitized Group Rations - A (UGR-A)
STP # 3009

5a. CONTRACT NUMBER SP4701-08-D-0004
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER Mantech (PE# 0708011S)

6. AUTHOR(S)
Mr. Henderikus B. Bruins
Dr Mukund Karwe
Dr Donald Schafner
Ms. Susan Harrington
Mr Bob Trottier

5d. PROJECT NUMBER CORANET STP # 3009
5e. TASK NUMBER
5f. WORK UNIT NUMBER A003

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Rutgers, The State University of New Jersey
Food Innovation Center - North
School of Enviromental and Biological Sciences
New Brunswick, NJ 08903

8. PERFORMING ORGANIZATION REPORT NUMBER FTR 304

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Defense Logistics Agency
8725 John J. Kingsman Rd
Fort Belvoir, VA 22060-6221

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. These rations are assembled in CONUS and shipped around the world for use in field feeding by deployed units. The frozen box containing perishable foods is stored at 0 F and must have 9 months remaining shelf life for OCONUS deliveries.
Food safety and quality of frozen products is largely dependent on maintaining the proper temperature during transportation, storage, and thawing/tempering. Understanding the potential for temperature abuse of food is an important element in designing effective food safety controls. New technology can assist the food industry and risk assessors in evaluating the temperature-related risk profile of perishable food products. The data can enable the industry to maximize product quality, while minimizing the food safety risk caused by potential temperature abuse that occurs after a product leaves a food manufacturing facility.

15. SUBJECT TERMS
Ration, UGR-A, Frozen, Shelf life, TTI

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	Unclassified	210	Henderikus B. Bruins	732-445-6130

Abstract:

The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. These rations are assembled in CONUS and shipped around the world for use in field feeding by deployed units. The frozen box containing perishable foods is stored at 0^0F and must have 9 months remaining shelf life for OCONUS deliveries.

Food safety and quality of frozen products is largely dependent on maintaining the proper temperature during transportation, storage, and thawing/tempering. Understanding the potential for temperature abuse of food is an important element in designing effective food safety controls. New technology can assist the food industry and risk assessors in evaluating the temperature-related risk profile of perishable food products. The data can enable the industry to maximize product quality, while minimizing the food safety risk caused by potential temperature abuse that occurs after a product leaves a food manufacturing facility.

This project studied quality deterioration at various storage temperature and time periods well beyond what can be expected during the normal life cycle of the product. Both sensory and analytical data indicate that quality deterioration to the point that the product has reached the end of its shelf life is very unlikely to occur. It is more likely that the product will go through defrost cycles that would either cause textural changes in the product or in the worst case, cause microbial growth resulting in safety concerns.

Mathematical heat transfer models were developed for the various UGR-A rations. Based on these models we evaluated various case studies with temperature upsets to predict when a microbial safety concern would develop if a UGR-A case is exposed to 35 F environmental temperature for 11 hrs or more. Similar, it expected that a microbial safety concern would develop after 195 hrs if a fully loaded, well insulated freezer would suddenly fail (compressor failure).

Because quality deterioration and microbial growth have distinct separate kinetic reaction constants, typical TTI's used for refrigerated product that were developed for microbial growth, might not work in frozen environments as they would react too quickly and indicate end of shelf life well before the actual end shelf life of the product has been reached. There are two solutions that were contemplated. The first solution would be to work with TTI's that have a trigger temperature, below which they would not react. The second solution would be to develop a TTI that compromises between the quality deterioration and the microbial growth kinetics. Both solutions are feasible and best solution would come down to implementation cost and ease of use.

Index

1 Results and Accomplishments

1.1 Introduction and Background

The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. These rations are assembled in CONUS and shipped around the world for use in field feeding by deployed units. The frozen box containing perishable foods is stored at 0^0F and must have 9 months remaining shelf life for OCONUS deliveries.

UGR-As are currently assembled and distributed by three different contractors and consist of seven different breakfast menu modules and fourteen different dinner menu modules.

Vendor	Contract
AmeriQual	SPM300-04-D-Z214 Mods (#72: 15-JUN-09)
Labatt Food Service	SPM300-04-D-Z216 Mods (#81: 17-JUN-09)
Wornick	SPM300-04-D-Z217 Mods (#117: 24-JUN-09)

The product is assembled in three boxes, of which one box contains the frozen item. A breakdown of the frozen components per menu module can be found in the appendix 4.1.

All current menu modules require multiple perishable components. These should be assembled into shipping containers and packed in a manner which ensures product quality and integrity at the destination and throughout the life cycle of the ration. The components need to snugly fit to avoid the use of dunnage and prevent product damage. Each shipping container shall be grade V3c or 275# (69-33-69) wax impregnated medium. The assembly of these items is performed at each of the above mentioned contractors in a room that is maintained at 40^0F or less. The frozen item is at this temperature for about 1.5 hrs.

Unit loads for perishable items have the shipping containers arranged on a 40 inch by 48 inch pallet. The load is bonded with non-metallic strapping, shrink or stretch film or other means that comply with carrier rules and regulations applicable to the mode of transportation. The unit load height cannot exceed 43 inches.

For OCONUS delivery, the pre-shipment and receipt inspection are performed using the following criteria: The conveyance shall be pre-cooled (prior to loading) to 0 ^{0}F and the conveyance temperature should be set to 0 ^{0}F or below. Before and after shipment, the UGR-A shall show no evidence of thawing, refreezing or any other off-condition. The average internal temperature cannot exceed 10 ^{0}F and no individual component can exceed 14 ^{0}F (at loading and at receipt). The contractor will be responsible for the shipment of the meal modules directly to the OCONUS delivery point and is relying on the conveyor to store and transport the frozen product at temperatures below 0 ^{0}F.

Freezing is one of the most widely used processing technologies to stabilize food items, however it does not make them shelf stable since microbial load is not reduced; moreover it affects the quality of the product as water crystallizes, damaging the food matrix and having a negative effect on the texture. It is therefore necessary to avoid temperature increases during the shelf life of the product, as periods at temperatures above the freezing point would allow microorganisms to grow, affecting the safety, and would also make the product go through another freezing cycle once returned to freezing conditions, diminishing the quality.

While the storage requirements (0 ^{0}F) for the frozen UGR-A are adequate to maintain shelf life for 9 months, product might see higher temperatures during its life cycle due to system breakdowns, staging of materials at loading docks etc. There are several data bases available that can be used to predict microbial growth. The two main ones for food microbiology information are: Predictive Microbiology Information Portal (PMIP) and ComBase Initiative. PMIP was developed by USDA based on food microbiology research conducted in the USA, and allows the user to model microbial growth in a number of food products under several conditions. ComBase is a much larger database; it is collaboration between USDA, Food Standard Agency and Institute of Food Research from the UK, and the University of Tasmania Food Safety Center. It allows the user to search food microbiology research focused on growth and inactivation models based on food type, microorganism and environmental conditions (temperature, pH, water activity and salt concentration). Currently it contains 40,740 records, a much larger number than PMIP since it's an international collaboration, however it does not offer modeling toolboxes.

Quality degradation at low temperatures and due to freeze-thaw cycles has also been widely studied. Alvarez and Canet (2001) studied the rheological property changes of frozen vegetable purees due to freeze-thaw cycles, and found that the properties were more dependent on the type of thawing than on the number of cycles. Benjakul and Bauer (2000) found that freeze-thaw cycles have a negative effect on catfish meat, as it promoted oxidation. Similar observations were made by Boonsumrej et al. (2006), who concluded that freeze-thaw cycles promoted oxidation and increased the toughness of tiger shrimp. Dyer (1951), Dyer and Morton (1956), and Hanson and Olley (1965) studied fish protein denaturation at low temperatures, and found it to be highest at temperatures around -4ºC. Shenouda (1980) related protein denaturation with loss of texture quality. Wang et al. (2008) studied the structure changes of Chinese water chestnut starch gels subject to freeze-thaw cycles, and found out that it has a significant influence on textural properties (hardness and springiness). Pence and Standridge (1955) studied the kinetics of bread crumb firming at temperatures around freezing, and found that firming was fastest at -5ºC.

Food safety and quality of frozen products is largely dependent on maintaining the proper temperature during transportation, storage, and thawing/tempering. Understanding the potential for temperature abuse of food is an important element in designing effective food safety controls. New technology can assist the food industry and risk assessors in evaluating the temperature-related risk profile of perishable food products. The data can enable the industry to maximize product quality, while minimizing the food safety risk caused by potential temperature abuse that occurs after a product leaves a food manufacturing facility.

To indicate the time-temperature history of a product and determine if the product was exposed to conditions that might either affect the quality or safety of the product, TTI indicators can be used. Time-temperature full history integrators have been extensively researched and reviewed (Taoukis and Labuza, 2003; Selman, 1995; Collins, 2003). These indicators change according to exposure of the sensor to temperature and can be used to track the temperature history of a product.

The placement of these TTI indicators is critical. Ideally the indicators are on the outside of the case so that one can easily observe if and when the product was exposed to abusive conditions. However, the food is packaged inside the cases and the cases are stored on pallets. As such, the relationship between the environment temperature and the temperature of the product inside the case depends on the heat transfer rate and the phase changes of the product. Several tools are available that can solve the energy equation that includes phase change for a 3D object. Two of them are Fluent® and Comsol®. We use Comsol® to build a heat transfer model of the UGR-A ration that can be used to develop a performance requirement for TTI label that are placed on the outside of the case and reasonably predict abusive conditions to the product contained within.

1.2 Objectives

The objective of this project is to identify a mechanism to easily distinguish potential thermally abused UGR-A rations which would not meet the safety and quality parameters of the Army.

1.3 Results and Conclusions

Quality deterioration was studied at various storage temperature and time periods well beyond what can be expected during the normal life cycle of the product. Both sensory and analytical data indicate that quality deterioration to the point that the product has reached the end of its shelf life is very unlikely to occur. It is more likely that the product will go through defrost cycles that would either cause textural changes in the product or in the worst case, cause microbial growth resulting in safety concerns. Mathematical heat transfer models were developed for the various UGR-A rations. Based on these models we evaluated various case studies with temperature upsets to predict when a microbial safety concern would develop if a UGR-A case is exposed to 35 F environmental temperature for 11 hrs. or more. Similar, it expected that a microbial safety concern would develop after 195 hrs. if a fully loaded, well insulated freezer would suddenly fail (compressor failure).
Because quality deterioration and microbial growth have distinct separate kinetic reaction constants, typical TTI's used for refrigerated products that were developed for microbial growth, might not work in frozen environments as they would react too quickly and indicate end of shelf life well before the actual end shelf life of the product has been reached. There are two solutions that were contemplated. The first solution would be to work with TTI's that have a trigger temperature, below which they would not react. The second solution would be to develop a TTI that compromises between the quality deterioration and the microbial growth kinetics. Both solutions are feasible and best solution would come down to implementation cost and ease of use.

2 Program Management

The project was awarded on June 7, 2010, under SP4701-08-0004, delivery order 0004, with a partial obligation ($150,000) of the total requested amount of $438,583. Performance period for this delivery order was initially set at 24 months from June 7, 2010 through June 6, 2012.

The following modifications were issued:

- June 18, 2010 0005/01 Change in Block 15
- June 23, 2010 0005/02 Change in Block 15
- Nov 9, 2010 0005/03 Increased obligated funds to $250,559
- Nov 24, 2010 0005/04 Increased obligated funds to $280,120
- Nov 30, 2010 0005/05 Increased obligated funds to $287,120
- Dec 3, 2010 0005/06 Increased obligated funds to $292,120
- Feb 23, 2011 0005/07 Increased obligated funds to $344,258
- June 1, 2012 0005/08 No cost extension to September 30, 2012
- Sep 15, 2012 0005/09 No cost extension to October 30, 2012
- Oct 18, 2012 0005/10 No cost extension to December 31, 2012

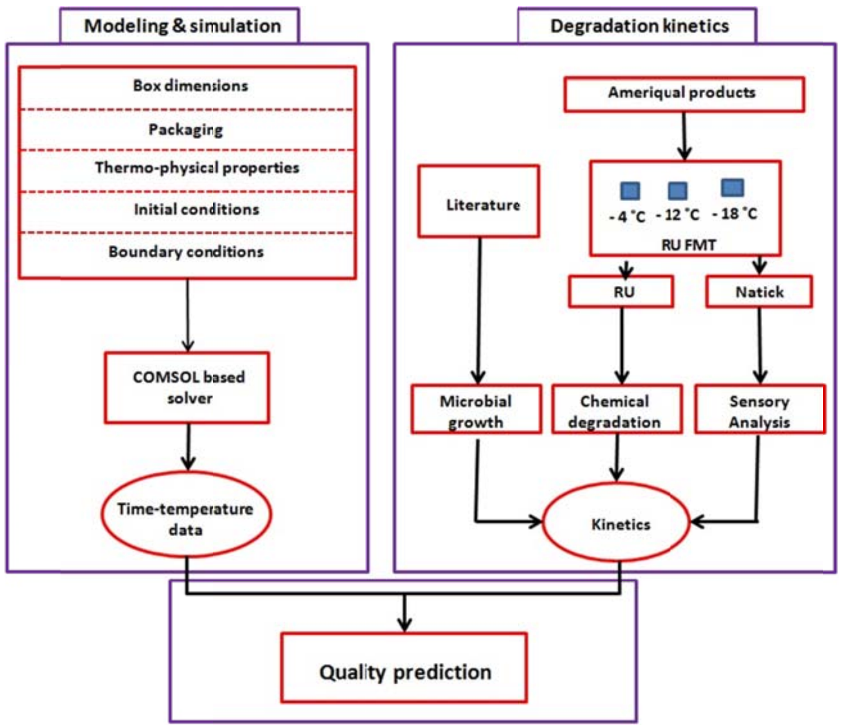
The project modeling task was delayed by six month due to insufficient funding at the onset of the project, preventing us from hiring a post-doctoral student. Also the shelf life studies took significant longer to complete as the products were less sensitive to temperature abuse than original anticipated based on literature data. These delays resulted in a six month anticipated completion date for the project. However, on September 14, 2012, a decision was made to end the project due to budget issues to fund the final six month of the project.

3 Short Term Project Activities

A kick-off meeting for this project was held on September 8, 2010 at Rutgers University. A copy of the presentation and meeting notes are attached as appendix 4.2. A second Interim Project Review was held at Natick on 9/13/2011. See appendix 4.3 for the presentation slides.

3.1 Phase I: Predictive Modeling for Food Safety and Quality

Predictive modeling for food safety and quality requires that a clear understanding of the kinetic reaction that occur for quality degradation and microbial growth and that a heat transfer model is built that can predict product temperature as function of the environmental temperature upsets. A schematic of the various tasks that needed to be accomplished is shown below.



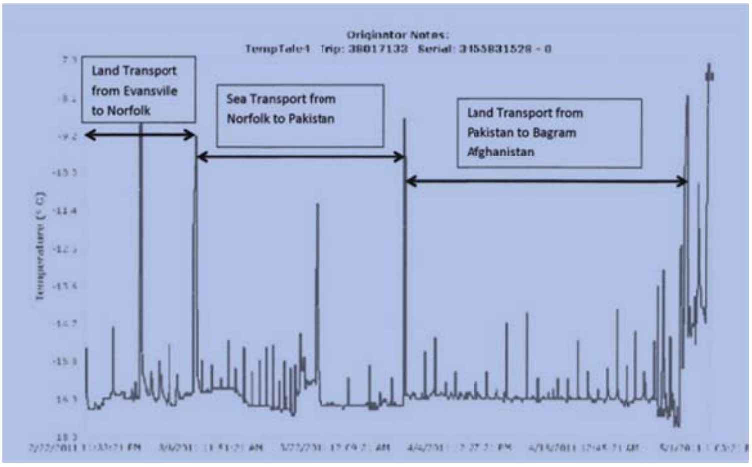
3.1.1 Review of existing modeling tools and literature data

An extensive literature search was completed to identify all available pertinent models for quality degradation and microbial growth in frozen food matrices. While the initial focus was on Blackened catfish and Biscuits and Shrimp Scampi, a decision was made at the kick-off meeting to focus instead on Steak, Chicken Cordon Blue and Shrimp Scampi. Based on literature, appropriate indicative chemical reactions were assigned to each of these model food product. TVB-N for shrimp scampi and TBARS for steak and chicken cordon bleu. The result of the literature review is summarized in a technical working paper (TWP#226) and is included as appendix 4.4.

3.1.2 Definition of the Transportation System

In a typical transport of UGR-A's from the contractor to the end point (for example Baghdad), the unit load goes through a sequence of storage and transportation steps. With the assistance of the Army and the producer, these steps were defined and potential hazards were identified that could compromise the safety and quality of the UGR-A. The UGR-A components are packed into shipping boxes. These boxes are stacked on pallets. The pallets are stored in refrigerated shipping containers and shipping containers are transported via road and sea to the prime vendor's warehouse. At the prime vendor, the shipping container is unloaded and the pallets are stored in a refrigerated warehouse.

One container was followed from the producer's site to the prime vendor warehouse in Bagram Air Force Base in Afghanistan. The route and the temperature record of the container can be seen in the figures below.



Temperature spikes can clearly be seen each time that a switch is made from one mode of transportation and/or energy source to another mode of transportation and/or energy source, however, at no time in this transportation did the container temperature exceed -7 degrees C.

The prime vendor will fill the orders for Forward Operating Bases (FOB). If necessary the original pallet will be broken down and sub-assemblies are made. The product is loaded in refrigerated trucks and transported to a FOB, where it is received and the product is stored in their freezers until it is time to prepare the food.

In discussion with the Army, we identified two potential hazards. The first potential hazard is during the temporary disruption of the cold chain during the transportation cycle, either due to failure of the compressor and/or disruption in the power source. This would lead to a gradual increase of the environmental temperature inside the shipping container until the problem is fixed at which time the environmental temperature would quickly be brought under control. This can happen anywhere in the transportation system. The second potential hazard is the movement of the product outside the freezer. This can happen during cross docking where the product is taken from one freezer, staged at ambient temperature for a certain time period and then put into a different freezer. The staging could happen in the assemblers or prime vendors warehouse, but could also happen if product is transported to a forward operating base in a none-refrigerated truck or at the FOB. Both "hazard" scenarios were evaluated using the heat transfer models to predict when the product unsafe to consume.

3.1.3 Quality Degradation Frozen Products

While some data was found in the literature regarding quality degradation of frozen product, most of these studies failed to include the effects of preservatives and packaging materials on quality degradation. It was therefore decided that shelf life studies should be performed on the three selected product items (steak, chicken and shrimp) and monitor quality degradation both analytically and via sensory testing. Products were stored at four different temperatures (-20 ^{0}C (sensory control samples at Natick), -18 ^{0}C. -12 ^{0}C and -4 ^{0}C.

-18 C Start: 3/14/11	-12 C Start: 3/14/11	-4 C Start: 3/14/11 Restart: 5/30/11
✓24 Weeks 8/29/11	✓8 Weeks 5/9/11	✓1 Week 3/21/11
✓48 Weeks 2/13/11	✓24 Weeks 8/29/11	✓2 Weeks 3/28/11
✓72 Weeks 7/30/12	✓40 Weeks 11/28/11	✓4 Weeks 4/11/11
	✓72 Weeks 7/30/12	✓6 Weeks 4/25/11
		✓12 Weeks 8/22/11
		✓16 Weeks 09/19/11

A complete discussion of the sensory analysis and analytical results are included in appendix 4.7 and 4.8 as TWP#229 and TWP#230. In general, the product was still highly acceptable when stored at -4 ^{0}C for 16 weeks and when stored at -12/-18 ^{0}C for 72 weeks. This excellent shelf life stability can in part be attributed to the packaging and use of preservatives and loss of product quality due to sub optimal freezing conditions is very unlikely.

It should be noted that quality deterioration was looked at from a constant temperature condition and not from a freeze/thaw cycle. Letting product thaw out and then let it refreeze causes recrystallization. This can cause changes in product texture and a more likely cause for product quality degradation.

3.1.4 Microbial Modeling for UGR-A

While microbial growth will very unlikely occur while the product is frozen solid, microbial growth in a defrosted product is of concern. Technical Working Paper #227 (Appendix 4.5) documents microbial growth of various pathogens such as *Listeria*, *Salmonella*, *E. coli*, *Clostridium botulinum*, *Staphylococcus aureus*, *Yersinia enterocolitica* and spoilage bacteria such as *Pseudomonas spp*. The growth rates were obtained from Combase Predictor (http://modelling.combase.cc/). Acceptable growth rates for pathogens were assumed to be less than a one log cycle increase, while acceptable growth rates for spoilage bacteria such as *Pseudomonas spp* is up to 2.5 log cycles with an assumption that the initial level can be as high as 10^5 CFU/gm.

As indicator organism, the growth rate of *Pseudomonas spp*. was used and the table below indicates how long a product can be at a certain temperature before it is spoiled.

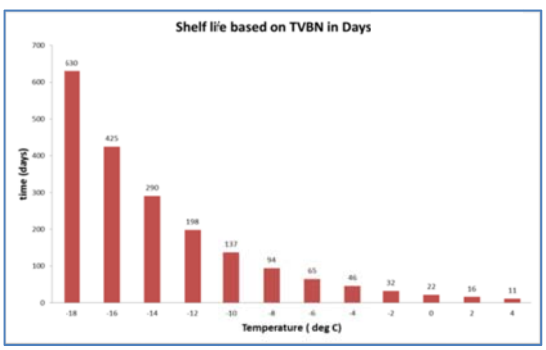
Temperature [C]	Spoilage Time [h]
-4	200 (extrapolated)
0	108
+4	62
+8	38
+12	24
+20	11

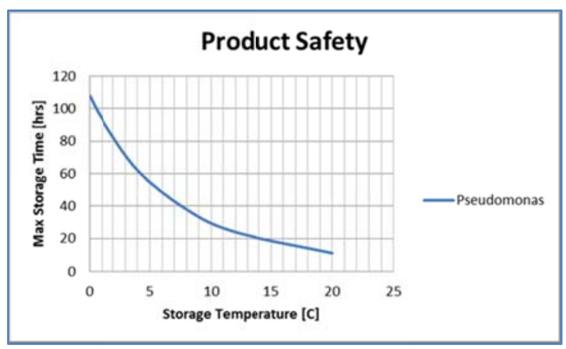
3.1.5 Heat Transfer Modeling

While the above table indicates the spoilage time when the product is at a certain temperature, it does not account for the time for required to bring the product from – 18 ^{0}C to this temperature. In order to predict the impact of temperature upsets on the quality and safety of food items, heat transfer models needed to be developed, using finite element analysis software from COMSOL® To build these models, physical characteristics of each of the menu items were determined and models were built for each food item, menu box and pallet load. Details of this work are documented in Technical Working Paper # 228 (Appendix 4.6)

3.1.6 Determination of Quality and Safety Alerts

Based on the literature and if stored at steady state conditions, TVBN spoilage will not occur within a year if the product is stored at -16 C or below. If the product is stored at +4 C TVBN spoilage will occur in 11 days. However, at this temperature the products are thawed and the rate of microbial spoilage is much greater than the TVBN kinetics and the shelf life is limited to 2.5 days.



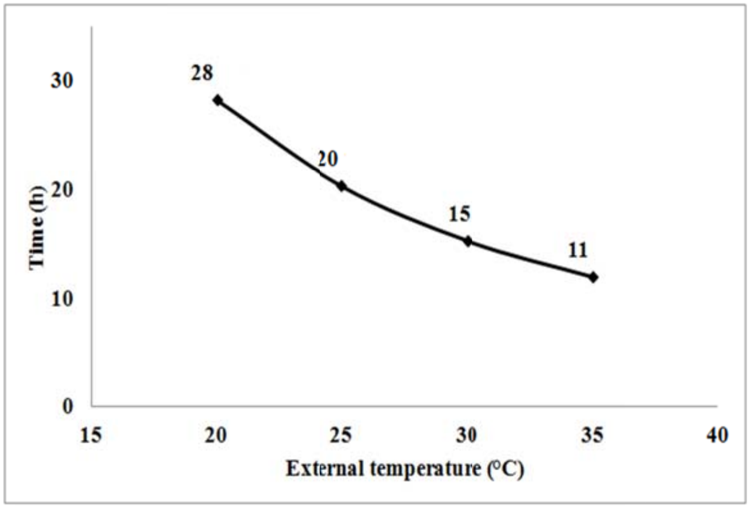


As the quality degradation reactions are rather slow, microbial growth was identified as the dominant mechanism that limits product shelf life during these temperature upset scenarios. Microbial growth will mainly occur on the surface of the product (higher initial count and higher temperature), while quality deterioration is more of a volume average function.

To predict safety and quality alerts for temperature upset events, Quality and Microbial kinetics were integrated with these heat transfer models to predict the impact of temperature upsets on quality and microbial load. The various transportation scenarios identified in section 3.1.2 were evaluated and guidelines developed in regards to the time that a certain product can be exposed to these temperature upsets before a quality and/or safety alert becomes a concern. Details of this work are documented in Technical Working Paper #228 (Appendix 4.6)

There are two scenarios that were simulated in the heat transfer model

- Under the first scenario, a UGR-A case with deep frozen product (-18 C) is left at ambient temperature for an extended period of time. The following table indicates the time period that the product can be exposed to this temperature before it is spoiled.



- In the second scenario, it is assumed that the compressor of the freezer fails. After the freezer breaks down, the temperature inside the freezer rises slowly causing the product temperature also to increase gradually. The rise of the temperature is function of the quantity of product inside the freezer and the insulating capacity of the freezer. The product takes comparatively longer time to reach 0 °C. Once the freezer restarts, the temperature inside freezer quickly drops down to -18 °C. Because of this relatively sharp decline in freezer temperature, the product freezes back in comparatively shorter time. The microbial quality analysis was carried on the beef under a certain real life scenario that had occurred in the field, which indicated that the freezer could breakdown for 195 hrs (~ 8 days) before the product would be spoiled.

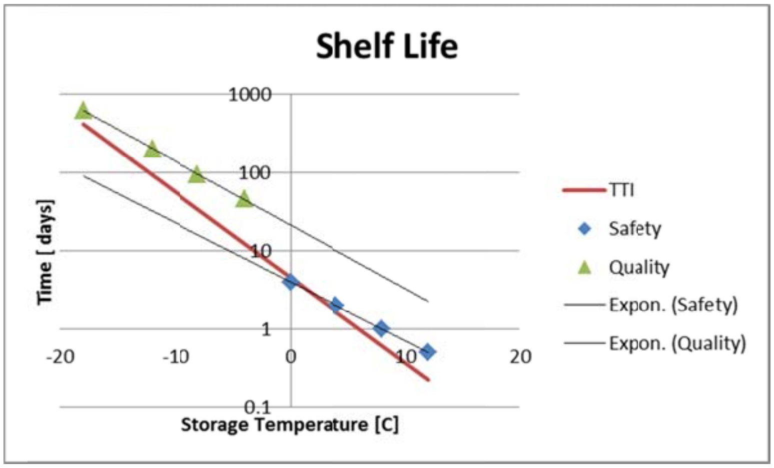
3.2 Phase II: Integrated Time-Temperature Technology Identification Adapter

3.2.1.1 TTI Technology Survey

An extensive technology survey was completed of various TTI. The results of this survey are summarized in the attached Technical Working Paper #231 (appendix 4.9). Based on the phase I research, requirements for a candidate TTI technology were defined. As indicated in the table below quality deterioration and microbial growth have different kinetic rates and temperature zone in which they occur. In frozen product, microbial growth is much slower than quality deterioration. Visa versa, microbial growth is much faster than quality deterioration once the product defrosts. This would require two different TTI's that operate within these temperature zones. This could be accomplished if there is a phase change in one of the reactive products of the TTI so that the reactions halt below the threshold temperature. Another option would be to develop a TTI that covers the entire temperature range with a compromise response between both reactions as indicated in the table below.

Storage Temp	Quality Shelf Life	Microbial Shelf Life	Desired TTI Response	Compromised Response
-18 C	630 days	>630 days	630 days	416 days
-12 C	198 days	>198 days	198 days	92 days

-8 C	**94 days**	**>94 days**	**94 days**	**34 days**
-4 C	**46 days**	**>46 days**	**46 days**	**12 days**
0 C	**>4 days**	**4 days**	**4 days**	**4.5 days**
+4 C	**>2 days**	**2 days**	**2 days**	**1.7 days**
+8 C	**>1 day**	**1 day**	**1 day**	**0.6 days**
+12 C	**>0.5 day**	**0.5 day**	**0.5 day**	**0.22 days**



The location of the TTI can influence the required response time. The above response time is based on steady state conditions, where the product is at the same temperature as the environment. However, in a dynamic situation where the product case is exposed to high environmental temperatures during cross docking, a TTI on the outside of the case would expire quickly, while the temperature of the product inside the case would still be solid frozen. It is therefore assumed that the best location of the TTI would be inside the product case where it would be shielded from sudden temperature shifts during cross docking operations.

Note: The project was premature closed due to budgetary issues. This final report with numerous appendices tries to capture all essential data required for a follow up project that would identify, test, develop and implement an appropriate TTI that can be used on a frozen UGR-A ration.

4 Appendix:

4.1 UGR-A Frozen Menu Items

4.2 Kickoff Meeting

4.3 Interim Project Review #1

4.4 Literature Review (TWP#226)

4.5 Microbial Modeling (TWP#227)

4.6 Phase I Technical Report (TWP#228)

4.7 UGR-A Sensory Data (TWP#229)

4.8 UGR-A Analytical Quality Data (TWP#230)

4.9 TTI Technology Survey (TWP#231)

Appendix 4.1

UGR-A Frozen Menu Items

Contractor:_________________

B1	Brk Menu 1	Ranchero Beef Steak
B2	Brk Menu 2	Ham Slice
B3	Brk Menu3	Steak & Eggs
B4	Brk Menu 4	Cheddar Sausage Gravy
B5	Brk Menu 5	Omelet and Bacon
B6	Brk Menu 6	Chorizo Breakfast Wrap
B7	Brk Menu 7	Beef Breakfast Skillet
D1	Lun/Din Menu 1	Chicken Fried Steak/Fried Chicken
D2	Lun/Din Menu 2	Hamburger/Hot Dog
D3	Lun/Din Menu 3	Pork in BBQ/Beef Brisket in BBQ sauce
D4	Lun/Din Menu 4	Turkey Cutlet
D5	Lun/Din Menu 5	Chinese Beef & Vegetables/Cashew Chicken
D6	Lun/Din Menu 6	Shrimp Scampi/Penne Pasta with Chicken in Alfredo Sauce
D7	Lun/Din Menu 7	Steak
D8	Lun/Din Menu 8	Rotisserie Chicken
D9	Lun/Din Menu 9	Spaghetti & Meatballs/ Sausage Scaloppini
D10	Lun/Din Menu 10	Enchiladas (Chicken and Beef)
D11	Lun/Din Menu 11	Chicken Teriyaki Thighs
D12	Lun/Din Menu 12	Chicken Nuggets (Buffalo and Plain)
D13	Lun/Din Menu 13	Prime Rib
D14	Lun/Din Menu 14	Chicken Cordon Bleu
D15	Lun/Din Menu 15	Tomatillo Pork
D16	Lun/Din Menu 16	Meatloaf

Menu Item	Required Servings and Size		Food/Ingredients/Supplies
FROZEN/PERISHABLE BOX - 8970-01-525-6726			
BACON & EGG QUESADILLA	*50*	*1 each, 3.75 oz*	*Quesadilla, Bacon &Egg, Individually Wrapped, Frozen*
RANCHERO BEEF	*50*	*6 oz*	*Beef, Ranchero, Boil-in-Bag, Frozen*
ORANGE JUICE	*50*	*¾ cup*	*Juice, 100% Orange, Frozen Concentrate*
CINNAMON ROLL	*45*	*1 each, 1.4 oz w/ .5 oz icing*	*Cinnamon Roll, Frozen*
FROZEN/ PERISHABLE BOX - 8970-01-525-6729			
CREAMED BEEF	*25*	*2/3 cup*	*Gravy, Creamed Beef, Frozen*
HAM SLICE	*50*	*6 oz*	*Ham Slice, Frozen,Bone-In*
BISCUITS	*50*	*2 each*	*Biscuit, Buttermilk, frozen, thaw and serve*
MUFFIN	*50*	*2.25 oz*	*Muffin, Variety Pack, Individually Wrapped*
FROZEN/PERISHABLE BOX - 8970-01-525-6733			
STEAK	*50*	*5.5 oz*	*Steak, Breakfast, uncooked*
PEPPERS & ONIONS	*40*	*2 oz*	*Peppers & Onions, frozen*
FRENCH TOAST AND SAUSAGE TAQUITO	*24*	*3.0 oz*	*Taquito, French Toast and Sausage, Frozen, Fully Cooked*
DANISH	*48*	*1 each, 1.25 oz*	*Danish, Assorted Mini, Frozen*
ORANGE JUICE	*50*	*¾ cup*	*Juice, 100% Orange, Concentrate, Frozen*
FROZEN/PERISHABLE BOX - 8970-01-525-6735			
PANCAKE SANDWICH	*48*	*1 each, 4.8 oz*	*Pancake, Sausage and Egg Sandwich, Individually wrapped, Frozen*
CHEDDAR SAUSAGE GRAVY	*25*	*1/2 cup*	*Sausage Gravy,Cheddar, Ready to Eat, Frozen*
BISCUITS	*50*	*2 each*	*Biscuit, Buttermilk, frozen, thaw and serve*
MUFFIN	*48*	*1 each, 2 oz*	*Muffin, Coffee Cake (with cinnamon), Individually wrapped*
FROZEN/PERISHABLE BOX - 8970-01-525-6739			
OMELET KIT	*50*	*1.92 oz*	*Omelet Kit, Frozen, Contains diced ham, diced green peppers, onions and shredded cheese*
BLUEBERRY PANCAKES	*48*	*3 each, 1.66 oz*	*Pancakes, Blueberry, Frozen*
ORANGE JUICE	*50*	*¾ cup*	*Juice, 100% Orange, Concentrate, Frozen*
DONUT	*48*	*1 each, 2.25 oz*	*Donut, Powdered Sugar, Individually wrapped*
FROZEN/PERISHABLE BOX - 8970-01-525-6740			
MAPLE SAUSAGE PATTIES	*50*	*2 each*	*Maple Flavored Pork Sausage, Patty, Frozen, Fully Cooked.*
EGG & CHORIZO WRAP	*36*	*1 each, 5 oz*	*Wrap, Egg & Chorizo, Frozen*
MUFFIN	*50*	*2.25 oz*	*Muffin, Variety Pack, Individually Wrapped*
FRENCH TOAST	*50*	*1 each, 3.25 oz*	*French Toast,Whole Grain, Frozen*
FROZEN/PERISHABLE BOX - 8970-01-525-6744			
SAUSAGE SKILLET POTATOES	*50*	*3/4 cup*	*Potatoes, Sausage Skillet, Frozen, Fully Cooked*
BROWN & SERVE SAUSAGES	*50*	*2 each*	*Sausage Links, Pork, Brown & Serve, Frozen, Precooked*
BAGEL	*48*	*1 each, 5.5 oz*	*Cinnamon Bagel w/ Apple Filling, Frozen, Individually Wrapped*
FROZEN/PERISHABLE BOX - 8970-01-525-6813			
CHICKEN FRIED STEAK	*25*	*5.5 oz*	*Chicken Fried Steak, Ready-to-Cook, Frozen*
FRIED CHICKEN	*25*	*3.0 oz*	*Fried Chicken, Fully Cooked, Frozen*
APPLE PIE	*48*	*1 each, 4 oz*	*Apple Pie Slice, Individually wrapped*
FROZEN/PERISHABLE BOX - 8970-01-525-6815			
GRILLED HAMBURGERS	*50*	*2 each, 3.8-4 oz patty*	*Beef Patties, Frozen, Fully-Cooked*
HOT DOGS	*50*	*1 each, 3.2 oz.*	*Hot Dog, Frozen, Fully cooked*
POTATO WEDGE	*50*	*3.5 oz*	*Potato wedge, seasoned*
PECAN PRALINE SNACK CAKE	*50*	*2.5 oz*	*Snack Cake, Pecan Praline*

FROZEN/PERISHABLE BOX - 8970-01-525-6816			
PORK IN BBQ SAUCE	25	8 oz	Pork in BBQ, Boil-in-Bag, Frozen
BEEF BRISKET w/ BBQ SAUCE	25	10 oz	Beef Brisket w/ BBQ Sauce, Boil-in-Bag, Frozen
CORNBREAD	48	1 each, 2 oz	Cornbread, mini loaves, 24 ct plain, 24 ct jalapeno
FROZEN/PERISHABLE BOX - 8970-01-525-6817			
TURKEY CUTLET	50	1-5 oz	Turkey Breast, Whole Muscle, Frozen, Fully-Cooked
HARVEST PUMPKIN CAKE	50	2.8 oz	Cake, Harvest Pumpkin, Frozen
FROZEN/PERISHABLE BOX - 8970-01-525-6818			
CHINESE BEEF & VEGETABLES	50	10 oz portion, 3 oz beef, 7 oz veg and sce	Beef, Chinese Style Sauce, Veg, Frozen, Boil-in-Bag
WHITE CHOCOLATE MACADAMIA COOKIE	48	1 each, 4 oz	Cookie, White chocolate chip macadamia nut, 2-2oz cookies per package
FROZEN/PERISHABLE BOX - 8970-01-525-6820			
SHRIMP SCAMPI w/ BOWTIE PASTA	25	11 oz portion, 1 cup cooked pasta, 3 oz cooked shrimp	Shrimp Scampi w/ Bowtie pasta, Frozen, Boil-in-Bag
PENNE PASTA w/ CHICKEN AND BROCCOLI	25	12 oz portion, 1 cup cooked pasta, 3 oz Chicken	Penne pasta w/ broccoli and chicken, Frozen, Boil-in-Bag
AMARETTO CAKE	50	2.8 oz	Cake, Amaretto Cream Cake, Frozen, Sheet
FROZEN/PERISHABLE BOX - 8970-01-525-6823			
GRILLED STEAK	50	9 oz	Steak, Beef Rib, Tri-tip, Frozen
PEPPER & ONION	40	2 oz	Peppers & Onions, Frozen
POTATO WEDGE	50	3.5 oz	Potato Wedge, Natural with Sea Salt, Frozen
CHOCOLATE CAKE	50	2.4 oz	Cake, Chocolate with Chocolate Icing, Frozen, Sheet
FROZEN/PERISHABLE BOX - 8970-01-525-6825			
ROTISSERIE CHICKEN	50	1 Quarter	Rotisserie Chicken, Quarters, Fully-Cooked, Frozen
CHOCOLATE CARAMEL BAR	48	1 each, 3.2 oz	Chocolate carmel bar with snickers, tray
FROZEN/PERISHABLE BOX - 8970-01-525-6827			
MEAT BALLS AND SAUCE KIT	25	3-1oz meatballs and ¾ cup sauce	Beef Meatballs, Fully-Cooked, Frozen in Marinara Sauce , Boil-in-Bag
SAUSAGE SCALOPPINI	25	10 oz Serving, 3.6 oz meat	Sausage Scaloppini, Frozen, Boil-in-Bag
PIZZA ROLL	48	1 each, 3oz	Pizza Roll, Frozen
CAKE	48	1 each, 2.8 oz	Cake, Italian Lemon, Layer, Frozen
FROZEN/PERISHABLE BOX - 8970-01-525-6830			
ENCHILADA KIT (CHICKEN AND BEEF)	50	2 each, Contains 3 oz meat, 1 oz enchilada sauce, 1 oz queso sauce, 1.1 oz tortilla	Enchiladas, Chicken and Beef, Boil-in-Bag, Frozen
APPLE TAQUITO	48	3.0 oz	Taquito, Apple, Frozen, Fully Cooked
FROZEN/PERISHABLE BOX - 8970-01-525-6832			
BLACKENED CATFISH	25	4.0 oz	Catfish, Blackened, Frozen, Boil-in-Bag
TERIYAKI CHICKEN THIGHS	25	4.0 oz	Chicken Thighs, In Teriyaki Sauce, Frozen, Boil-in-Bag
CHOCOLATE CHUNK COOKIE	48	1 each,4 oz	Cookie, Chocolate Chunk, 2-2oz cookies per package, Frozen
FROZEN/PERISHABLE BOX - 8970-01-525-6849			
BUFFALO CHICKEN CHUNKS	25	6 to 8 pcs	Chicken, Breast Chunks, Buffalo Glazed, Fully Cooked, Frozen
BREADED CHICKEN CHUNKS	25	6 to 8 pcs	Chicken, Breast Chunks, Breaded, Fully Cooked, Frozen
POTATO WEDGE	50	3.5 oz	Potato wedge, seasoned
BROWNIE	48	1 each, 2.50 oz	Brownie, Turtle, Individually wrapped, Frozen

FROZEN/PERISHABLE BOX - 8970-01-525-6852			
PRIME RIB	***50***	***10 oz***	***Prime Rib, Fully Cooked, Frozen, Boil-in-Bag***
PECAN PIE	***48***	***1 each, 4 oz***	***Pecan Pie Slice, Individually wrapped***
FROZEN/PERISHABLE BOX - 8970-01-525-6856			
CHICKEN CORDON BLEU	***50***	***1 each, 5.5 oz portion***	***Chicken Cordon Bleu, Ovenable Film ,Frozen, Fully Cooked***
CHOCOLATE CAPPUCCINO CAKE	***48***	***2.8 oz***	***Cake, Chocolate Cappuccino, Frozen, Sheet***

UGR-A 10 Table II

NOTE: Where a brand name is shown in the item description, products must be equal to or better than the salient characteristics of that brand name item.
Also, all products must meet Table I requirements for serving sizes. Sizes/weights are minimums.
For Meat Items, no soy, filler, or added water is permitted unless otherwise specified. All Meat Items specified by a NAMP number must have COC verification. Assemblers must have COC documentation on file.
All Portion Control condiments must be packaged in a pouch. Portion control cups are not permitted.

LSN: MENU COMPONENTS/ ITEM DESCRIPTION (STANDARD)

FROZEN MEAT, POULTRY, FISH & EGGS

ALL ITEMS ARE REQUIRED FROM AN APPROVED SOURCE

8940-01-E10-1659	BEEF, BEEF AND VEGETABLES, FULLY COOKED, FRZN, separate Boil-in-Bags for beef, sauce, and IQF vegetables, Grade A (Blend Contains broccoli florets, sugar snap peas, and carrot sticks) Heat treated Flank Steak (NAMP # 193) slices. Min Avg. raw weight 0.5 oz verified by COC. Combined products contain not less than 30 % cooked beef, 38.5% vegetables and 30% sauce. Contains min. 3 oz. beef per Table I serving. (Sunrise Foods, UPC 38-1090)
8940-01-E10-1918	BEEF, BREAKFAST SKILLET, FULLY COOKED, FRZN, Boil-in-Bag, Ground Beef (78% lean) in a biscuit gravy with potatoes and a vegetable blend of jalapenos, green chiles and tomatillos. COC required to verify % lean beef. Contains not less than 16% beef, Sauce shall contain not less than 21% natural cheddar cheese. COC required to verify % beef. (JTM Food Group, Item # 46160) **Cheese required from an Approved Source**
8905-01-E10-1806	BEEF, CHICKEN FRIED BEEF STEAK, READY-TO-COOK, FRZN, Breaded (not more than 20% breading), 80% lean, 5.5 oz. piece Avg. Wt. COC required to verify % lean(raw) beef. (Quantum, UPC 3634)
8940-01-E10-1661	BEEF, BRISKET, FULLY COOKED, FRZN, Boil-in-Bag, naturally smoked, in barbeque sauce. Contains not less than 80 % cooked beef and 20% sauce. Deckle-Off derived from NAMP # 120. 3/16" slice thickness. (Quantum, UPC 1766)
8905-01-E10-1553	BEEF, FRANK, 5X1, 7 ", FULLY COOKED, FRZN, Vacuum packed, NAMP 800D Contains 2% or less of Salt, Flavoring, Potassium Lactate, Sodium Lactate, Sodium Phosphates, Sodium Diacetate, Sodium Erythorbate, Sodium Nitrite, Extract of Paprika. (John Morrell, Black Label Gourmet, UPC 70100-02752)
8940-01-E10-1920	BEEF, MEATLOAF PORTIONS, FULLY COOKED, FRZN, Boil-in-Bag derived from 80% lean 100% ground Beef, NAMP 136, Portions Ind Seared in Trans fat free Oil, in tomato based sauce, No More than 4% filler, No Soy added, No BHT/BHA or TBHQ added, COC required to verify % filler. (Quantum UPC 1532) **Egg ingredients must be from an Approved Source.**
8940-01-E10-1612	BEEF, RANCHERO BEEF STEAK, FULLY COOKED FRZN, Boil-in-Bag. Derived from NAMP 115, Beef Chuck Boneless. Contains not less than 42% Beef. Blend of cooked beef strips in a slightly spicy tomato based sauce w/ chopped green chili peppers. (MissaBay, UPC 1420)
8905-01-E10-1808	BEEF, RIB EYE ROLL for PRIME RIB, FULLY COOKED, FRZN, Boil-in-Bag NAMP 112, Average 3-5 whole rolls per case, BNLS, 1% topical rub, 10% marination, vacuum packed, 50 servings per case min. (Quantum, UPC 1060)
8905-01-E10-0180	BEEF, STEAK PATTIES, FULLY COOKED, FRZN, all beef, chopped and formed , natural shape hamburger, product derived from 75% lean (raw), flame broiled, 3.8 to 4.0 oz. each, not less than 50 count per container, derived from NAMP 1136 only. COC required to verify 75% lean (raw) beef. (Zartic, UPC 80038)

8905-01-E10-1162	BEEFSTEAK, TRI-TIP, BNLS, FRZN, USDA Select or higher, 5.5 oz. +/- 0.25 oz., Marinated, NAMP 1185D, Bottom Sirloin Butt, Tri-Tip, max 15% solution containing Ficin as a tenderizer, No Papain Allowed, Flat Pack. (Quantum, UPC 5304)
8905-01-E10-1221	BEEFSTEAK, TRI-TIP, BNLS, FRZN, USDA Select or higher, 9 oz. +/- 0.5 oz., Marinated, NAMP 1185D, Bottom Sirloin Butt, Tri-Tip, max 15% solution containing Ficin as a tenderizer, No Papain Allowed, Flat Pack. (Quantum, UPC 5307)
8905-01-E10-1701	CHICKEN, BREAST CHUNKS, FULLY COOKED, FRZN, Breaded (not more than 30% breading), Whole Muscle, White Meat, Avg. Wt. per piece 0.80 oz., Wt. range 0.60 to 1.0 oz. Max 5% Soy. COC required to verify % soy. (Pierce/Pilgrim's Pride, UPC 110286)
8905-01-E10-1703	CHICKEN, BREAST CHUNKS, FULLY COOKED, FRZN, Buffalo Style Glazed, Breaded (not more than 30%) Whole Muscle, White Meat, Avg. Wt. per piece 0.80 oz., Wt. range 0.60 to 1.0 oz. Max 5% Soy. COC required to verify % soy. (Pierce/Pilgrim's Pride , UPC 110428)
8940-01-E10-1922	CHICKEN, BREAKFAST CHICKEN FILLETS, FULLY COOKED, FRZN, Boneless, Skinless Breaded Chicken breast with rib meat (not more than 30% breading). Avg. Wt. 2.0 oz per piece (Chris P Chicken/Pierce Chicken®/Pilgrim's Pride Foodservice™, UPC 7512)
8940-01-E10-1924	CHICKEN,WITH CASHEW NUTS, FULLY COOKED, FRZN, Separate Boil-in-Bags for chicken, sauce, cashew nuts & IQF vegetables. Grade A blend of sliced vegetables (carrots, celery and water chestnuts). White Meat, whole muscle chicken in a corn starch & egg white tempura batter (not more than 1 mm thick). Soy may be used as a cooking medium and sauce may contain soy. Soy fillers are not allowed. Combined product contains not less than 31% chicken, 35% vegetables, 31% chicken based sauce and 3% cashew nuts. Prepared entrée must contain a min. of 3.0 oz. chicken per Table I serving. (Sunrise Foods, UPC 37-1024)
8940-01-E10-1812	CHICKEN, CORDON BLEU, FULLY COOKED, FRZN, Boneless, Breaded Stuffed chicken breasts, sectioned and formed with rib meat. Contains a filling of blended cheeses (Swiss and American) and water added cooked ham. Not more than 16% filling, Avg. Wt. 5.5 oz., individually wrapped, ovenable film. NO MSG or hydrogenated oils used. COC required for % filling. (Barber Foods, UPC 0233034) **Cheese Required from an Approved Source**
8905-01-E10-1814	CHICKEN, FRIED, FULLY COOKED, FRZN, Breaded, Reduced Sodium, Ovenable, 8 pc cut-up from a 2.3-2.5 lb fryer or broiler WOG, May contain max 5% Soy. COC required to verify % soy.(Perdue/Suzanna's Kitchen, UPC 80946)
8905-01-E10-1171	CHICKEN, ROTISSERIE STYLE, QUARTERS, FULLY COOKED, FRZN, marinated chicken quarters coated w/topical seasoning, from a whole USDA grade A equiv bird without giblets (WOG), 4 quarters (2 front, 2 back), Total bone-in weight of the four quarters after cooking should be NLT 2 pounds. Weight range for quarters will be 7-9 ounces for the back and 8-10 ounces for the front. (Perdue UPC)
8940-01-E10-1816	CHICKEN, THIGHS IN TERIYAKI SAUCE, FULLY COOKED, FULLY PASTEURIZED, FRZN, Boil-in-Bag, Seared, Skin On,, Avg. Wt. 4.5 oz. +/- 0.5 oz. Average raw material weight of chicken is 6 oz. (Cuisine Solutions, Item #3397)
8905-01-E10-1818	HAM, STEAK, BONE IN, FULLY COOKED, FRZN, Hickory Smoked, Water added, Avg. Wt. 6 oz., bone not to exceed an avg. wt. of 0.5 oz. and a diameter of 1 inch +/- 0.25 inch. (Rose Packing, UPC 04606)
8940-01-E10-1820	ENCHILADA KIT, BEEF & CHICKEN, FULLY COOKED, FRZN, Kit contains individual Boil-in-Bags of: *Beef Taco Filling* (minimum 53% beef by formulation; max 4.5% soy protein by formulation; less than 6g fat and less than 400mg sodium per 100 grams; beef shall resemble the size of

	beef typically produced by a 3/8 inch grinder plate) COC required to verify all Beef Taco Filling % requirements. *Chicken Taco Filling* (minimum 32% chicken based on finished product analysis; chicken is natural proportion of light and dark meat; chicken shall be in the form of chunks and shreds, not ground; max 1.5% soy protein by formulation), COC required to verify % soy protein. *Queso Sauce* (natural cheddar cheese, tomatoes and Tex-Mex seasonings; minimum 44% natural cheddar cheese by formulation) COC required to verify % cheese. *Enchilada Sauce* (medium heat level in a traditional Tex-Mex red sauce containing tomatoes, green chilies and lime juice) *Tortillas* heat pressed flour tortillas, min 1 oz, 6 +/- .50 inch diameter. (JTM, Item #40010) **Cheese and Tortillas Required from an Approved Source**
8940-01-E10-1616	MEATBALLS AND SAUCE KIT, FULLY COOKED, FRZN, Boil-in-Bag, Meatballs, Beef and Pork, derived from ground beef and pork. Not more than 25% fat raw. Meatballs may contain a Max of 5% Soy verified by COC. Avg. Wt. 1 oz. each, not more than 35% fillers in the meatball verified by COC. Kit includes Meatballs in Sauce and 1 bag of marinara sauce w/o meat. (MissaBay, UPC 1460)
8940-01-E10-1926	PASTA, PENNE WITH CHICKEN AND TURKEY BACON IN A TOMATO ALFREDO SAUCE, FULLY COOKED, FRZ, Boil-in-Bag, 24% pasta, not less than 1.5 inch in length, not less than 21% chicken, min of 2.5% combination of sun dried tomatoes and turkey bacon verified by COC. Min. 3 oz. whole muscle grilled white meat chicken per serving, COC required to verify portion. (Ragozzino, UPC 6282)
8940-01-E10-1928	PORK, PULLED IN TOMATILLO SAUCE, FULLY COOKED, FRZN, Boil-in-Bag, Derived from NAMP 405B. Min. 60% pork. Thin pieces of pork cushion practically free of fat (not greater than 12%). COC required to verify % fat and % pork. (Sunrise Foods, UPC 44734)
8940-01-E10-1630	PORK, CHOPPED IN BBQ SAUCE, FULLY COOKED, FRZN, Boil-in-Bag, Derived from NAMP 405B. Contains not less than 51% pork. Thin pieces of pork shoulder practically free of fat, not greater than 9%. COC required to verify % fat. Natural hickory smoke flavor. (MissaBay, UPC 1480)
8940-01-E10-1417	SHRIMP, SCAMPI WITH BOWTIE PASTA, FRZN, RAW SHRIMP, Boil-in-Bag, 50/60 count per pound of shrimp, with blanched bowtie pasta in seasoned garlic sauce, 3 oz. of cooked shrimp per serving verified by COC. Gulf, Brown, Wild White, or Pond Raised White Shrimp must be peeled and de-veined and domestically sourced. Shrimp must be Grade A or equivalent verified by COC or USDC Grading Certificate. Broken shrimp pieces not to exceed 18%. (Ragozzino, UPC 9161) **Shrimp Required from an Approved Source**
8905-01-E10-0031	SAUSAGE, BREAKFAST LINKS, FULLY COOKED, FRZN, pork, w/casing, NAMP 802B, 1.5 oz. avg. wt. per link , max 28% fat, max 3% water and 0.5% sodium phosphates. COC required to verify % fat. (Jimmy Dean, UPC 19312)
8940-01-E10-1638	SAUSAGE, GRAVY w/ CHEDDAR, FULLY COOKED, FRZN, Boil-in-Bag, Pork sausage (max 20% fat) with not less than 16% natural cheddar cheese in a biscuit gravy base, not less than 9% sausage, COC required to verify % fat of pork sausage and % cheddar cheese. (JTM, Item # 46070) **Cheese Required from an Approved Source**
8905-01-E10-1394	SAUSAGE, MAPLE BREAKFAST PATTIES, FULLY COOKED, FRZN, Pork, Avg. Wt. 1.3 oz. each and avg. 2.5 inch diameter per patty, max 30% fat, may contain max 7% textured vegetable protein(TVP), max 20% water and max 0.5% sodium phosphates. COC required verifying all percentages. (JTM, UPC 66120).
8940-01-E10-1822	SAUSAGE, ITALIAN PORK SAUSAGE SCALOPPINI, FULLY COOKED, FRZN, Boil-in-Bag, Blend of Italian pork sausage and vegetables (onions, red and green bell peppers), Sausage, sliced, all pork (no fillers), Must contain no less than 36% Italian pork sausage, 31% vegetables. (MissaBay, UPC 080131)

8905-01-E10-0946	TURKEY, BREAST, FILET, SLICED, FULLY COOKED, FRZN, whole muscle, with rib meat, max 15% water solution, min 5 oz. +/- 0.5 oz. each. (Quantum, UPC 2254)

LSN: ***FROZEN GROCERIES***

8920-01-E10-1824	BAGEL, CINNAMON WITH APPLE FILLING, FRZN, FULLY BAKED, Individually Wrapped, Ovenable Film, Avg. Wt. 5.5 oz. (SJR Foods, UPC 04606)
8920-01-E10-0908	BISCUITS, BUTTERMILK, FRZN, FULLY BAKED, Easy Split /Sliced, TransFat Free min 2.5 oz. each, min 3 inch diameter, ovenable paper tray and ovenable outer film. (Ralcorp/Bakery Chef, UPC 21008)
8920-01-E10-1581	BROWNIE, TURTLE, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped, Brownie with pecans, caramel and chocolate chunks, Avg. Wt. 2.5 oz. (Caravan Trading Co, UPC 20516)
8920-01-E10-1826	CAKE, AMARETTO CREAM, FRZN, Layer Cake, FULLY BAKED, Thaw & Serve. (Sterling Foods , UPC 075037-4) **Dairy filling ingredients required from an Approved Source**
8920-01-E10-1930	CAKE, COFFEE, CARAMEL APPLE PECAN, FRZN, FULLY BAKED, Thaw & Serve, coffee cake with apples, pecans and caramel topped with cinnamon streusel (Sterling Foods, UPC 088026 75040 6)
8920-01-E10-1830	CAKE, CHOCOLATE CAPPUCCINO, FRZN, Layer Cake, FULLY BAKED, Thaw & Serve. (Sterling Foods, UPC 075036-4) **Dairy filling ingredients required from an Approved Source**
8920-01-E10-1711	CAKE, CHOCOLATE WITH CHOCOLATE FROSTING, topped with mini chocolate chips, FRZN, Sheet Cake, FULLY BAKED, Thaw & Serve. (Sterling Foods, UPC)
8920-01-E10-1828	CAKE, HARVEST PUMPKIN, FRZN, Layer Cake, FULLY BAKED, Thaw & Serve. (Sterling Foods, UPC 075035-4) **Dairy filling ingredients required from an Approved Source**
8920-01-E10-1401	CAKE, ITALIAN LEMON, FRZN, Layer Cake, FULLY BAKED, Thaw & Serve. (Sterling Foods, UPC 0 88026 75060 4) **Dairy filling ingredients required from an Approved Source**
8920-01-E10-1932	CAKE, PINEAPPLE COCONUT, FRZN, Layer Cake, FULLY BAKED, Thaw & Serve, coconut cake with pineapple cream cheese filling topped with streusel. (Sterling Foods, UPC 088026 75039 0) **Dairy filling ingredients required from an Approved Source**
8920-01-E10-1832	CAKE, PECAN PRALINE, FRZN, Mini Loaves, FULLY BAKED, Thaw & Serve, Avg. Wt. 2.5 oz. (Sterling Foods, UPC 075038-4)
8920-01-E10-1936	CHEESECAKE BITE, DULCE DE LECHE, MINI, FRZN, FULLY COOKED, bulk packed, cheesecake and caramel filling in a golden crunchy flour tortilla, Avg. Wt. 2 oz. (Ruiz Foods Mfr #23993) **Dairy filling ingredients and Tortilla required from an Approved Source**
8920-01-E10-1719	CINNAMON ROLL,WITH ICING, FRZN, FULLY BAKED, Thaw & Serve. (Sterling)
8920-01-E10-1938	COOKIE DOUGH, WITH CANDY COATED CHOCOLATE DISKS, FRZN, READY-TO-BAKE, Avg. Wt. 1.5 oz, 120 dough pucks per case. Case contains parchment paper for baking (SJR Foods, UPC 04598) **Dairy ingredients required from an Approved Source**
8920-01-E10-1587	COOKIE, CHOCOLATE CHUNK, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped. Twin pack, Avg. Wt. 2 oz. per cookie. (Otis Spunkmeyer, UPC 57700)
8920-01-E10-1589	COOKIE, WHITE CHOCOLATE CHUNK MACADAMIA NUT, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped, Twin pack, Avg. Wt. 2 oz. per cookie. (Otis Spunkmeyer, UPC 57707)
8920-01-E10-1593	CORNBREAD, PLAIN, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped, mini loaves, Avg. Wt. 2.0 oz., 24 ct. (SJR Foods, UPC 04605)

8920-01-E10-1591	CORNBREAD, JALAPENO, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped, mini loaves, Avg. Wt. 2.0 oz., 24 ct. (SJR Foods, UPC 04625)
8920-01-E10-1595	DANISH, MINI ASSORTED, FRZN, FULLY BAKED, Thaw & Serve. Varieties: Cheese, Raspberry, Apple, Cinnamon Raisin, min. 1.25 oz. each, min. 3 1/8" diameter, min. 3/4" center ht. Total topping Wt.. min. 0.5 oz.., Assortment packed in trays with 6 of each variety per tray, 24 Danish per tray. (Pepperidge Farm, UPC 06747) **Cheese Required from an Approved Source**
8920-01-E10-1405	DONUT, POWDERED SUGAR, FRZN, FULLY BAKED, Thaw & Serve, Individually wrapped, Avg. Wt. 2.25 oz. each. (SJR FOODS, UPC 50728)
8915-01-E10-1277	JUICE, 100% ORANGE, FRZN, concentrate, unsweetened, US Grade A, min 14:1 brix-acid ratio, US Standards for grades, product description. (4), style (a) (Minute Maid)
8920-01-E10-1834	FRENCH TOAST, WHOLE GRAIN, FULLY COOKED, FRZN, Cinnamon Glazed, Avg. Wt. 3.25 oz. (Michael Foods, SKU 46025-85883-00)
8920-01-E10-1836	MUFFIN, VARIETY PACK, FULLY BAKED, FRZN, Thaw & Serve, Contains 6 Wild Blueberry (real wild blueberries), 6 Chocolate Chocolate Chip (Barry Callebaut semi sweet chocolate chips), and 6 Strawberry Shortcake (real strawberries and a crumb topping), Avg. Wt. 2.25 oz. Individually Wrapped, 0 grams Trans Fat. (Otis Spunkmeyer, UPC 013087191035)
8940-01-E10-1618	OMELET KIT, FRZN, Contains 1-24 oz. bag of each of the following components: Country Fresh Cooked Ham (1/4" dice), White Shredded Mild Cheddar Cheese, Diced Green Peppers, Diced White Onions. Vegetables must be Grade A or equivalent verified by COC. (MissaBay, UPC 1430) **Cheese required from an Approved Source**
8920-01-E10-1731	PANCAKE, BLUEBERRY FRZN, FULLY COOKED, 4.5 inch, Avg. Wt. 1.6 oz., Made with real blueberries (Ralcorp/Krusteaz, UPC10362)
8940-01-E10-1622	PANCAKE SANDWICH, PORK SAUSAGE AND EGG, FRZN, FULLY COOKED, ovenable film, Avg. Wt. 4.8 oz. each, 1.3 oz. Maple flavored pork sausage patty, 1.2 oz. egg between two 1.15 oz. Maple flavored pancakes. (Pierre Foods, UPC 0919) **Egg required from an Approved Source**
8940-01-E10-1620	PANCAKE AND SAUSAGE ON A STICK, FRZN, FULLY COOKED, Pancake batter (slightly sweet blueberry flavor) wrapped1 oz precooked pork sausage link on a stick. Avg. Wt 2.5 oz. COC required to verify precooked sausage weight. (State Fair/Sara Lee, SKU 72601)
8920-01-E10-1624	PIE, APPLE, FRZN, FULLY BAKED, Thaw & Serve, Individual slices with lattice crust. Individually packaged, Avg. Wt. 4 oz. (Sara Lee, SKU 07140)
8920-01-E10-1838	PIE, PECAN, FRZN, FULLY BAKED, Thaw & Serve, Individual Slices, topped with pecan halves. Individually packaged, Avg. Wt. 4 oz. (Sara Lee, UPC 05117)
8940-01-E10-1626	PIZZA ROLL, FRZN, FULLY BAKED, Individually wrapped, Ovenable film, Avg. Wt. 3 oz., Roll shape filled with tomato sauce, cheese and spices. (SJR Foods, UPC 04924) **Cheese required from an Approved Source**
8940-01-E10-1942	QUESADILLA, BEEF SAUSAGE, EGG & CHEESE, FULLY COOKED, FRZN, Avg. Wt. 4.0 oz., not less than 50% filling. Tortilla 8 inch +/- .25 inch. (Sunrise Foods, UPC 44635) **Egg, cheese and tortilla required from an Approved Source.**
8940-01-E10-1745	TAQUITO, APPLE CINNAMON, FRZN, FULLY COOKED, Bulk Packed, Avg. Wt. 3 oz., Apple & Cinnamon Filling wrapped in a Freshly Baked Battered Tortilla, Crisply Fried. (Ruiz, Mfr #86713)
8940-01-E10-1747	TAQUITO, FRENCH TOAST AND PORK SAUSAGE, FRZN, FULLY COOKED, Bulk Packed, Avg. Wt. 3 oz., Breakfast Pork Sausage wrapped in a Freshly Baked Battered Tortilla, Crisply Fried. (Ruiz, Mfr #86268)

8920-01-E10-0915	TORTILLAS, FLOUR, FRZN, 6 +/- .25 inch diameter, 1 oz each. (Tyson) **Tortilla required from an Approved Source**
8940-01-E10-1640	WRAP, EGG & CHORIZO, FRZN, FULLY COOKED, flour tortilla filled with cooked eggs, chorizo and cheese sauce, Not less than 15% chorizo. 10 inch Tortilla, Avg. Wt. 2 oz. Total Avg. Wt. 5.0 oz. COC required to verify % chorizo (Rose Packing/Baja Foods, UPC 3870) **Egg, cheese and tortilla required from an Approved Source**

VEGETABLES-FROZEN

8915-01-E10-1940	POTATOES, LOADED, FULLY COOKED, FRZN, Boil-in-bag, Contains blend of real mashed potatoes and potato pieces, real sour cream, real bacon, real chives and natural cheddar cheese. (B Smith Brand/ Missabay, UPC #1497) **Dairy ingredients required from and Approved Source**
8915-01-E10-1840	POTATO, WEDGE, FRZN, Skin-On, Coated with sea salt, bakeable. (Penobscot McCrum, Item # 11204-00123)
8915-01-E10-1632	POTATO, WEDGE, FRZN, seasoned, precooked, bakeable. (McCain's, UPC 80008352)
8935-01-E10-1934	CHOWDER, ROASTED POBLANO & CORN, FRZN, Boil-in-Bag, Chowder contains real potatoes, real roasted poblano peppers and corn. Not less than 37 % vegetables COC required to verify % vegetables. (B Smith Brand/ Missabay, UPC # 1496)
8915-01-E10-1944	VEG, COLLARD GREENS, WITH SMOKED TURKEY, FRZN, Boil-in-Bag, Collard Greens with not less than 9% Smoked Turkey Ham. Contains not less than 43% vegetables. COC required to verify % vegetables, % turkey ham. (B Smith Brand/Missabay, UPC # 1498)
8915-01-E10-0907	VEG, PEPPERS & ONIONS, PRECOOKED, FRZN or shelf-stable, contains onions, bell peppers (red and green, may include yellow), Veg oil, seasoning. 90% of vegetables are ½ inch width. (Simplot, UPC 10071179677796)

VEGETABLES (#10 Can or Institutional Pouch)

8915-01-E10-0037	VEG, BEANS, GREEN, CANNED, US Grade A (Sysco)
8915-01-E10-1433	VEG, BEANS, GREEN, ITALIAN STYLE (ROMA), US Grade A (Furmanos, UPC 10279)
8915-01-E10-0038	BAKED BEANS, CANNED, US Grade A, Style A, In Brown sugar, Molasses or New England Style Sauce seasoned with bacon. (Bush Boston Baked Beans, UPC 039400019558)
8915-01-E10-1572	BEANS, CANNED, MEXICAN CHILI BEANS, pinto beans in a Mexican chili sauce. (Allens)
8915-01-E10-1281	VEG, CARROTS, CANNED, SLICED, Not more than 3/8' " thick, ¾ " to 2.5" diameter sliced, US Grade A (Sysco)
8915-01-E10-0060	VEG, CORN, CANNED, golden, whole kernel or whole grain, US Grade A. (Monarch)
8915-01-E10-0083	VEG, MIXED, PEAS & CARROTS, CANNED, US Grade A, Carrot dices shall be ¼-3/8", Peas not less than 50% of drained weight, Carrots not less than 25% of drained weight. (Sysco)
8915-01-E10-0082	VEG, PEAS, CANNED, early or sweet, US Grade A, Not more than a number 4 sieve. (Sysco)
8915-01-E10-0086	VEG, POTATO MIX, DEHY, au gratin style. (Basic American, UPC 20922)
8915-01-E10-0088	VEG, POTATOES, DEHY, INST, agglomerates. (Sysco)
8915-01-E10-1576	VEG, POTATOES, DEHY, Instant Mashed Potatoes, Roasted Garlic Mashed Potatoes, 16 oz. pouch. (Idahoan, SKU 10050000415158)

8915-01-E10-1574	VEG, POTATOES, DEHY, Instant Mashed Potatoes, Herb & Butter Mashed Potatoes, 16 oz. pouch. (Idahoan, SKU # 10050000415103)
8915-01-E10-0087	VEG, POTATOES, DEHY, shredded (hash browns). (Basic American Foods Golden Grill Russet Premium, UPC 10084)
	FRUITS
8915-01-E10-1115	FRUIT, MIXED, Individual cups, natural or light syrup pack. (Del Monte)
8915-01-E10-1117	FRUIT, APPLESAUCE, Individual cups. (Whitehouse)
8915-01-E10-0061	FRUIT, CRANBERRY SAUCE, CANNED, jellied or strained, US Grade A. No. 303 or similar size. (Ocean Spray Brand)
8915-01-E10-1121	FRUIT, PEARS, Individual cups, natural or light syrup pack.(Del Monte)
8915-01-E10-1527	FRUIT, PEACHES, Individual cups, in strawberry banana flavored light syrup. (Del Monte)
8915-01-E10-1529	FRUIT, CHERRY MIXED FRUIT, Individual cups, peaches, pears, and cherries in naturally flavored light syrup. (Del Monte)
	CEREALS
8920-01-E10-1846	Oatmeal, Golden Brown Maple, Instant,1g Soluble Fiber From Oats; 100% Daily Value of 3 B Vitamins, Low Sodium, Individual Packets.(Kellogg's Kashi Brand, SKU 511007)
8920-01-E10-1844	Oatmeal, Apple Cinnamon, Instant, Individual Packets. (Kellogg's Kashi Brand, SKU 511014)
8920-01-E10-0070	HOMINY GRITS, QUICK, white, enriched, cylinder container not allowed. (Quaker Brand, UPC 04170)
	BAKERY, SHELF STABLE
8920-01-E10-1717	BAR, CRISP RICE AND MARSHMALLOW, Individually Wrapped, Shelf Stable, Avg. Wt. 1.3 oz. (Kellogg's Rice Krispie Treats, SKU 26547)
8920-01-E10-1399	CAKE, CONFETTI, CUPCAKE, W/ WHITE FROSTING AND CONFETTI STYLE SPRINKLES. (Sterling Foods, UPC 0 88026 75059 8)
8920-01-E10-1725	COOKIE, FRENCH TOAST GRAHAM, Shelf Stable, Bite Size, Avg. Wt. 1.76 oz. per package. (Kellogg's Crunchmania, SKU 24520)
8920-01-E10-1721	COOKIE, CHOCOLATE CHIP, Bite Size, Shelf Stable, Avg. Wt. 2 oz. per package. (Famous Amos, UPC 76677-98016)
8920-01-E10-1850	COOKIE, OATMEAL RAISIN, Bite Size, Shelf Stable, Avg. Wt. 2 oz. per package. (Famous Amos, UPC 76677-98017)
8925-01-E10-1411	CANDY, PAN COATED DISKS WITH PEANUT BUTTER, PLAIN, Individually packaged, Avg. Wt. 1.53 oz. package. (Reese's Pieces, UPC 760371)
8925-01-E10-1608	CANDY, PAN COATED DISKS, CHOCOLATE, PLAIN, Individually packaged, Avg. Wt. 1.69 oz. package. (M&M's)
8925-01-E10-1946	CANDY, PAN COATED, CHOCOLATE WITH ALMOND, Avg. Wt. 1.31 oz. package (Almond M&M's®, UPC 40000-1280)
8920-01-E10-1968	BAR, FRUIT FILLED, APPLE CINNAMON, 1.3 oz, individually wrapped. (Kellogg's Nutri-Grain 38000 35645)
8920-01-E10-1970	BAR, FRUIT FILLED, BLUEBERRY, 1.3 oz, individually wrapped. (Kellogg's Nutri-Grain 38000 35745)
8920-01-E10-1972	BAR, FRUIT FILLED, STRAWBERRY, 1.3 oz, individually wrapped.(Kellogg's Nutri-Grain 38000 35945)
8920-01-E10-!948	MUFFIN, BLUEBERRY, SHELF STABLE, with blueberry pieces, Avg. Wt. 2.3 oz. (Sterling Foods, UPC 088026 75041 3)
8920-01-E10-1603	TOASTER PASTRY, BLUEBERRY, FROSTED, Individually wrapped, Avg. Wt. 1.83 oz. (Kellogg's Pop-Tarts, SKU 00499)
8920-01-E10-1950	TOASTER PASTRY, STRAWBERRY, Whole Grain, Frosted, Individually wrapped, Avg. Wt. 1.76 oz. (Kellogg's® Grab 'N Go Pop-Tarts®, UPC 38000-36657)
8920-01-E10-1952	TOASTER PASTRY, BROWN SUGAR CINNAMON, Whole Grain, Frosted,

	Individually wrapped, Avg. Wt. 1.76 oz. (Kellogg's® Grab 'N Go Pop-Tarts®, UPC 38000-36651).

BEVERAGES

8960-01-E10-0156 – bag **8960-01-E10-0040 -CAN**	BEV BASE, GRAPE, powder with nutritive carbohydrate sweeteners and ascorbic acid composite can (Kool Aid) or bag (Thirster Brand)
8960-01-E10-0160 – bag **8960-01-E10-0043 -CAN**	BEV BASE, LEMONADE, PINK, powder with nutritive carbohydrate sweeteners and ascorbic acid, composite can, (Country Time Brand) or bag (Thirster Brand)
8960-01-E10-0159 – bag **8960-01-E10-0041 -CAN**	BEV BASE, LEMONADE, powder with nutritive carbohydrate sweeteners and ascorbic acid, composite can (Country Time Brand) or bag (Thirster Brand)
8955-01-E10-0249 - can	BEV BASE, ICED TEA, Lemon Flavor, powder with nutritive carbohydrate sweeteners and ascorbic acid, instant, composite can (Lipton) or bag (Thirster Brand)
8955-01-E10-1670	BEV BASE, ICED TEA, Peach Flavor, powder with nutritive carbohydrate sweeteners, instant, composite can, 28 qt yield. (4C Foods Brand UPC 10240)
8960-01-E10-1423-co 8960-01-E10-1442-2.5 gal 8960-01-E10-1444- 6 gal	BEV BASE, CARBOHYDRATE ELECTROLYTE, LEMON LIME, powder, 2 gal yield plastic container or 2.5 gal yield pouch or 6 gal yield pouch. (Gatorade, UPC CO 03962, 2.5 gal 03969, 6 gal 03967)
8960-01-E10-1421-co 8960-01-E10-446- 2.5 gal 8960-01-E10-1448- 6 gal	BEV BASE, CARBOHYDRATE ELECTROLYTE**,** FRUIT PUNCH , powder, 2 gal yield plastic container or 2.5 gal yield pouch or 6 gal yield pouch. (Gatorade, UPC CO 03804, 2.5 gal 33691, 6 gal 33690)
8960-01-E10-1427-co 8960-01-E10 -1450- 2.5 gal 8960-01-E10-1452- 6 gal	BEV BASE, CARBOHYDRATE ELECTROLYTE, ORANGE , powder, 2 gal yield plastic container or 2.5 gal yield pouch or 6 gal yield pouch . (Gatorade, UPC CO 03964, 2.5 gal 03970, 6 gal 03968)
8960-01-E10-1425-co 8960-01-E10-1454-2.5 gal 8960-01-E10-1456- 6 gal	BEV BASE, CARBOHYDRATE ELECTROLYTE, MIXED BERRY, Blend of blueberry, strawberry, grape and lime flavors, powder, 2 gal yield plastic container or 2.5 gal yield pouch or 6 gal yield pouch. (Gatorade Riptide Rush, UPC CO 33653, 2.5 gal 33673, 6 gal 33672)
8960-01-E10-1854	BEV BASE, NON-NUTRITIVE SWEETENED, CRANBERRY POMEGRANATE, powdered mix sticks, Individually Packaged, yield 16.9 oz. (4C, UPC 4138731755-8)
8960-01-E10-1856	BEV BASE, NON-NUTRITIVE SWEETENED, FRUIT PUNCH, powdered mix sticks, Individually Packaged, yield 16.9 oz. (4C, UPC 4138732482-2)
8955-01-E10-1644	BEV BASE, NON-NUTRITIVE SWEETENED, PEACH TEA, Individually Packaged, Yield 20 oz. (Crystal Light, UPC 430000079700)
8960-01-E10-1650	BEV BASE, NON-NUTRITIVE SWEETENED, RASPBERRY ICE, Individually Packaged, Yield 20 oz. (Crystal Light, UPC 430000079800)
8960-01-E10-1648	BEV BASE, NON-NUTRITIVE SWEETENED, LEMONADE, Individually Packaged, Yield 20 oz. (Crystal Light, UPC 430000084500)
8955-01-E10-1858	BEV BASE, NON-NUTRITIVE SWEETENED, WHITE TEA BLUEBERRY, powdered mix sticks, Individually Packaged, yield 16.9 oz. (4C, UPC 413871254-5)
8960-01-E10-1860	BEV BASE, NON-NUTRITIVE SWEETENED, WILD BERRY, powdered mix sticks with added calcium, Individually Packaged, yield 16 oz. (Sturm Foods)
8960-01-E10-1755	BEV BASE, NON-NUTRITIVE SWEETENED, LEMON-LIME ELECTROLTYE, Individually packaged, yield 20 oz. (Tang Sport)
8960-01-E10-1753	BEV BASE, NON-NUTRITIVE SWEETENED, FRUIT PUNCH ELECTROLTYE, Individually Packaged, yield 20 oz. (Tang Sport)
8960-01-E10-1749	BEV BASE, NON-NUTRITIVE SWEETENED, CAFFEINATED APPLE, Individually Packaged, yield 16.9 oz. (Spark)
8960-01-E10-1751	BEV BASE, NON-NUTRITIVE SWEETENED, CAFFEINATED CRANBERRY, Individually Package, yield 16.9 oz. (Spark)
8955-01-E10-0918	CAPPUCCINO, BEV POWDER, INST, SWEETENED, nonfortified, French Vanilla flavor, individual packets, min. 8 oz. yield (Kraft Foods, UPC 4300070730)
8955-01-E10-1024	CAPPUCCINO, BEV POWDER, INST, SWEETENED, nonfortified, Irish Cream flavor,

	individual packets, min. 8 oz. yield
8960-01-E10-0054	COCOA BEV POWDER, SUGAR SWEETENED, nonfortified (Carnation)
8955-01-E10-0893	COFFEE, FILTER PACK, GROUND, Arabica blend. Filter pack. Will provide 30 6-oz. cups of coffee. Minimum shelf-life 12 months (Cain's)
8940-01-E10-0062	CREAMER, NON-DAIRY, POWDER (Coffeemate)
8915-01-E10-1707	JUICE, TROPICAL FRUIT BLEND, 100% Juice, Concentrate (Welch's)
8915-01-E10-1672 (11.8 oz. can conc)	JUICE, APPLE, 100% juice, Conc. (Welch's UPC 382-00 can)
8915-01-E10-0073 (Aseptic container) 8915-01-E10-0151 (11.5 oz. can concentrate)	JUICE, 100% GRAPE, Conc. (Lyons Magnus (aseptic)/(Welch's (can) UPC 380-00)

SHELF STABLE COMPONENTS, DRY MIXES, SAUCES AND SPICES

8940-01-E10-1737	BEEF CHILI WITH BEANS, SHELF STABLE, Institutional Size Pouch, Boil-in-Bag, Ground beef, light red kidney bean in tomato sauce with green peppers and seasoned with various spices. The meat shall contain not greater than 31% fat. Pre-retort, the meat shall be 29% of the batch size, green bell peppers 3%, and kidney beans 23%. COC required to verify percentages of fat, meat, peppers and kidney beans. (à la smart, The Wornick Company)
8905-01-E10-1699	BACON, PRECOOKED, SHELF STABLE, Sliced in flexible pouches. 150 slices per pouch. Water activity not greater than 0.860, precooked salt content not to exceed 6.5%. Certificate of Analysis (COA) required. Reference CID, PKGQAP A-A-20081E. (Brookfield Farms/Westin Packaged Meat/Shelby County Cookers)
8910-01-E10-1568	EGG MIX, BUTTER FLAVORED, Pasteurized, Uncooked, Dehydrated in a Boil-in-Bag pouch w/ fitment. Analytical requirements: Not less than 36% Protein, Not Greater than 5% moisture, salt content 0.5-1.0% (rehydrated product). (Oregon Freeze Dried, UPC 0063-431-9) **Required from an Approved Source**
8940-01-E10-0065	GRAVY MIX, BROWN, 1 gal yield. (LeGout)
8940-01-E10-0066	GRAVY MIX, CHICKEN, 1 gal yield. (LeGout)
8940-01-E10-1868	GRAVY MIX, COUNTRY GRAVY WITH BLACK PEPPER, 1 gal yield .(Total Ultimate Foods)
8940-01-E10-0068	GRAVY MIX, PORK, 1 gal yield. (LeGout)
8940-01-E10-0069	GRAVY MIX, TURKEY, 1 gal yield. (LeGout)
8940-01-E10-0948	MACARONI & CHEESE, elbow macaroni, cheese sauce must contain at least 11.5% cheese solids, with cheese listed as first ingredient. COC required to verify % cheese solids Max 2 gal water to prepare (Total Ultimate Foods) **Cheese Required from an Approved Source**
8920-01-E10-0102	PASTA, SPAGHETTI, DRY, thin, long form, regular cooking. (Prince Brand)
8920-01-E10-0093	RICE, INSTANT, long grain, white, enriched, shall not contain greater than 13.5% moisture verified by COC. (Uncle Ben's)
8920-01-E10-0911	RICE, MEXICAN, instant, enriched. (Uncle Ben's)
8920-01-E10-0094	RICE PILAF MIX, Rice, orzo and seasonings. (Precision Foods/Milani Gourmet, UPC 072058 30037)
8920-01-E10-1954	RICE, PRIMAVERA, Parboiled Rice with a blend of vegetables. (New Orleans Style Cuisine/NuChoice Foods, SKU 747553122086)
8920-01-E10-0154	STUFFING MIX, Cornbread. (Uncle Ben's)
8950-01-E10-0193	SPICE BLEND, BARBECUE STLYE (salt, spices, red pepper, paprika, dehy garlic, and smoke flavor) tamper proof seal, 0.9 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***

8950-01-E10-0196	SPICE BLEND, CINNAMON MAPLE SPRINKLES, (sugar spices, cornstarch, and natural flavors) tamper proof seal, 1.25 oz. polypropylene co w/sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0198	SPICE BLEND, ITALIAN STLYE, tamper proof seal, 0.25 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0199	SPICE ONION, MINCED, DEHY, tamper proof seal, 0.70 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0200	SPICE PAPRIKA, GRD, tamper proof seal, 0.70 oz. polypropylene co w/ sprinkle style twist-off top, CID A-A-20001 ***(Mandatory Item)***
8950-01-E10-0201	SPICE BLEND POULTRY SEASONING, (may include black pepper, marjoram, nutmeg, rosemary, sage, and thyme) tamper proof seal, 0.40 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0202	SPICE BLEND STEAK SEASONING, (salt, dehy garlic, black pepper, dehy onion, spices and red pepper) tamper proof seal, 1.10 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0203	SPICE BLEND VEG SEASONING, W/O SALT (dehy onion, spices, dehy garlic, and black pepper) tamper proof seal, .75 oz. polypropylene co w/ sprinkle style twist-off top. ***(Mandatory Item)***
8950-01-E10-0204	SPICE PEPPER, BLACK, GRD tamper proof seal, .70 oz. polypropylene co w/ sprinkle style twist-off top, CID A-A-20001 ***(Mandatory Item)***
8950-01-E10-0205	SALT, TABLE, iodized, tamper proof seal, polypropylene co w/ sprinkle style twist-off top, CID A-A-20001 ***(Mandatory Item)***

CONDIMENTS

8910-01-E10-0051	CHEESE, PARMESAN, GRATED, Portion Control. (Diamond Crystal) **Required from an Approved Source**
8925-01-E10-1956	HONEY, 40 gram pouch, Portion Control. (Thermo Pac)
8930-01-E10-0071	JELLY, GRAPE, concord, Portion Control. (Welch's)
8930-01-E10-0072	JAM, STRAWBERRY, preserves, Portion Control. (Smuckers)
8950-01-E10-1271	CATSUP, JALEPENO, Portion Control. (JK Co)
8950-01-E10-0077	MUSTARD, YELLOW, Portion Control. (French's)
8950-01-E10-1768	MUSTARD, HONEY 1 oz. pouch, Portion Control. (Portion Pac)
8950-01-E10-1770	KETCHUP, 18 gram pouch, Portion Control .(Heinz)
8940-01-E10-1429	BUTTER GRANULES, 100% Natural Butter Flavor, 2 oz. pouch .(Butter Buds)
8925-01-E10-0106	SYRUP, MAPLE, IMITATION, thick, Portion Control. (PPI, Log Cabin)
8930-01-E10-0080	PEANUT BUTTER AND JAM, Portion Control, twin pack, peanut butter, smooth, stabilized, unfortified, US Grade A or Fancy, and jam, strawberry, US Grade A, perforated common sides. (Squeezers Brand)
8930-01-E10-0079	PEANUT BUTTER AND JELLY, Portion Control, twin pack, peanut butter, smooth, stabilized, unfortified, US Grade A or Fancy, and jelly, grape (Concord), US Grade A, perforated common sides. (Squeezers Brand)
8950-01-E10-0092	RELISH, SWEET, Portion Control. (Heinz)
8950-01-E10-0155	SALAD DRESSING, Portion Control. (Miracle Whip)
8950-01-E10-0950	PICANTE/SALSA, MED, Portion Control. (Old El Paso)
8950-01-E10-1766	SAUCE, BARBEQUE 1 oz. pouch, Portion Control. (Portion Pac)
8950-01-E10-1958	SAUCE, CARAMEL, DESSERT TOPPING, Squeeze Bottle, 17 oz. bottle. (Lyons Magnus, Item # 2661)
8950-01-E10-1864	SAUCE, ALL PURPOSE CONDIMENT, Extra Spicy, Portion Control, 19 gram (0.66oz.) pouch. (Buffalo Bobs Everything Sauce, UPC AR5050)
8950-01-E10-1866	SAUCE HORSERADISH, 12 gram pouch. (Heinz UPC 532200)
8950-01-E10-1960	SAUCE, HOT, Chile 'n Lime, 12 oz bottle. (FRANK'S® REDHOT® Chile 'n Lime™ Hot Sauce #77580)

8950-01-E10-1642	SAUCE, HOT, .75 oz. bottle. (Frank's Red Hot)
8950-01-E10-0816	SAUCE, STEAK, Portion Control. (A-1 Brand)
8950-01-E10-0219	SAUCE,SOY Portion Control. (Kikkoman)
8945-01-E10-0916	VEGETABLE OIL, PLAIN OR BUTTER FLAVORED, 4 OZ. (Heartland Mist)

PUDDINGS

8940-01-E10-1109	PUDDING, BUTTERSCOTCH, 4 oz. cup/ 3.5 oz. fill, Individual. (Hunts)
8940-01-E10-1111	PUDDING, CHOCOLATE, 4 oz. cup/ 3.5 oz. fill, Individual. (Hunts)
8940-01-E10-1113	PUDDING, VANILLA, 4 oz. cup/ 3.5 oz. fill, Individual. (Hunts)

NON-FOOD ITEMS

8105-01-521 –6616	BAG, PLASTIC, Linear Low Density Polyethylene, Heavy duty, quality 34 gallon bag with good puncture and tear resistance. Translucent natural color, 32" x 44" features closure ties. 1.25 mil gauge, 75 pound load capacity for dry or wet loads. Bags will be 4 bags per roll, twist ties included in roll and roll will be secured with label. Bags shall meet Degradable requirements of ASTM D3826-98. ***(Mandatory Item)***
7350-01-E10-0112/75 ct **7350-01-E10-0810/100ct**	CUPS, DISPOSABLE, PAPER, for hot and cold drinks, non-white, subdued color (tan/sand/brown), white interior and base approved, 8 oz. capacity. (**Mandatory Item**)
7360-01-E10-0113	DINING PACKET, BIOBASED, fork, knife, spoon (tan/sand/beige), 2 sugar, 1 salt,1 pepper and napkin/pg, CID-A-A-3012A, type IV. ***(Mandatory Item)***
8415-01-E10-1027	GLOVES, DISPOSABLE, foodservice, multipurpose, ambidextrous, latex free, polyethylene, 1.25 mil. thick, size large, 10 count pack. (American Health Products 1-800-828-2964)
7350-01-411-5266	TRAY, MESS, 5 COMPARTMENT, rigid fiberboard only, grease and water resistant, smooth pressed finish, non-white, subdued color. (tan/sand/brown) CID A-A 5217 (Chinet)

Appendix 4.2

Kickoff Meeting

Alert to Temperature Abuse of UGR-A's
STP#3009

Project Kick-Off Meeting

Rutgers University
CAFT/FMT Facility
120 New England Avenue
Piscataway, NJ 08854

September 8, 2010 1:00 pm – 4:00 pm

Agenda:

- **Welcome and Introductions**
- **Project Outline and Management**
- **Literature Review**
- **Transportation System**
- **Model Products**
- **Next Steps**

Attendees:

Name	Title/Co	Email
Col John C. Smith	DSCP, CORANET program director	john.c.smith@dla.mil
LTC Mark Bohannon	DLA, CORANET program manager	mark.bohannon@dla.mil
Bob Trottier	Natick, CORANET Liaison	Robert.Trottier@us.army.mil
CW3 William Warren	VETCOM, San Antonio, CORANET Liaison	William.Warren2@amedd.army.mil
Rick Byrd	Chief QA DIG JCOE	Alphonzo.byrd@us.army.mil
Shane Shepherd	Ameriqual, Industrial Partner	sshepherd@ameriqual.com
Dr. Mukund V. Karwe	Rutgers, Food Science	karwe@AESOP.Rutgers.edu
Dr. Don Schaffner	Rutgers, Food Science	schaffner@aesop.rutgers.edu
Rieks Bruins	Rutgers University	Bruins@aesop.rutgers.edu
Jeff Canavan	Rutgers University	jscanavan@yahoo.com
Li Zhang	Rutgers, Food Science	lizh@Eden.Rutgers.edu

Meeting Notes:

Project Outline
After introductions, an overview of the project was given by Rieks Bruins. Details can be found in the attached "STP#3009_Kick-off" presentation. This is a two year project divided in three phases. Phase I is the modeling phase, phase II is TTI technology survey and during phase III, we will develop an implementation plan for the best suited TTI. Phase I started in June 2010. Phase II will start in February 2011 and run concurrently with phase I. Phase III will start in January 2012.

Literature Review
The first task in the project is a review of the literature. Li Zhang, a graduate Food Science student, conducted this review and gave a presentation summarizing his findings. Details of his presentation can be found in the attached "Literature Review UGR-A" presentation. Based on the literature, Li identified three product types whose quality is most sensitive during frozen storage: shrimp, ground/high fat beef or pork and bakery products. Raw shrimp deteriorates due to lipid oxidation and protein denaturation which can be measured by total volatile basic nitrogen (TVB-N) value. Ground/high fat beef or pork such as beef patties deterioration mechanism is lipid oxidation. Bakery products tend to stale in the freezer due to starch retro-gradation which can be quantified via texture analysis and sensory testing. Literature indicates however that texture change is a first order reaction, while sensory changes are a zero order reaction. These reactions are affected by the manner that the product is processed before freezing, the rate of freezing and the packaging material used. The data available in the literature does not always specify these conditions and it is therefore recommended that independent studies are done as part of this project to establish the deterioration rate of these UGR-A products as function of the storage temperature.

Shane commented that T-bar is not always an appropriate indicator and that he suggests that sensory data is included in our analysis of quality deterioration.

Microbial growth is different from deterioration in quality. Microbial growth will not occur at temperature below -10 C and only starts to occur when the product temperature is close to its freezing point. The microbial organism of concern is very product dependent and a function of the preparation procedures of the product (cooked vs. raw) and the packaging method (aerobic vs. anaerobic) and if any preservatives have been used in the product. Because of this diversity, we will rely on ComBase to simulate the microbial growth/survival and identify the "critical" bacteria. Because ComBase has only limited records for frozen food, we might conduct shelf life studies on specific foods with targeted microbial contamination to identify the time temperature relationships that are of concern for product safety.

Transportation System
Rieks Bruins continued the presentation with a review of the transportation system of the UGR-A from the assembler to the soldier in the field. The presentation is attached as "Transportation System UGR-As". It was confirmed that both the pictorial diagram as

well as the detailed flow sheet, depicted the various steps accurately. It was commented that "Step 17" in the flow chart is last step were food is inspected by VET and it would be at this location that the information collected by the TTI would be most useful to make logistic decisions regarding the product. Should it be shipped out first, condemned or can it be kept in storage for future delivery. After this point the product is in transit to the soldier and only the cook would be able to make decisions on either to use the product or condemn the product.

The most common reason that product quality or product safety could be compromised is a failure of the refrigeration system of the container. Either some one forgot to plug the unit in or a mechanical failure occurred of the refrigeration system. Also, as the ration is distributed to the Base, (steps 18 and beyond in the flow sheet) the product might be loaded on a shared truck that is only partial frozen or refrigerated and the truck might breakdown or being delayed for unloading, causing the product temperature to rise and possible defrost. CW3 Warren is going to check with his folks in theatre if any time temperature data is available that could be used to simulate the temperature conditions that a regular frozen ratio is exposed to.

Rutgers wants to develop a heat transfer model of the case, the pallet and possible the container, we could run simulation models to predict what would happen to the product when temperature upsets occur.

We also discussed the possible location of the TTI and the type of TTI. As pallets are moved from one freezer to another freezer, the outside of a pallet might see high temperatures. However, this does not mean that the product inside the case significantly increases in temperature, or lead to quality degradation and or safety issues. It was agreed that a label on the outside of box would be most convenient for the inspector to make decision of "go - no-go". If this label would indicate "go", no further investigation would be necessary, as the product would have seen normal temperature fluctuations, and the product can be released. If the label would indicate temperature abuse that might affect either quality and/or safety of the product, the inspector should open the box and inspect the product inside. A second TTI can be used inside the box on the actual product to indicate if serious damage occurred to the product. Also it was agreed that the pallets as built by the assembler stay intact up the delivery to the FOB (forward operating base) and that only then the pallet is broken apart to serve the various menu's. It is therefore feasible to use smart RFID's at the pallet level to identify temperature abuse. Because of the expense in reading equipment, smart RFID's might only be useful up to step 17 in the flow sheet.

Model Product Selection

The discussion then focused on the product selection. The project intends to develop models for three products. Based on initial research, we recommended shrimp scampi (Lunch/Dinner Menu #6), beef patties (Lunch/Dinner Menu #2) and biscuits (Breakfast Menu #4). Most of these products are however fully cooked. Breakfast Menu #3 contains a steak which is raw and Natick recommended to consider this as an alternate candidate to evaluate. Also, the chicken cordon bleu (Lunch/Dinner Menu #14) is a

product that contains chicken, ham, cheese and a coating and some issues with this product have been observed. From a quality degradation point of view, we might have to rely on sensory attributes. If this menu doesn't work out, then the biscuit is an acceptable alternative. In conclusion, the following product were selected as model systems for quality degradation and microbial growth:
Lunch/Dinner Menu #6: Shrimp Scampi
Breakfast Menu #3: Steak (raw)
Lunch/Dinner Menu #14: Chicken Cordon Bleu
Alternate: Breakfast Menu #3: Biscuit

During the meeting one question came up regarding the preparation of the meal. In general all products (except the baked goods) are heated to 180 F. However, each box has specific instructions on how to prepare the meal and we will follow these instructions to evaluate sensory characteristics.

At the end of the meeting, we reviewed response of e-mails that were received from Natick and from AVI regarding specific rations. The questions and answers are included in the appendix

Next Steps:
The next step of this project is to visit Ameriqual and monitor assembly of one of these selected menus. We would like to take pictures of the items and take dimensions so that we can start building our heat transfer model of the case, of the pallet and of the trailer. Next we will complete our literature review and write a technical working paper on this. We will also acquire the necessary hardware and software to develop heat transfer models for the UGR-A and to conduct storage studies on the various selected rations

Appendix:
STP#3009_Kick-off
Literature Review UGR-A
Transportation System UGR-As
Natick response to questions for UGR-A
AVI response to transportation questions

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-A's

Principal Investigators:
Rieks Bruins
Mukund Karwe
Donald Schaffner
Li Zhang
José Maldonado

RUTGERS Center for Advanced Food Technology

Background

- The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. The UGR-A's are assembled in CONUS and shipped around the world for use in field feeding by deployed units. **The frozen box containing perishable foods is stored at 0^0F and must have 9 months remaining shelf life for OCONUS deliveries.**
- Placing temperature monitors in the shipping containers can be effective in monitoring storage conditions. However these monitors do not account for the time that frozen boxes may be outside the container and they are not tamper proof. **It is desired to have a technological solution for the UGR-A frozen box that would alert the end user to possible temperature abuse.** This project will determine what time-temperature combinations would be effective in ensuring safe and high quality food products based on the most sensitive item in the frozen box

RUTGERS Center for Advanced Food Technology

Objective

- **Identify a mechanism to easily distinguish potential thermally abused UGR-A rations which would not meet the safety and quality parameters of the Army**

RUTGERS Center for Advanced Food Technology

Scope

- Determine the critical temperature conditions at which the frozen UGR-A will no longer meet the 9 month shelf life and to determine the best available time temperature indicators that can be used to warn the user of product that is close to the end of its shelf life or has deteriorated to such extent that it is no longer safe to consume.
- The project is divided in three phases.
  - Phase I: Predictive Modeling for Food Safety and Quality
  - Phase II: Integrated Time-Temperature Technology Identification
  - Phase III: Implementation Plan for TTI Technology

RUTGERS Center for Advanced Food Technology

Phase I: Predictive Modeling for Food Safety and Quality

- Identify predictive modeling tools for food safety and food quality. Where possible, we will rely on existing data for microbial growth and quality deterioration.
- Store three products at different temperature conditions and measure quality degradation as function of time and temperature.
- Define the transportation system and identify potential hazards
- Develop a heat transfer model that predicts the effects of environmental temperature "upsets" on product temperature, using three filled menu boxes supplied by one of the UGR assemblers.

RUTGERS Center for Advanced Food Technology

Phase II: Integrated Time-Temperature Technology Identification

- TTI Technology Survey
  - Conduct a TTI technology survey of available TTI for frozen product distribution and meet with representatives of the various companies to discuss the needs of this project.
- Business case analysis for the most promising technology
  - Compare the technologies based on capability, maturity and cost and develop a comparison matrix with weight factors that would rate each of the technologies.

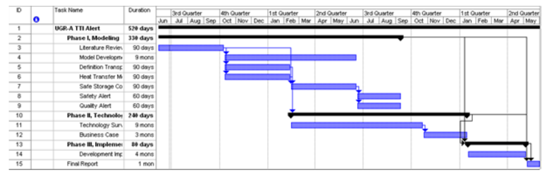
RUTGERS Center for Advanced Food Technology

Phase III: Implementation Plan for TTI Technology

- Develop a transition and implementation plan for the most promising TTI identified under phase II
  - In cooperation with the technology supplier of the top candidate TTI:
    - A top-level systems architecture for how the recommended technology would be implemented in the field.
    - Identification of any technology development efforts that might be required to implement this in the field, as well as any development efforts needed to tailor the existing temperature abuse technologies to optimally support the UGR-A frozen box supply chain.
    - Development of a decision tree that gives instructions to the user of what actions to take when a TTI indicator gives certain alerts.
    - A specific proposal for a pilot program for testing out the full systems approach prior to launching the full deployment.
    - An estimate of costs required to deploy the pilot program identified in this section.
    - If an existing technology is readily available, a demonstration will be arranged of this technology in a simulated supply chain

RUTGERS Center for Advanced Food Technology

Time Table



RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-As

Literature Review

Li Zhang

RUTGERS — Center for Advanced Food Technology

Predictive Modeling

- **Identify predictive modeling tools for food safety and food quality. Where possible, we will rely on existing data for microbial growth and quality deterioration.**
- Store three products at different temperature conditions and measure quality degradation as function of time and temperature.
- Define the transportation system and identify potential hazards.
- Develop a heat transfer model that predicts the effects of environmental temperature “upsets” on product temperature, using three filled menu boxes supplied by one of the UGR assemblers.

RUTGERS — Center for Advanced Food Technology

UGR-A Menu

Major Food Products

Egg, cheese, onion, potato, biscuit, pancake, muffin, cake, sausage, beef steak, beef patty, beef rib, pork, chicken, turkey breast, shrimp, etc.

PSL in Months for Selected Food Products

Product	Storage Temperature −18°C
Vegetables	
Beans (green)	15
Broccoli	15
French fried potatoes	24
Spinach	18
Onions	10
Meat and meat products	
Beef, ground/minced	10
Beef steaks	18
Pork (steaks, cuts, chops)	10
Bacon (sliced, vacuum packed)	12
Chicken (whole or cuts)	18
Turkey (whole)	15
Seafood	
Shrimps (cooked/peeled)	2
Eggs	
Whole egg	12
Bakery and confectionery	
Cakes (cheese, sponge, chocolate, fruit)	15
Breads	3
Raw dough	12

Sun D.W., 2005. Handbook of Frozen Food Processing and Packaging, CRC Press LLC.

RUTGERS — Center for Advanced Food Technology

Food Quality – Beef Patty

Deterioration Mechanism

Lipid oxidation

Quality Effects

Rancidity

Discoloration

Indicator

Thiobarbituric acid reactive substances (TBARS) value

Limit value: 8 μmole/kg dry meat

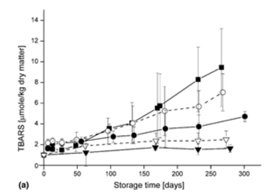


Fig. 4. TBARS measured in pork patties during frozen storage at constant or fluctuating temperatures. Values are averages of three samples each analysed three times. Standard deviation is indicated by error bars. (a) Patties made from pork belly: −10 °C (–■–), −10/−23 °C (–○–), −23 °C (–●–), −23/−40 °C (–▽–), −40 °C (–▼–).

Hansen, E., *et al.*, 2004. Oxidative stability of frozen pork patties: Effect of fluctuating temperature on lipid oxidation. Meat Science, 68, 185-

---

RUTGERS — Center for Advanced Food Technology

Food Quality – Shrimp

Deterioration Mechanism

Lipid oxidation

Protein denaturation

Quality Effects

Off-flavor

Textural change

Indicator

Total volatile basic nitrogen (TVB-N) value

Limit value: 25 mgN/100 g

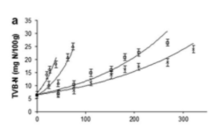


Fig. 6. Changes in (a) TVB-N and (b) in TMA-N of frozen shrimp during storage at ○: −5 °C, △: −8 °C, □: −12 °C and *: −15 °C. (Error bars indicate standard error of measurements of two different samples.)

Table 1
Shelf life of frozen shrimp stored at −5, −8, −12, −15 and −18 °C

Storage temperature (°C)	Shelf life of frozen shrimp (days)	
	Sensory scoring (limit = 5)	TVB-N (limit = 25 mgN/100 g)
−5	51	45
−8	90	82
−12	194	187
−15	351	353
−18	644[a]	677[a]

[a] Calculated using the models developed.

Tsironi, T., *et al.*, 2009. Shelf life modeling of frozen shrimp at variable temperature conditions. LWT – Food Science and Technology, 42, 664-671.

RUTGERS — Center for Advanced Food Technology

Food Quality – Biscuit

Deterioration Mechanism

Staling

Quality Effects

Increased hardness

Starch retrogradation

Indicator

Sensory data

Instrumental texture analysis

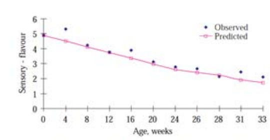


Fig. 6. Observed and predicted flavour quality characteristic for multigrain bread (γ_1).

Vulicevic, I.R., *et al.*, 2004. Quality and storage life of par-baked frozen breads. LWT, 37, 205-213.

RUTGERS Center for Advanced Food Technology

Food Quality – Shelf Life Study

Storage Conditions

-18 °C, -12 °C, and -4 °C

Analysis

Beef Patty – TBARS (spectrophotometer)

Shrimp – TVB-N (Kjeldahl rapid distillation unit)

Biscuit – Sensory / instrumental texture analysis

RUTGERS Center for Advanced Food Technology

Food Safety – Current Literature

- According to Evans, microbial deterioration mechanism is not a problem in frozen foods because they are stored at temperatures below the lower limits of microbial growth (approximately -10 °C).
- However, Tsironi showed that slow microbial growth was measurable at -5 °C and -8 °C.

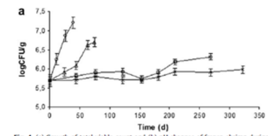
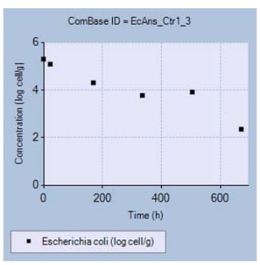


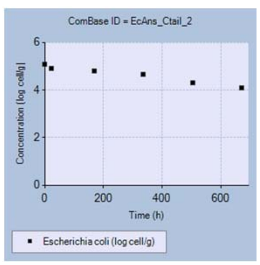
Fig. 4. (a) Growth of total viable count and (b) pH changes of frozen shrimp during storage at ○: −5 °C, Δ: −8 °C, □: −12 °C and *: −15 °C. (Error bars indicate standard error of measurements of two different samples.)

Evans J.A., 2008. Frozen Food Science and Technology, Blackwell Publishing.
Tsironi, T., *et al.*, 2009. Shelf life modeling of frozen shrimp at variable temperature conditions. LWT – Food Science and Technology, 42, 664-671.

RUTGERS Center for Advanced Food Technology

Food Safety – ComBase Database



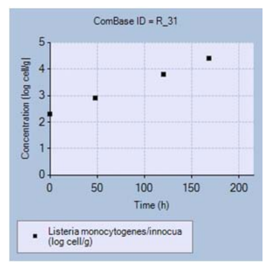


Growth of *Escherichia coli* in Frozen Ground Beef at -2 °C

Ansay *et al.*, 1999. Survival of *Escherichia coli* O157:H7 in ground beef patties during storage. Journal of Food Protection, 62(11),1243-1247.

RUTGERS Center for Advanced Food Technology

Food Safety – ComBase Database



Growth of *Listeria monocytogenes* in Shrimp at 4 °C

Farber *et al.*, 1991. *Listeria monocytogenes* in Fish Products. Journal of Food Protection, 54(12), 922-924.

RUTGERS Center for Advanced Food Technology

Food Safety – Simulation Study

Transportation System

Understand the time-temperature profile during transportation and storage.

Simulation Study

Use ComBase to simulate the microbial growth / survive.

Identify the “critical” bacteria.

Shelf Life Study (Optional)

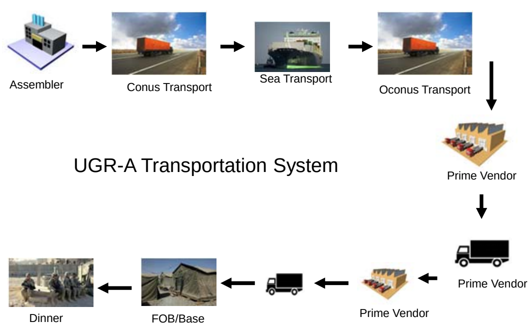
RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-As

Transportation System

Objective

- Define the transportation system and identify potential hazards



	UGR-A Transportation System		
1	Product Receipt	12	Unloading Container
2	Frozen Storage	13	Storage Prime Vendor
3	Assembly	14	Load Truck
4	Frozen Storage	15	Move Product
5	Loading Container	16	Unloading Truck
6	Transportation Container to Port	17	Storage Distribution Warehouse
7	Loading Boat	18	Loading Truck
8	Sea Transport	19	Transportation to Base/FOB
9	Unloading Boat	20	Unload Truck
10	Custom Clearance	21	Storage in Base Freezer
11	Transportation Container	22	Defrost Product
		23	Heat Product
		24	Serve Product

HACCP Analysis Distribution Chain

- Is the product protected from physical, chemical, radiological or microbiological contamination during storage and transportation?
- Meat, Poultry and Egg Products are particular vulnerable to microbiological hazards because of their moisture, pH levels and high protein content.
- Not all meat and poultry products "fully cooked – not shelf stable", some are raw products or partial cooked. Are any product historically more sensitive to quality degradation and/or safety concern?
- During transportation and storage, the challenge is to maintain proper refrigeration temperatures and keep the "cold-chain" from breaking during palletizing, staging, loading and unloading of containers and in storage
- What are the most likely to occur hazards in the "cold-chain"?
- What is the extend of the hazard?
- What kind of controls are in place or can be put in place to prevent or detect adulteration?

UGR-A Menu's FY'10

Brk Menu 1	Ranchero Beef Steak	
Brk Menu 2	Ham Slice	
Brk Menu3	Steak & Eggs	Raw
Brk Menu 4	Cheddar Sausage Gravy	Ready to eat
Brk Menu 5	Omelet and Bacon	
Brk Menu 6	Chorizo Breakfast Wrap	Cooked
Brk Menu 7	Beef Breakfast Skillet	Cooked
Lun/Din Menu 1	Chicken Fried Steak/Fried Chicken	Ready to Cook
Lun/Din Menu 2	Hamburger/Hot Dog	Fully Cooked
Lun/Din Menu 3	Pork in BBQ/Beef Brisket in BBQ sauce	Boil in Bag
Lun/Din Menu 4	Turkey Cutlet	Fully Cooked
Lun/Din Menu 5	Chinese Beef & Vegetables/Cashew Chicken	Boil in Bag
Lun/Din Menu 6	Shrimp Scampi/Penne Pasta with Chicken in Alfredo Sauce	Boil in Bag
Lun/Din Menu 7	Steak	
Lun/Din Menu 8	Rotisserie Chicken	Fully Cooked
Lun/Din Menu 9	Spaghetti & Meatballs/ Sausage Scaloppini	Fully Cooked & Boil in Ba
Lun/Din Menu 10	Enchiladas (Chicken and Beef)	Boil in Bag
Lun/Din Menu 11	Chicken Teriyaki Thighs	Boil in Bag
Lun/Din Menu 12	Chicken Nuggets (Buffalo and Plain)	Fully Cooked
Lun/Din Menu 13	Prime Rib	Boil in Bag
Lun/Din Menu 14	Chicken Cordon Bleu	Fully Cooked
Lun/Din Menu 15	Tomatillo Pork	Fully Cooked
Lun/Din Menu 16	Meatloaf	Fully Cooked Boil in Bag

Natick response to questions for UGR-A

Questions to Bob

1) In reviewing the menu items of the UGR-A, we selected as our model products for quality degradation:
   - Shrimp scampi with bowtie pasta
   - Biscuits
   - Cooked Hamburger Patties or Ham Slices (final selection will be made at the kick-off meeting)

   Reasoning:
   The shrimp was selected as there is an existing literature data on quality degradation of shrimp
   Biscuits was selected as a representative bakery product that could stale if not properly stored
   Hamburger patties or ham slices were selected as a replacement of blackened catfish as this is not longer in the menu. Hamburger and ham slices are high in fat and can generate lipid oxidation reactions if not properly stored
   Please review with the Natick team if they agree that these products are representative for quality degradation.

   Steak may be another item to consider. This is the only raw meat in the UGR-A program.

2) Based on information collected, the transportation and storage of UGR-A is as follow:
   - An assembler receives the product frozen and stores it frozen in their freezers (<0 F) until assembly. The internal product temperature at time of receiving will be checked and has to be less than 10 F for an average of multiple checks and no individual check can exceed 14 F.
   - The assembly process is done in a refrigerated room Temp < 40 F. Frozen product is moved into this refrigerated room for not longer than 90 minutes before the product is moved back into a freezer that is < 0 F
   - At time of shipment the shipping container is cooled down to < 0 F before it is loaded
   - The container is loaded and the doors are sealed. Shipping Container temperature is maintained at < 0 F
   - The container is shipped to a port and loaded on a ship. The temperature of the shipping container is maintained at < 0 F. Q: How is the compressor fueled and is the temperature of each individual container monitored?
   - Fueled by assembler on diesel during the trucking, once on rail they are plugged in. Who keeps the chart recordings? Each container has chart, which is received by Supreme/Anham (Prime Vendor (PV)) for review (OCONUS).
   - At the destination port, the container is unloaded and quarantined by customs
   - Once customs releases the container, a DoD prime vendor/contractor takes possession of the container and ships it to one of its frozen warehouses.
   - The container is unloaded and the product is placed into freezers. Product might be exposed to ambient temperature for not more than ?15? minutes). These freezers are maintained at < 0 F
   - Product might be moved twice to a different warehouse by this DoD contractor to bring the product closer to its final destination. During each relocation the product might be exposed to ambient temperatures for not more than ?15? minutes to load and to unload the shipping container. The temperature of the

shipping container will be < 0 F prior to loading and maintained at < 0F during transport. Q: Who will be monitoring and maintaining the records? UGR-A becomes a GFM item (OCONUS), so DLA-Troop Support/ PV responsible for tracking and monitoring records.

- A Base or FOB (Forward Operating Base) will place an order and the prime vendor will load the requested frozen items in a frozen container and ship the product. The shipping container will be < 0 F prior to loading and maintained at < 0 F during transport.
- At final destination, the product will be unloaded and stored into a dining facility freezer or a field kitchen freezer container. These freezers are maintained at <0 F. Q: Who will be monitoring and maintaining the records? PV/DLA-Troop Support.
- The product is taken out of these freezers and the product is defrosted for … hrs in a ??? refrigerated room??? , before it is heated and served to the troops. Q: what are the protocols for defrosting and heating? Dependent upon capabilities. Ideally, product that requires defrosting is defrosted in a refrigerator overnight. Typically, the cooks pull product for the next meal after they finish serving a meal. Most items do not require thawing prior to heating. Most bakery/desserts are thaw and serve.

3) What kind of data does Natick have on the shelf life of the UGR-A ration? What components are typical indicators for quality deterioration?
Since the UGR-A consists of commercial components; the vendors are responsible for providing shelf-life data. Each vendor provides a shelf-life verification letter with the assembler, who maintains the files.

4) It was stated in the RFP that "predictive modeling tools are available that, based on isothermal growth studies, effectively predict the shift from lag phase to log phase growth of various pathogens in a range of food items. The capabilities of these tools are being expanded to include additional food matrixes and pathogens in a Natick Soldier Research, Development and Engineering Center (NSRDEC) Food Safety & Defense Team research effort". Q: Is there a report that can be shared with us discussing the results of this research effort

5) Q: Using the HACCP principles on the product distribution system, the critical control points are obvious storage temperature in each step, however, in which step is it most likely to become a problem based on past history and what is the reason for it.

6) Q: Has Natick done any evaluation of TTI's for frozen applications. No??

AVI response to transportation questions

CW3 William Warren e-mail 8/19/2010 based on input from CW3 Dodge in Afghanistan:

"UGR-As are shipped by boat over to CENTCOM Theater. They are then trucked into Afghanistan and delivered directly to Prime Vendor in Kabul. Boat and truck ride to Prime vendor can take weeks if not months at times. There at the Prime Vendor they remain stored until Bases/FOBs place orders. They can remain stored at Prime Vendor for an unknown period of time, it was not uncommon to receive expired UGR-As at the Bases/FOBs. Once on the Base/FOB they remain in storage until used. Again an unknown period of time. I do know proper FIFO was hard to come by at the Bases/FOBs at times. Also proper storage at Bases/FOBs was challenging at times."

CW3 William Warren e-mail 8/26/2010 based on input from Soldier returned from Iraq 18 month ago:

The product is received by the prime vendor (Agility- Kuwait, Turkey & Jordan) in the original container in which it was placed when shipped from the assembler such as Ameriqual.

The prime vendor unloads the product from this container and stores the pallets in their frozen warehouse.

When the Bases/FOB's place an order, the prime vendor ships the items on refrigerated or frozen trucks or split loads. The product is not repackaged, they may be stretch wrapped, however.

Q- Do the Bases/FOB's have their own frozen storage rooms in which the product is then placed until used or does will the product stay inside the frozen shipping container from the prime vendor?
Response- Some FOB's/ JSS/ COP's may have refrigerated storage or they maintain rations in a Class I yards due to space and logistics. (Class I yards were usually abandoned buildings or hangers) Overall problem they were not enough refrigerated units to support all rations in the Iraqi theater (Oct 07- Jan 09)

Q- I assume that once the product is scheduled to be used that it is defrosted. Is there a protocol in place for how it is to be defrosted and for how long before it has to be heated and served?
Response- IAW with the applicable Appendices. (Warren: We may have to check w/JCCoE, Natick, or DLA Troop Support on this one)

Q-Are there any storage temperature records available at the AVI which might indicate storage temperature abnormalities at the Base/FOB and the reasons for these storage temperature abnormalities?

Response- If available, the temperature logs would be maintained on the outside of the conveyance. If not available or refer breakdown then the AVI would generate a 1232/ 817 (general correspondence forms) & 7538 (Subsistence Serviceability Certificate) to keep record of the condemnations.

Q-Are they due to the high temperature outside and thus cyclical or due to power failures and/or other reasons?
Response- Mainly due to high temperatures, which places a lot of strain on your generator, especially if you have multiple units, which are all stored under hot conditions.

Q-Are there any records in the Lotus Notes Database that identifies quality and/or safety issues that were encountered during the last three years with the Frozen UGR-A items. Are any food items more sensitive to incorrect storage temperature/time?
Response- Due to the sensitive nature of reporting in Iraqi, nothing was reported in lotus notes to date.
The last question, I do not have answer for trends & analysis.

Appendix 4.3

Interim Project Review #1

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-A's

Principal Investigators:
Rieks Bruins
Mukund Karwe
Donald Schaffner
Kiran Desai
Karthikeya Sankaran
Neha Bhide

RUTGERS — Center for Advanced Food Technology

Background

- The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. **Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box**. The UGR-A's are assembled in CONUS and shipped around the world for use in field feeding by deployed units. **The frozen box containing perishable foods is stored at 0^0F and must have 9 months remaining shelf life for OCONUS deliveries.**

- Placing temperature monitors in the shipping containers can be effective in monitoring storage conditions. However these monitors do not account for the time that frozen boxes may be outside the container and they are not tamper proof. **It is desired to have a technological solution for the UGR-A frozen box that would alert the end user to possible temperature abuse.** This project will determine what time-temperature combinations would be effective in ensuring safe and high quality food products based on the most sensitive item in the frozen box

RUTGERS — Center for Advanced Food Technology

Project Summary (1)

- **Objective:** Identify a mechanism to easily distinguish potential thermally abused UGR-A rations which would not meet the safety and quality parameters of the Army
- **Scope:** The project is divided in three phases
  - Phase I: Predictive Modeling for Food Safety and Quality
  - Phase II: Integrated Time-Temperature Technology Identification
  - Phase III: Implementation Plan for TTI Technology
- **Partners:**
  - Rutgers University: PI's
    - Mukund Karwe, Donald Schaffner, Rieks Bruins
  - Industrial Partner: Ameriqual
  - CORANET Liaisons: Bob Trottier and CW3 William Warren

RUTGERS — Center for Advanced Food Technology

Project Summary (2)

- Project funding
  - Total project funding: $438,583
  - Funding received to date: $344,258
  - Funding spent to date: $186,631 (7/31/11)
- Implementation Strategy:
  - Phase I defines the Time Temperature limits for quality and safety.
  - Phase II evaluates the various Time Temperature Monitoring systems
  - Phase III recommends an implementation plan for Time Temperature Monitoring systems.
- Projected Benefit:
  - Cost avoidance by alerting end user when to rotate stock and avoid quality or safety concerns

RUTGERS — Center for Advanced Food Technology

Phase I: Predictive Modeling for Food Safety and Quality

- Identify predictive modeling tools for food safety and food quality. Where possible, we will rely on existing data for microbial growth and quality deterioration.
- Store three products at different temperature conditions and measure quality degradation as function of time and temperature.
- Define the transportation system and identify potential hazards
- Develop a heat transfer model that can predict the effects of environmental temperature "upsets" on product temperature, using three filled menu boxes supplied by one of the UGR assemblers.

RUTGERS — Center for Advanced Food Technology

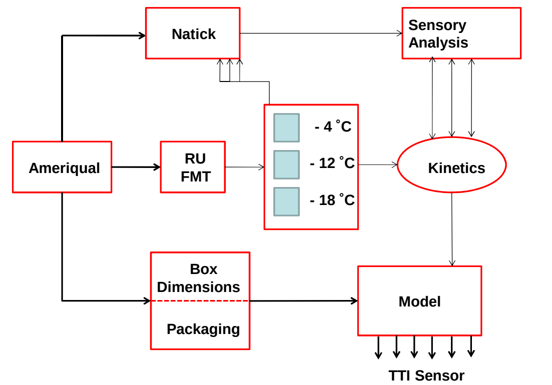
Model Products


Steak (Raw)
Breakfast Menu #3


Shrimp Scampi
Dinner Menu #6


Chicken Cordon Bleu
Dinner Menu #14

RUTGERS Center for Advanced Food Technology



RUTGERS Center for Advanced Food Technology

Phase II: Integrated Time-Temperature Technology Identification

- TTI Technology Survey
  - Conduct a TTI technology survey of available TTI for frozen product distribution and meet with representatives of the various companies to discuss the needs of this project.
- Business case analysis for the most promising technology
  - Compare the technologies based on capability, maturity and cost and develop a comparison matrix with weight factors that would rate each of the technologies.

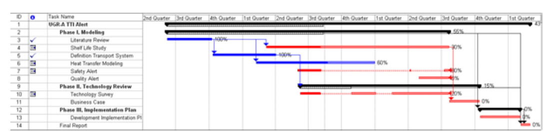
RUTGERS Center for Advanced Food Technology

Phase III: Implementation Plan for TTI Technology

- Develop a transition and implementation plan for the most promising TTI identified under phase II
  - In cooperation with the technology supplier of the top candidate TTI:
    - A top-level systems architecture for how the recommended technology would be implemented in the field.
    - Identification of any technology development efforts that might be required to implement this in the field, as well as any development efforts needed to tailor the existing temperature abuse technologies to optimally support the UGR-A frozen box supply chain.
    - Development of a decision tree that gives instructions to the user of what actions to take when a TTI indicator gives certain alerts.
    - A specific proposal for a pilot program for testing out the full systems approach prior to launching the full deployment.
    - An estimate of costs required to deploy the pilot program identified in this section.
    - If an existing technology is readily available, a demonstration will be arranged of this technology in a simulated supply chain

RUTGERS Center for Advanced Food Technology

Project Timeline



- 6 month delay in start of modeling tasks due to delay in funding
- Shelf Life Studies taking significant longer than anticipated as product is less sensitive to temperature abuse than anticipated

RUTGERS Center for Advanced Food Technology

Project Status

- Phase I: Predictive Modeling
  - ✓ Literature Review (100%)
  - – Shelf Life Studies to determine safe storage conditions (30%)
  - ✓ Definition Transportation System (100%)
  - – Developing Heat Transfer Model (70%)
  - – Determination of Safety alert conditions (80%)
  - – Determination of Quality alert conditions (0%)
- Phase II: TTI Technology
  - – Technology Survey (10%)
  - – Business Case Analysis (0%)

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-A's

Microbial Growth Modeling

RUTGERS Center for Advanced Food Technology

Microorganism of Concern

- *Meat, Pork, Poultry*
  - *Salmonella, Escherichia coli O157:H7 and Campylobacter* be present in raw meat or poultry, but should have been killed by proper cooking
  - Spore forming bacteria (*Clostridium perfringens and Clostridium botulinum*) can survive cooking when in heat resistant spore form.
  - Recontamination with bacteria (*Listeria monocytogenes and Staphylococcus aureus*) must be considered
- Fish and Seafood
  - Seafood is more perishable due to high level of soluble nitrogen compounds in the tissue
  - Cooked seafood, especially crustaceans that are heavily handled during processing is subject to contamination by *Staph aureus*, *Salmonella* spp, *L. monocytogenes*, *Shigella* spp and other enteric microorganisms. Also *Clostridium botulinum* spores may survive
- Bread
  - Mold is the primary microbial mode of failure for baked goods

RUTGERS Center for Advanced Food Technology

Assumptions

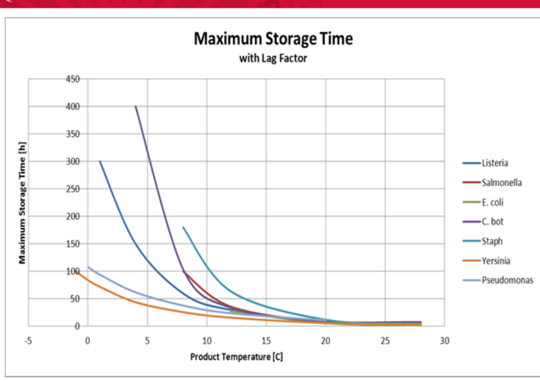
- Pathogens of Concern:
  - *Listeria,*
  - *Salmonella,*
  - *E. coli,*
  - *Clostridium botulinum,*
  - *Staphylococcus aureus,*
  - *Yersinia enterocolitica*
- Spoilage bacteria of concern:
  - *Pseudomonas spp.*
- Maximum growth increases for pathogens were assumed to be less than a one log cycle increase, while Maximum growth rates for spoilage bacteria such as *Pseudomonas spp* is up to 2.5 log cycles with an assumption that the initial level can be as high as 5 log10 CFU/gm.

RUTGERS Center for Advanced Food Technology

Modeling Tool: ComBase Predictor

ComBase is the no.1 web-based resource for Quantitative and Predictive Food Microbiology. Its main components are: a database of observed microbial responses to a variety of food-related environments and a collection of relevant predictive models. ***ComBase*** is managed by the **ComBase Consortium** consisting of the Institute of Food Research (IFR) in the United Kingdom, the USDA Agricultural Research Service (USDA-ARS) in the United States, and the University of Tasmania Food Safety Centre (FSC) in Australia. The purpose of ***ComBase*** is to provide electronic repository for food microbiology observations and to make such data and the generated predictive tools freely available and accessible to the wide community.

RUTGERS Center for Advanced Food Technology



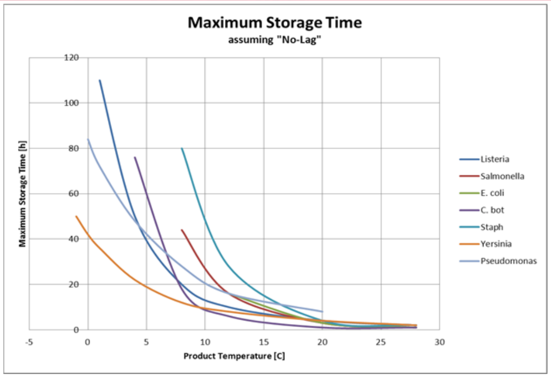
RUTGERS Center for Advanced Food Technology

Required TTI Behavior for Microbial Safety

assuming Microbial Lag

Temperature [C]	Maximum Exposure Time [h]
-4	200 (extrapolated)
0	108
+4	62
+8	38
+12	24
+20	11

RUTGERS Center for Advanced Food Technology



RUTGERS Center for Advanced Food Technology

Required TTI Behavior for Microbial Safety

assuming NO Microbial Lag

Temperature [C]	Maximum Exposure Time [h]
-4	90 (extrapolated)
0	44
+4	22
+8	12
+12	6
+20	1

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

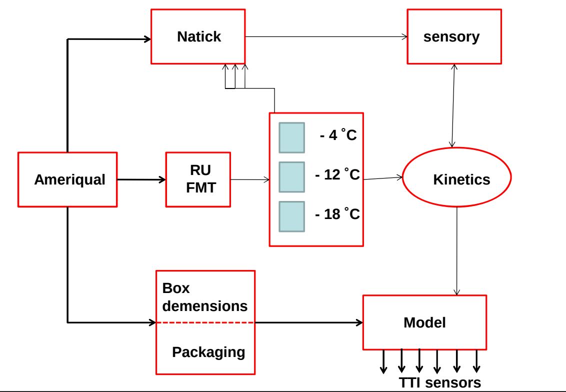
Stability analysis of UGR-A rations

IPR Meeting, Natick MA

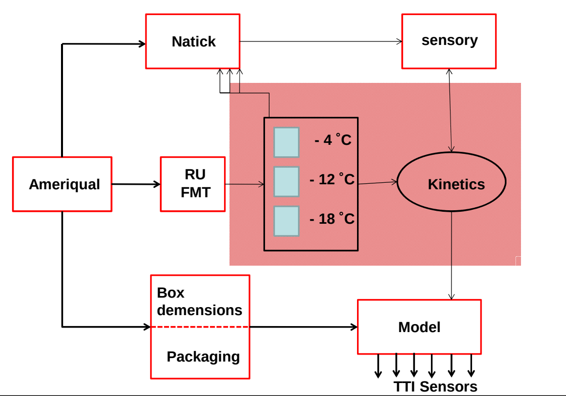
09/13/2011

Neha Bhide
Dr. Mukund Karwe
Rieks Bruins
Dr. Kiran Desai
J S Karthikeyan

RUTGERS Center for Advanced Food Technology

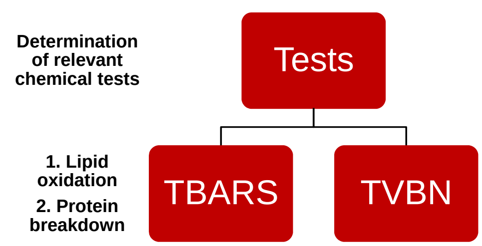


RUTGERS Center for Advanced Food Technology



RUTGERS Center for Advanced Food Technology

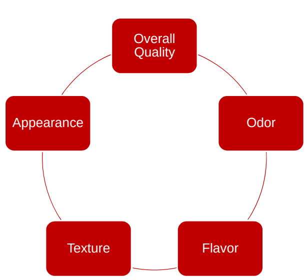
Outline of chemical analysis



RUTGERS Center for Advanced Food Technology

Sensory analysis (At Natick):

Parameters:



RUTGERS Center for Advanced Food Technology

Timeline

Temp	-4 °C		-12 °C		-18 °C	
	Weeks	Date	Weeks	Date	Weeks	Date
Storage Time	0	03/14/2011	0	03/14/2011	0	3/14/2011
	1	03/21/2011	8	05/9/2011	24	8/29/2011
	2	03/28/2011	24	08/29/2011	48	2/13/2012
	4	04/11/2011	40	11/28/2011	72	7/30/2012
	6	04/25/2011				
	12 (starting from new start date 05/30/2011)	08/22/2011				
	16	09/19/2011				
	24	11/14/2011				

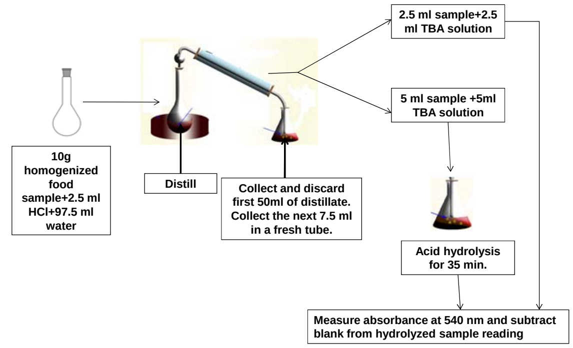
RUTGERS Center for Advanced Food Technology

Samples:

Beef Steak | Chicken Cordon Bleu | Shrimp Scampi | Separated Shrimp

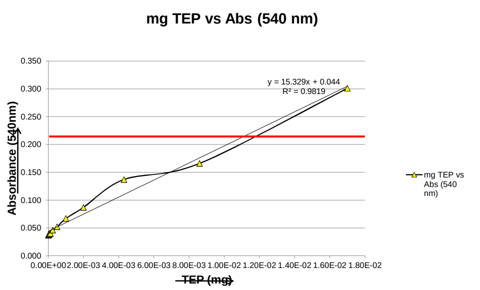
RUTGERS Center for Advanced Food Technology

TBARS (Thiobarbituric Acid Reactive Substances)



RUTGERS Center for Advanced Food Technology

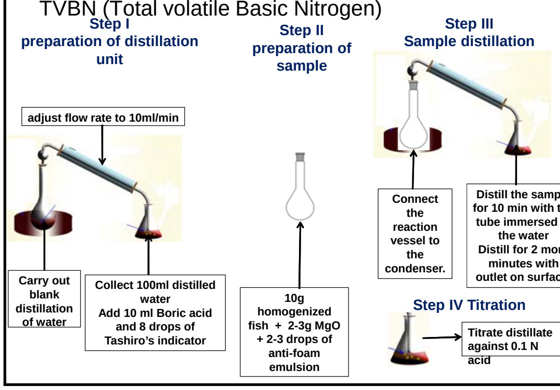
TEP* Standard curve



*1,1,3,3-tetraethoxypropane

RUTGERS Center for Advanced Food Technology

TVBN (Total volatile Basic Nitrogen)



RUTGERS Center for Advanced Food Technology

Results: (at - 4 °C)

Wk.	TBARS (Absorbance) Threshold Abs 0.2 at 540nm			TVBNs (mg TVBN/ 100g sample) Threshold value is 25mg/ 100g food			Sensory
	Shrimp scampi	Chicken Cordon bleu	Beef steak	Shrimp scampi			
1	0.0016	0.0053	0.012	20	-	-	NS
2	0.002	0	0.0086	18.3	-	-	NS
4	0.0018	-	0.011	18.8	-	-	NS
6	0.0023	0	0.0066	20	-	-	NS
12	0.002	0.001	0.001	18.3	-	-	NS

*T. Tsironi, et. al., LWT, 2009

RUTGERS Center for Advanced Food Technology

Implications

There was no significant difference in quality of all three samples at -4 °C at the end of 12 weeks, owing to:

1. Controlled temperature conditions
2. Preservatives added in the foods

RUTGERS Center for Advanced Food Technology

Further Study

- Most sensitive meat of the three: Shrimp
- Experiments done on frozen raw shrimp
- Shrimp obtained from manufacturers
- Experiments conducted on :

1. IQF shrimp stored loose
2. IQF shrimp vacuum packed in MRE pouches

RUTGERS Center for Advanced Food Technology

Raw shrimp experiment samples

- IQF loose shrimp
- IQF vacuum packed in MRE pouch

RUTGERS Center for Advanced Food Technology

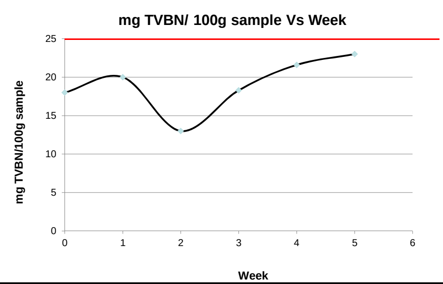
Study on raw shrimp

	IQF		MRE	
Time	TBARS (Absorbance)	TVBN (mg/ 100g sample)	TBARS (Absorbance)	TVBN (g/ 100g sample)
0 day	-	18	-	-
1 week	-	20	-	-
2 week	0.00	13	0.001	13
3 week	0.001	10	0.002	18.3
4 week	0.0095	13	0.0095	21.6
5 week	0.010	23	0.0098	23
6 week	0.02		0.022	

RUTGERS Center for Advanced Food Technology

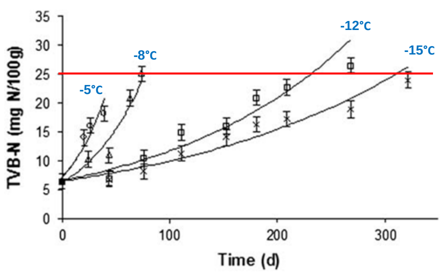
Changes in TVBN of raw shrimp:

Changes in TVBN for samples vacuum packed in MRE pouches, stored at -4°C over 6 weeks



RUTGERS Center for Advanced Food Technology

Reference



Changes in TVB-N of frozen shrimp during storage at 0: -5°C, Δ: -8°C, □:-12°C and x:-15°C.

T. Tsironi, et. al., LWT, 2009

RUTGERS Center for Advanced Food Technology

Future Objectives:

•Continuation of current shelf-life study to determine the period of stability Shrimp Scampi, Beef Steak and Chicken Cordon Bleu.

•Verification of consistency in chemical and sensory data and building a relation between the two

•Experiments with fresh shrimp (non frozen, not preservative-treated)

•Experiments with Organic (with no-preservative) meat (beef and/or chicken)

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Heat Transfer Modeling for UGR-A Rations

IPR meeting, Natick, MA
09/13/2011

Dr. Mukund Karwe
Rieks Bruins
Dr. Kiran Desai
J S Karthikeyan
Neha Bhide

RUTGERS Center for Advanced Food Technology

Outline

- Objectives
- Computational techniques
- Thermo-physical properties measurements
- Model food system
- Modeling and simulation results
- Conclusions and future plans

RUTGERS Center for Advanced Food Technology

Objectives

- **Develop a heat transfer model** using computational techniques that predicts the effects of environmental temperature "upsets" on product temperature profile
- **Simulate various scenarios** real / foreseen to obtain time temperature profile during storage and transportation
- **Combine heat transfer model with predictive modeling tools** for microbial and chemical food safety and quality, using either experimental data or existing models for microbial growth and quality deterioration

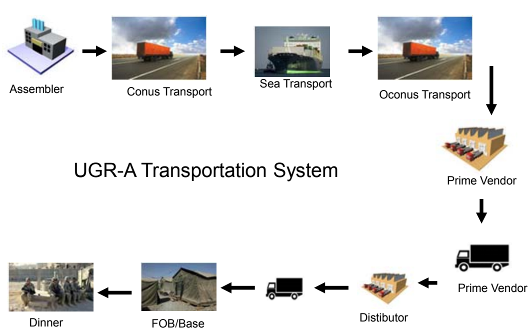
---

RUTGERS Center for Advanced Food Technology

Digital Time Temperature Monitor attached to the last pallet loaded in the container

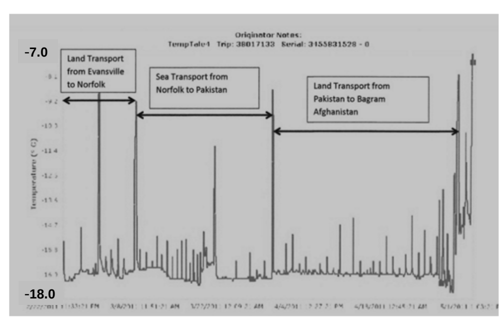
---

RUTGERS Center for Advanced Food Technology



RUTGERS Center for Advanced Food Technology

Temperature Data



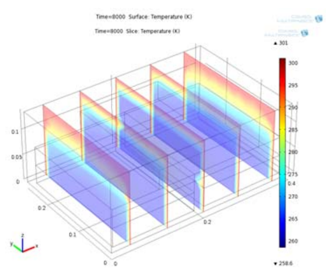
COMPUTATIONAL TECHNIQUE

Why Computational Approach

- It is a useful tool for predicting fluid flow, flow of heat, mass transfer, phase change, chemical reaction, etc using computers
- We can compute:
  Forces: pressure, viscous stress etc.
  velocity field: local flow streamlines
  temperature distribution
- Using computational methods, we can determine heat transfer and flow characteristics in the region of interest and that information can be used to predict the behavior of systems, to design more efficient systems etc..

Steps in computational method

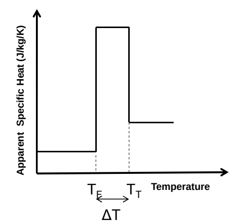
- Geometry
- Discretization
- Physics of the model
- Boundary and initial conditions
- Equations are solved iteratively for transient state
- Analysis and visualization of resulting solution



Apparent specific heat method

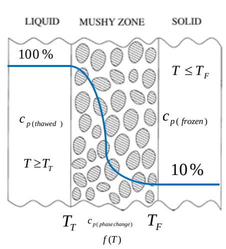
$$\rho c_p \frac{\partial T}{\partial t} = \nabla (k \nabla T) + S$$

Latent heat is ***merged with sensible heat*** *to* produce a specific heat curve with a large peak around the freezing point



$$\rho c_{P(app)} \frac{\partial T}{\partial t} = \nabla (k \nabla T)$$

$unfw\ \%(\Phi)$



$$c_{p(app)} = \begin{cases} c_{p(frozen)} & T \le T_F \\ c_{p(phase\ change)} & T_F \le T \le T_T \\ c_{p(thawed)} & T \ge T_T \end{cases}$$

$$unfw\ \%(\Phi) = \begin{cases} 10 & T \le T_F \\ f(T) & T_F \le T \le T_T \\ 100 & T \ge T_T \end{cases}$$

THERMO-PHYSICAL PROPERTIES

RUTGERS Center for Advanced Food Technology

Thermo-physical properties

$$\rho\, c_{P(app)} \frac{\partial T}{\partial t} = \nabla (k \nabla T)$$

- Thermal conductivity (*k*)
- Density (ρ)

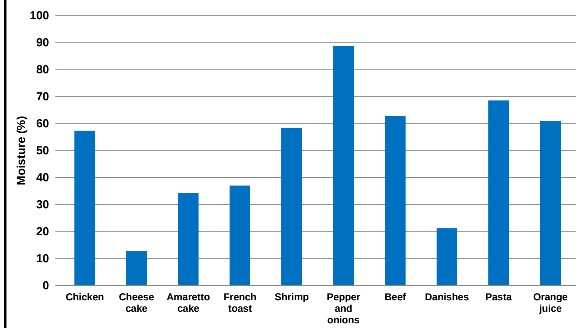
(calculated using components data)

- Apparent specific Heat
- Unfrozen water content

(measured using Differential scanning calorimeter)

RUTGERS Center for Advanced Food Technology

Total water content



RUTGERS Center for Advanced Food Technology

Thermal conductivity (*k*) and Density (ρ)

Food material is divided into three component:

- Dry material (dm): carbohydrate, protein, fat, ash, fiber
- Total water content
  (Unfrozen water and Ice)
  Total water (x_w) = unfrozen water (x_{unf}) + ice (x_i)

$$k(T) = k_{dm}\, x_{dm} + k_{unf}\, x_{unf} + k_i\, x_i$$

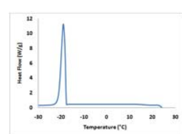
$$\rho(T) = \rho_{dm}\, x^v_{dm} + \rho_{unf}\, x^v_{unf} + \rho_i\, x^v_i$$

$$x_{unf} \text{ Vs } T$$

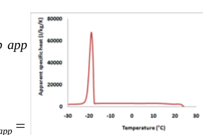
RUTGERS Center for Advanced Food Technology

DSC

- A calorimeter measures the heat into or out of a sample relative to a reference, while heating the sample with a linear temperature ramp.
- Endothermic heat flows into the sample.
- Exothermic heat flows out of the sample.



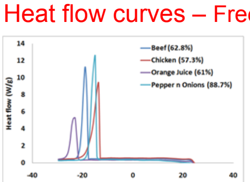
$C_{p\ app}$ ... $\frac{dt}{dT}$

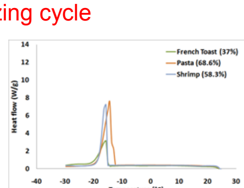


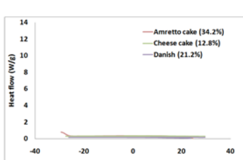
$C_{p\ app} =$ ... $/g)$ ... dT/dt ... heat scanning rate (K/s)

RUTGERS Center for Advanced Food Technology

Heat flow curves – Freezing cycle

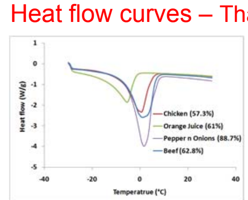


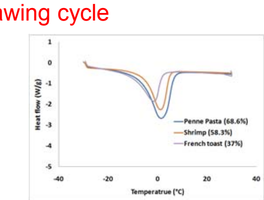


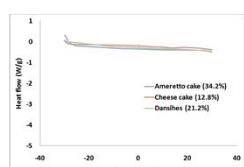


RUTGERS Center for Advanced Food Technology

Heat flow curves – Thawing cycle

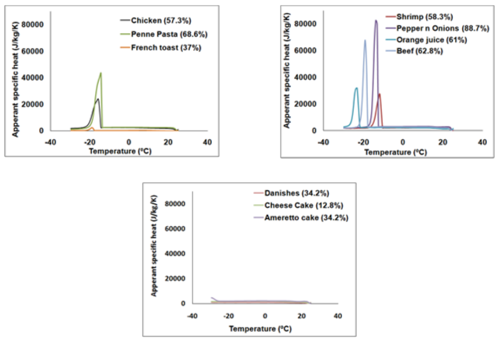






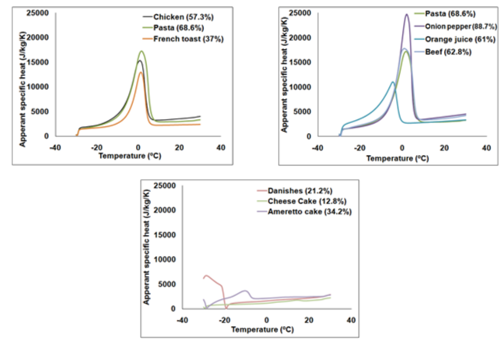
RUTGERS Center for Advanced Food Technology

Cp app curve - Freezing cycle



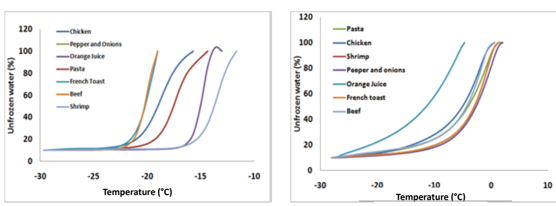
RUTGERS Center for Advanced Food Technology

Cp app curves - Thawing cycle



RUTGERS Center for Advanced Food Technology

Unfrozen water content



Freezing cycle

Thawing cycle

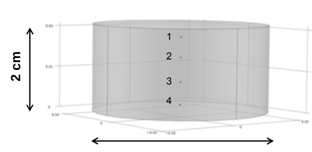
RUTGERS Center for Advanced Food Technology

MODEL FOOD SYSTEM

RUTGERS Center for Advanced Food Technology

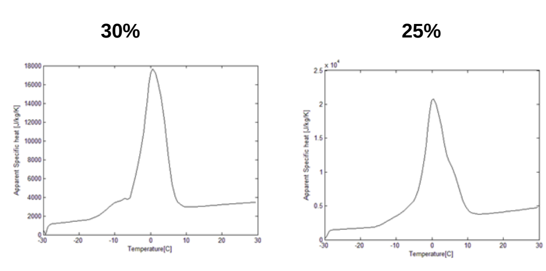
Model food system

- 30% gelatin + 70% water
- 25% gelatin + 75% water



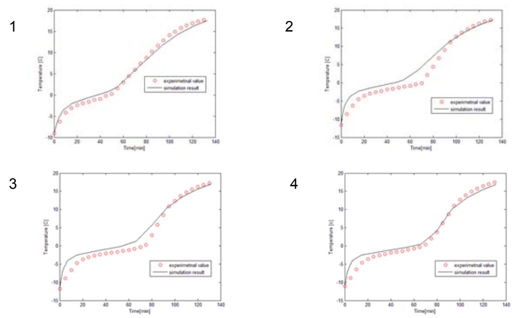
RUTGERS Center for Advanced Food Technology

DSC based apparent Cp curve in Thaw cycle



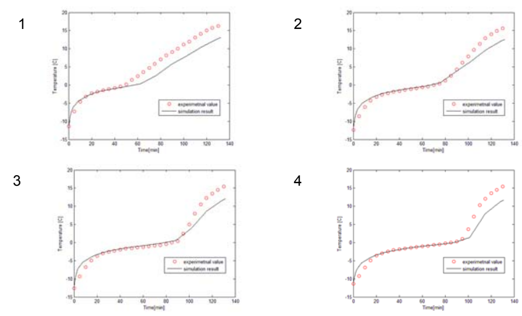
RUTGERS Center for Advanced Food Technology

30% thawing in open air



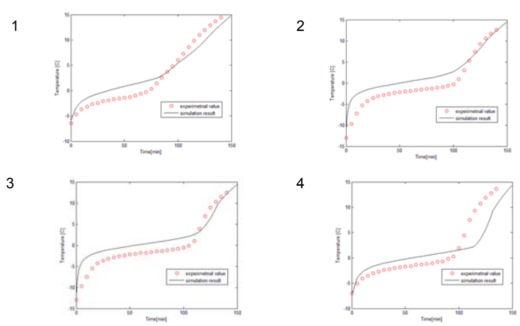
RUTGERS Center for Advanced Food Technology

25% thawing in open air



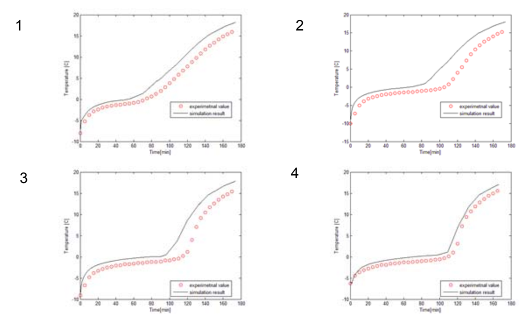
RUTGERS Center for Advanced Food Technology

30% thawing in insulated box



RUTGERS Center for Advanced Food Technology

25% thawing in insulated box



RUTGERS Center for Advanced Food Technology

SIMULATION RESULTS

RUTGERS Center for Advanced Food Technology

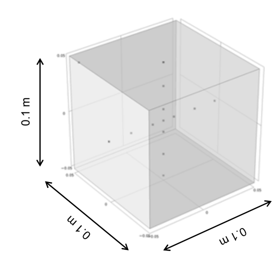
Comparison of individual food items under same heat transfer condition

Initial temp – (-15 °C)

Boundary condition – Heat flux
24 °C (h= 5 $W/m^2/K$)

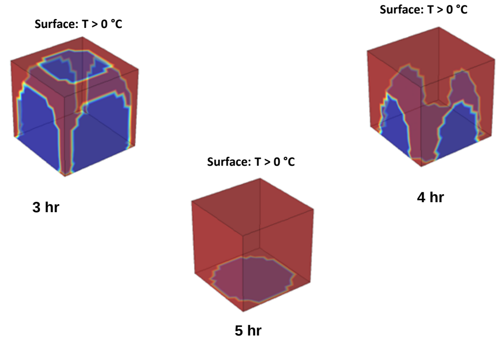
Time = 14 hr

No of elements – 14,000



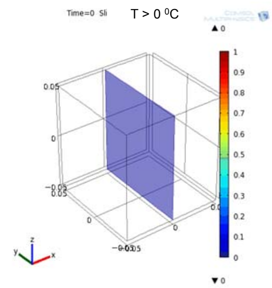
RUTGERS Center for Advanced Food Technology

Surface temperature for beef block

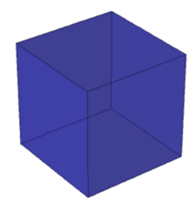


RUTGERS Center for Advanced Food Technology

2D slice plot



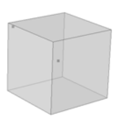
3D surface plot

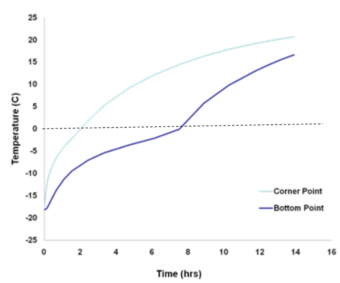


Thawing initiation time ~ 2.5 hr
Thawing completion time ~ 7 hr

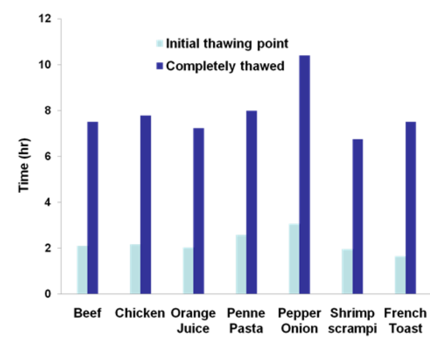
RUTGERS Center for Advanced Food Technology

2D point graph for beef





RUTGERS Center for Advanced Food Technology

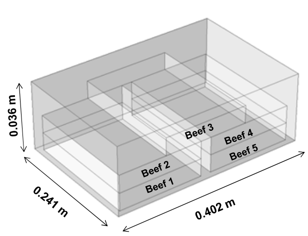


RUTGERS Center for Advanced Food Technology

Beef Box

Initial temp (-16 °C)

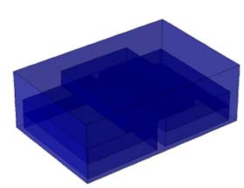
Boundary condition – Heat flux
24 °C (h= 5 W/m²/K)

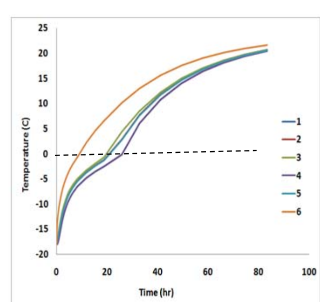


RUTGERS Center for Advanced Food Technology

Beef box

Time=0 Surface: T>274



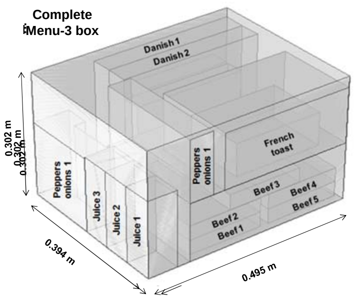


RUTGERS Center for Advanced Food Technology

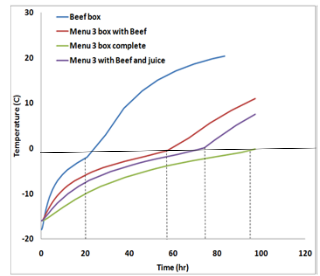
Menu-3 Configurations

Initial temp (-16 °C)

Boundary condition – Heat flux 24 °C (h= 5 W/m²/K)



RUTGERS Center for Advanced Food Technology



Configuration	Time to complete thawing (hr)
Beef box	18
Menu 3 with Beef box	57
Menu 3 with Beef box and 3 Juice boxes	72
Complete menu 3	94

RUTGERS Center for Advanced Food Technology

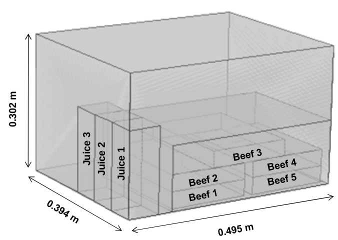
Menu 3 box with Beef Steak and Juice

Initial temp – (-16 °C)

Boundary condition – Heat flux 24 °C (h= 5 W/m²/K)

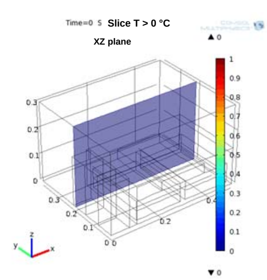
Time = 84 hrs

No of elements – 30,000

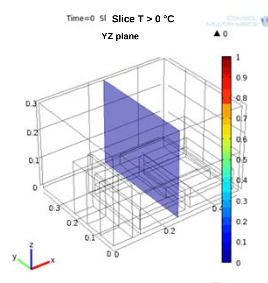


RUTGERS Center for Advanced Food Technology

2-D Temperature slice plot



Beef
Thawing initiation time ~ 50 hr
Thawing completion time ~ 84 hr



Juice
Thawing initiation time ~ 2.2 hr
Thawing completion time ~ 14 hr

RUTGERS Center for Advanced Food Technology

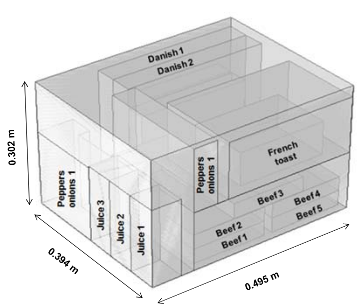
Menu 3 complete box

Initial temp – (-16 °C)

Boundary condition – Heat flux 24 °C (h= 5 W/m²/K)

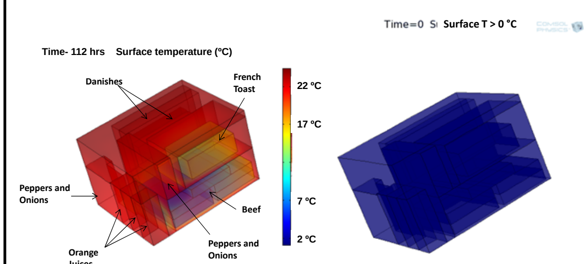
Time = 97 hrs

No of elements – 45,000

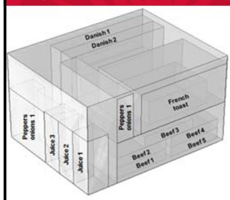


RUTGERS Center for Advanced Food Technology

Menu-3 Surface temperature

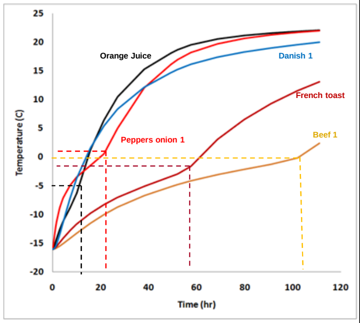


RUTGERS Center for Advanced Food Technology



Food	Initial freezing point (°C)	Thawing time (hr)
Beef	0.8	101
French toast	-1.2	58
Peppers onion	2.1	22
Juice	-5.2	13
Danish	NA	NA

Temperature profile at center points



RUTGERS Center for Advanced Food Technology

CONCLUSIONS

RUTGERS Center for Advanced Food Technology

- COMSOL based model was develpoed which successfully incorporates phase change phenomena
- Experimental verification was carried out using model food system
- Among all food items, juice and french toast are earliest to start thawing
- Synergic effect was observed, i.e., adding / deleting one item, effects the thawing time of others
- Time temperature profile of all individual items in box were obtained

RUTGERS Center for Advanced Food Technology

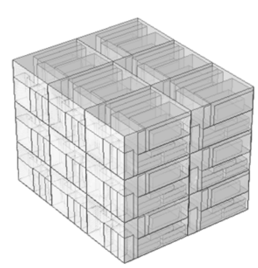
FUTURE PLAN

RUTGERS Center for Advanced Food Technology

- Simulations for remaining two menu boxes
- Simulations for pallet of menu boxes
- Simulations for real time data of temperature fluctuations
- Combining temperature profiles with microbial growth kinetics and chemical degradation kinetics

RUTGERS Center for Advanced Food Technology

Pallet with 18 (Menu-3) boxes



RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Alert to Temperature Abuse of UGR-A's

TTI Technology Survey

RUTGERS Center for Advanced Food Technology

Phase II: Integrated Time-Temperature Technology Identification

- TTI Technology Survey
  - Conduct a TTI technology survey of available TTI for frozen product distribution and meet with representatives of the various companies to discuss the needs of this project.
- Business case analysis for the most promising technology
  - Compare the technologies based on capability, maturity and cost and develop a comparison matrix with weight factors that would rate each of the technologies.

RUTGERS Center for Advanced Food Technology

Time Temperature Indicators (1)

- FreshPoint, Ciba/BASF
  - Aluminum Technology
    - CoolVu - Food
    - CoolVu - Thaw and Sell (Advanced Development)
    - CoolVu - Active Barcode (Advanced Development)
    - CoolVu - RF Compatible (Under Development)
  - Active Ink Technology
    - OnVu
    - OnVu Ice
    - OnVu Logistics


RUTGERS Center for Advanced Food Technology

Time Temperature Indicators (2)

- CheckPoint (VITSAB AB, Malmo Sweden)
  - CheckPoint I: enzymatic reaction leading to pH change
    - B2-3H (Ice Cream)
    - B2-12H (Processed Foods)
    - B2-36H (Meats)
  - CheckPoint III: diffusion reaction leading to pH change

- Timestrip (London UK)
  - Counts time that temperature is above certain set point

- CRYOLOG (Nates FR)
  - Based on microbial growth

RUTGERS Center for Advanced Food Technology

Time Temperature Indicators (3)

- TempTime (Morris Plains NJ)
- 3M:
  - Monitor Mark (not applicable for UGR-A)
- CoolID
  - Invenview Company (Dansk Poland)
- Avery Dennison
  - TT Sensor: (not applicable for UGR-A)

Appendix 4.4

Literature Review (TWP#226)

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Literature Review on UGR-A Project

Technical Working Paper (TWP) #226

Li Zhang

Dr. Mukund Karwe

Henderikus Bruins

February 17, 2011

Sponsored by:
DEFENSE LOGISTICS AGENCY
8725 John J. Kingman Rd.
Fort Belvoir, VA 22060-6221

Contractor:
Rutgers, The State University of New Jersey
THE CENTER FOR ADVANCED FOOD TECHNOLOGY
School for Environmental and Biological Science
N.J. Agricultural Experiment Station
New Brunswick, New Jersey 08903

1. Introduction

Low-temperature storage has been applied for many decades, and grown to be one of the major preservation techniques associated to high-quality foods. The principles of low-temperature storage are for the most part due to the advantageous effect of reduced temperature on various chemical and biochemical reactions responsible for food spoilage, as well as on microbial growth and spore germination (Enrique Ortega-Rivas, 2010).

Although frozen foods, in principle, can be stored for an indefinite period, quality changes and microbial deteriorations inevitably occur during long-term storage. Even at -18 °C, food are not totally frozen, and biochemical and chemical reactions may still happen at a slow rate. In addition, temperature fluctuations or partial thawing during storage may facilitate moisture migration and loss, accelerate spoilage reactions, and may even provide sufficient conditions for the growth of pathogenic micro-organisms (Enrique Ortega-Rivas, 2010).

In regard to chemical reactions, lipid oxidation, enzymatic browning, flavor deterioration, protein insolubilization and degradation of cholorophyll, other pigments and vitamins can proceed during extended frozen storage (Fennema, 1973). Although reaction rates are reduced, deterioration can still occur at temperatures well below 0 °C, eventually leading to degradation of components and development of off-flavors and odors, which will ultimately limit shelf life of frozen food product.

Microbial deterioration mechanism is not a problem in frozen foods because they are stored at temperatures below the lower limits of microbial growth (approximately -10 °C). However, with temperature fluctuations during storage and distribution, these may become significant (Evans, 2008). The dominant micro-flora of concern in frozen foods will generally consist of psychrotrophs, which is capable of growing at temperatures down to -5 °C (Adams and Moss 1995). While mesophilic organisms will not grow at low temperatures, they may become a problem in situations of temperature abuse.

The Unitized Group Ration - A (UGR-A) is the only military operational ration that contains frozen food components. This literature review is conducted to provide a solid scientific background for the “Alert to Temperature Abuse of UGR-As” project. In this report, major deterioration modes and practical storage life of frozen foods have been reviewed, followed by the reason why three model food products are chosen from UGR-A menu. Typical indicative chemical reactions and microorganisms will be further discussed for each model foods. In the end, the design of shelf life study will be addressed.

2. Deterioration Mechanisms for Frozen Foods

Different frozen food products have different major deterioration modes due to their intrinsic components. Labuza and Fu (1997) listed a range of common deterioration mechanisms for specific foods (Table 1).

Table 1 Deterioration Mechanisms for Frozen Foods

Food	**Deterioration Process**
Frozen meats, poultry, and seafood	Rancidity
	Toughening (protein denaturation)
	Discoloration
	Desiccation (freezer burn)
Frozen fruits and vegetables	Loss of nutrients (vitamins)
	Loss of texture (temperature abuse)
	Loss of flavor (lipoxygenase, peroxidase)
	Loss of tissue moisture (forming pakage ice)
	Discoloration
Frozen concentrated juices	Loss of nutrients (vitamins)
	Loss of flavor
	Loss of cloudiness
	Discoloration
	Yeast growth (temperature abuse)
Frozen dairy products	Iciness (recrystallization of ice crystals)
	Sandiness (lactose crystallization)
	Loss of flavor
Frozen bakery products	Staling (becoming leathery)
	Loss of fresh aroma

Many vegetables and fruits exhibit significant off-flavors, off-odors, and discoloration after thawing. These detrimental effects have been shown to be a result of the membrane disruption and the enzyme activation within the cells. Therefore, many vegetables need to be blanched prior to freezing, which can inactivate the enzymes responsible for generating the off-flavors and off-odors (Taub and Singh, 1997).

For the meat products, oxidation of lipids and pigments tend to happen during the frozen storage. There is also evidence for an insolubilization of proteins, which may contribute the textural change. Another factor that will affect the storage life is the degree of comminution, which increase the surface area to volume ratio and facilitate the access of oxygen. It accounts for the lower stability of ground or minced meat product (Taub and Singh, 1997).

Seafood products are particularly unstable during frozen storage. High-fat fish tend to have a short shelf life in frozen storage due to lipid oxidation, which produces a variety of off-flavors. For frozen shrimp, a postmortem reduction of trimethylamine oxide by bacterial enzymes may leads to a dramatic increase in trimethylamine (TMA-N) (Krzymien and Elias, 1990), which is accompanied by a significant production of ammonia and other basic nitrogenous compounds. They are collectively known as total volatile basic nitrogen (TVB-N), and responsible for the development of off-odor.

3. Practical Storage Life for Frozen Foods

Practical storage life (PSL) is defined as the period of storage during which the frozen food retains its quality characteristics and is suitable for consumption (Anonymous, 1986). Table 2 is reproduced from the IIR publication which includes the effects of both temperature and food type.

According to the UGR-A Frozen Menu 2010, egg, cheese, onion, potato, biscuit, pancake, muffin, cake, sausage, beef steak, beef patty, beef rib, pork, chicken, turkey breast, shrimp are the major food products included. Most of the food products in the menu are fully cooked, expect beef steak and shrimp. Generally, microbial safety should not be the issue for fully cooked products. Therefore, focus should be laid on raw beef steak and raw shrimp in respect of microbial growth. In addition, shrimp has been found to be one of the most perishable frozen food products in terms of practical storage life in Table 2, which makes shrimp scampi (in Lunch / Dinner Menu 6) a good candidate as a model food for shelf life study. Steak (in Breakfast Menu 3) is another food product being selected for shelf life study, because it is the only raw meat product in the menu, which could give a comprehensive understanding of both quality deterioration and microbial growth in frozen food product. The third selection of model foods is chicken cordon bleu (in Lunch / Dinner Menu 14), which is fully cooked before frozen. It is a multi-component product that contains chicken, ham, and cheese with bread coating outside. Therefore, it is a good representative to study the effect of interaction between different food components through sensory analysis.

4. Design of Shelf Life Study for Model Foods

4.1 Shrimp Scampi

Shrimp is the major component in shrimp scampi, which is also the limiting factor of its shelf life. During storage of frozen shrimp, the most important quality changes are color fading, lipid oxidation, and denaturation of protein, which can lead to off-flavors, rancidity, textural changes, increase in volatile basic nitrogen, and microbial spoilage as well (Tsironi, et al., 2009).

A thorough shelf life study of frozen shrimp was conducted by Tsironi, et al., 2009, in which they did measurements of color, texture, pH, and chemical indices (TBARS, TVB-N, and TMA-N), and sensory analysis for samples stored at variable temperature conditions (-5, -8, -12, and -15 °C). Their results (Figure 1, Figure 2, and Table 3) showed that TVB-N, which is commonly known as a important characteristic for the assessment of seafood spoilage (Dhaouadi, et al., 2007), and sensory scores had more consistently correlation with time-temperature history of the products. In addition, TVB-N value (Figure 3) was proven to be able to well predict the food quality and remain shelf life of frozen shrimp product through the fluctuating temperature storage experiment.

Table 2 PSL in Months for Selected Food Products

Product	**Storage Temperature**		
	-12 °C	**-18 °C**	**-24 °C**
Fruits			
Peaches, apricots, cherries (raw)	4	18	>24
Raspberries, strawberries (raw)	5	24	>24
Concentrated fruit juice	-	24	>24
Vegetables			
Asparagus (with green spears)	3	13	>24
Beans (green)	4	15	>24
Broccoli	-	15	24
Carrots	10	18	>24
Cauliflower	4	12	24
Cut corn	4	15	18
Peas	6	24	>24
French fried potatoes	9	24	>24
Spinach	4	18	>24
Onions	-	10	15
Meat and meat products			
Beef (ground/minced)	6	10	15
Beef steaks	8	18	24
Lamb steaks	12	18	24
Pork steaks	6	10	15
Bacon (sliced, vacuum packed)	12	12	12
Chicken (whole or cuts)	9	18	>24
Turkey (whole)	8	15	>24
Seafood			
Shrimps (cooked / peeled)	-	2	5
Eggs			
Whole egg	-	12	>24
Milk products			
Butter (lactic, salted, pH 4.7)	8	12	14
Cream	-	12	15
Bakery and confectionery			
Cakes (cheese, chocolate, fruit)	-	15	24

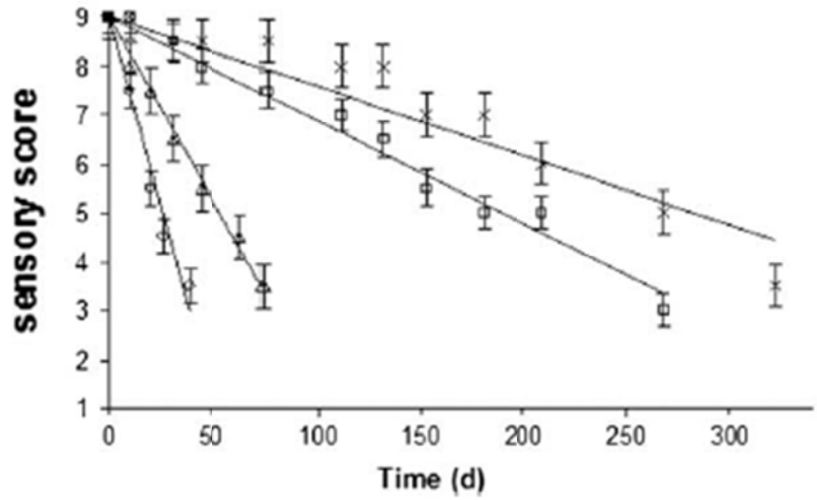


Figure 1 Sensory scores for color of thawed non-peeled frozen shrimp during storage at ○: -5 °C, △: -8 °C, □: -12 °C, *: -15 °C.

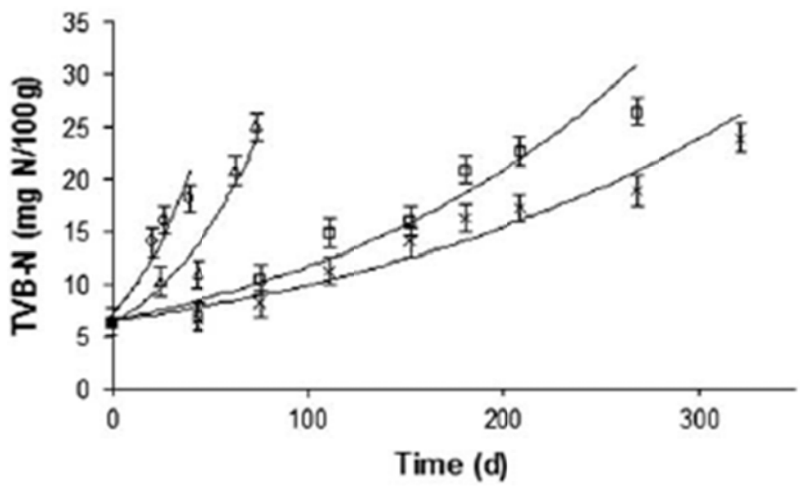


Figure 2 Changes in TVB-N value of frozen shrimp during storage at ○: -5 °C, △: -8 °C, □: -12 °C, *: -15 °C.

Table 3 Shelf Life of Frozen Shrimp Stored at -5, -8, -12, -15, and -18 °C

Storage temperature (°C)	Shelf life of frozen shrimp (days)	
	Sensory scoring (limit = 5)	TVB-N (limit = 25 mgN/100 g)
−5	51	45
−8	90	82
−12	194	187
−15	351	353
−18	644[a]	677[a]

[a] Calculated using the models developed.

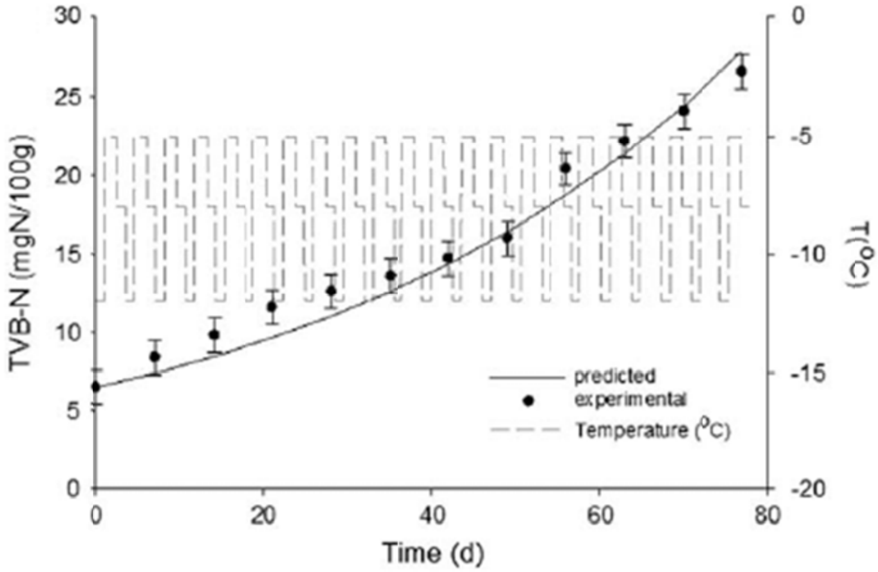


Figure 3 Comparison of experimental and predicted changes in TVB-N of frozen shrimp at temperature profile of the non-isothermal experiment (Teff = -7.3 °C).

Therefore, total volatile basic nitrogen (TVB-N) has been selected as a indicator in order to establish the kinetics model of quality deterioration for the frozen shrimp scampi, which will be validated by sensory analysis.

4.2 Steak

Lipid oxidation is a major deterioration mode of meat products involving changes of flavor, color, texture. During frozen storage, the oxidation process are slowed down, but not completely hindered (Kanner, 1994). Steak is the only raw meat product in UGR-A Menu 2010, which makes it an ideal candidate as a model food to study the oxidative stability of frozen meat products.

Oxidative stability of pork patties during frozen storage has been studied by Hansen, et al., 2004, which was measured as secondary oxidation products, thiobarbituric acid reactive substances (TBARS), during storage at -10, -23, and -40 °C and with fluctuations between these temperatures. Figure 4 showed that TBARS value in pork patties decreased with decreasing frozen storage temperature, and fluctuation of the storage temperatures between these temperatures resulted in oxidation intermediate to storage at the corresponding constant (high and low) temperatures, but did not further increase the lipid oxidation (Hansen, et al., 2004).

Lanari, Schaefer, and Scheller, 1995, suggested that TBARS values of about 0.5 mg MDA / kg meat (equivalent to 8 µmol MDA / kg meat) corresponds to the threshold value for rancid odors in fresh pork. Therefore, it is possible to establish a kinetic model for the lipid oxidation by using TBARS value in order to predict the shelf life of frozen steak. The exact detection limit for rancidity of steak should be further determined by sensory analysis.

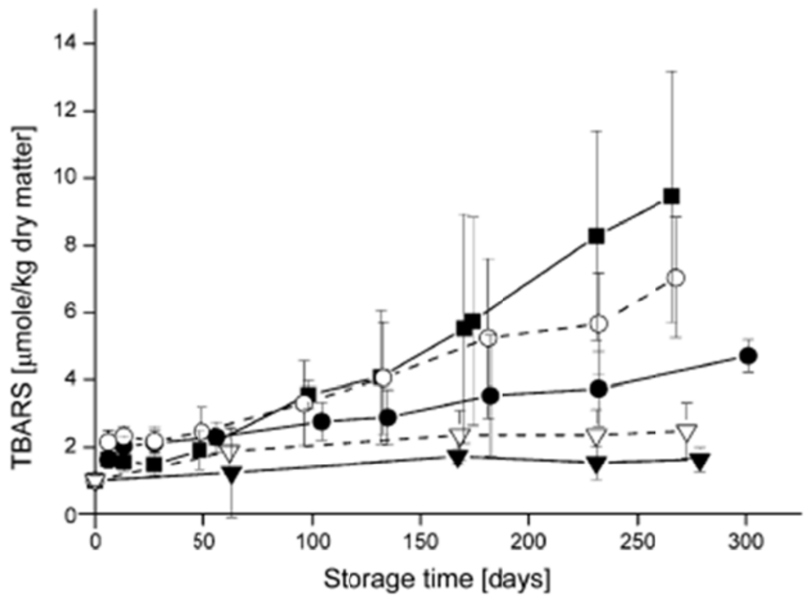


Figure 4 TBARS measured in pork patties during frozen storage at constant of fluctuating temperatues ■: -10 °C, ○: -10 / -23 °C, ●: -23 °C, ▽: -23 / -40 °C, ▼: -40 °C.

4.3 Chicken Cordon Bleu

Chicken cordon bleu is a complicated food product, which has a bread coating outside and contains chicken, ham, and cheese inside. This makes it a good candidate for studying the interaction effect between different food components during long term frozen storage.

Lipid oxidation is the major quality deterioration for this product. Therefore, TBARS will be carried out for the same reason of steak. However, since chicken cordon bleu is a multi-component food product, the interaction between different components may interfere the TBARS value. Thus, the kinetic model will be derived mainly from the sensory analysis in this case, because sensory score can give an overall understanding about the food quality.

4.4 Design of Shelf Life Study Conditions

The objective of this project is to distinguish potential thermally abused UGR-A rations which would not meet the safety and quality parameters of the Army by using time-temperature integrator (TTI). The operation of a TTI is based on irreversible changes of certain mechanical, chemical or enzymatic systems. The time-temperature integrators show a physical or a color change, and an essential condition is that the kinetics of TTI should coincide with the major deterioration of the food they are monitoring (Evans, 2008). Therefore, accurate kinetic models for each model food products are required for future numerical simulation and TTI selection.

Although plenty of literature are available to provide the kinetic models for these model food products, it is still necessary to conduct our own shelf life study, because many other factors, in addition to food product itself, may affect the deterioration kinetics. The conditions for the shelf life study are shown in Table 4.

Table 4 Shelf Life Study Conditions for Model Food Products

Temperature	Testing Date					
-4 °C	0 week	1 week	2 week	4 week	6 week	8 week
-12 °C	0 month	2 month	4 month	6 month	8 month	10 month
-18 °C	0 month	3 month	6 month	9 month	12 month	15 month

5. Conclusion

In this report, literature on quality and safety changes in frozen storage of food products are reviewed. Based on the sensitivity of food products, three model foods have been chosen for further shelf life studies. An appropriate indicative chemical reaction has been assigned to each of the model foods, TVB-N for shrimp scampi and TBARS for steak and chicken cordon bleu. The model foods will also go through sensory analysis during the shelf life test to verify the kinetic model derived from the chemical indicators. If necessary, microbial tests will be carried on as well. We expect to obtain a reasonable kinetic model for each model food products from shelf life studies, which will provide useful information for numerical simulation and TTI selection in the future.

Reference

Adams M.R. and Moss M.O., 1995. Food Microbiology. Cambridge, U.K.: The Royal Society of Chemistry.

Anonymous, 1986. Recommendations for the processing and Handling of Frozen Foods. Paris: International Institute of Refrigeration.

Enrique Ortega-Rivas, 2010. Chapter 11: Effects of Chilling and Freezing on Safety and Quality of Food

Dhaouadi, A., Monser, L., Sadok, S., and Adhoum, N., 2007. Validation of a flow-injection-gas diffusion method for total volatile basic nitrogen determination in seafood products. Food Chemistry, 103, 1049-1053.

Products. Processing Effects on Safety and Quality of Foods, CRC Press.

Evans J.A., 2008. Chapter 11: Frozen Storage. Frozen Food Science and Technology, Blackwell Publishing.

Fennema O.R., 1973. Nature of the freezing process. In Low-Temperature Preservation of Foods and Living Matter. Marcel Dekker, New York

Hansen, E., Lauridsen, L., Skibsted, L.H., Moawad, R.K., and Andersen, M.L., 2004. Oxidative stability of frozen pork patties: Effect of fluctuating temperature on lipid oxidation. Meat Science, 68, 185-191.

Kanner, J., 1994. Oxidative process in meat and meat product: Quality implications. Meat Science, 36, 169-189.

Krzymien M.E. and Elias L., 1990. Feasibility study on the determination of fish freshness by trimethylamine headspace analysis. Journal of Food Science, 55, 1228-1232.

Labuza T.P. and Fu B., 1997. Shelf life of frozen foods. Shelf life testing: procedures and prediction methods. In: Hong Y.C., ed., Frozen Food Quality. Denver: CRC Press, 377-415.

Lanari, M.C., Schaefer, D.M., and Scheller, K.K., 1995. Dietary vitamin E supplementation and discoloration of pork bone and muscle following modified atmosphere packaging. Meat Science, 41, 237-250.

Taub I.A., Singh R.P., 1997. Chapter Fourteen: Freezing preservation of fresh foods: quality aspects. Food Storage Stability, CRC Press LLC.

Tsironi, T., Dermesonlouoglou, E., Giannakourou, M., and Taoukis, P., 2009. Shelf life modeling of frozen shrimp at variable temperature conditions. LWT – Food Science and Technology, 42, 664-671.

Appendix 4.5

Microbial Modeling (TWP#227)

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Microbial Growth Modeling

Technical Working Paper (TWP) #227

Henderikus Bruins

Dr. Donald Schaffner

August 29, 2011

Sponsored by:

DEFENSE LOGISTICS AGENCY

8725 John J. Kingman Rd.

Fort Belvoir, VA 22060-6221

Contractor:

Rutgers, The State University of New Jersey

THE CENTER FOR ADVANCED FOOD TECHNOLOGY

School for Environmental and Biological Science

N.J. Agricultural Experiment Station

New Brunswick, New Jersey 08903

Introduction:

The UGR-A menus contain a wide variety of products that are kept frozen (-18 ^{0}C) to preserve shelf life (9 month). However, in hot climates such as Iraq and Afghanistan, the storage conditions are challenging and the probability that the products will see temperature higher than -18 ^{0}C is great. It is also possible that the product will encounter a situation that it will defrost. While microbial growth will very unlikely occur while the product is frozen solid, microbial growth in a defrosted product is of concern. This working paper documents microbial growth of various pathogens such as *Listeria, Salmonella, E. coli, Clostridium botulinum, Staphylococcus aureus, Yersinia enterocolitica* and spoilage bacteria such as *Pseudomonas spp*. The growth rates were obtained from Combase Predictor (http://modelling.combase.cc/). Acceptable growth increases for pathogens were assumed to be less than a one log cycle increase, while acceptable growth rates for spoilage bacteria such as *Pseudomonas spp* is up to 2.5 log cycles with an assumption that the initial level can be as high as 10^5 CFU/gm.

In the following sections, growth rates of various pathogens and spoilage bacteria will be determined at different temperatures and the time will be calculated to reach unacceptable growth.

Listeria monocytogenes

Listeria growth models are available in Combase Predictor for temperature ranging from 1 C to 40 C. The following input values were used to generate maximum growth rate: NaCL: 1%; Acetic Acid: 0; pH 7;

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
1	0.01984	0.01	34.71	110	300
4	0.01984	0.02	17.71	50	150
8	0.01984	0.04	7.92	20	60
12	0.01984	0.08	3.94	10	30
20	0.01984	0.22	1.34	4	8
28	0.01984	0.43	0.70	2	6

Salmonellae

Growth models are available in Combase Predictor for temperature ranging from 7 C to 40 C. The following input values were used to generate maximum growth rate: NaCL: 0.5%; Nitrate: 0ppm; pH 7;

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
8	0.04978	0.02	13.83	44	100
12	0.04978	0.06	5.25	16	36
20	0.04978	0.26	1.17	3	8
28	0.04978	0.64	0.47	1	3

Escherichia coli
Growth models are available in Combase Predictor for temperature ranging from 10 C to 42 C. The following input values were used to generate maximum growth rate: NaCL: 0.5%; pH 7;

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
12	0.1653	0.06	5.39	16	28
20	0.1653	0.27	1.13	3	6
28	0.1653	0.67	0.45	1	2

Clostridium botulinum (non-proteolytic)
Growth models are available in Combase Predictor for temperature ranging from 4 C to 30 C. The following input values were used to generate maximum growth rate: NaCL: 0.5%; pH 7.0;

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
4	0.00003	0.01	23.14	76	400
8	0.00003	0.05	5.92	18	104
12	0.00003	0.15	2.01	6	34
20	0.00003	0.56	0.54	1	9
28	0.00003	0.67	0.45	1	8

Staphylococcus aureus
Growth models are available in Combase Predictor for temperature ranging from 7.5 C to 30 C. The following input values were used to generate maximum growth rate: NaCL: 0.5%; pH 7.0;

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
8	0.04504	0.01	25.05	80	180
12	0.04504	0.04	8.60	28	64
20	0.04504	0.18	1.69	4	12
28	0.04504	0.45	0.66	2	4

Yersinia enterocolitica
Growth models are available in Combase Predictor for temperature ranging from -1 C to 37 C. The following input values were used to generate maximum growth rate: NaCL: 0.5%; pH 7.0;

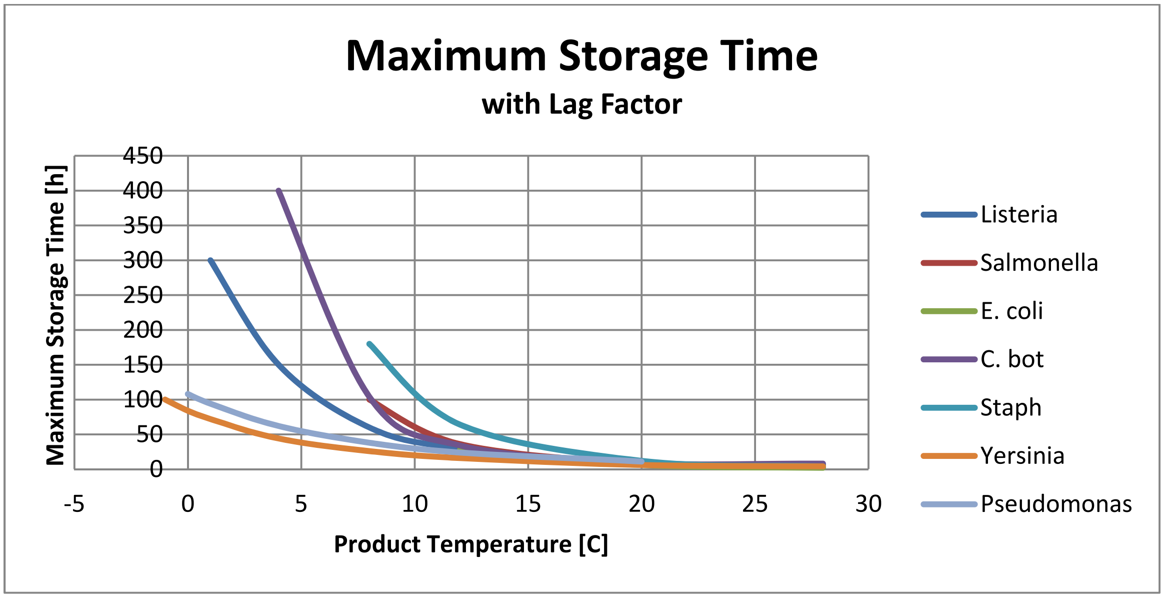
Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <1Log Cycle w/o Lag [h]	Time <1Log Cycle with Lag [h]
-1	0.12245	0.02	17.29	50	100
1	0.12245	0.02	12.44	36	72
4	0.12245	0.04	7.84	22	44
8	0.12245	0.07	4.5	12	26
12	0.12245	0.11	2.77	8	16
20	0.12245	0.23	1.29	4	6
28	0.12245	0.38	0.79	2	4

***Pseudomonas spp*. (spoilage bacteria)**
Growth models are available in Combase Predictor for temperature ranging from 0 C to 20 C. The following input values were used to generate maximum growth rate: NaCL: 1.5%; pH 6.5; As an initial load we assumed 5 Log CFU/g and as maximum (spoilage) load we assumed ~ 7.5 log CFU/g.

Temp [C]	Lag Factor	Max Rate [log.conc/h]	Doubling Time [h]	Time <7.5Log w/o Lag [h]	Time <7.5Log with Lag [h]
0	0.1827	0.03	10.07	84	108
1	0.1827	0.03	8.75	72	94
4	0.1827	0.05	5.84	48	62
8	0.1827	0.08	3.56	28	38
12	0.1827	0.13	2.28	16	24
20	0.1827	0.28	1.08	8	11

Results:

If we compile the time required to increase the pathogen by less than one log cycle or the spoilage bacteria by less than 2.5 log cycles into a single graph, we observe that the microbial safety of the product is determined by the growth rate of *Yersinia* (not likely to exist), *Pseudomonas* (spoilage bacteria that is likely present in most meat type products) and *Listeria* (previously selected as our primary microorganism of concern in seafood). While data from the Combase predictor should be extrapolated only with great care, it appears that growth of these three bacteria might occur at temperatures below 0 C. One paper on growth of Listeria at -2C was identified in the Combase database (source: *Bajard (et al.), 1996: The particular behaviour of* Listeria monocytogenes *under sub-optimal conditions. International Journal of Food Microbiology 29: 201 – 211*). Most other papers that cover microbial growth at temperatures below 0 C address microbial growth in products that are irradiated, which is not applicable to the UGR-A menu.



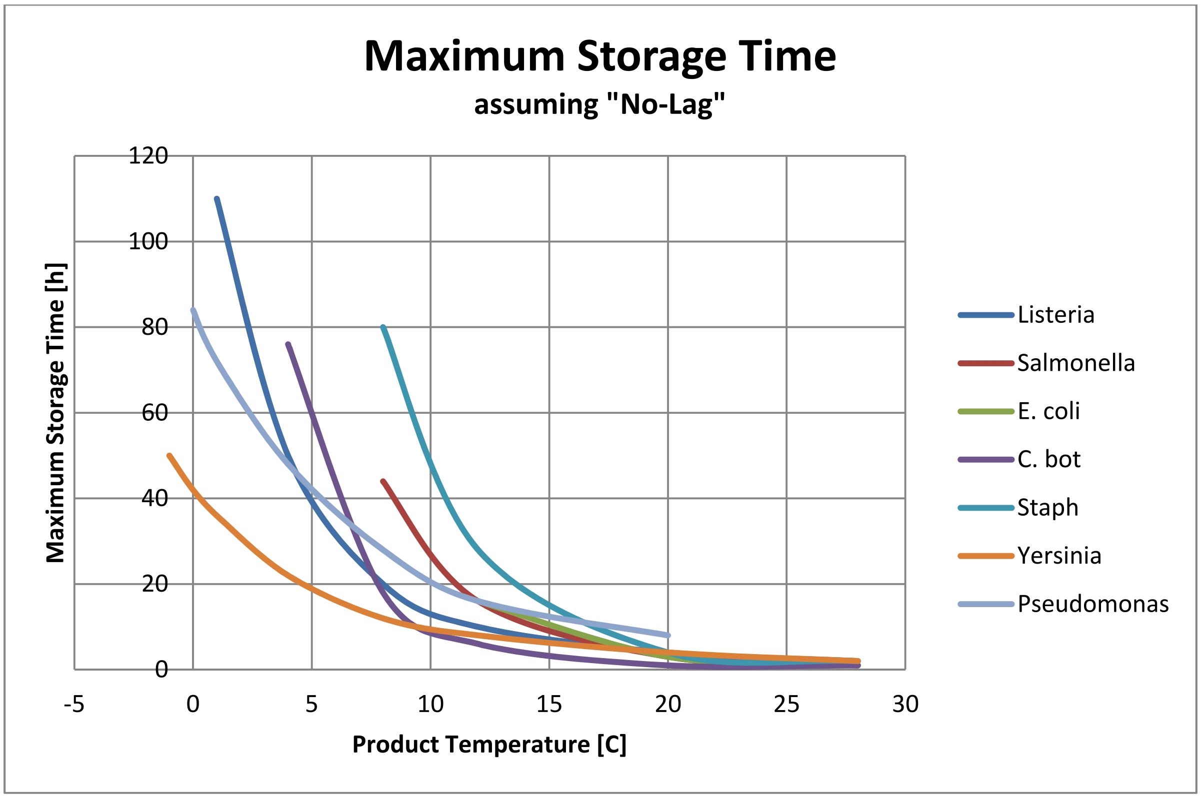
Based on the above data, we can determine the required TTI behavior that is needed to warn the user for time temperature exposure that might have resulted into unsafe microbial conditions. As indicator organism we used the growth rate of *Pseudomonas* spp. Maximum exposure time at -4 C was extrapolated.

Temperature [C]	Maximum Exposure Time [h]
-4	200 (extrapolated)
0	108
+4	62
+8	38
+12	24
+20	11

Growth Rate w/o Lag Factor

If we disregard the lag factor during growth and assume instantaneous growth than the allowable time of the product in a defrosted stage is greatly reduced and the minimum time that the product can be a at certain temperatures is determined by *Yersinia* at the lower temperatures range and *C. botulinum* at the temperatures exceeding 10 C

Based on the data without lag factor, the required TTI behavior to indicate unsafe microbial conditions is based on target organism, we used the growth rate of *Yersinia* and *C. botulinum*. Maximum exposure time at -4 C was extrapolated.



Temperature [C]	Maximum Exposure Time [h]
-4	90 (extrapolated)
0	44
+4	22
+8	12
+12	6
+20	1

Appendix 4.6

Phase I Technical Report (TWP#228)

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Alert to Temperature Abuse of UGR-As

Phase I Report

Technical Working Paper (TWP) #228

Dr Kiran Desai
J S Karthikeyan
Neha Bhide
Dr Mukund Karwe
Dr Donald Schaffner
Rieks Bruins

April 10, 2012

Sponsored by:
DEFENSE LOGISTICS AGENCY
8725 John J. Kingman Rd.
Fort Belvoir, VA 22060-6221

Contractor:
Rutgers, The State University of New Jersey
THE CENTER FOR ADVANCED FOOD TECHNOLOGY
School for Environmental and Biological Science
N.J. Agricultural Experiment Station
New Brunswick, New Jersey 08903

Table of contents

List of figures

List of Tables

1. Justification and Objectives

The Unitized Group Ration – A (UGR-A) is the most highly accepted ration in the UGR family. It is the only military operational ration that contains frozen food components. Each UGR-A module is made up of 2 shelf stable boxes and 1 frozen box. These rations are assembled in the United States (CONUS) and shipped around the world for use in field feeding by deployed units. The frozen box containing perishable foods is stored at -18 °C and must have 9 months remaining shelf life for deliveries outside the United States (OCONUS).

Freezing is one of the most widely used processing technologies to stabilize food items, however it does not make them shelf stable since microbial load is not reduced. It is therefore necessary to avoid temperature increases during the shelf life of the product, as elevated temperatures can accelerate the quality degradation of the product and temperatures above the freezing point would allow microorganisms to grow, affecting the safety[13,14]

Food safety and quality of frozen products is largely dependent on maintaining the proper temperature during transportation, storage, and thawing/tempering. Understanding the potential for temperature abuse of food is an important element in designing effective food safety controls. New technology can assist the food industry and risk assessors in evaluating the temperature-related risk profile of perishable food products. The data can enable the industry to maximize product quality and minimizing the food safety risk caused by potential temperature abuse that occurs after a product leaves a food manufacturing facility.

Placing temperature monitors in the shipping containers can be effective in monitoring storage conditions. However, these monitors do not account for the time that frozen boxes may be outside the container and they are not tamper proof. It is desired to have a technological solution for the UGR-A frozen box that would alert the end user to possible temperature abuse. This project will determine what time-temperature combinations would be effective in ensuring safe and high quality food products based on the most sensitive item in the frozen box.

As deterioration of frozen products originates from periods at above freezing temperature and freeze-thaw cycles, we propose to identify time-temperature sensors which, based on kinetic models of microbial growth and quality deterioration and heat transfer simulation under different packing and storage scenarios, would indicate that the product is no longer suitable for consumption either based on safety concerns or based on deteriorating quality.

The scope of this project is to determine the critical temperature conditions at which the frozen UGR-A will no longer meet the 9 month shelf life and to determine the best available time temperature indicators that can be used to warn the user of product that is close to the end of its shelf life or has deteriorated to such extent that it is no longer safe to consume.

The project is divided in three phases. Under phase I, we will identify predictive modeling tools for food safety and food quality. Where possible, we will rely on existing data for microbial growth and quality deterioration. We will also store three products at different temperature conditions and measure quality degradation as function of time and temperature. In addition we will develop a heat transfer model that predicts the effects of environmental temperature "upsets" on product temperature, using three filled menu boxes supplied by one of the UGR assemblers. Under phase II, which will run concurrently with phase I, we will conduct a TTI technology survey of available TTI for frozen product distribution and meet with representatives of the various companies to discuss the needs of this project. We will compare the technologies based on capability, maturity and cost and develop a comparison matrix with weight factors that would rate each of the technologies.

Under phase III, we propose to develop an implementation plan for the most promising TTI identified under phase II

This reports deals with phase I of the project. The objectives of this report (phase I) are listed as below:

Objective I: Develop a heat transfer model using computational techniques that predicts the effects of environmental temperature "upsets" on product temperature profile

Objective II: Simulate various scenarios real / foreseen to obtain time temperature profile during storage and transportation

Objective III: Combine heat transfer model with predictive modeling tools for microbial and chemical food safety and quality, using either experimental data or existing models for microbial growth and quality deterioration

2. Approach

This section describes the approach followed to achieve the objectives given in section 1. Figure 1 shows schematics of approach.

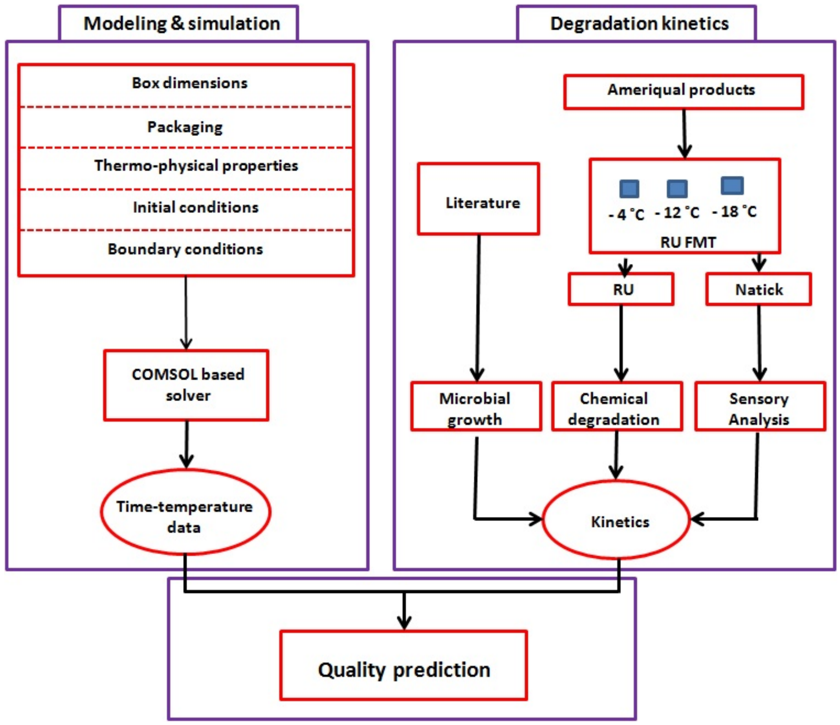


Figure 1: Schematics of approach

The first block shows the necessary steps needed for modeling and simulations in order to obtain time - temperature profile for various simulated scenarios. Various parameters such as box dimensions, product orientations, packaging specification, thermo-physical properties (such as density, thermal conductivity, specific heat capacity and latent heat), initial conditions and boundary conditions are used as input parameters to the model. The model is solved using commercial software COMSOL® to obtain time -temperature profiles.

The second block shows steps required to obtain kinetics of degradation. Microbial growth, chemical degradation and sensory analysis are used as quality parameters. Sensory analysis is a qualitative parameter that is not used in the model, but served as a validation parameter to the chemical degradation reactions. Microbial growth kinetics were obtained using Combase database. Chemical degradation kinetics were experimentally obtained.

The final module shows a schematic of approach for objective III. In this step, time - temperature profile were combined with degradation kinetics to predict final quality of the products.

3. Introduction

The earlier section described justification, overall objectives and approach. This section gives an introduction of the system and descriptions of various phenomenon, experimental and computational techniques, which are relevant to this project.

3.1 System description

The three menu items that were used in the model for this project were obtained from Ameriqual. Table 1 below shows the various items that were included in each of the menu items.

Table 1: Description of food items in each menu box

Menu item	**Food/Ingredients/Supplies**
Menu - 3	
Steak	Steak, Breakfast, uncooked
Peppers & onions	Peppers & Onions, frozen
French toast and sausage taquito	Taquito, French Toast and Sausage, Frozen, Fully Cooked
Danish	Danish, Assorted Mini, Frozen
Orange juice	Juice, 100% Orange, Concentrate, Frozen
menu - 14	
Chicken cordon bleu	Chicken Cordon Bleu, Ovenable Film, Frozen, Fully Cooked
Chocolate cappuccino cake	Cake, Chocolate Cappuccino, Frozen, Sheet
menu - 6	
Shrimp scampi w/ bowtie pasta	Shrimp Scampi w/ Bowtie pasta, Frozen, Boil-in-Bag
Penne pasta w/ chicken in alfredo sauce	Penne pasta w/ chicken and turkey bacon in a tomato alfredo sauce, Frozen, Boil-in-Bag
Amaretto cake	Cake, Amaretto Cream Cake, Frozen, Sheet

The menu boxes were assembled into shipping containers (grade V3c or 275# (69-33-69) wax impregnated medium) and packed in a manner which ensures product quality and integrity at the destination and throughout the life cycle of the ration. The assembly of these items was performed at Ameriqual in a room that was maintained at 4.4 °C or less. The frozen item was at this temperature for not more than 1.5 hrs.

For OCONUS delivery, the pre-shipment and receipt inspection are performed using the following criteria: The conveyance shall be pre-cooled (prior to loading) to -18 °C and the conveyance temperature should be set to -18 °C or below. Before and after shipment, the UGR-A shall show no evidence of thawing, refreezing or any other off-condition. The average internal temperature cannot exceed -12 °C and no individual component can exceed -10 °C (at loading and at receipt). The contractor is responsible for the shipment of the meal modules directly to the OCONUS delivery point and is relying on the conveyor to store and transport the frozen product at temperatures below -18 °C.

Thus, from this system description, following conclusions can be made:

1. The dimensions of packages and boxes, packaging materials and orientation of products in boxes are standardized and fixed.
2. Till the products are assembled and ready to dispatch, they are stored at -18 C.
3. The assembly time is very short and has no negative effect on product quality
4. The initial and nominal temperature of product storage is - 18 C

Based on dialog with the Army Veterinary Inspection Agency (AVI), the following scenarios could occur that warrant the use of TTI's:

1. Products can be exposed to ambient temperature for prolonged time, while loading and unloading at changeover points.
2. Refrigerator failure during which the surrounding temperature will steadily increase from -18 C onwards.

Heat transfer models needed to be developed, using finite element analysis software from COMSOL® in order to predict the quality degradation and microbial growth of the products, in response to the above described temperature upsets. In order to build these models, physical characteristics of each menu item is needed.

3.2 Freeze - thaw basics

The understanding of the liquid–solid phase change phenomena is critical for modeling and simulation. For pure materials, phase change occurs at a fixed temperature resulting in an interface which separates distinct solid and liquid phases, e.g. freezing of water or rapid solidification of metals. In contrast, for multi-component substances such as thawing of foods, phase change occurs over a temperature range and the solid and liquid phases are separated by a 'mushy' region which is characterized by solids suspended in a liquid region[2,4], as shown in Figure 2.

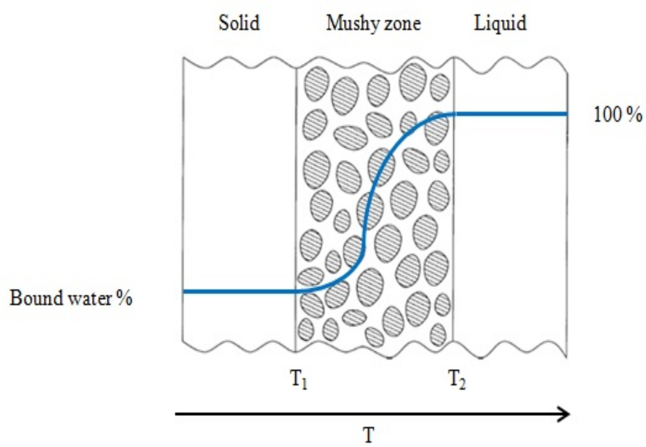


Figure 2: Description of mushy zone

Figure 2 shows schematics of thawing of food products in which temperature is increasing from left to right. The phase change occurs between temperature T_1 and T_2. The blue line represents the unfrozen water content. A small part of total moisture content is bound water which never gets frozen. In mushy zone, the unfrozen water content changes as a non-linear function of temperature and in liquid zone, unfrozen water content is 100%. The unfrozen water content (ϕ) is given by following equation.

$$unfw(\phi) = \begin{cases} w_b & T < T_1 \\ f(T) & T_1 > T > T_2 \\ 100 & T > T_2 \end{cases} \tag{1}$$

3.3 Apparent specific heat method

The major difficulty in the numerical solution of heat transport equation is in dealing with the large latent heat, which evolves over a very small temperature range. Various numerical methods have been developed to solve phase change problems for pure as well as multi-component substances. In the temperature method, strictly applicable for pure substances, the energy balance equation is solved separately for both solid and liquid phases and the moving phase change front is tracked with the appropriate interface conditions. In contrast, the latent heat methods, developed for multicomponent substances, requires a single energy balance equation (as shown below) for the entire domain consisting of co-existing solid, liquid and mushy states.

$$\rho c_p \frac{\partial T}{\partial t} = \nabla(k \nabla T) + S \tag{2}$$

Of the latent heat methods, some treat latent heat as a source term. This term is not suitable for most foods for which latent heat is released over a wide range of temperature and hard to distinguish from sensible heat. The most popular technique is the *apparent specific heat method*. In this method, latent heat is merged with sensible heat to produce a specific heat curve with a large peak around the freezing point (as shown in Figure 3).

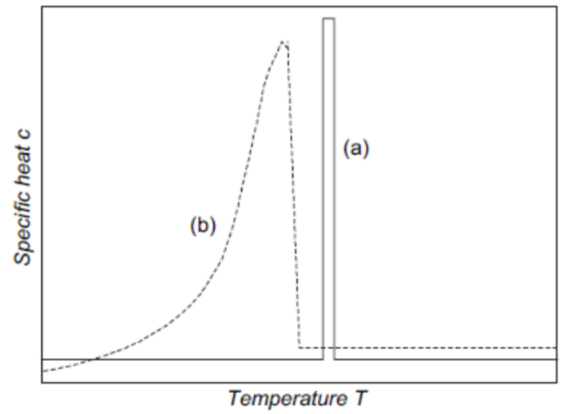


Figure 3: Apparent specific heat capacity

According to the finite element approach, latent heat effects can be approximated by an equivalent heat capacity over a small temperature range[4]. An equivalent heat capacity in a mushy range is invoked to take into account both the sensible and the latent heat, and is discontinuous depending on the temperature at the bounds of mushy range. Intermediate states and the phase change region are determined from the equilibrium liquid volume fraction (ϕ) vs temperature (T) relationship (as shown in following equations), thereby avoiding the necessity for a front tracking algorithm. Hence, the method is ideal for studying phase change in multi-component materials and in situations involving volumetric heat sources where multiple fronts exist[12,16].

$$c_p(app) = \begin{cases} c_{p(frozen)} & T < T_1 \\ c_{p(phase\ change)} & T_1 > T > T_2 \\ c_{p(thawed)} & T > T_2 \end{cases} \tag{3}$$

3.4 Computational techniques

Freezing time and temperature profile of foods can be determined experimentally or predicted by either analytical or numerical methods. Experimental procedures are often too expensive, time consuming and may lack a generalized theoretical description of the process. By comparison, numerical solution method is more effective to analyze the actual situation. For the freezing process, the food can be divided into three zones: unfrozen, frozen and mushy zone. A complete mathematical model has to solve the heat transfer in all three zones. The mathematical model is a system of partial differential equations of the parabolic type. The phase change heat transfer is a severe non-linear problem in mathematics. The analytic or the exact solution of this problem is impossible due to its complexity. Therefore, an approximate analytical approach, numerical simulation method, and experimental method have to be applied (Lin, 1992). The widely used finite difference method has difficulty in dealing with the boundary condition for problems with complicated shape and severe non-linear problems, and sometimes has weak stability and slow convergence. In contrast, the finite element method (FEM), especially the Galerkin finite element method, has an advantage in solving such kind of problems, though it is not used widely[12]. Therefore, FEM based numerical simulation method was used for modeling.

The key steps in FEM analysis (carried out using commercial software COMSOL®) are:

1. Definition of the physical problem
2. Formulation of the governing equations
    - Systems of PDE, ODE, algebraic equations,
    - definition of initial conditions and/or boundary conditions to get a well-posed problem.
3. Discretization of the equations
4. Solution of the discrete system of equations
5. Interpretation of the obtained results

The specific details such as governing equations, initial and boundary conditions are described in next section.

3.5 Differential scanning colorimeter (DSC)

For freeze-thaw process modeling, many parameters representing thermo-physical properties of food products are required. These parameters are specific heat for unfrozen and frozen state, thermal conductivity, density, temperature range for phase change, latent heat of fusion and initial freezing temperature, etc. Initial freezing point is the temperature at which crystallization begins. It is one of the basic parameters in thermal property models that are used in the estimation of freezing times. This property is often a function of product composition. Unfreezable water content is the amount of water remaining unfrozen in a product at the reference temperature of -30 °C. The reference temperature of -30 °C has been used by many investigators because this temperature covers the typical range of industrial processes. Unfrozen water fraction is the amount of water remaining unfrozen at a certain temperature. Both unfreezable water and unfrozen water weight fractions are needed in the theoretical calculation of the enthalpy of a food system.

DSC is widely used method to determine these thermo-physical properties. DSC measurements gives specific enthalpy data for food products, which is a measure of the total heat to be removed and the rate of heat removal during phase change process of food products. This method is based on a differential heat flux measurement between the sample cell and an empty reference cell. The DSC's main advantages rely on rapid and pretty simple measurement and, on the fact that, more valuable information can be obtained by a single thermogram, namely the specific enthalpy, the apparent heat capacity and the frozen water fraction[6,7,17]. Nevertheless, the sample size is very small and, in the case of heterogeneous materials, sampling should be done with a great care so that the small sample is representative of the investigated food. The details of DSC measurements and analysis are given in the methodology section.

4. Methodology

This section describes the methodologies and computations for obtaining thermo-physical properties, FEM based numerical simulations and kinetics of degradation.

4.1 Differential Scanning Calorimeter (DSC)

DSC was used to obtain following properties:

- initial freezing temperature
- temperature range for phase change
- unfrozen / frozen water content
- bound water content
- enthalpy of phase change
- apparent specific heat

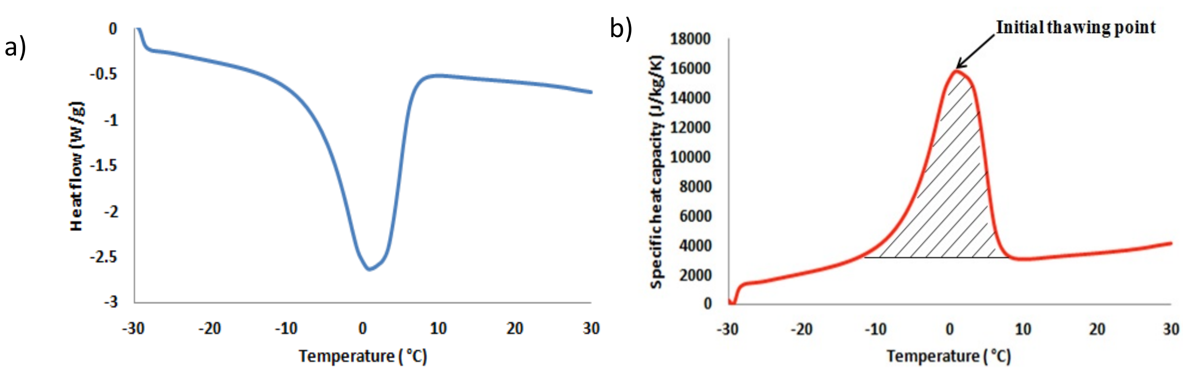


Figure 4: DSC a) Heat flow curve b) DSC Analysis

DSC heat flow curves were obtained for all the items in menu for freezing and thawing cycles. Freezing curves were obtained by reducing temperature from 30 C to -30 C at 10 C/min and thawing curves were obtained by first equilibrating sample at -30 C, and then heating it up to 30 C at 10 C/min. Figure 4a shows typical enthalpy or heat flow rate (W/g) curve. Figure 4b shows apparent specific heat curve derived from heat flow curve (Figure 4a) using following equations.

$$c_{p(app)} = \frac{dH}{dT} = \frac{dH/dt}{dT/dt} = \frac{Heat\ flow\ rate\,(W/kg)}{Temperature\ ramp\ rate\,(K/s)} = \frac{J}{kg\,K} \tag{4}$$

The temperature corresponding to peak is initial freezing temperature. The area under the curve (H_{fw}) is enthalpy of phase change.

The unfreezable water or bound water (w_b) at low temperature can be measured by DSC, simply by difference between total water content and the amount of water detected by the fusion endotherm, as described in following equations.

$$x_b = x_t - \frac{H_{fw}}{L} \tag{5}$$

where, x_t is total moisture content; *L* is latent heat of fusion for water.

The unfrozen water content is calculated as proportional to the area under the apparent specific heat curve. The apparent specific heat curve is modeled as a cubic function of temperature with its peak adjusted to match the area under curve.

Bound water is the portion of water in frozen food which are termed as unfrozen water under low temperatures. They are bound to food matrix and will never undergo phase change. To evaluate the thermal properties of the frozen foods bound water value has to be calculated. Following formula was used[6].

$$Bound\ water = Total\ moisture\ content - \frac{Area\ under\ the\ curve}{L_o} \tag{6}$$

In the mushy zone (Figure 2), ice fraction changes as a function of temperature. During freezing experiment, ice fraction will be zero till initial freezing point and will increase till the food is frozen completely i.e., when it reaches the bound water content. Ice fraction in the mushy zone is calculated by the following formula[6].

$$ice\ fraction(T) = (Total\ moisture - Bound\ water)\left(1 - \frac{T_1}{T}\right) \tag{7}$$

Similar to ice fraction, in mushy zone the remaining portion of total moisture will be unfrozen water. Unfrozen water will be 100% at initial freezing point and it reduces till it reaches the bound water fraction when the food is completely frozen.

4.2 Component analysis

Density and thermal conductivity were expressed as the function of temperature, based on the component of each food item[19]. Thermal properties of the individual component used in this study were tabulated below. For completely thawed food, when the temperature is above initial freezing/thawing point, water fraction was considered as 100%. In completely frozen food, bound water percentage was expressed as the properties of water and remaining water fraction as ice. And in mushy zone the water and ice fraction changes, their properties were evaluated accordingly.

Table 2: Thermo-physical properties of individual food component

	Fat	Carbohydrates	Protein	Ash	Fiber	Water	Ice
Density (Kg/m3)	925.5	1599.1	1329.9	2423.8	1311.5	997.18	916.89
Thermal Conductivity (W/mK)	0.18071	0.20141	0.17881	0.32961	0.18331	0.5711	2.2196
Specific heat capacity (J/kg/K)	1984.2	1548.8	2008.2	1092.6	1845.9	4176.2	2062.3

[16,19]

Density was calculated from the component data using the following formula. Mass fraction of each individual component were multiplied with the respective density value[19].

$$\rho(T) = \frac{1}{\frac{x_i}{\rho_i} + \frac{x_{unf}(T)}{\rho_w} + \frac{x_{ice}(T)}{\rho_{ice}}} \tag{8}$$

where i includes, dry components namely fat, carbohydrates, protein, ash, fiber. 'x_{unf}' is mass fraction of unfrozen water and 'x_{ice}' is mass fraction of ice.

Thermal conductivity was calculated from the component data using the following formula. Volume fraction of each individual component were multiplied with the respective thermal conductivity value[16] .

$$k(T) = k_i X_i + k_w X_{unf}(T) + k_{ice} X_{ice}(T) \tag{9}$$

4.3 Modeling techniques

A finite element based commercial computational software, COMSOL® Multiphysics (Version 4.2, COMSOL Inc., Burlington, MA), was used for numerical simulation of time temperature profile for temperature abuse of UGR-A ration. Microbial growth kinetics developed using data obtained from COMBASE was also incorporated in COMSOL® model to predict the extent microbial growth. A 3D geometry depicting respective menu boxes with the actual product orientation were used for modeling. Figure 5 shows 3D geometry of the menu 3 box with food items.

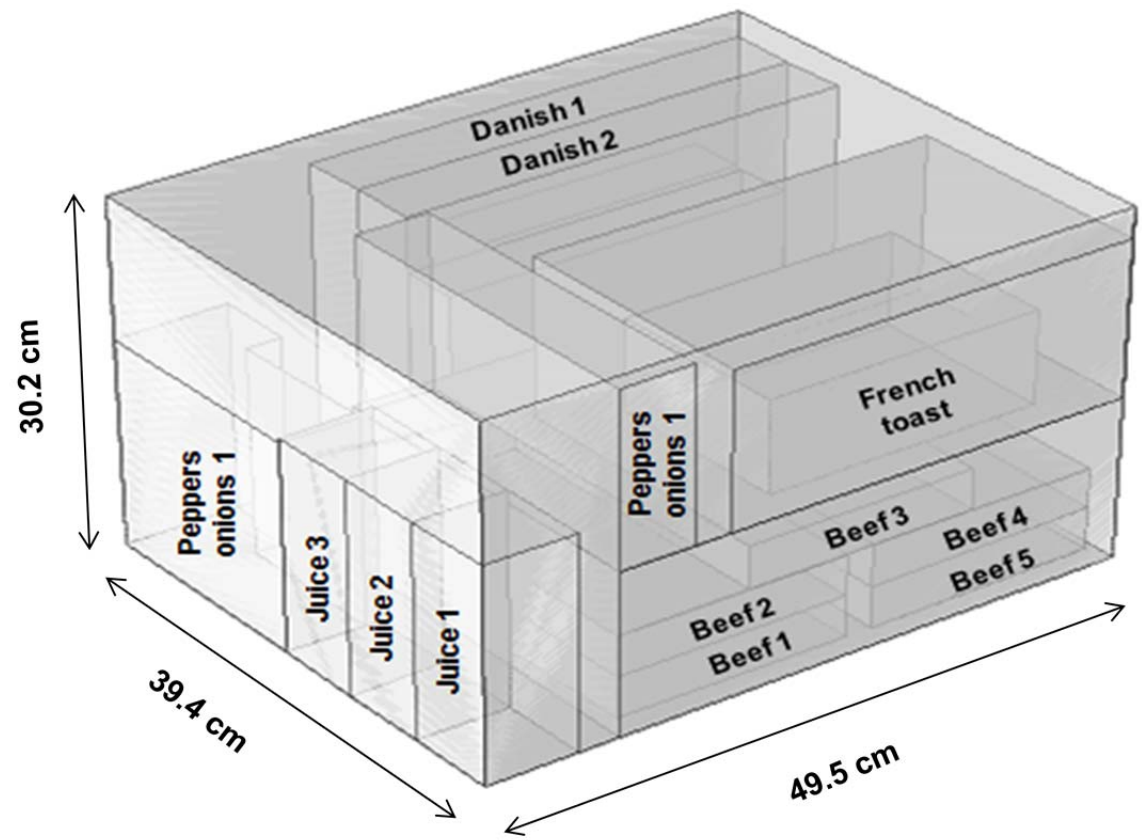


Figure 5: 3D pictorial representation of menu box 3

Governing equations

Heat transfer in the system occurs via two modes; i) conduction in solids; and ii) natural convection in the air. The grashof number of the air in the headspace is in the range of 10^6. Hence, we assumed the flow to be laminar in the mathematical modeling. Therefore, the case is solved in COMSOL by conjugate heat transfer model accounting for laminar flow, in which the heat transfer is described by conservation of heat per unit volume over an infinitesimally small volume lying in the interior of the flow domain[10].

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p u_{trans} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q \tag{10}$$

It has the material property specific heat capacity Cp, density ρ, thermal conductivity k, Q is the heat source. To include the contribution of moving heat source due to natural convection, the second term was included, where u_{trans} is the translational velocity. The material properties obtained from DSC were defined as the input in the model. The headspace of the box was air, and its thermal properties were utilized from the built-in material library in COMSOL®.

For laminar flow due to natural convection, the condition of the wall is similar to the single-phase flow settings. To maintain the continuity of temperature the internal wall separating a fluid domain and solid domain the wall was defined with the equation.

$$u = 0 \tag{11}$$

The natural convective airflow due to temperature difference was incorporated as heat transfer in fluid. The volume force equation used was

$$\rho \frac{\partial u}{\partial t} + \rho(u \cdot \nabla)u = \nabla \cdot \left[-pI + \mu\left(\nabla u + (\nabla u)^{T}\right)\right] + F \tag{12}$$

This is the incompressible flow equation with the volume force term 'F' which incorporates the flow of air in the negative z direction with respect to the density of the air.

Apparent specific heat capacity

Apparent specific heat curve obtained from DSC experiment were used for defining the food property. Three methods were compared for calculating the apparent specific heat.

(i) Cubic spline fit

Matlab 2009b was used to fit a cubic spline fit to the apparent specific heat curve. The curve was considered only for the mushy zone and on the completely thawed and frozen zone respective constant value of specific heat value obtained from the graph was used[1,8,17].

(ii) Heaviside function

Heaviside function is a continuous function with a second derivative without overshoot. The apparent specific heat graph is regenerated as a smoothed heaviside function and defined as the property of each food[5]. Flc2hs function was used in defining the "heaviside function" while specifying apparent specific heat as material property of food items

(iii) Derivative method

According to Saad &Scott, 1996, specific heat was expressed as the component function. Mass fraction of individual component was multiplied with the respective thermal properties. Latent heat was also incorporated in to the formula by a differential term[6]. Following formula was used.

$$Cp_{app}(T) = Cp_i x_i + Cp_w x_{unf}(T) + Cp_{ice} x_{ice}(T) + L_0 \frac{dx_w(T)}{dT} \quad (13)$$

Where Lo is the latent heat of fusion of water at 0 °C and was expressed in J/kg.

Boundary conditions

On the external layer of box, the boundary condition was defined as the following heat transfer equation.

$$-n \cdot (-k\nabla T) = h \cdot (T_{ext} - T) \quad (14)$$

It has the two important terms: i) external temperature T_{ext}, ii) convective heat transfer coefficient h in W/m2K. Heat transfer coefficient was determined based on the results from experimental validation.

Packaging property

Each food item was packed differently. Incorporating all of theirs packaging thickness and their thermal property would increase the number of nodes and result in computational complications. To overcome this challenge thin thermal resistive function was used. For each of the packaging materials, the thermal conductivity and their thickness was defined so that the following equations were solved accounting for the resistance provided by those material for heat flow.

$$-n_d \cdot (-k_d \nabla T_d) = -k_s \frac{(T_u - T_d)}{d_s} \quad (15)$$

$$-n_u \cdot (-k_u \nabla T_u) = -k_s \frac{(T_d - T_u)}{d_s} \quad (16)$$

where u and d refer to the upside and the downside of the slit.

Mesh and Time step

Computational mesh was created using the built-in mesh generating code in COMSOL® Multiphysics. For a typical case, the computational domain was discretized into approximately 20,000 tetrahedral elements. The governing equations mentioned above were solved for these finite elements at appropriate nodes with the time step of 1 sec. Computational time needed for running a simulation case was about 20 hours on a Dell® workstation with Intel® Xeon®E5640 processor and 24 GB RAM.

4.4 Experimental validation

The model developed above was evaluated by the experiments carried out with both model food system and real food system.

4.4.1 Real food system

All the food items were arranged in a cardboard box using actual orientation. Four type 'T' Omega hypodermic needle thermo couple probes were inserted inside the specific point of four items viz., beef steaks, orange juice, peppers and onions and french toast. The whole box was frozen at -18 °C. The frozen box was then stored in the ambient environment of average temperature 24 °C. While thawing, the temperature at the four specific points was recorded using a data acquisition system from National Instruments (LabVIEWTM 7 Express), Austin, TX.

4.4.2 Model food system

Gelatin gel was used as model food system. Gelatin gels were prepared at two different solid concentration of 25% and 30% using the method described in (ref) [3,9,11] and casted in a cylindrical mold. Four type 'T' thermocouples were inserted along the axis of the cylindrical gel. The cylindrical gels were frozen to -18 °C. Both frozen gels were thawed at two different temperature conditions: i) thawing back at ambient temperature, and ii) thawing inside an insulated box. The thawing in insulated box addition was carried out to verify the temperature gradient that had been imposed by natural convection inside the headspace of box. The thawing curves were obtained by recording temperature at mentioned four axial points in figure 6.

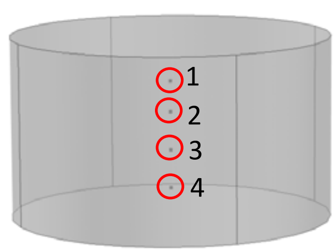


Figure 6: 3D geometry of cylindrical gel with four thermocouple locations (shown by red circles)

4.5 Shelf life studies

The microbial growth and chemical degradation will determine the shelf life of the product. To assess the quality of the product under different conditions, we combined the heat transfer model with predictive kinetic degradation models for quality degradation and microbial growth.

4.5.1 Chemical study

While the literature gave us some information regarding the kinetics for quality degradation, effect of packaging material was mostly overlooked in these studies. Therefore, we studied quality degradation of the three selected items while still packed in their original primary packaging material to confirm or adjust the data that was found in the literature.

Three storage cabinets that cover the temperature range of -20 °C to +20 °C were acquired and installed in the CAFT pilot plant at the Cook Campus. The storage cabinets were set at -18, -12 and -4 °C temperature. The items of concern for quality degradation from each of the menu were procured from Ameriqual and stored in each cabinet. Products, from the same lots, were also sent to the Natick Soldier RD&E Center, as controls for the sensory testing, where they were stored at -20 °C. The time table for the shelf life studies is given in the following Table 3. The products are taken from respective cabinet for chemical degradation and sensory analysis.

Table 3: Time table for shelf life studies

Storage Temp	-18 C:	-12 C	-4 C
Storage Time	3 Month	2 Month	1 Week
	6 Month	4 Month	2 Week
	9 Month	6 Month	4 Week
	12 Month	8 Month	6 Week
	15 Month	15 Month	8 Week

- **Chemical analysis:** Rancidity in food and feedstuff may result from oxidation of the lipid component of the sample, microbiological deterioration of the sample or both. Development of rancidity can be measured using thiobarbituric-acid-reactive (TBAR) substances. TBAR was used for all three items. For quality assessment of shrimp scrampi, in addition to TBAR, total volatile basic nitrogen (TVB-N) was used. These studies were carried out at Rutgers University.

- **Sensory analysis:** Sensory analysis was carried out at the US Army NSRDEC. The duplicates of chemical analysis samples were used for sensory analysis. The samples were deep frozen for a day at -18 °C for a day before being shipped to U.S. Army Natick Soldier RD&E Center (NSRDEC), using dry ice.

The three item of concern for quality degradation in each of these menus are:

- Breakfast menu 3: Steak (uncooked)
- Dinner menu 6: Shrimp scampi w/ bowtie pasta (uncooked)
- Dinner menu 14: Chicken cordon bleu (fully cooked)

4.5.2 Microbial growth

There are several literature sources available to predict microbial growth. The two main ones for food microbiology are: Predictive Microbiology Information Portal (PMIP) and ComBase Initiative. PMIP was developed by USDA based on food microbiology research conducted in the USA, and allows the user to model microbial growth in a number of food products under several conditions. ComBase is a much larger database; it is collaboration between USDA, Food Standard Agency and Institute of Food Research from the UK, and the University of Asmania Food Safety Center. It allows the user to search food microbiology research focused on growth and inactivation models based on food type, microorganism and environmental conditions (temperature, pH, water activity and salt concentration). Currently it contains 40,740 records, a much larger number than PMIP since it's an international collaboration, however it does not offer modeling toolboxes.

Out of three food items, beef was considered to be most susceptible to microbial spoilage, because it was raw/uncooked and can contain a relative high bacterial count on the surface. The most common spoilage microorganism in beef is *Pseudomonas spp*. Com Base predictor data base was used for the model development. The initial microbial load was assumed to be 10^5 (CFU/ml). The critical limit, microbial log increase before the food is spoiled was assumed to 2.5 log (5.10^7 CFU/ml). The microbial log increase was predicted for five different temperatures 0, 5, 10, 15, 20 °C. Using the following two Arrhenius equations the growth kinetics, A and Ea activation energy was evaluated.

$$\log\left(\frac{N}{N_0}\right)=kt \tag{17}$$

$$k = A\,e^{(-E_a/RT)} \tag{18}$$

N_0 and N are the initial and final microbial load in CFU/ml, k is the microbial growth constant, t in time sec, E_a is activation energy expressed in J/mol, A the pre-exponential factor, R has a constant value of 8.314 J/mol/K and T the temperature in degrees K.

The extracted growth kinetic was used to evaluate the microbial growth on the surface volume at the most sensitive corner of the beef steak.

5. Results and Discussions

In this section, we discuss the DSC based analysis of the food products, experimental validations of the modeling techniques developed, thawing characteristics in various storage temperature conditions, shelf life studies in terms of chemical and microbial spoilage kinetics and finally microbial quality prediction by combining time-temperature profiles obtained using simulations with microbial growth kinetics.

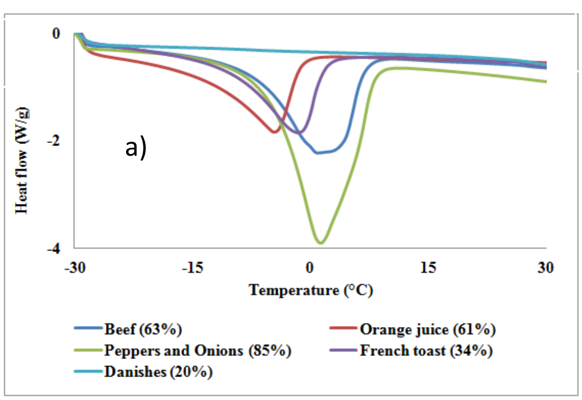
5.1 DSC based analysis

Differential scanning calorimeter (DSC) was used to determine the thermo-physical properties of individual food items. First, heat flow curves were obtained during freezing and thawing modes that were then analyzed to obtain various properties, as described below:

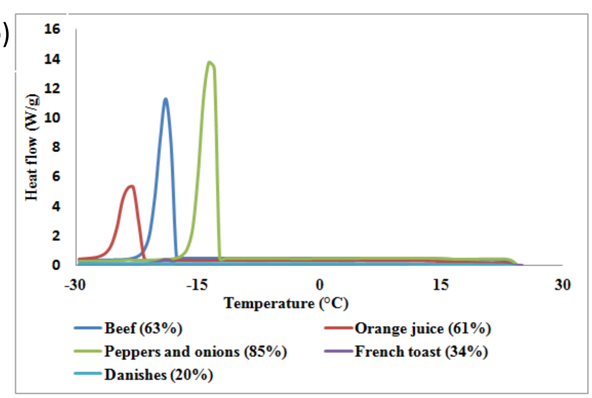
5.1.1 Heat flow curves

Figure 7 shows typical average heat flow curve obtained from DSC during thawing and freezing respectively, for different food items. The values in the parenthesis represent the total moisture content of individual food item. The peak represents energy required during phase change. It can be noticed that the height of the peak is proportional to the total moisture content; higher moisture content requires more energy during the phase change. There was no peak observed for certain food items, namely danishes and cheese cake, which suggested that most of the moisture content is in the form of bound water and it does not undergo any phase change. The thermo physical properties namely initial thawing point, bound water fraction, ice/unfrozen water fraction and apparent specific heat were calculated using these DSC curves as described in materials and methods.

a)



b)



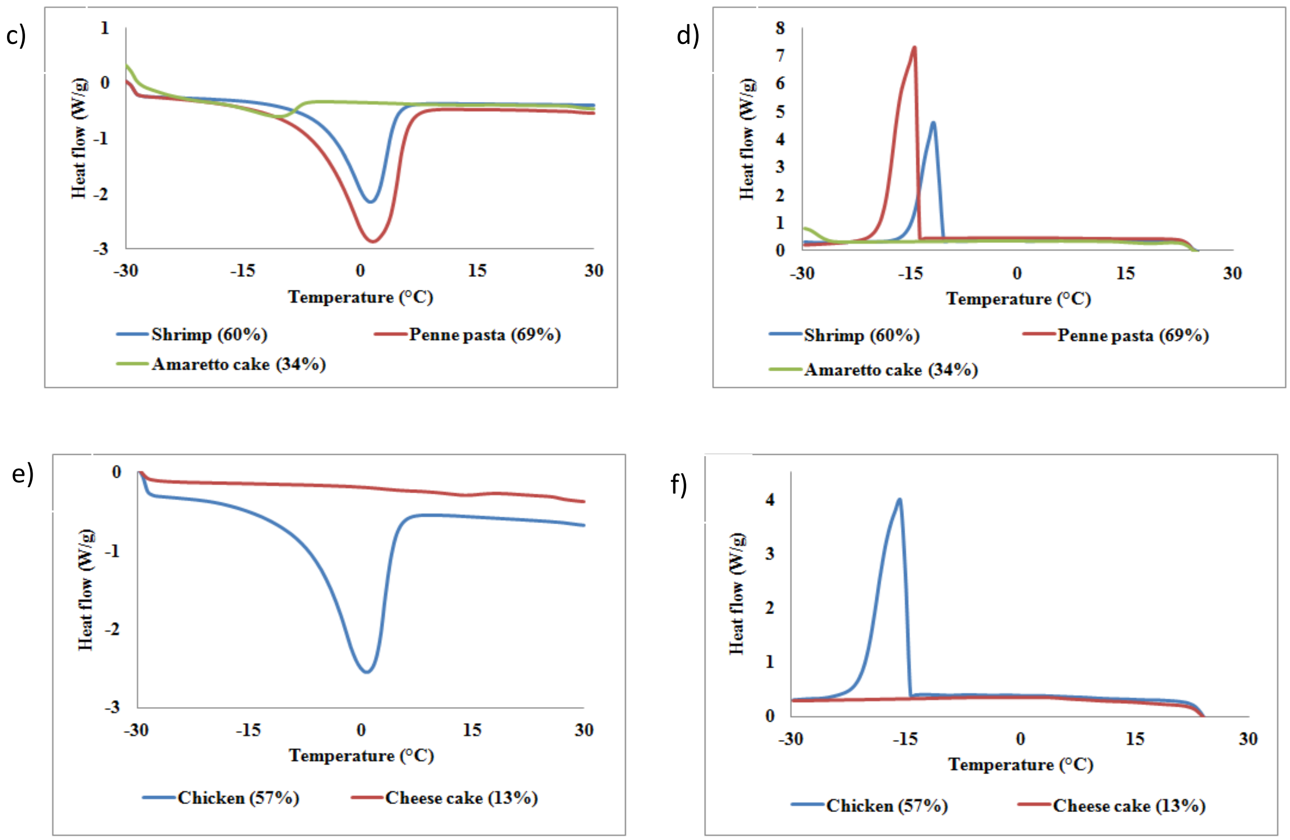


Figure 7: DSC Heat flow curves for different food items: a) menu 3 thawing curve b) menu 3 freezing curve c) menu 6 thawing curve d) menu 6 freezing curve e) menu 14 thawing curve f) menu 14 freezing curve

5.1.2 Freezing curve correction

DSC curves obtained in freezing models indicated that freezing for the food items occurred in the range from -12 to -24 °C. This lower than expected freezing temperature can be attributed to small sampling size during DSC experiment. At such small quantities, the moisture present in the samples gets saturated with dissolved solids which were responsible for the observed super cooling. This deviation was corrected by shifting the freezing curves to its actual freezing temperature obtained experimentally. The experiments with real food samples were carried out in which thawed food items were frozen at -18 °C. The freezing curve was obtained by monitoring temperature using type 'T' thermocouples.

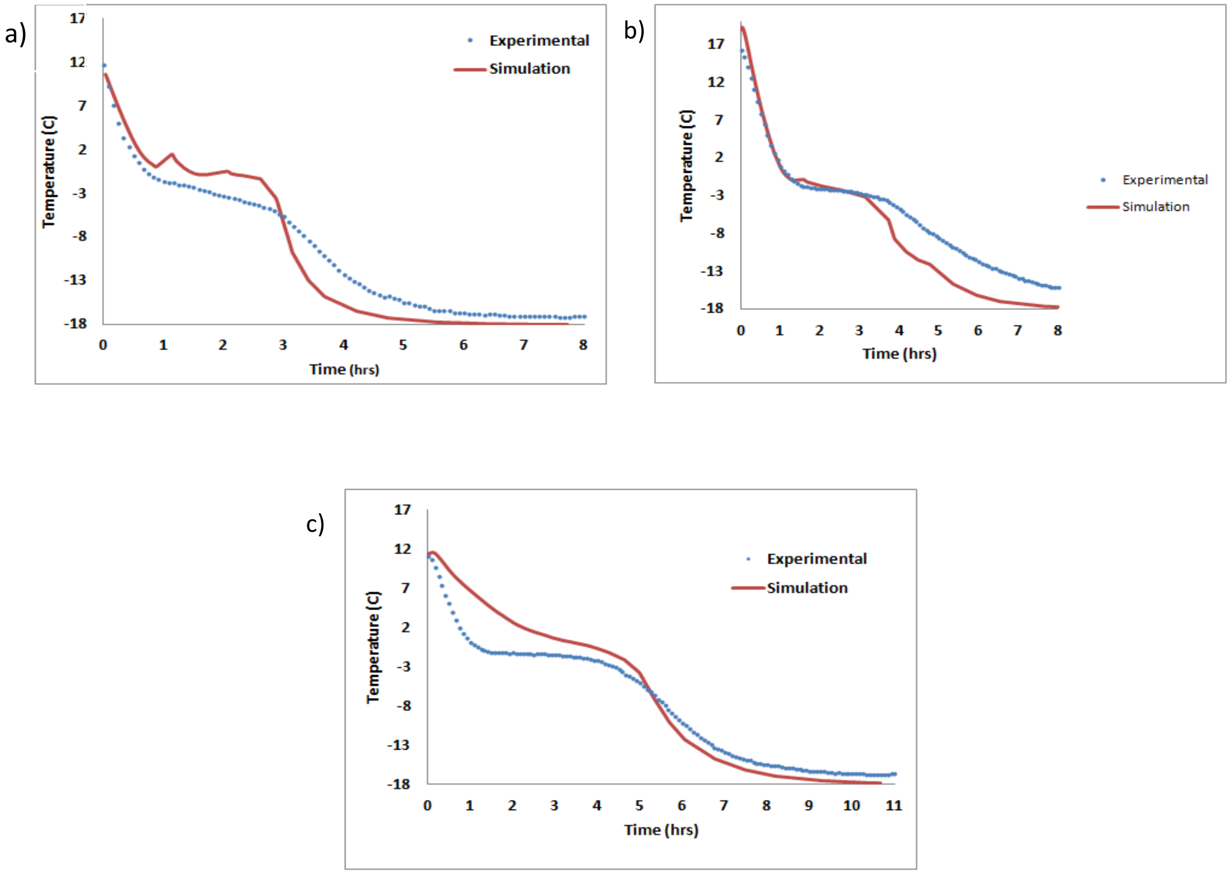


Figure 8: Comparison between experimental and predicted values of time temperature profile for freezing of individual products, dotted line and solid line represents experimental and predicted values, respectively a) beef, b) penne pasta, c) shrimp pasta

The model for freezing process was developed using ASH obtained from modified freezing heat flow curve. The modified freezing heat flow curves were validated by comparing time temperature profile for freezing obtained experimentally and obtained from simulation using modified freezing heat flow curves. The experimental verification was carried for freezing behavior of three products, namely beef, shrimp pasta and penne pasta (shown in Figure 8). The excellent agreement between predicted and experimental freezing temperature profiles confirmed that modifications made in heat flow curve are reasonable.

5.1.3 Apparent specific heat curves

a) b)

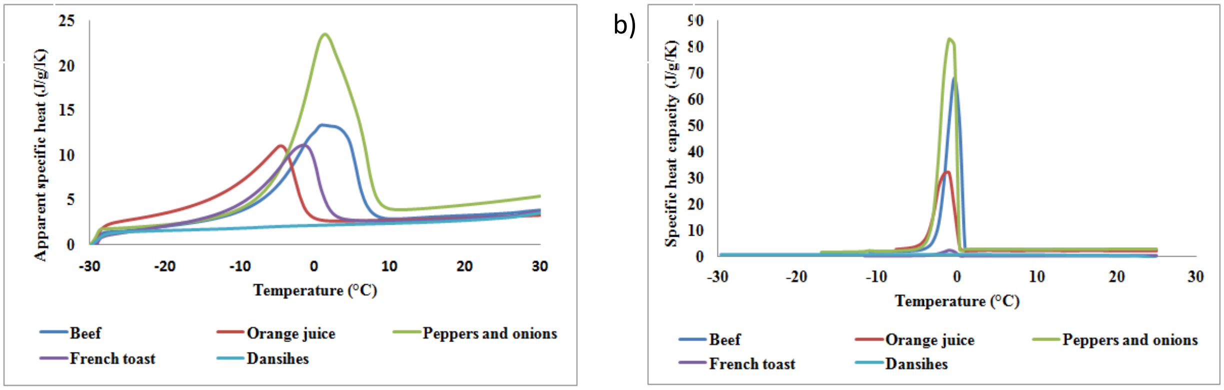


Figure 9: Apparent specific heat curves for menu-3 a) thawing curve b) freezing curve

Apparent specific heat curves were computed from DSC heat flow curves for both thawing and freezing cycle using equation 4. Figure 9 shows apparent specific heat curves for freezing and thawing modes for menu-3. The freezing curves are based on modified heat flow curve. The ASH curves for thawing showed long tailing where as ASH curves for freezing relatively narrow peak width. The peak heights for thawing ASH curves were shorter than that for freezing. This indicates that during thawing, phase change will occur over the wider range of temperature and more gradually. The phase change region in freezing curve will be more flat than in thawing curves.

5.1.4 Bound water content

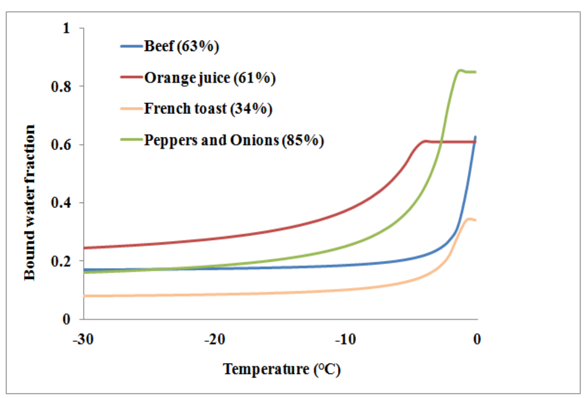


Figure 10: Unfrozen water fraction

Bound water percentage, ice fraction and unfrozen water fraction as a function of temperature were calculated using equation 5, 6 and 7. Figure 10 shows unfrozen water fraction as a function of temperature for different products in menu 3 during thawing. The unfrozen water fraction at -

30 °C is bound water fraction. As temperature increases, the unfrozen water fraction increases and at initial freezing point all the moisture in the product is in unfrozen water.

5.2 Experimental validation

The modeling technique described in materials and methods needed to be experimentally verified before it can be used for simulating desired situations. The experimental verification was carried out by using model and real food system. The purpose of experimental validation was to confirm that modeling techniques, governing equations, boundary conditions and simplifications used in modeling were justified. Apparent specific heat was one of the input parameter in the modeling, which was obtained experimentally from DSC. The mathematical description of ASH as a function of temperature can be obtained by using following three methods (details are described in section 4.3): 1) cubic spline curve; 2) heaviside function; and 3) derivative method. The experimental validation was also used to choose the best method to describe ASH.

5.2.1 Model food system

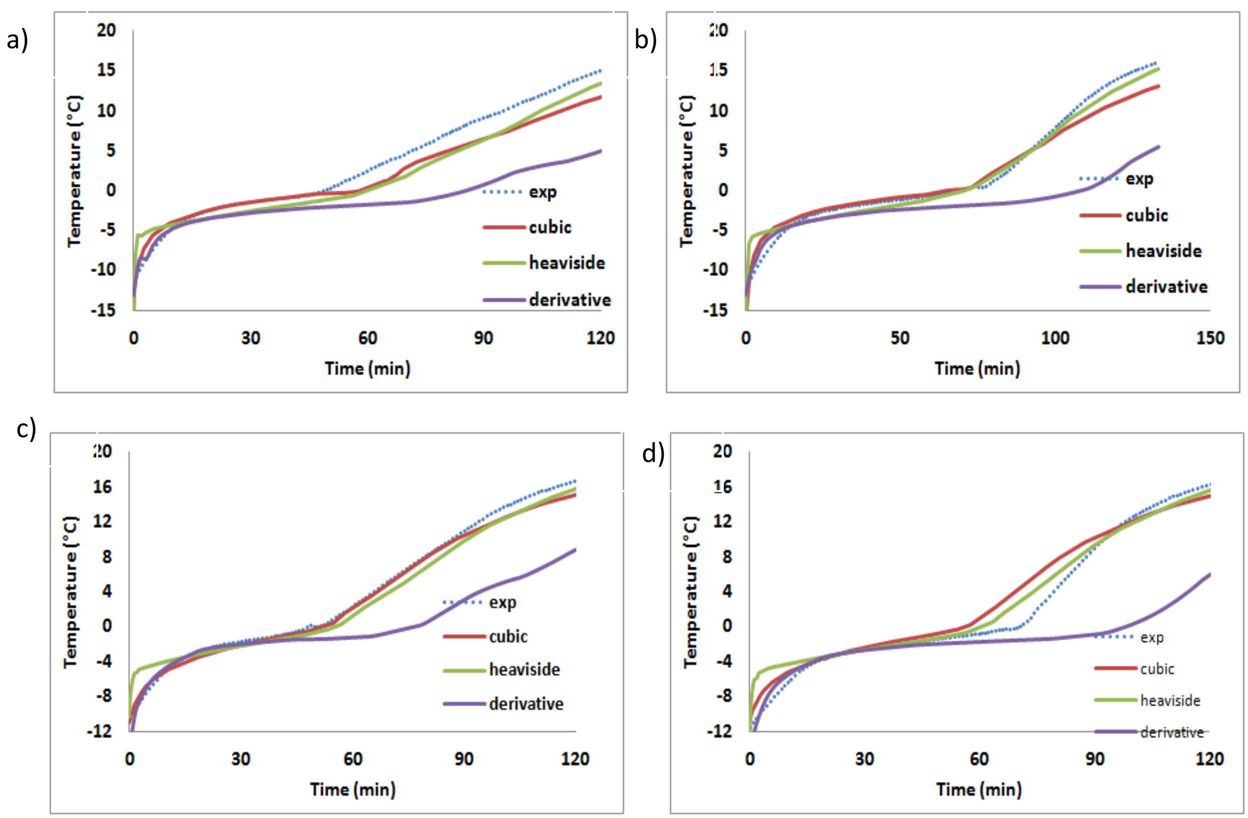


Figure 11: Experimental validation of model food system at a particular location 2 a) 25% gel left in ambient b) 25% gel inside an insulated box c) 30% gel left in ambient d)30% gel inside an insulated box

Four different experiments were carried out with model food system.

➢ 25% gel left in ambient
➢ 25% gel inside an insulated box
➢ 30% gel left in ambient
➢ 30% gel inside an insulated box

Figure 11 shows the comparison between experimental and simulated data at location 2 (Figure 6) for all four experiments. The kink around the 0°C in experimental data (blue dotted line) represents the completion of phase change. It could be inferred from experimental validation that cubic spline fit and heaviside function fits the experimental data better than the derivative method curve. This can be attributed to the fact that derivative method recalculates the curve using latent heat of phase change and specific heat data of components, where as cubic spline method and Heaviside method use actual experimental curve for ASH approximation.

5.2.2 Real food system:

In this section, we report the results of experimental validation with actual menu food items. The experimental verification was carried out for menu-3 which contains 5 different food items and menu-6 which contains three food items. The T-type hypodermic needle thermocouple was used as a temperature sensors and data was collected using Labview software. After placing the thermocouple, the menu box was sealed and kept in -20 °C blast freezer to equilibrate the temperature. The frozen box was then stored at ambient temperature and its temperature was recorded during thawing.

Menu 3: Figure 12 is a pictorial representation which delineates menu-3 box with food item orientation and the data acquisition system with location of thermocouples. Figure 13 shows the comparison between the experimental and numerically predicted temperature profile using three different apparent specific heat capacity incorporation methods for different real foods namely beef steaks, orange juice, peppers and onions and french toast respectively.

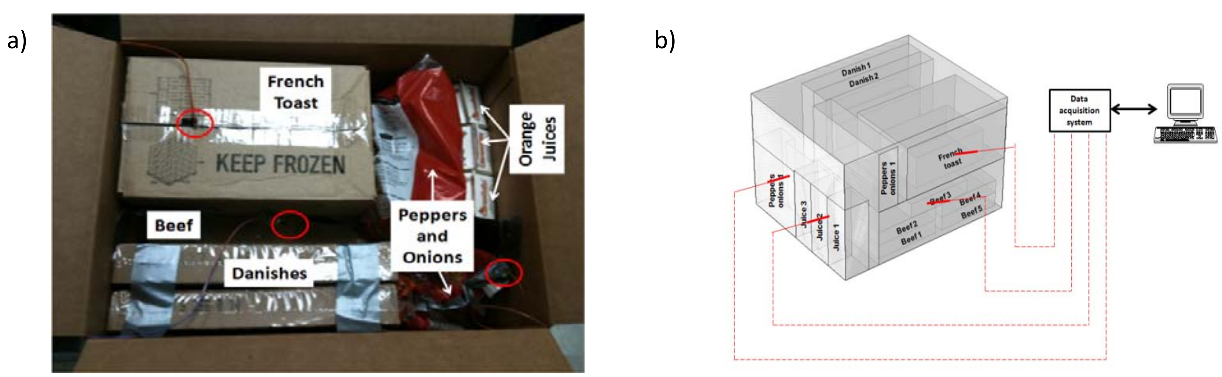


Figure 12: a) Top view of menu-3 box with product distribution and thermocouples location (shown by red circles); b) Schematic representation of data acquisition system for menu-3 box, box is frozen at -18 C and kept in ambient temperature

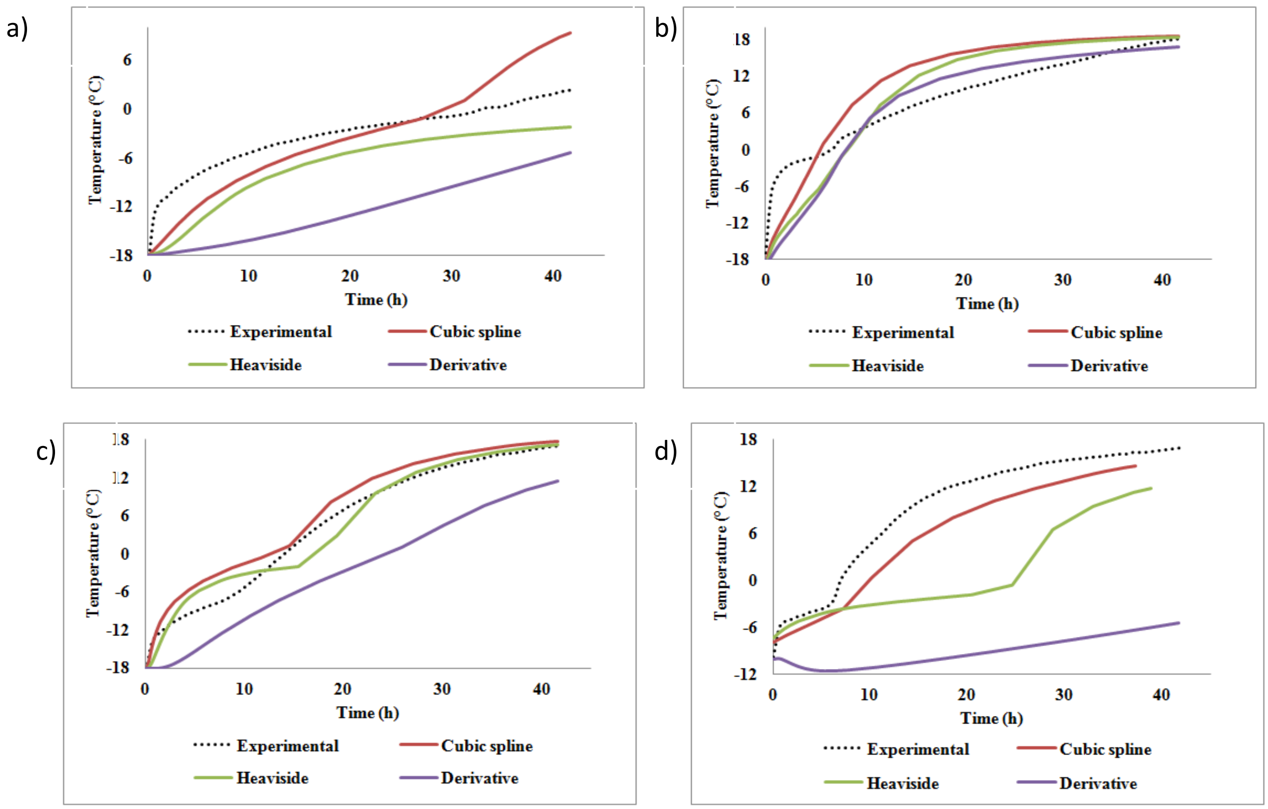


Figure 13: Experimental validation for real food systems (a) Beef steak (b) Orange juice (c) Peppers and Onions and (d) French toast

It can be seen that cubic spline method fits the experimental data better than the other two approximation function. The derivative method showed the greatest deviation from experimental data. As discussed in earlier section, this can be attributed to fact that in this method ASH curves are recalculated, using component data. It was expected that the deviation in the predicted curve will be greater than seen for model food system. This can be attributed to the fact that model food system is homogenous in nature and gelatin is freeze thaw stable whereas real food system is complex and heterogeneous in nature, also the position of thermocouples gets disturbed once the food starts thawing. The observed predictive capacity for real food system is reasonable. The experimental validation was also used to estimate actual the heat transfer coefficient between outer surface box and surroundings (5 $W/m^2/K$ on the base and 20 $W/m^2/K$ on all other sides of the box).

Menu-6: The experimental validation was also performed for menu-6, using the same method as that for menu-3. Figure 14 shows data acquisition system for menu-6. The HTC of 5 $W/m^2/K$ on the base and 20 $W/m^2/K$ on all other sides of the box was found to be optimum. The discontinuities in the experimental curve can be attributed to the movement of temperature probe as thawing proceeds. Figure 15 shows comparison between experimental and predicted data for shrimp pasta, penne pasta and amaretto cake. Cubic spline method was reconfirmed as best suited method for modeling ASH.

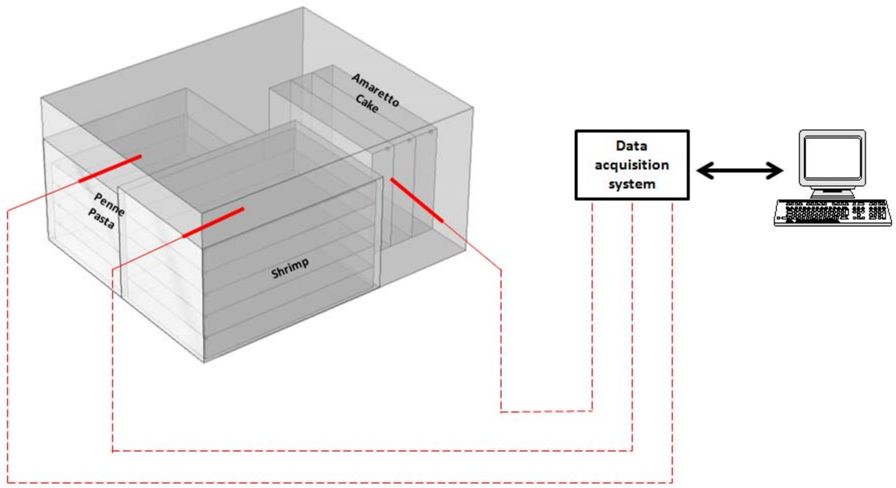
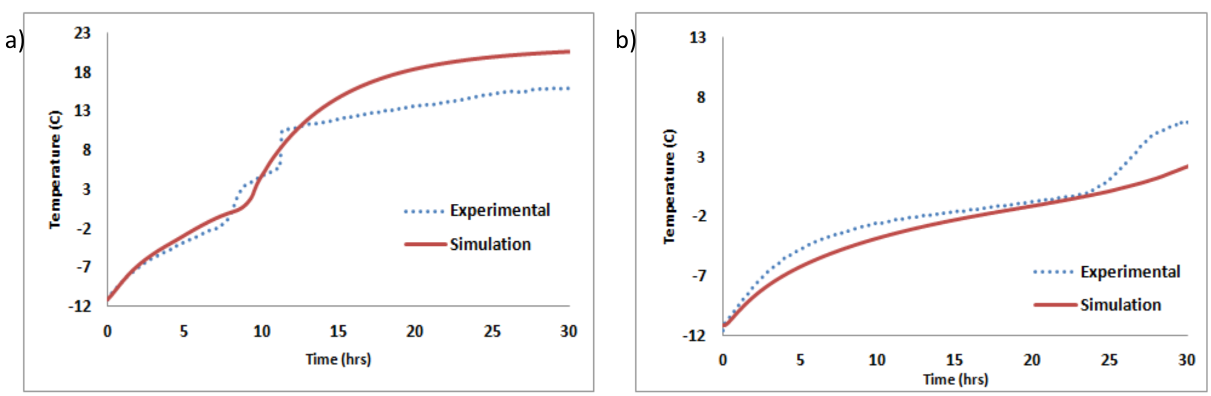


Figure 14: Schematic representation of data acquisition system for menu-6 box with product distribution and thermocouple locations, box is frozen at -18 °C and then stored at ambient temperature



c)

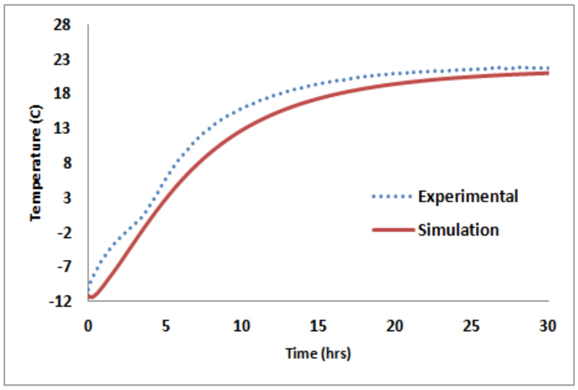


Figure 15: comparison between experimental and predicted values of time temperature profile for menu-6 box thawing, dotted line and solid line represents experimental and predicted values, respectively a) penne pasta, b)shrimp pasta, c) amaretto cake

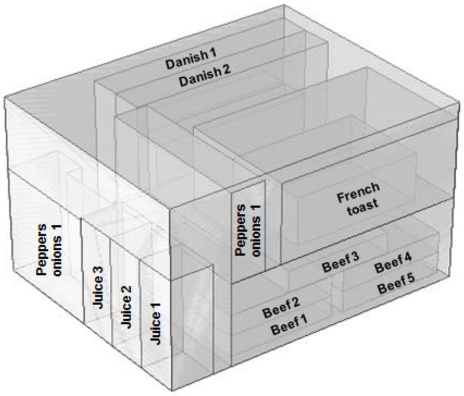
5.3 Thawing characteristics in various scenarios

The experimental data indicated the best performance of the heat transfer model when the cubic spine method is used. In the following sections we used therefore the cubic spine method and modeled the heat transfer rates to determine the temperatures profiles

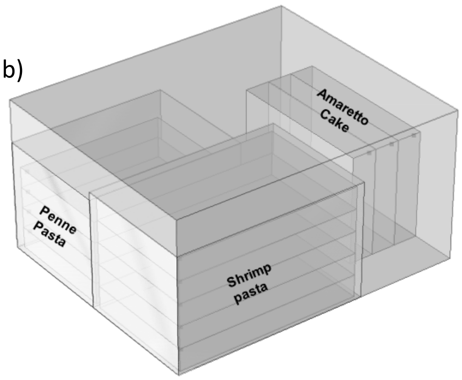
5.3.1 Menu boxes frozen to -18 °C and kept in ambient (25 °C) condition

The effect of no refrigeration (thawing in ambient temperature) was simulated for menu boxes (menu-3, menu-6 and menu-14). Figure 16 shows schematic representation of menu boxes with product distribution. The simulations were carried out for menu boxes at initial temperature of -18 °C and then stored at ambient temperature (25 °C) to thaw.

a)



b)



c)

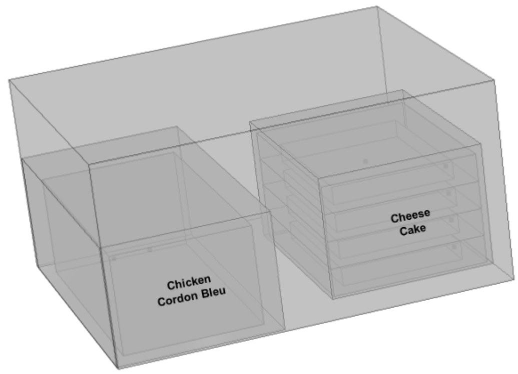


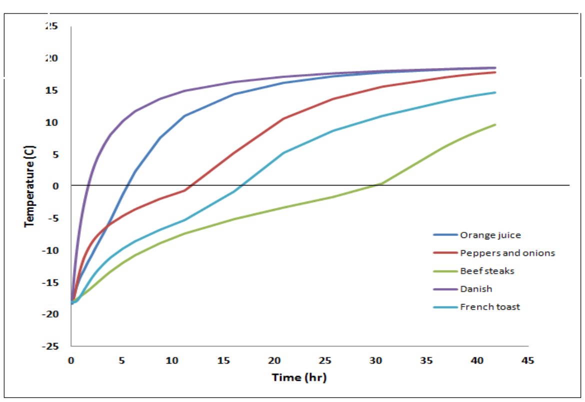
Figure 16: Schematic representations of menu boxes with product distribution a) menu-3, b) menu-6, c) menu-14

Menu-3: Figure 17a shows the thawing characteristics of all the individual items for menu-3 box. Beef steaks took the longest (30 hr) to thaw and orange juice (5 hr) took the shortest time to thaw. In the apparent specific heat curve section we saw that danishes showed no peak that signifies phase change phenomena. All other items showed the peak in apparent specific heat (ASH), signifying latent heat of phase change. In temperature profile curves, the completion of phase change is signified by a kink in temperature curve at freezing point. Since danishes don't have any freezable water, the curve of temperature profile is smooth. This is also an indication that model is capturing the phase change phenomena.

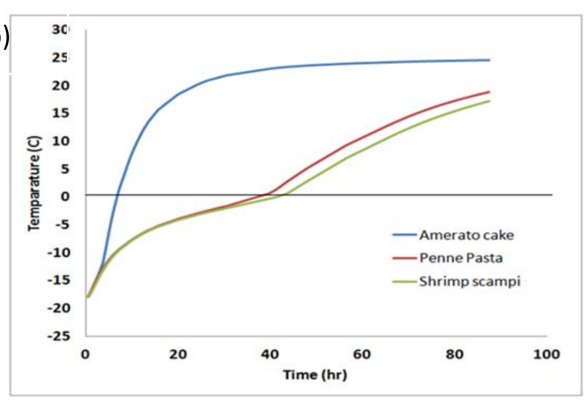
Menu-6: Figure 17b shows the thawing characteristics of all the individual items for menu-6 box. Shrimp pasta took the longest (44 hr) to thaw and penne pasta (40 hr) took relatively short time to thaw.

Menu-14: Figure 17c shows the thawing characteristics of all the individual items for menu-14 box. In the apparent specific heat curve, chicken cordon blue showed latent heat peak and cheese cake showed no thawing peak which signifies phase change phenomena. Thus, only chicken cordon bleu showed phase change phenomena in the form of kink in temperature profile. Since cheese cake doesn't have any freezable water, its temperature profile curve is smooth. The chicken cordon bleu thawed completely in 22 hr. Table 4 gives the time for individual food items in each menu box to reach a state of complete thawing.

a)



b)



c)

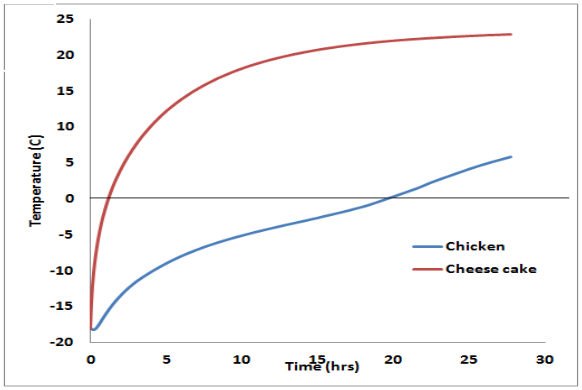


Figure 17: Time temperature prediction for individual products in menu boxes, a) menu-3, b) menu-6, c) menu-14

Table 4: Summarizes thawing time for individual food items in all menu boxes.

Menu-3		
Food Item	**Initial freezing point (C)**	**Thawing time / time taken to reach 0 C (hr)**
Beef	0.8	30
French toast	-1.2	17
Peppers onion	2.1	11
Orange Juice	-5.2	5
Danish	NA	2
Menu-6		
Penne pasta	1.3	40
Shrimp pasta	1.3	44
Amaretto cake	-10	7
Menu-14		
Chicken cordon bleu	0.5	22
Cheese cake	NA	3

5.3.2 Pallets frozen to -18 °C and kept in ambient (25 °C) condition

During storage and transportation, menu boxes are stacked in pallets. Single Pallet of menu-3 consists of 18 boxes and that of menu-6 and menu-14 consists of 12 boxes. In this section, we simulate thawing curves for fully loaded pallets, frozen at -18 °C and kept in ambient air. The symmetry planes were used where ever possible to reduce the computational load and time.

These simulations predict the time required for individual products to thaw completely when a frozen pallet (at -18 °C) is left outside the freezer at ambient temperature (25 °C).

Menu-3: Pallet of menu-3 consists of 18 boxes, arranged in 3×2×3. For simulation, we have used center symmetry. Figure 18 shows schematic of pallet with symmetry plane with connotations used for individual boxes in pallet. In previous case, we examined thawing characteristics for single menu boxes in no refrigeration (stored in ambient air) conditions. Table 5 gives thawing time for individual food items in each box when stacked on a pallet. It can be seen that products in the bottom layer take relatively longer time to thaw than their counter parts in upper tier. The thawing times were longer than that for single menu box. Beef took 30 hr to thaw completely in single box, but when stored in a pallet configuration, beef took a minimum of 50 hrs to thaw completely. Orange juice and peppers and onions thawed again relatively faster in 8 – 12 hr and in 18 – 22 hr, respectively. The French toast thaws in 65 – 80 hr.

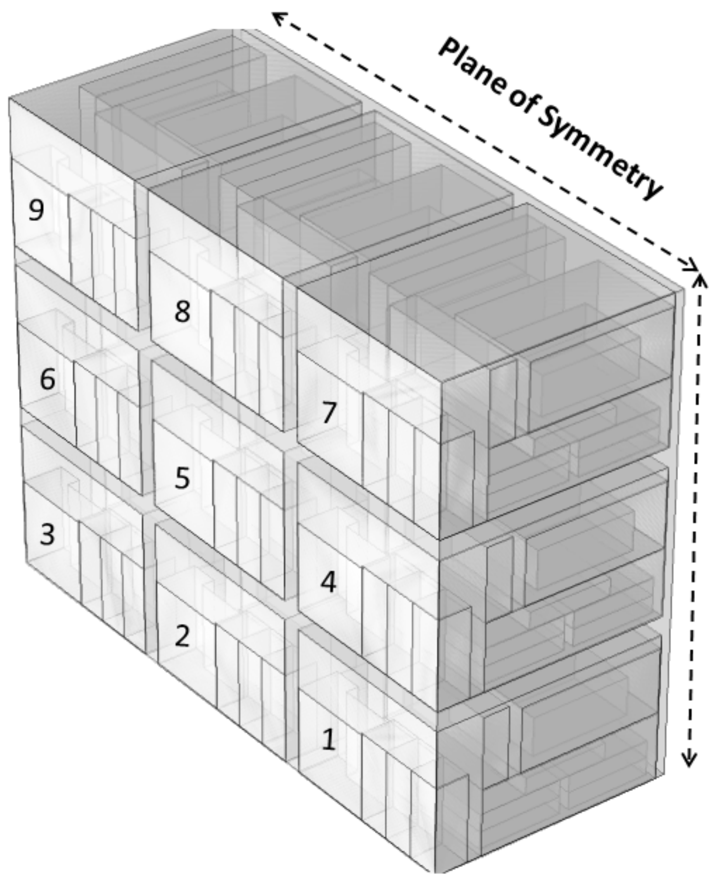


Figure 18: Schematic of menu-3 pallet with symmetry plane with connotations used for individual boxes in pallet

Table 5: Thawing time for individual food items in each box in menu-3 pellet

	Thawing time (hr)			
Menu-3 boxes	**Beef**	**Orange Juice**	**Peppers onions**	**French toast**
1	112	11	22	68
2	118	10	22	82
3	116	10	18	81
4	50	9	21	64
5	54	9	21	77
6	53	10	18	76
7	50	9	20	59
8	53	9	21	72
9	53	10	18	71

Menu 6: Pallet of menu-6 consists of 12 boxes, arranged in 2×2×3. For simulation, we used two planes of symmetry. Figure 19 shows schematic of pallet with two perpendicular symmetry planes with connotations used for individual boxes in pallet. We examined thawing characteristics for single menu-6 box if left at ambient temperature conditions. Table 6 gives thawing time for individual food items in each box in pallet. If stored on a pallet, shrimp and penne pasta will take 100 - 140 hr to completely thaw, as compared to ~ 40 hr in single box. Amaretto cake reached 0 C in 10 hr.

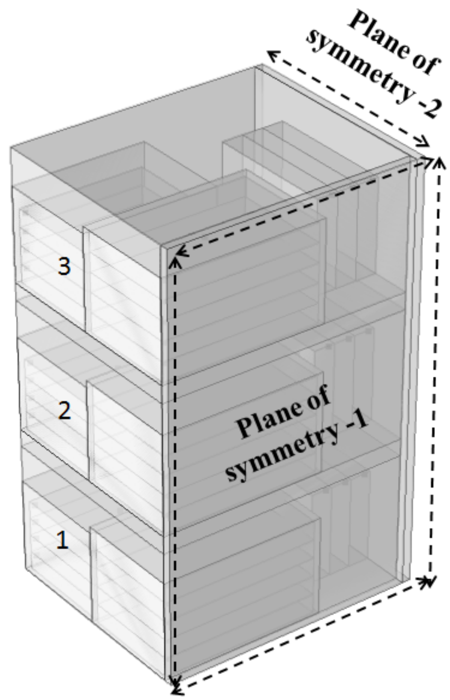


Figure 19: Schematic of pallet of menu-6 with two perpendicular symmetry planes with connotations used for individual boxes in pallet

Table 6: Thawing time for individual food items in each box in menu-6 pallet

Menu-14 boxes	**Thawing time (hr)**		
	Shrimp	**Penne Pasta**	**Amaretto cake**
1	124	136	11
2	105	114	10
3	100	109	9

Menu-14: Pallet of menu-14 consists of 12 boxes, arranged in 2×2×3 Figure 20 shows schematic of pallet with two perpendicular symmetry planes with connotations used for individual boxes in pallet. In previous case, we examined thawing characteristics for single menu boxes in no refrigeration (stored in ambient air) conditions. Table 7 gives thawing time for individual food items when the boxes are stacked on a pallet and stored at ambient temperature conditions. On a pallet, chicken in different boxes thaws at 55-70 hr, as compared to 22 hr in single box. Figure 21 shows the time-temperature profile for chicken cordon bleu and cheese cake.

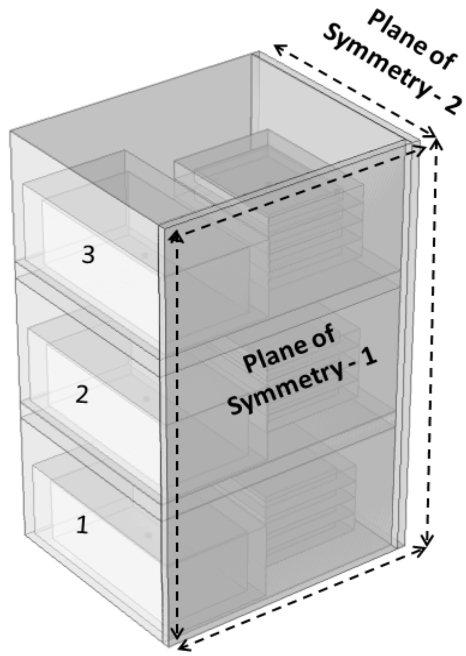


Figure 20: Schematic of pallet of menu-14 with two perpendicular symmetry planes with connotations used for individual boxes in pallet

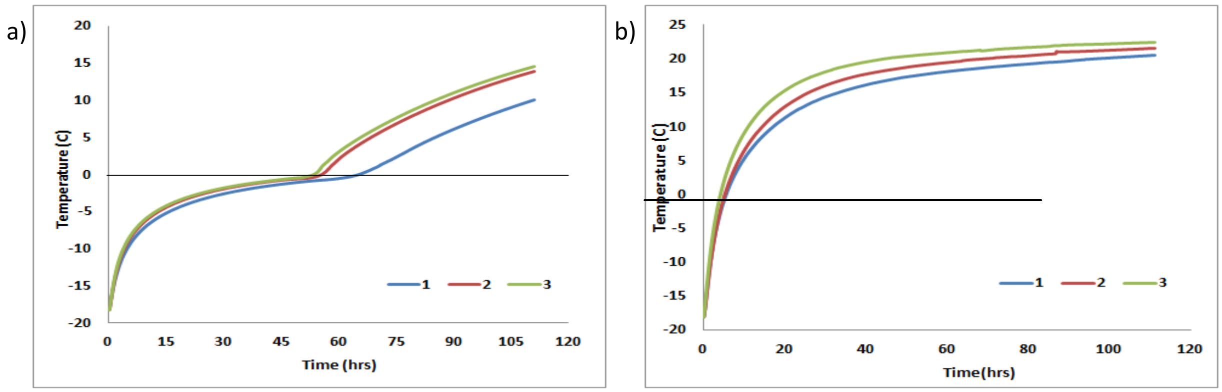


Figure 21: Time-temperature profile in menu-14 pallet, a) chicken cordon bleu, b) cheese cake

Table 7: Thawing time for individual food items in each box in menu-14 pallet

	Thawing time (hr)	
Menu-14 boxes	**Chicken**	**Cheese cake**
1	68	6
2	57	5
3	55	4

5.3.3 Real time temperature fluctuation observed in field: The real time data of environmental temperature fluctuation documented during refrigeration failure was obtained from the field, as shown in Table 8. The temperature of the menu box was -18 °C at time when boxes were loaded in trailer. The initial temperature of the trailer was – 5 °C. During the next 96 hours, the temperature of the trailer increased gradually to 7 °C and then stabilized at this temperature for the next 80 hrs. The product was then transferred to an alternate trailer and the temperature of the trailer was brought back to -17 °C in a 12 hr period and kept at that temperature for next 56 hrs. The simulations were carried out for all three menu boxes if exposed to these real time fluctuations. These simulations demonstrated effect of freeze thaw cycles on time-temperature distribution of products. Our model has ability to switch between freezing and thawing conditions based on environmental temperature fluctuations. If the individual product temperature is increasing ($dT/dt > 0$), model is switched to thawing parameters else freezing parameters.

Table 8: Environmental real time temperature fluctuation data

Time [hr]	Temperature [C]
0	-5
96	+7
176	+7
188	-17
244	-17

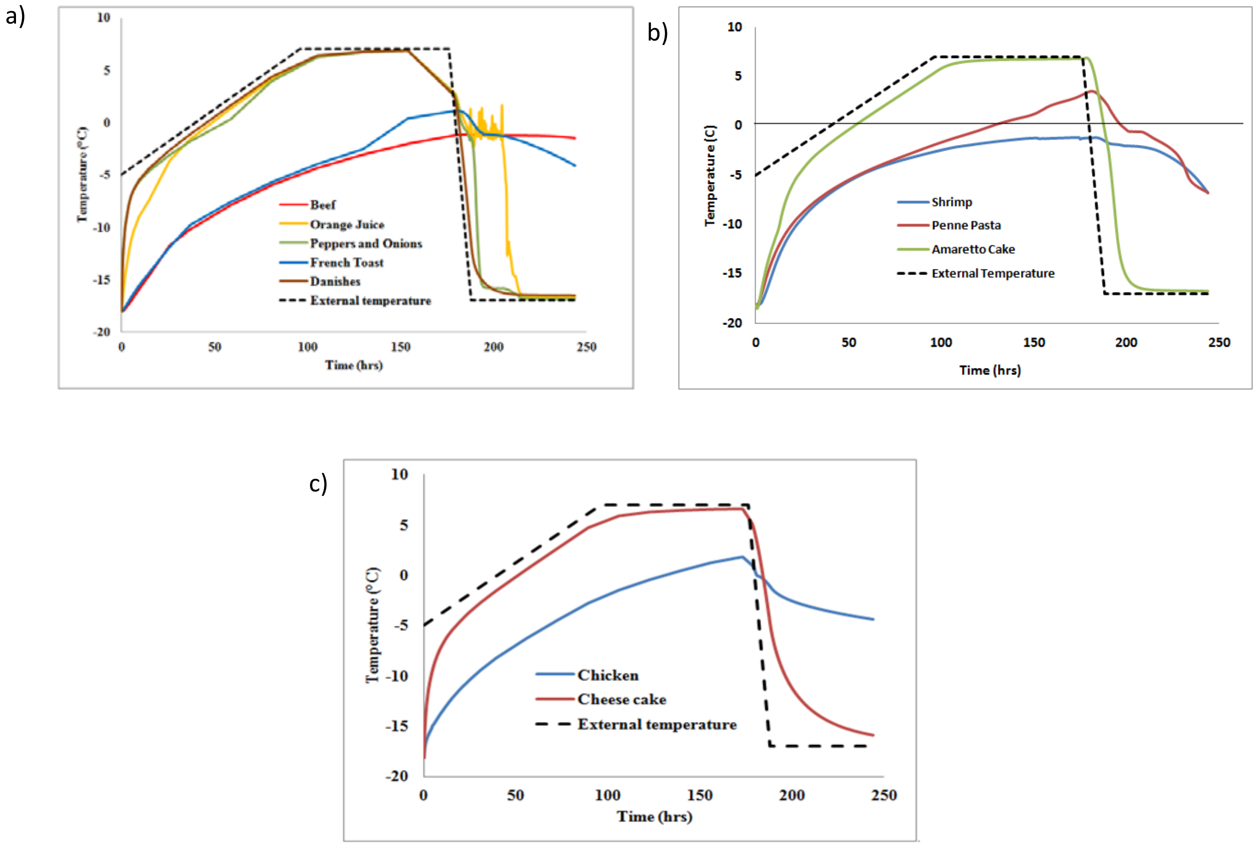


Figure 22: Time temperature data at sensitive points of each food item for real time temperature fluctuation in a) menu-3; b) menu-6 and c) menu-14

Menu 3: Figure 22a shows the time temperature data at center points of each food item. The initial temperature of the product was -18 C and the changes in the environmental temperature is shown by black dotted line. It can be seen in the Figure 22a that danishes, orange juice, peppers and onions thawed quickly at around 50 hr. These products also showed very high freezing rate and froze at around 5 hr, once freezer started at 176 hr. French toast thawed around in 150 hr. The maximum temperature reached by the french toast is 2 °C and thus it also has very short freezing back time (~ 8 hr). The beef showed slowest thawing rate and it never completely thawed out.

Menu 6: Figure 22b shows time-temperature distribution for menu-6 items. It can be seen that model could incorporate freeze thaw sequence successfully. Amaretto cake thawed first and reached up to 5 °C and dropped to -15 °C when box was moved again -17 °C refrigerator. Penne pasta thawed completely at 130 hr. The shrimp pasta was not thawed fully. The geometric center of this product reached -3 °C. The temperature of both products started dropping when external temperature was dropped.

Menu 14: Figure 22c shows results for menu 14. Cheese cake thawed first at 50 hr. Chicken thawed more slowly, around 125 hr, and froze back just after cheese cake.

5.4 Shelf life study

In section 5.3, thawing behavior of food items in different menu boxes at various temperature scenarios were discussed. In this section, we briefly discuss various chemical and microbial quality parameters and their degradation kinetics. Based on rate of degradation, the quality parameter for shelf life prediction will be selected.

5.4.1 Chemical quality analysis

Development of rancidity is studied using thiobarbituric-acid-reactive (TBAR) substances. Rancidity in food and feedstuff may result from oxidation of the lipid component of the sample and/or microbiological deterioration of the sample. TBAR was used for all three food items. For quality assessment of shrimp scrampi, in addition to TBAR, total volatile basic nitrogen (TVB-N) was used.

Table 9 shows results TBAR and TVBN for – 4 C till 12 weeks for shrimp scampi, chicken cordon blue and beef steaks. At 12 week, there were no significant changes in the TBAR and TVBN values observed and thus no specific trend in chemical degradation could be determined. The literature reports threshold for TBAR and TVBN are 0.2 (absorbance at 540 nm) and 25 (mg N/kg of dry matter). Our TBAR values are order of magnitude lower than threshold values, whereas TVBN values were closer but below their threshold value.

Also, during the same time period, samples were submitted to NSRDEC for sensory analysis. Also, no significant degradation in quality was observed from a sensory point of view, under scoring that the quality in the selected items are a lot less sensitive to the temperature abuse than originally assumed.

It should be noted at this time that, based on the DSC data, a food item defrosts at a higher temperature than that it freezes. With other words, a food product can be in either state (frozen or defrosted) in a certain temperature range depending of its previous state. Chemical reactions could therefore be higher if the product was allowed to defrost and then refrozen.

Table 9: Chemical degradation values at -4 °C

Wk.	TBARS (Absorbance) Threshold Abs 0.2 at 540nm			TVBNs (mg TVBN/ 100g sample) Threshold value is 25mg/ 100g food			Sensory
	Shrimp scampi	Chicken Cordon bleu	Beef steak	Shrimp scampi			
1	0.0016	0.0053	0.012	20	-	-	NS
2	0.002	0	0.0086	18.3	-	-	NS
4	0.0018	-	0.011	18.8	-	-	NS
6	0.0023	0	0.0066	20	-	-	NS
12	0.002	0.001	0.001	18.3	-	-	NS

*NS – no significant change as compared to control

TVBN kinetics: The results of shelf life study had failed to capture in significant increase in levels of TBAR and TVBN in the products under consideration. It is assumed that use of high barrier packaging materials and/or use of preservatives influenced these chemical reactions. As packaging material and preservatives are not required per specification, products could be used in the UGR-A without these additional hurdles, it was decided to use the chemical kinetics data for TBAR and TVBN from reported literature for similar products that did not have these additional hurdles. The appropriate kinetic equations were then plugged into COMSOL® based heat transfer model to predict chemical degradation.

Figure 23a shows the reconstructed data for TVBN in shrimp[18]. The data was modeled using first-order kinetics. The temperature dependence of kinetic rate constant was modeled using Arrhenius model. The kinetic equation is described as follows in equation 19.

$$c = c_0 . \exp\left(-k_0 . \exp\left[-\frac{E_a}{RT} \right] . t \right) \tag{19}$$

E_a - Arrhenius activation energy (J/mol)

k_0 - kinetic rate constant (s^{-1})

c, c_0 - final and initial value of TVBN (mg N/ 100 g)

The dotted line Figure 23a shows acceptable limit of TVBN (25 mg N/ 100 g). Figure 23b shows time required for shrimp to reach that limit when stored at various temperatures.

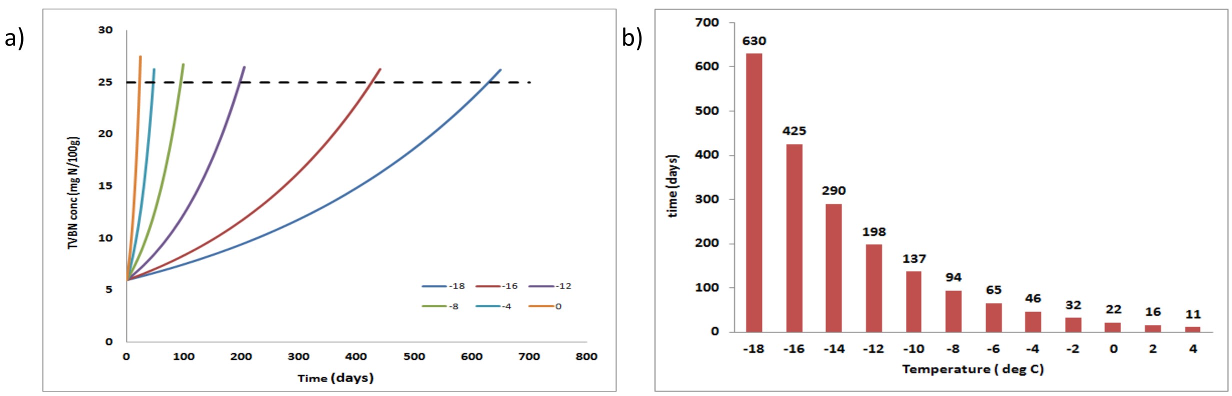


Figure 23 a) Reconstructed data for TVBN in shrimp obtained from Tsironi, *et al*., 2009, (LWT – Food Science and Technology, 42, 664-671), b) Time required for shrimp to reach that limit when stored at various temperatures.

Based on the literature, TVBN spoilage will not occur within a year if the product is stored at -16 C or below. If the product is stored at +4 C TVBN spoilage will occur in 11 days. However as we will see in the next section when products are thawed, the rate of microbial spoilage is much greater than TVBN kinetics or TBARs kinetics. This suggests that products are chemically stable in frozen condition and during thawed condition microbial spoilage rate is much higher than chemical degradation rate. Thus, it was decided to consider only microbial growth as the parameter for quality analysis.

5.4.2 Microbial growth kinetics

Microbial growth of various pathogens such as *Listeria, Salmonella etc.*, and spoilage bacteria such as *Pseudomonas spp* were evaluated. It was noticed that microbial growth is very unlikely to occur in frozen solid foods, so defrosted product is of concern. The spoilage bacteria *Pseudomonas spp* is considered as more predominant, and so it was chosen as model microorganism for defining microbial safety of the products. The initial level was assumed to be as high as 10^5 log CFU/gm, and at 2.5 log increase (5.10^5 CFU/gm), the product is considered as spoiled. It should be noted that the military specification do not specify a maximum TPC (Total Plate Count). The growth data for *Pseudomonas spp* at different temperature was obtained using the predictive database COMBASE. The results are shown in figure 24a.

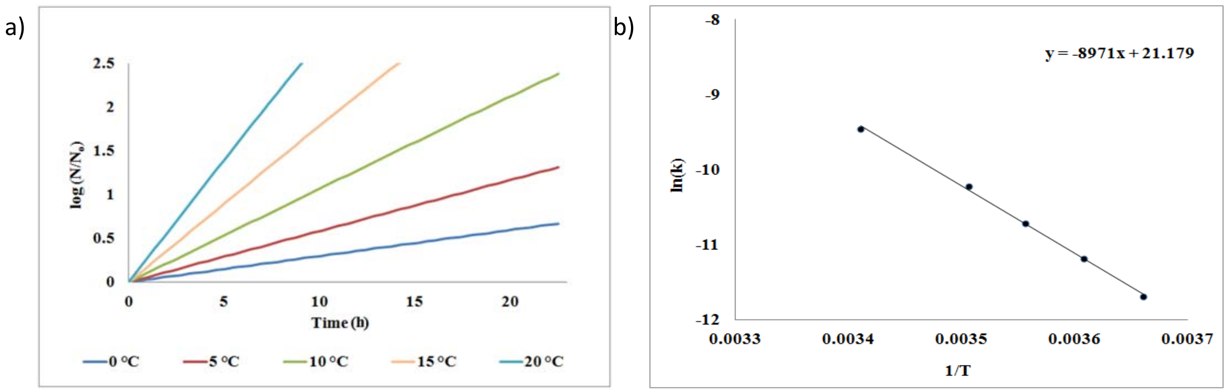


Figure 24: a) microbial log increase of *Pseudomonas spp* for different temperature condition obtained using the modeling database COMBASE, b) Arrhenius plot

By fitting the microbial growth model as shown in equation 18, the microbial growth rate 'k' is obtained for each temperature. The value of 'k' increased with increase in temperature. Dependence of growth constant on temperature was modeled using Arrhenius equation (equation 19). The Arrhenius constant (A) and activation energy (E_a) for this specific microorganism were obtained using Arrhenius plot as shown in the Fig 24b. Their values are A = 1.403E+09 s^{-1} and E_a = 7.423E+04 J/mol.

5.5 Microbial quality prediction

In this section, the time temperature data obtained from simulation was combined with microbial growth kinetics to predict the microbial quality of food. Beef was chosen as the most susceptible food for microbial spoilage, out of all the food products in menu boxes. The dependence of microbial quality of beef with respect to surrounding temperature was predicted. This data can be used in design of an appropriate time temperature integrator (TTI).

Simulation was used to determine the location were microbial growth in beef would be the highest. The highlighted region in the figure 25a represents the most sensitive portion. During exposure to higher external temperature, this region thawed first and remained at a higher temperature than the other regions. Also, we know that microbial growth is predominant on the surface, so a small volume at the sensitive corner, as shown in figure 25b was chosen to evaluate microbial growth. The volume average integration (equation 20) with respect to time was used to evaluate average microbial growth in the selected portion. Growth kinetics constants were used in this equation. Microbial growth was evaluated for two different case studies.

$$\log\left(\frac{N}{N_0}\right)=\frac{1}{V}\iint k\,dv\,dt=\frac{1}{V}\iint\left(Ae^{(-E_a/RT)}\right)dv\,dt \qquad (20)$$

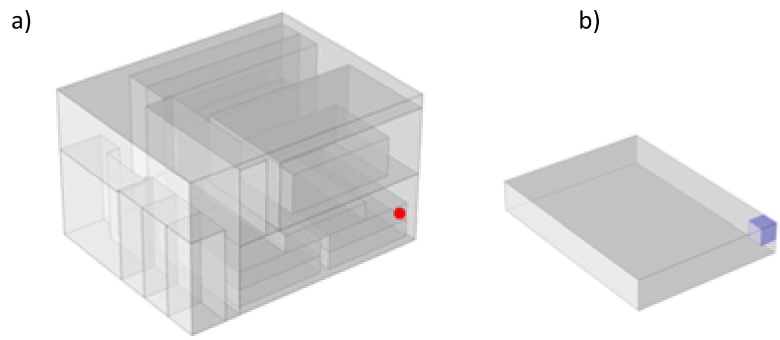


Figure 25 a) Temperature sensitive point of beef b) corner portion in single beef block

Case 1: Menu box-3 frozen to -18 °C and kept in varying ambient temperature (20 - 35 °C) condition

Microbial growth was evaluated for a menu box, frozen at -18 °C that was then exposed to different ambient temperatures (20, 25, 30, 35 °C). After certain time of exposure, the box was put back in freezer of -18 °C. This scenario would simulate a condition in which product was transferred from one freezer to another during which it would be exposed to ambient temperature conditions. Both freezing and thawing curves were simulated depending upon the direction in which temperature of the product is changing. The red curve showed in Fig 26 represents typical time temperature profile for the most temperature sensitive region of beef. Black dotted line represents the external temperature. It can be seen that the temperature of frozen food (beef), which was initially at -18 °C rises slowly, till the boxes were moved back to freezer. Even after the products were put back in freezer, it will take some time (freezing time, T_f) to freeze back below 0 °C.

These time temperature curves and growth kinetics were used to predict the maximum allowable time of exposure of the product to higher temperature before they became microbially unsafe. Firstly, the time required for 2.5 log increase was calculated (spoilage time, T_s) for chosen volume. In the freeze thaw curve, the total time required to freeze, the product back to 0 °C should be subtracted from the spoilage time. Thus, the maximum allowable exposure time (T_m)

i.e. time before which frozen products should be moved back in freezer to avoid microbial spoilage, is given by the formula $T_m = T_s - T_f$ (Fig 26).

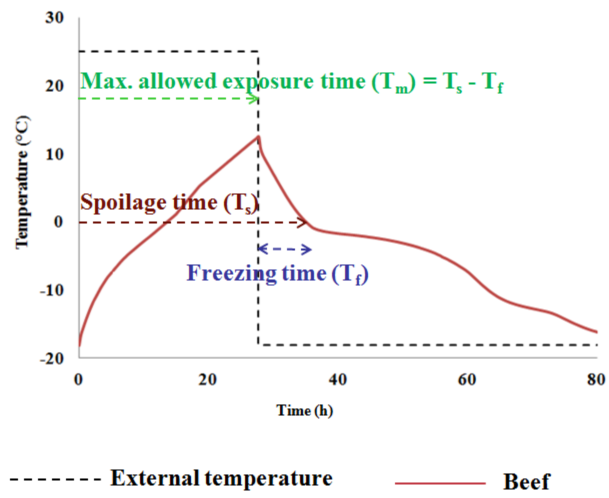


Figure 26: Time-temperature profile of temperature sensitive point of beef

Menu 3 box which has beef, orange juice, peppers and onions, french toast and danishes were subjected to different external temperature conditions and their initial thawing point is evaluated. Figure 27 shows the initial thawing time for each product, when menu-3 box was exposed to different external temperature. It was observed that as external temperature increased, the initial thawing point of products decreased. Danishes, orange juice, peppers and onions showed less dependence on external temperature. Initial thawing point of beef and french toast showed greater dependence on external temperature.

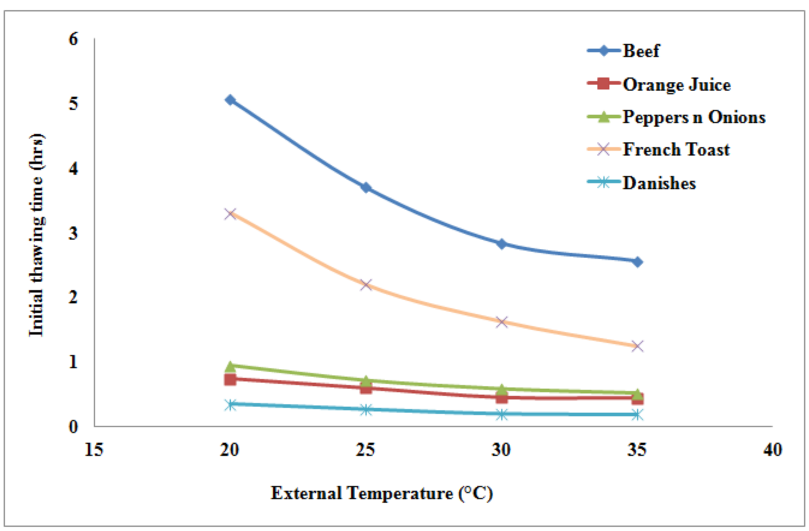


Figure 27: The initial thawing time for each product, when menu-3 box was exposed to different external temperature

The freezing time for the most temperature sensitive point of beef (Figure 28b) was evaluated for different exposure time. The freezing time is the time taken by the product to reach its initial freezing point (around 0 °C) from the maximum temperature reached. The temperature of the product will depend upon the time for which it was exposed to higher external temperature. Higher the exposure time, greater the temperature of the product and longer the freezing time. Figure 28a explains the relation between the maximum temperature reached by the product and the time it takes to freeze the product back below its initial freezing point.

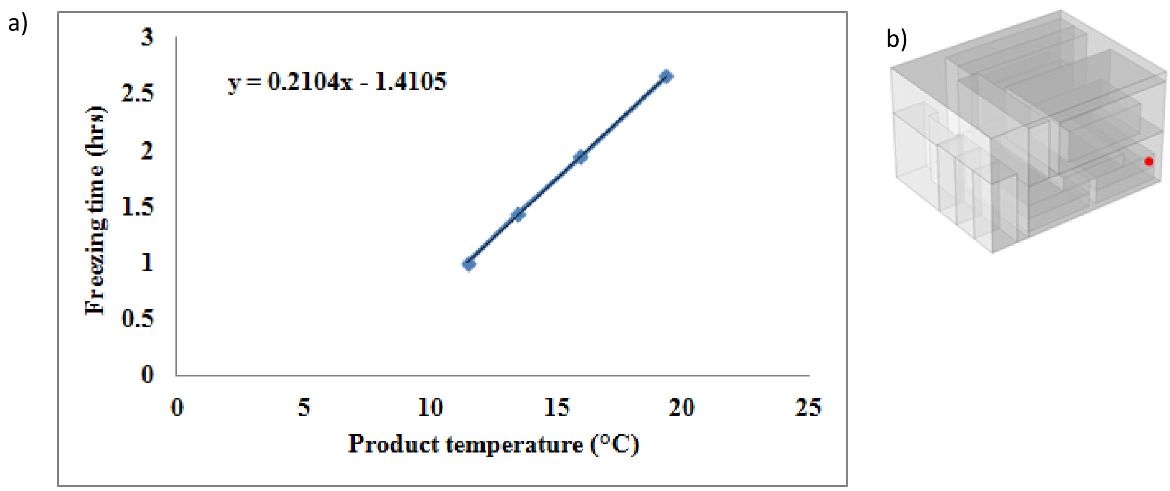


Figure 28: a) relation between the freezing time and maximum temperature reached by the product, b) most temperature sensitive point of beef

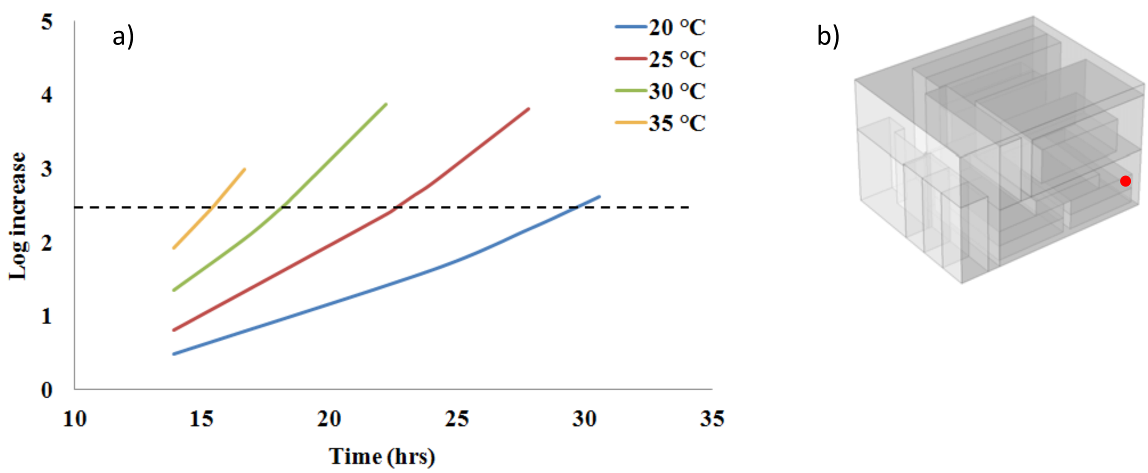


Figure 29: a) Microbial growth profile in the highlighted region of beef (Fig 9b), when exposed to different high external temperature, b) temperature sensitive point in beef

This Figure 29a shows microbial growth profile in the highlighted region of beef (figure 29b), when exposed to different high external temperature. For each temperature, the time at which the microbial log increase reaches 2.5 can be considered as the spoilage time (T_s). Table 10 shows the spoilage time for each external temperature. The freezing time (T_f) calculated for each external temperature are shown in the Table 10. The maximum time for which the product is allowed to stay out of freezer (T_m) is calculated by subtracting freezing time from spoilage time (T_m=T_s-T_f). Figure 30 shows the relation between external temperature and maximum allowed exposure time. The region below the curve is considered as microbially safe zone and the region above can be considered as microbially unsafe.

Table 10: Analysis of the frozen menu-3 exposed to different ambient temperatures

External temperature (°C)	Spoilage time (h) T_s	Freezing time (h) T_f	Maximum allowed time (h) T_m=T_s-T_f
20	29.8	1.5	~28
25	22.7	2.4	~20
30	18.2	2.9	~15
35	15.5	3.5	~11

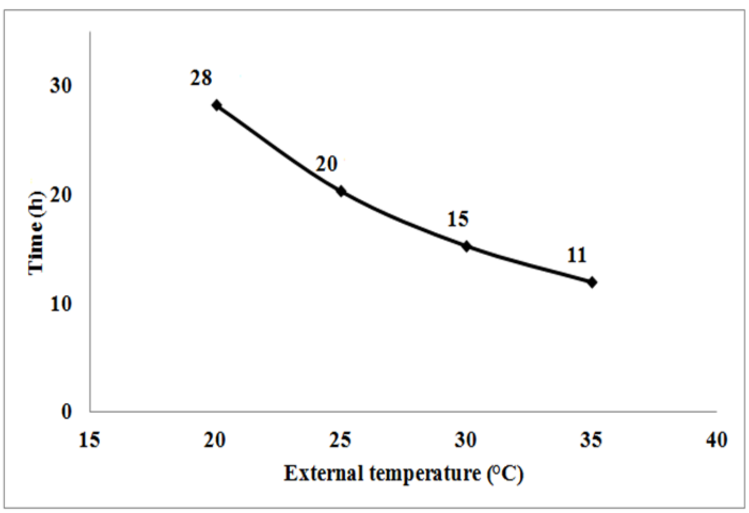


Figure 30: The relation between external temperature and maximum allowed exposure time

Case 2: Freezer breakdown

In the previous case, we analyzed the situation where the frozen product was left in higher external temperature and then put back in freezer, where products are abruptly exposed to ambient and freezing temperatures. This case study examines the scenario of freezer breakdown. The products are initially at -18 °C inside the freezer. If the freezer breaksdown, the temperature inside the freezer will rise slowly to ambient temperature and once the freezer restarts, temperature will gradually drops to -18 °C. The rate at which this temperature rise and fall was obtained from on field real cases as shown in Table 8. The rate of change temperature values evaluated by extrapolating this data are: for temperature rise from -18 °C to 0 °C the temperature changes at a rate of 0.125°C/h, and from 0°C to any positive value the rate of change temperature was 0.216 °C/h. While cooling back when freezer works, irrespective of temperature range the rate was assumed to be -2 °C/h. This external temperature behavior is shown by the black dotted line in figure 31. The quality prediction analysis which is described in case 1 was also performed for this case.

The red curve shown in figure 31 represents typical time temperature profile for a point in a highlighted region of beef for freezer breakdown scenario. Black dotted line represents the external temperature experienced by the product inside the freezer during breakdown. It can be observed that after the freezer breaks down, the temperature inside the freezer rises slowly causing the product temperature also to increase gradually. The product takes comparatively longer time to reach 0 °C (~200 hrs). Once the freezer restarts, the temperature inside freezer quickly drops down to -18 °C. Because of this relatively sharp decline in freezer temperature, the product freezes back in comparatively shorter time. The microbial quality analysis was carried out for this time temperature profile as described in previous case to obtain spoilage time (T_s), freezing time (T_f) and maximum allowable freezer breakdown time (T_m).

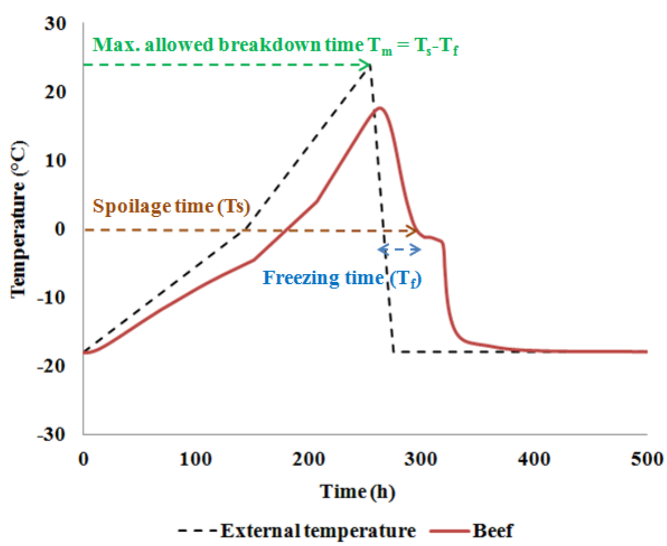
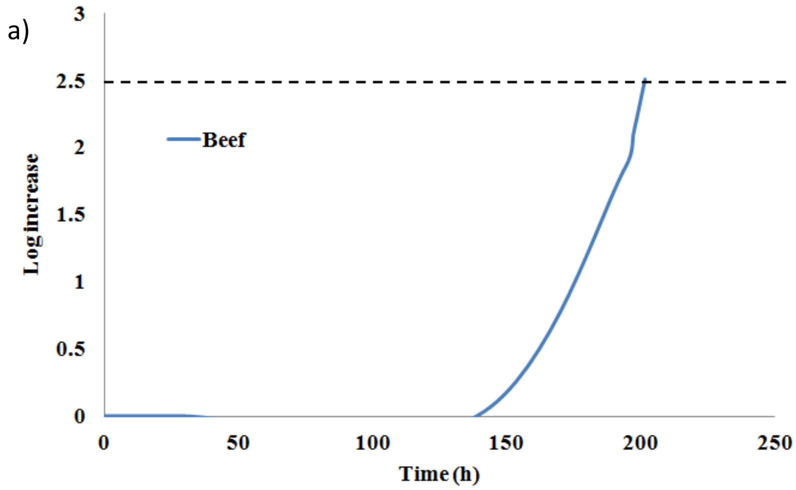


Figure 31: Time-temperature profile for freezer breakdown scenario

This Figure 32a shows microbial growth profile in the highlighted region of beef, when the freezer breaksdown. The time (T_s) at which microbial count reaches 2.5 log increase was ~ 209 hrs. The freezing time (T_f) was ~14 hrs for this case. Thus the maximum allowable time for the freezer breakdown is ~195 hrs. The results are summarized in the Table 11.



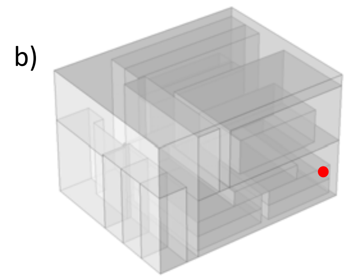


Figure 32: a) microbial growth profile, b) sensitive point in beef

Table 11: Analysis of the frozen menu-3 exposed for freezer breakdown scenario

Spoilage time (h) T_s	Freezing time (h) T_f	Maximum allowed time (h) $T_m = T_s - T_f$
209	14	~195

6. Conclusion

1. The freeze thaw models were developed using commercial software COMSOL® and experimentally validated. The experimental verification showed excellent agreement with model predictions.
2. The model successfully incorporated phase change behavior, 3D geometry with dimensions and their orientation, packaging material properties and microbial growth kinetics.
3. The time temperature modeling was carried out for all 3 menu boxes for the following cases:
    - case 1: menu boxes frozen at -18 C exposed to ambient temperature
    - case 2: menu box pallets frozen at -18 C exposed to ambient temperature
    - case 3: menu boxes frozen at -18 C exposed to accidental temperature fluctuations

   The time temperature distributions and initial thawing point were obtained for each case.
4. Simulations for freezing of the thawed product were carried to obtain the time required for the freezing in different scenarios.
5. Shelf life study showed that the chemical degradation is negligible when products are frozen and in thawed state, microbial spoilage in product is dominant.
6. The kinetic model for microbial growth was developed using 'COMBASE'.
7. Time temperature profile during freeze thaw cycle was combined with the microbial growth kinetics to predict the quality of food products in two possible temperature fluctuation / abuse scenarios.
    - case 1: menu boxes frozen at -18 C exposed to different ambient temperature
    - case 2: freezer breakdown

   The spoilage time and maximum allowed time before products put back in freezer was calculated.
8. The correlation between external /storage temperature conditions and spoilage time was obtained and it can be used to design Time – Temperature Integrators (TTI)

References:

1. Andrew G.F. Staple, Healther Tewkesbury, Peter J. Fryer (1999) The effects of shear and temperature history on the crystallization of chocolate. Journal of the American Oil Chemists' Society. 76:677-685.
2. Battacharya. M , Tanmay Basak, K.G. Ayappa (2002) A fixed-grid element based enthalpy formulation for generalized phase change problems: role of superficial mushy region. International Journal of Heat and Mass Transfer 45: 4881-4898.
3. Chevalier-Lucia. D, Le Bail. A, Ghoul. M, Chourot. M. (2003) High pressure calorimetry at sub zero temperature: evaluation of the latent heat and frozen water ratio of gelatin gels. Innovative Food Science & Emerging Technologies. 4: 361-366.
4. Franke Knut.(2000) A new approach for the numerical calculation of freezing and thawing processes of foods using a modified fictitious heat flow method. Journal of Food Engineering 44:23-29.
5. Groulx Dominic, Wilson Ogoh (2009) Solid-Liquid phase change simulation to a cylindrical latent heat energy storage system. Excerpt from the proceedings of the COMSOL conference 2009 Boston.
6. Hamdami Nasser, Jean-Yves Monteau, Alain Le Bail (2004) Transport properties of a high porosity model food at above and sub-freezing temperatures. Part 1: Thermophysical properties and water activity. Journal of Food Engineering 62:373-383.
7. Le Reverend B.J.D., Fryer P.J., Bakails S. (2008) Modelling crystallization and melting kinetics of cocoa butter in chocolate and application to confectionery manufacturing. The Royal Society of Chemistry. 10.1039/b809446b.
8. Matuda T.G, Pessoa P.A, Tadini C.C (2011) Experimental data and modeling of the thermodynamic properties of bread dough at refrigeration and freezing temperatures. Journal of Cereal Science 53:126-132.
9. Michon. C, Cuvelier. G, Launary. B. (1997) Influence of thermal history on the stability of gelatin gels. International Journal of Biological Macromolecules. 30:259-264.
10. Narasimhan T.N (1999). Fourier's heat conduction equation: History, influence, and connections. Reviews of Geophysics, 37, 1.
11. Nazzal. S, Wang. Y (2001) Characteristics of soft gelatin capsules by thermal analysis. International Journal of Pharmaceutics. 230:1, 35-45.
12. Pham Q.T (2006) Modelling heat and mass transfer in frozen food: a review. International Journal of Refrigeration. 29,6:876-888.

13. Reid. D.S.(1990). Optimizing the quality of frozen foods. Food Technology, 44(7): July,78-84.
14. Rules on the general labeling of pre-packaged food stuffs. Official Gazette of Republic of Slovenia (1999). No.30/1999. [SD-008].
15. Saad, Z., & Scot, E.P. (1996). Estimation of temperature dependent thermal properties of basic food solutions during freezing. Journal of Food engineering, 28, 1-19
16. Satyam kumar, Subhendu panigrahi (2009) Modeling of temperature fluctuations in frozen fish. Excerpt from the proceedings of the COMSOL conference 2009 Bangalore.
17. Sebnem Tavnam, Seher Kumcuoglu, Volker Gaukel (2007) Apparent specific heat capacity of chilled and frozen meat products. International Journal of Food Properties 10:103-112.
18. Tsironi, T., Dermesonlouoglou, E., Giannakourou, M., Taoukis, P. (2009). Shelf life modeling of frozen shrimp at variab;e temperature conditions. Food Science and Technology, 42, 664-671.
19. Watzke. B, Deyber. H and Limbach H.J (2010) Heat and mass transfer in partially frozen food. Excerpt from the proceedings of the COMSOL conference 2010 Paris.

Appendix 4.7

UGR-A Sensory Data (TWP#229)

COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION

UGR-A Sensory Data

Technical Working Paper (TWP) #229

Henderikus Bruins

December 11, 2012

Sponsored by:

DEFENSE LOGISTICS AGENCY

8725 John J. Kingman Rd.

Fort Belvoir, VA 22060-6221

Contractor:

Rutgers, The State University of New Jersey

THE CENTER FOR ADVANCED FOOD TECHNOLOGY

School for Environmental and Biological Science

N.J. Agricultural Experiment Station

New Brunswick, New Jersey 08903

1. Introduction

The UGR-A menus contain a wide variety of products that are kept frozen (-18 ^{0}C) to preserve shelf life (9 month). However, in hot climates such as Iraq and Afghanistan, the storage conditions are challenging and the probability that the products will see temperature higher than -18 ^{0}C is great. Under Short Term Project #3009, the sensory quality of UGR-A frozen rations was evaluated as function of time and storage temperatures. Three items were selected for this study: 1) Breakfast Steak, 2) Chicken Cordon Bleu, 3) Shrimp Scampi. Control samples were stored at Natick at -20C during the duration of the project and served as reference samples. The remaining product was stored at Rutgers at -18C, -12 C and -4C for variable time.

Natick conducted sensory test on the samples using an internal panel of 10-15 people that was asked to score the product on five quality attributes: appearance, odor, flavor, texture and overall quality. At each setting, they were given the temperature abused product and a reference product that was stored at -20 C for the same time duration.

This report analyzes the data that was obtained from this sensory test. Two analyses were performed:

1) Changes in quality attributes over time as function of storage temperature
2) Differences between the reference sample and the time/temperqature abused product

2. Storage Temperature/Time:

The product samples were stored at Rutgers at three different temperatures while the product was still packed in their primary and secondary packaging materials. The product was pulled at set time intervals (see table 1) to determine the degradation in quality attributes. Some product was used to evaluate the product for analytical attributes typical associated with quality degradation, while the remainder of the product were send to the Natick Soldier Center for a sensory test. **Samples that were shipped were transfered to** the -18 C storage box for at least 24 hrs before they were packed on dry ice in an insulated box and shipped overnight to Natick. The product was stored stored in a -20 C box until a sensory panel was assembled to compare the "temperature abused" samples against the reference product. All products were heated according to the instructions listed in the Cooking Instructions before it was tested for sensory attributes.

Due to a malfunction of the temperature control system, the study was interrupted at the six week pull and was restarted for the 16 week pull.

-18 C **Start: 3/14/11**	**-12 C** **Start: 3/14/11**	**-4 C** **Start: 3/14/11** **Restart: 5/30/11**
✓24 Weeks **8/29/11**	**✓8 Weeks** **5/9/11**	**✓1 Week** **3/21/11**
✓48 Weeks **2/13/11**	**✓24 Weeks** **8/29/11**	**✓2 Weeks** **3/28/11**
✓72 Weeks **7/30/12**	**✓40 Weeks** **11/28/11**	**✓4 Weeks** **4/11/11**
	✓72 Weeks **7/30/12**	**✓6 Weeks** **4/25/11**
		✓12 Weeks **8/22/11**
		✓16 Weeks **09/19/11**

Table 1: Sample Storage Conditions

3. Cooking Instructions:

The following cooking instructions were used to prepare the samples for sensory testing:

Breakfast Steak: Pre-heat grill to approximately 350° F. Use approximately 1 cup of vegetable oil per 50 steaks to grease the grill. Grill steaks for approximately 6 minutes on each side. Ensure steaks are cooked to reach a minimum internal temperature of 165°.

Chicken Cordon Bleu: Pre-heat oven to desired temperature and bake according to the following:

- **350 deg F - 30 minutes**
- **400 deg F - 25 minutes**
- **450 deg F - 20 minutes**

Ensure internal product temp of at least 140 deg F. Allow to cool for 2-3 mins before slicing

Shrimp Scampi: Put water in pot and bring temperature to 200 degrees. Place pouches of Scampi in water for 50 - 60 minutes. Make sure shrimp are cooked and appear pink in color.

4. Sensory Results:

All product quality attributes were scored by panelist based on a 9 point scale. Criteria for acceptable quality are "6" or higher. Marginal quality is between "5" and "6". Unacceptable quality is less than "5". The response data from each panelist was used and analyzed using Statgraphics' Anova analysis of variance to determine if there were significant differences between the means, variances and/or medians, using. We conducted two analyses. The first analysis uses the quality sensory scores of the temperature abused samples and determined if significant differences existed at a 95% confidence interval between samples stored at a set temperature for different time periods (Analysis I). The second analysis determined if significant differences existed at a 95% confidence interval between product stored for the longest time at a set temperature to a sample that was stored for the same time period at -20 C (Analysis II). In the following sections, the results of each analysis will be reviewed.

4.1. Storage Temperature -4 C

Product was stored at -4 C for up to 16 weeks. In the following sections we will analyze each individual product.

4.1.1. Breakfast Steak

Attribute	Breakfast Steak 6oz; Initial Panel Controls	Breakfast Steak (Sample); 1week	Breakfast Steak (Sample); 2week	Breakfast Steak (Sample); 4week	Steak - -4C 16weeks
APPEARANCE Quality	6.68	6.83	6.77	6.63	7.04
ODOR Quality	7.02	6.93	6.84	6.9	7.02
FLAVOR Quality	7.04	6.97	6.81	7.05	7.11
	ab	ab	a	a	b
TEXTURE Quality	6.72	6.87	6.65	6.7	7.08
OVERALL Quality	6.85	6.88	6.72	6.73	7.06

Table 2: Breakfast Steak Scores @ -4C

Analysis I:

No Significant Differences in overall quality of breakfast steak was detected (P-value=0.4281 & F-ratio=0.98) when it was stored at 4 C for 0, 1, 2. 4 and 16 weeks.

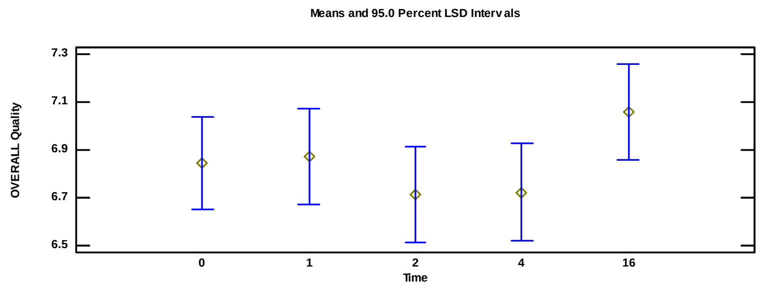


Figure 1: Means Plot Breakfast Steak for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
2	12	6.71667	X
4	12	6.725	X
0	13	6.84615	X
1	12	6.875	X
16	12	7.05833	X

Table 3: Breakfast Steak Multiple Range Test for Overall Quality

Analysis II:

Also no significant differences were detected in overall quality between the reference sample (Control=1) and breakfast steak that was stored for 16 weeks @ - 4 C (P-value=0.9236 F-ratio=0.01)

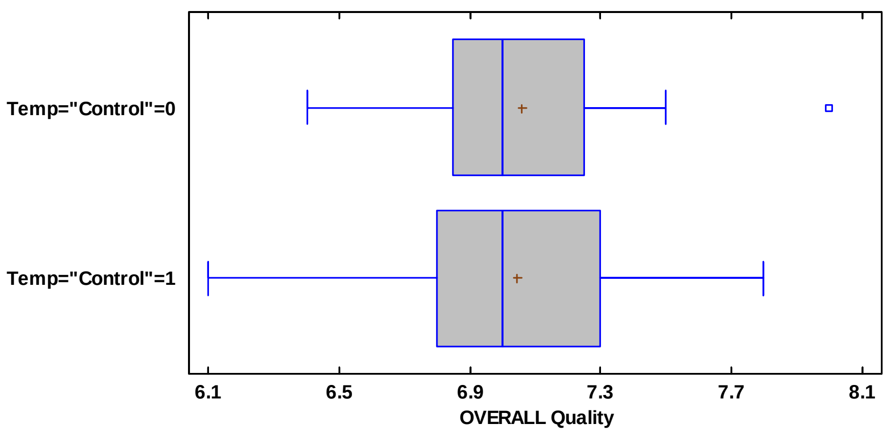


Figure 2: Box and Whisker Plot Breakfast Steak for Overall Quality

4.1.2. Chicken Cordon Bleu:

Attribute	Chicken Cordon Bleu; Initial Panel Controls	Chicken Cordon Bleu (Sample); 1week	Chicken Cordon Bleu (Sample); 2week	Chicken Cordon Bleu (Sample); 4week	Chicken Cordon Bleu - -4C 16weeks
	ab	c	a	bc	abc
APPEARANCE Quality	6.89	7.27	6.82	7.19	7.01

	ab	b	a	ab	ab
ODOR Quality	6.87	7.16	6.79	7.06	7.04
	ab	b	a	ab	ab
FLAVOR Quality	6.83	7.15	6.7	7.04	7.01
	ab	ab	a	b	ab
TEXTURE Quality	6.79	7.08	6.73	7.13	6.86
	ab	b	a	ab	ab
OVERALL Quality	6.84	7.13	6.76	7.06	6.83

Table 4: Chicken Cordon Bleu Scores @ -4C

Analysis I:

There was no Significant Differences detected in the mean of overall quality of chicken cordon bleu (P-value=0.1580 & F-ratio=1.72) when stored at -4 C for 0,1,2,4 and 16 weeks. However, in a pair-wise comparison differences were found between samples stored at different temperatures as indicated in the tables 4 and 5.

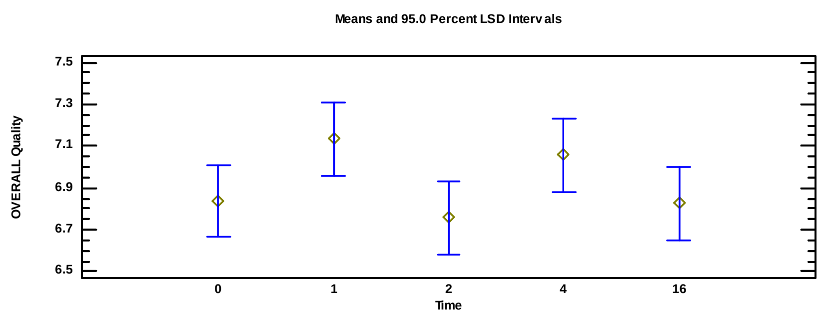


Figure 3: Means Plot Chicken Cordon Bleu for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
2	12	6.75833	X
16	12	6.825	XX
0	13	6.83846	XX
4	12	7.05833	XX
1	12	7.13333	X

Table 5: Chicken Cordon Bleu Multiple Range for Overall Quality

Analysis II:

No Significant Differences at 95% confidence interval were detected between reference sample stored at -20 C and the chicken cordon bleu product stored for 16 weeks @ - 4 C (P-value=0.0727, F-ratio=3.55)

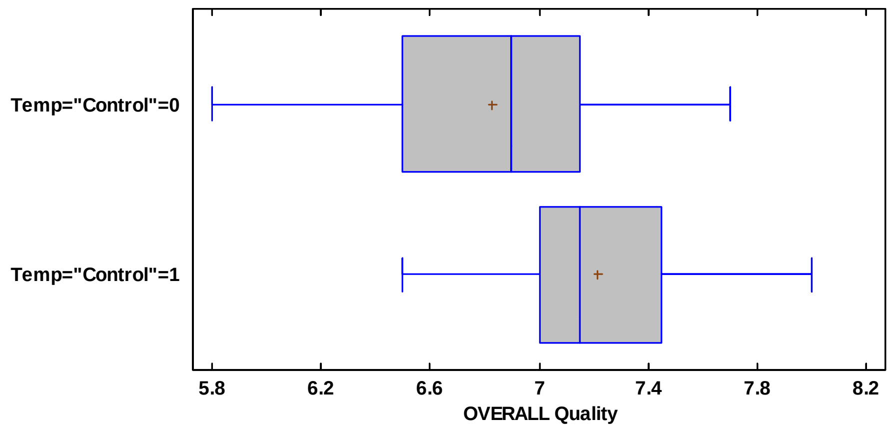


Figure 4: Box and Whisker Plot Chicken Cordon Bleu for Overall Quality

4.1.3. Shrimp Scampi:

Attribute	Shrimp Scampi; Initial Panel Controls	Shrimp Scampi (Sample); 1week	Shrimp Scampi (Sample); 2week	Shrimp Scampi (Sample); 4week	Shrimp Scampi - - 4C 16weeks
APPEARANCE Quality	6.91	7.11	6.8	6.97	6.85
ODOR Quality	6.86	7.03	6.82	7	6.83
	bc	c	ab	bc	a
FLAVOR Quality	6.89	7.11	6.65	6.97	6.43
	ab	b	a	ab	ab
TEXTURE Quality	6.84	7.08	6.64	6.92	6.75
	b	b	ab	b	a
OVERALL Quality	6.88	7.08	6.7	6.93	6.45

Table 6: Shrimp Scampi Scores @ -4C

Analysis I:

There was a Significant Difference detected in overall quality of shrimp scampi when stored at -4 C for 0,1,2,4 and 16 weeks. (P-value=0.0382 & F-ratio=2.73). The cause for quality degradation appears to be flavor related. However, in spite to the degradation in quality the quality after 16 weeks at -4C is still judged to be acceptable.

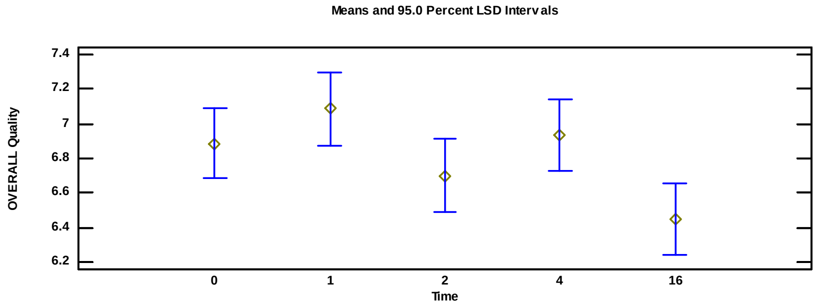


Figure 5: : Means Plot Shrimp Scampi for Overall Quality

Time	Count	Mean	Homogeneous Groups
16	12	6.45	X
2	12	6.7	XX
0	13	6.88462	X
4	12	6.93333	X
1	12	7.08333	X

Table 7: Shrimp Scampi Multiple Range Test for Overall Quality

Analysis II:

There is also significant differences in overall quality between reference sample and the sample that was stored at -4 for 16 weeks with one observation of <"5" (P-value=0.0172 and F-ratio=6.65). It is clear that shrimp scampi started to degrade in quality at 16 weeks due to the storage temperature. However, the average score is still above "6" and thus acceptable in quality.

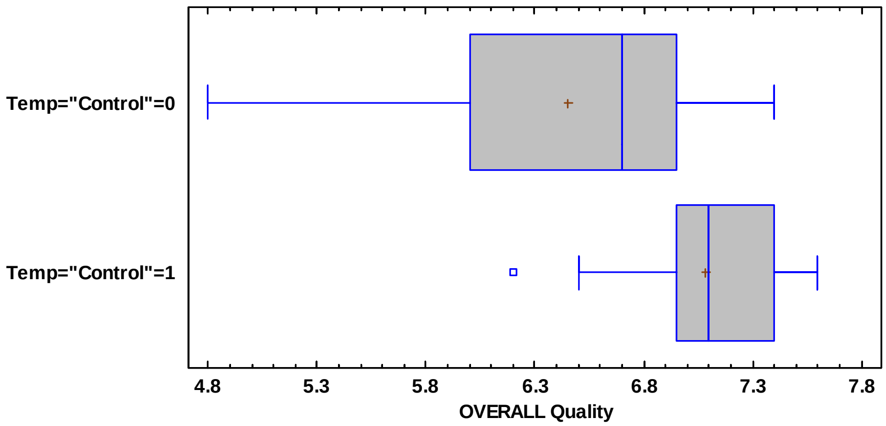


Figure 6: Box and Whisker Plot Shrimp Scampi for Overall Quality

4.2. Storage Temperature -12 C

Next we analyzed quality degradation when the product is stored at -12 C for up to 72 weeks, well beyond the required 9 month shelf life criteria.

4.2.1. Breakfast Steak

Attribute	Breakfast Steak 6oz; Initial Panel Controls	Steak; -12; 24 weeks	Steak; 40wks; -12	Steak; 18mos; -12
	b	ab	b	a
APPEARANCE Quality	6.68	6.59	6.93	6.51
	b	ab	ab	a
ODOR Quality	7.02	6.92	6.89	6.6
	b	ab	b	a
FLAVOR Quality	7.04	6.83	6.93	6.4
	b	b	b	a
TEXTURE Quality	6.72	6.71	6.74	6.18
	b	ab	b	a
OVERALL Quality	6.85	6.73	6.85	6.25

Table 8: Breakfast Steak Scores @ -12 C

Analysis I:

No Significant Differences in overall quality of Breakfast Steak (P-value=0.0970 & F-ratio=2.23) was detected when stored up to 72 weeks at -12 C. However, in a pair wise comparison, the 72 week sample was different from the 0 week and 40 week sample. Difference occurred in all five quality attributes.

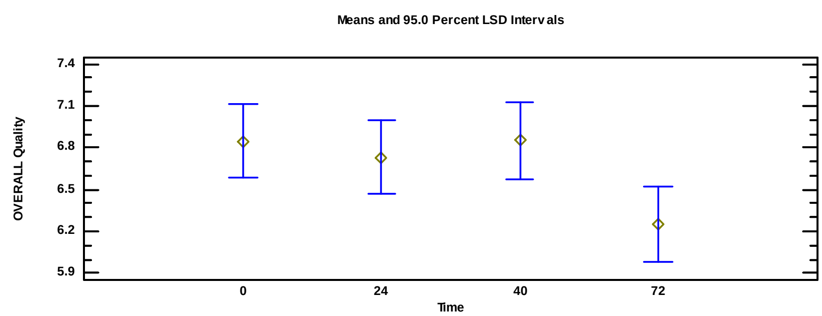


Figure 7: Means Plot Breakfast Steak for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
72	12	6.25	X
24	13	6.73077	XX
0	13	6.84615	X
40	12	6.85	X

Table 9: Breakfast Steak Multiple Range Test for Overall Quality

Analysis II:

Also, Significant Differences in overall quality was determined between the reference sample (6.95) and the breakfast steak sample stored at -12 C for 72 weeks, with two people scoring it at 4.8 (P-value=0.0258 and F-ratio=5.71). However, the average score is still above “6” and thus acceptable in quality.

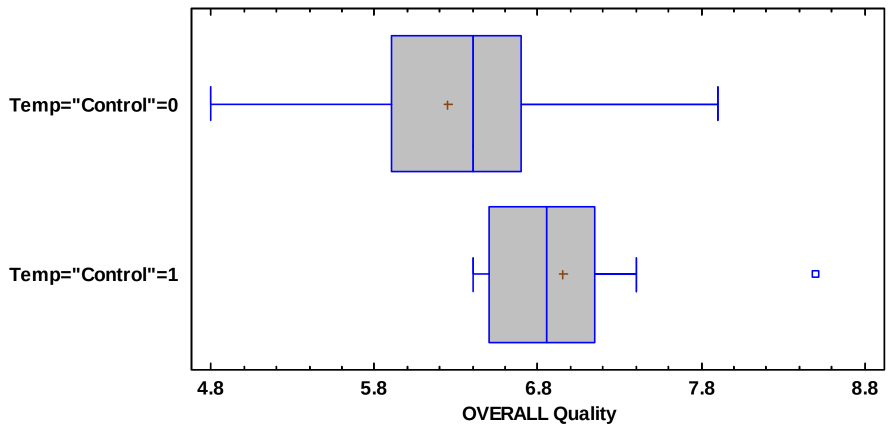


Figure 8: Box and Whisker Plot Breakfast Steak for Overall Quality

4.2.2. Chicken Cordon Bleu

Attribute	Chicken Cordon Bleu; Initial Panel Controls	Chicken Cordon Bleu; -12; 24 weeks	Chicken Cordon Blue; 40wks; -12	396; Chicken Cordon Bleu; 18mos; -12
APPEARANCE Quality	6.89	7.02	6.88	6.83
ODOR Quality	6.87	6.87	6.91	6.76
FLAVOR Quality	6.83	6.72	6.82	6.81
TEXTURE Quality	6.79	6.79	6.86	6.67
OVERALL Quality	6.84	6.72	6.85	6.75

Table 10: Chicken Cordon Bleu Scores @ -12 C

Analysis I:

No Significant Differences were detected in the Chicken Cordon Bleu samples (P-value=0.8610 & F-ratio=0.25) when stored at -12 C for 72 weeks. Also in a pairwise comparison, no differences were identified for any of the quality attributes indicating excellent quality retention at this storage temperature..

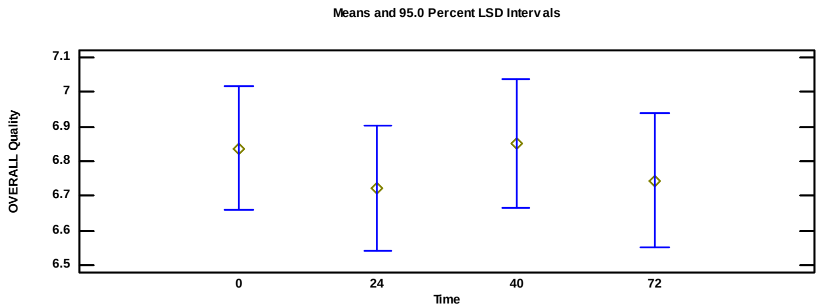


Figure 9: : Means Plot Chicken Cordon Bleu for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
24	13	6.72308	X
72	11	6.74545	X
0	13	6.83846	X
40	12	6.85	X

Table 11: Chicken Cordon Bleu Multiple Range Test for Overall Quality

Analysis II:

Also no significant difference was detected in overall quality between reference sample and Chicken Cordon Bleu sample stored at -12 C for 72 weeks. (P-value=0.2992, F-ratio=1.14)

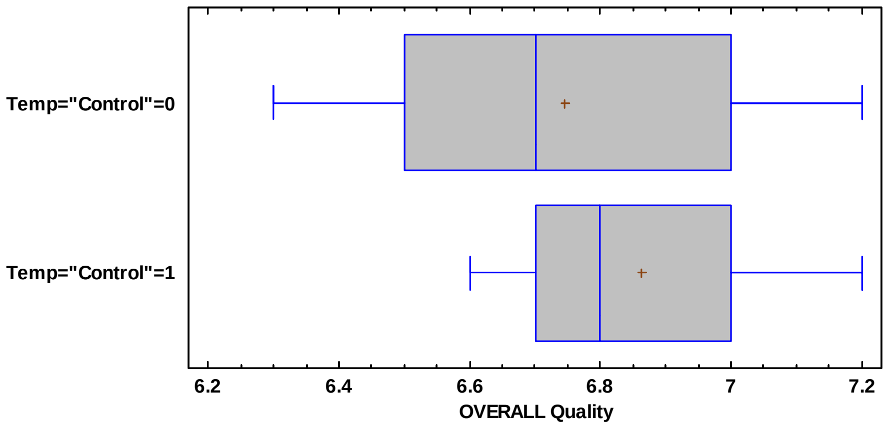


Figure 10: Box and Whisker Plot Chicken Cordon Bleu for Overall Quality

4.2.3. Shrimp Scampi

Attribute	Shrimp Scampi; Initial Panel Controls	Shrimp Scampi; -12; 24 weeks	Shrimp Scampi; 40wks; -12	537; Shrimp Scampi; 18mos; -12
	b	b	ab	a
APPEARANCE Quality	6.91	6.91	6.75	6.46
	ab	b	ab	a
ODOR Quality	6.86	6.98	6.68	6.64
	ab	b	a	ab
FLAVOR Quality	6.89	6.9	6.56	6.55
	bc	c	ab	a
TEXTURE Quality	6.84	6.89	6.5	6.41
	b	b	a	a
OVERALL Quality	6.88	6.88	6.49	6.44

Table 12: Shrimp Scampi Scores @ -12 C

Analysis I:

There was a significant change in overall quality of Shrimp Scampi when stored at -12 C for 72 weeks. (P-value=0.0125 & F=ratio=4.05). The degradation in quality occurred between 24 and 40 weeks. But even at 72 weeks, the quality of the product is still acceptable indicating excellent shelf stability.

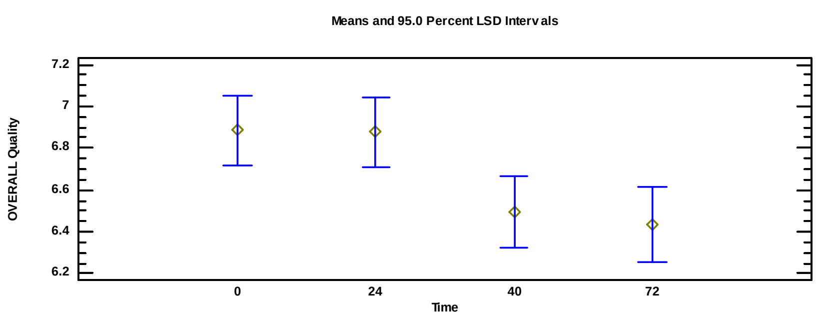


Figure 11: : Means Plot Shrimp Scampi for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
72	11	6.43636	X
40	12	6.49167	X
24	13	6.87692	X
0	13	6.88462	X

Table 13: Shrimp Scampi Multiple Range Test for Overall Quality

Analysis II:

No Significant Difference was detected between the reference sample and the shrimp scampi sample stored at -12 C for 72 weeks. (P-value=0.4034, F-ratio=0.73), indicating that the quality deterioration is more time related and not as much by the difference in storage temperature.

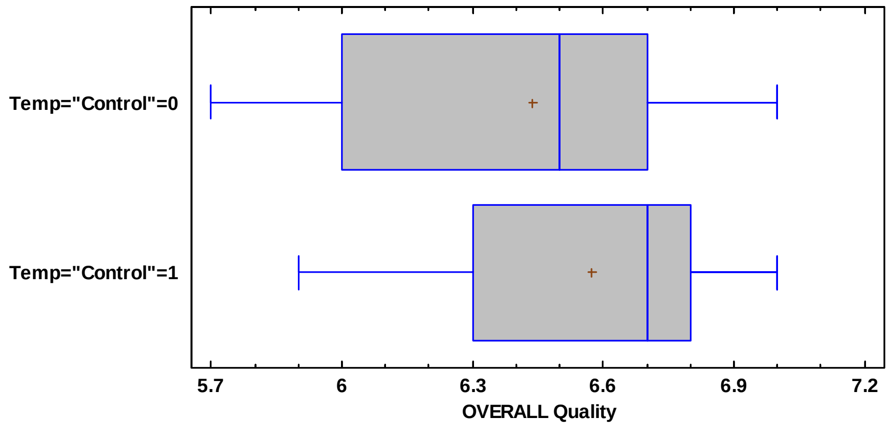


Figure 12: Box and Whisker Plot Shrimp Scampi for Overall Quality

4.3. Storage Temperature -18 C

Product was stored at -18 C for up to 72 weeks, the recommended storage temperature for the UGR-A ration, but well beyond the required 9 month shelf life criteria.

4.3.1. Breakfast Steak

Attribute	Breakfast Steak 6oz; Initial Panel Controls	Steak; -18; 24 weeks	Breakfast Steak; 36wks@-18	Steak; 18mos; -18
APPEARANCE Quality	6.68	6.52	6.73	6.73
ODOR Quality	7.02	6.72	6.68	6.79
FLAVOR Quality	7.04	6.61	6.62	6.77
TEXTURE Quality	6.72	6.53	6.38	6.31
OVERALL Quality	6.85	6.58	6.53	6.48

Table 14: Breakfast Steak Scores @ -18 C

Analysis I:

No Significant changes was detected in overall quality of breakfast steak when stored at -18 C for 72 weeks (P-value=0.5773 & F-ratio=0.67). Also no differences were found in a pair wise comparison.

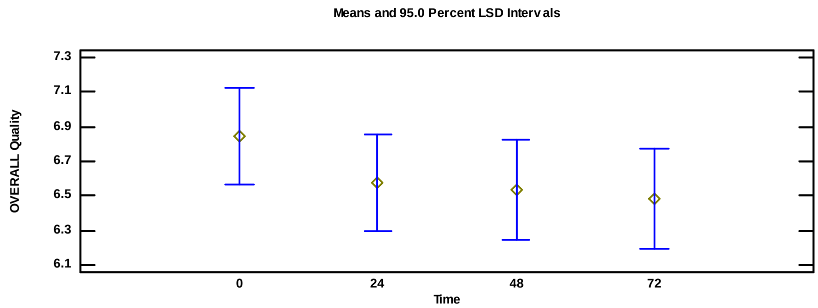


Figure 13: Means Plot Breakfast Steak for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
72	12	6.48333	X
48	12	6.53333	X
24	13	6.57692	X
0	13	6.84615	X

Table 15: Breakfast Steak Multiple Range Test for Overall Quality

Analysis II:

No Significant Differences were found between the reference sample and Breakfast Steak stored for 72 weeks @ - 18 C (P-value=0.1666 and F-ratio=2.05), but a sample did receive a score of “4”, which appears to be an outlier.

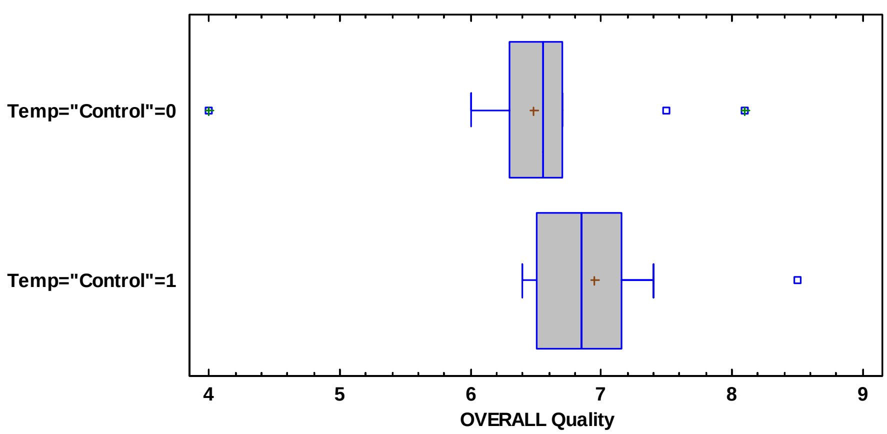


Figure 14: Box and Whisker Plot Breakfast Steak for Overall Quality

4.3.2. Chicken Cordon Bleu

Attribute	Chicken Cordon Bleu; Initial Panel Controls	Chicken Cordon Bleu; -18; 24 weeks	Chicken Cordon Bleu; 36wks@-18	716; Chicken Cordon Bleu; 18mos; -18
APPEARANCE Quality	6.89	6.92	6.98	6.65
	ab	b	ab	a
ODOR Quality	6.87	6.9	6.83	6.52

FLAVOR Quality	6.83	6.83	6.76	6.48
	b	b	b	a
TEXTURE Quality	6.79	6.87	6.81	6.41
	b	ab	ab	a
OVERALL Quality	6.84	6.82	6.79	6.44

Table 16: Chicken Cordon Bleu Scores @ -18 C

Analysis I:

No significant difference was detected between Chicken Cordon Bleu samples that where stored at -18 C for 72 weeks (P-value=0.1415 & F-ratio=1.91), but in a pairs wise comparison the 0 week and 72 weeks sample were different. It should be noted that the average overall quality score for samples stored at -18 C (6.44) was surprisingly lower than for samples stored at -12 C (6.75). However, the average score is still above “6” and thus acceptable in quality.

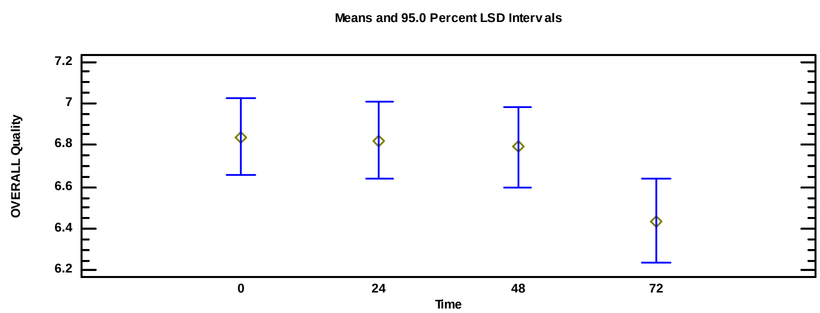


Figure 15:: Means Plot Chicken Cordon Bleu for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
72	11	6.43636	X
48	12	6.79167	XX
24	13	6.82308	XX
0	13	6.83846	X

Table 17: Chicken Cordon Bleu Multiple Range Test for Overall Quality

Analysis II:

Significant Differences were observed between reference sample and Chicken Cordon Bleu stored for 72 weeks @ - 18 C (P-value=0.0084, F-ratio=8.54), but as noted in Analysis I, the average overall quality score for Chicken Cordon Blue seems to be lower than expected based on storage data at -12 C.

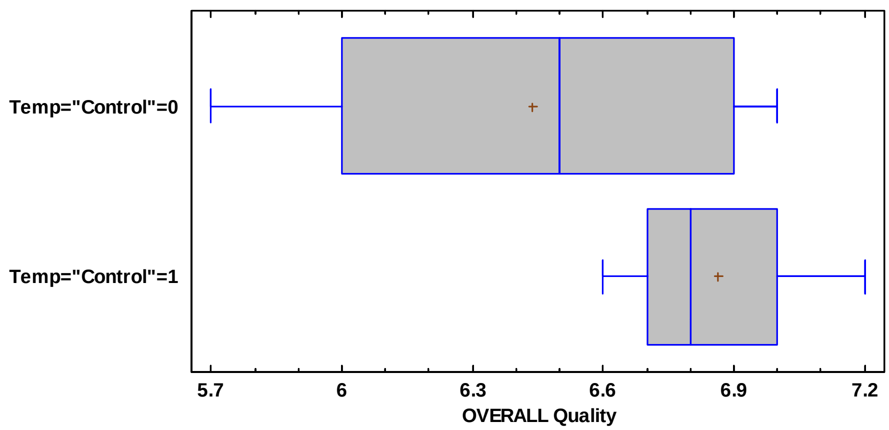


Figure 16: Box and Whisker Plot Chicken Cordon Bleu for Overall Quality

4.3.3. Shrimp Scampi

Attribute	Shrimp Scampi; Initial Panel Controls	Shrimp Scampi; -18; 24 weeks	Shrimp Scampi; 36wks@-18	196; Shrimp Scampi; 18mos; -18
	b	b	ab	a
APPEARANCE Quality	6.91	6.75	6.63	6.35
	ab	b	ab	a
ODOR Quality	6.86	6.91	6.84	6.55
	b	b	b	a
FLAVOR Quality	6.89	6.83	6.81	6.33
	b	b	b	a
TEXTURE Quality	6.84	6.88	6.73	6.17
	b	b	b	a
OVERALL Quality	6.88	6.8	6.73	6.26

Table 18: Shrimp Scampi Scores @ -18 C

Analysis I:

There was a significant difference detected in the mean of overall quality (p=0.0101 & F=4.24) when the Shrimp Scampi is stored at -18 C for 72 weeks. Also differences were found in pairwise comparisons. However, it should be noted that the mean scored was above “6” and thus still acceptable

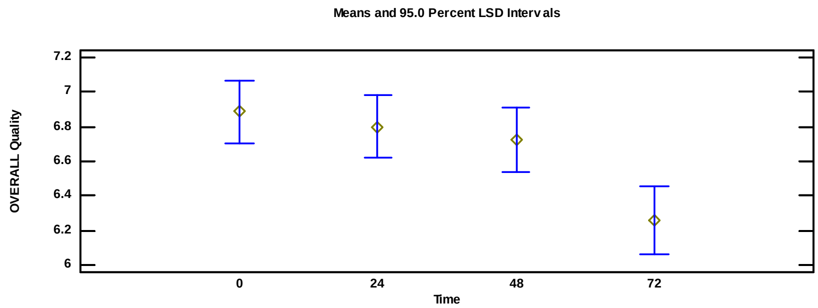


Figure 17:: Means Plot Shrimp Scampi for Overall Quality

Time	*Count*	*Mean*	*Homogeneous Groups*
72	11	6.26364	X
48	12	6.725	X
24	13	6.8	X
0	13	6.88462	X

Table 19: Shrimp Scampi Multiple Range Test for Overall Quality

Analysis II:

No significant differences were found between the reference sample and the sample stored at -18 C for 72 weeks (P-value=0.1210 and F-ratio=2.62), indicating that the differences in storage temperature between control and sample had no effect on the quality.

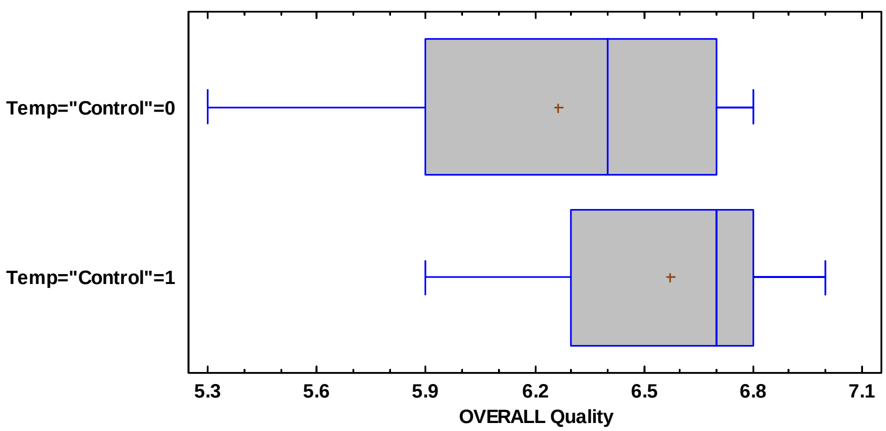


Figure 18: Box and Whisker Plot Shrimp Scampi for Overall Quality

5. Summary

5.1. Breakfast Steak

No Significant Differences in overall quality of breakfast steak was detected (P-value=0.4281 & F-ratio=0.98) when it was stored at 4 C for 16 weeks. Also no significant differences were detected in overall quality between the reference sample (Control=1) and breakfast steak that was stored for 16 weeks @ - 4 C (P-value=0.9236 F-ratio=0.01)

No Significant Differences in overall quality of Breakfast Steak (P-value=0.0970 & F-ratio=2.23) was detected when stored up to 72 weeks at -12 C. However, in a pair wise comparison, the 72 week sample was different from the 0 week and 40 week sample. Difference occurred in all five quality attributes. Also, Significant Differences in overall quality was determined between Control (6.95) and the breakfast steak sample stored at -12 C for 72 weeks, with two people scoring it at 4.8 (P-value=0.0258 and F-ratio=5.71). However the average score is still above “6” and thus acceptable in quality.

No Significant changes was detected in overall quality of breakfast steak when stored at -18 C for 72 weeks (P-value=0.5773 & F-ratio=0.67). Also no differences were found in a pair wise comparison. No significant differences were found between control and Breakfast Steak stored for 72 weeks @ - 18 C (P-value=0.1666 and F-ratio=2.05), but a sample did receive a score of “4”, which appears to be an outlier.

5.2. Chicken Cordon Bleu

There was no significant differences detected in the mean of overall quality of chicken cordon bleu (P-value=0.1580 & F-ratio=1.72) when stored at -4 C for 16 weeks. However, in a pair-wise comparison differences were found between samples stored at different temperatures. No significant differences at 95% confidence interval were detected between reference sample stored for 16 weeks at -20 C and the chicken cordon bleu product stored for 16 weeks @ - 4 C (P-value=0.0727, F-ratio=3.55)

No Significant Differences were detected in the Chicken Cordon Bleu samples (P-value=0.8610 & F-ratio=0.25) when stored at -12 C for 72 weeks. Also in a pairwise comparison, no differences were identified for any of the quality attributes indicating excellent quality retention. Also no significant difference was determined between reference sample and Chicken Cordon Bleu sample stored at -12 C for 72 weeks. (P-value=0.2992, F-ratio=1.14)

No significant diference was detected between Chicken Cordon Bleu samples that where stored at -18 C for 72 weeks (P-value=0.1415 & F-ratio=1.91), but in a pairs wise comparison the 0 week and 72 weeks sample were different. It should be noted that the average overall quality score for samples stored at -18C was lower than for samples stored at -12 C. Significant differences were observed between control and Chicken Cordon Bleu stored for 72 weeks @ - 18 C (P-value=0.0084, F-ratio=8.54), but as noted in Analysis I, the average overall quality score for Chicken Cordon Blue seems to be lower than expected based on storage data at -12 C.

5.3. Shrimp Scampi

There was a significant difference detected in overall quality of shrimp scampi when stored at -4 C for 16 weeks. (P-value=0.0382 & F-ratio=2.73). The cause for quality degradation appears to be flavor related. However, in spite to the degradation in quality the quality after 16 weeks at -4 C is still judged to be acceptable. There is also significant differences in overall quality between the reference sample and the sample that was stored at -4 for 16 weeks with one reading of <"5" (P-value=0.0172 and F-ratio=6.65), indicating that the degradation of shrimp scampi is due to the storage temperature.

There was a significant change in overall quality of Shrimp Scampi when stored at -12 C for 72 weeks. (P-value=0.0125 & F=ratio=4.05). The degradation in quality occurred between 24 and 40 weeks. But even at 72 weeks, the quality of the product is still acceptable indicating excellent shelf stability. No Significant Difference was detected between the reference sample and the shrimp scampi sample stored at -12 C for 72 weeks. (P-value=0.4034, F-ratio=0.73), indicating that the quality deterioration is more time related and affect as much by the temperature difference.

There was a significant difference detected in the mean of overall quality (p=0.0101 & F=4.24) when the Shrimp Scampi is stored at -18 C for 72 weeks. Also differences were found in pairwise comparisons. However, it should be noted that the mean s cored was above "6" and thus still acceptable. No significant difference was found between the reference sample and the sample stored at -18 C for 72 weeks (P-value=0.1210 and F-ratio=2.62), indicating that the differences in storage temperature between control and sample had no effect on the quality.

6. Conclusion

Breakfast Steak, Chicken Cordon Bleu and Shrimp Scampi have excellent shelf life stability and surpassing expectations based on literature review. No sample scored has a mean score that was lower than a "6" in any of the temperature/time abused samples.

As expected, based on literature review, Shrimp Scampi was the most sensitive product to quality degradation and is expected to be the first product to score below a "6" is stored at less than ideal temperatures and/or excessive time.

7. Appendix:

7.1. Sensory Data

Sample Description	APPEARANCE Quality	ODOR Quality	FLAVOR Quality	TEXTURE Quality	OVERALL Quality	Temp	Time	Product
Breakfast Steak 6oz; Initial Panel Controls	6.4	6.7	6.5	6.4	6.5	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7.5	7.5	7.5	7.5	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7.2	7	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7.5	7.6	7.5	7.5	7.5	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.2	6.5	6.5	6.2	6.3	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	5.8	7	7	6	6	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6	7.2	7.2	6.7	7.1	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	7.4	7.3	6.4	6.6	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7.5	6.7	7.1	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.6	6.9	6.8	6.4	6.7	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.8	6.9	6.6	6.9	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7	7	Control	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.7	6.8	6.7	6.8	Control	0	Steak
Chicken Cordon Bleu; Initial Panel Controls	6.6	7.5	6.8	6.7	6.8	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7	6.7	6.8	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	6.7	6.7	6.7	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6.7	6.7	6.8	6.7	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6	6	6.5	6.1	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.5	6.8	6.5	6.7	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	6.6	6.5	6.5	6.7	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.5	7.4	7.5	7.1	7.5	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7.5	7.5	7.5	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.2	7.3	7.3	7.2	7.3	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.7	6.7	6.7	6.8	6.8	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	7	6.7	6.7	6.7	Control	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.6	6.6	6.6	6.6	Control	0	Chicken

Shrimp Scampi; Initial Panel Controls	7.3	7.3	7.2	7.1	7.1	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.7	7	7	6.9	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.8	6.8	6.8	6.8	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.5	7.2	7	7	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.7	6.5	6.2	6.2	6.4	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.5	6.8	7	6.7	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	7	6.3	6.4	6.6	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7.2	6.7	6.9	7	7	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7	7.5	7	7.5	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.3	7.4	7.2	7.3	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.5	6.6	6.6	6.6	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	6.5	6.7	6.7	6.7	Control	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.9	7	6.9	6.9	Control	0	Shrimp
Breakfast Steak (Control); 1week	6.7	6.8	6.5	6.2	6.3	Control	1	Steak
Breakfast Steak (Control); 1week	6.7	7	6.2	6.2	6.3	Control	1	Steak
Breakfast Steak (Control); 1week	6.7	7.5	6.8	6.8	6.7	Control	1	Steak
Breakfast Steak (Control); 1week	7.4	7.2	7.4	7.5	7.4	Control	1	Steak
Breakfast Steak (Control); 1week	7.5	7.5	7.5	7.5	7.5	Control	1	Steak
Breakfast Steak (Control); 1week	7.5	7.5	7.5	7	7.4	Control	1	Steak
Breakfast Steak (Control); 1week	6.8	6.9	6.8	6.9	6.8	Control	1	Steak
Breakfast Steak (Control); 1week	6.6	6.8	6.8	6.8	6.8	Control	1	Steak
Breakfast Steak (Control); 1week	6.6	6.6	6.7	6.6	6.6	Control	1	Steak
Breakfast Steak (Control); 1week	6.8	6.8	6.9	6.7	6.9	Control	1	Steak
Breakfast Steak (Control); 1week	6.2	6	7.4	7	6.7	Control	1	Steak
Breakfast Steak (Control); 1week	6.7	6.7	6.7	6.7	6.7	Control	1	Steak
Breakfast Steak (Sample); 1week	6.7	6.7	6.7	6.7	6.6	-4	1	Steak
Breakfast Steak (Sample); 1week	7	7	7	6.7	6.8	-4	1	Steak
Breakfast Steak (Sample); 1week	6.7	7.5	7.2	7.3	7.3	-4	1	Steak
Breakfast Steak (Sample); 1week	6.7	7.2	7	7.1	6.9	-4	1	Steak
Breakfast Steak (Sample); 1week	7.5	7.5	7.5	7.5	7.4	-4	1	Steak
Breakfast Steak (Sample); 1week	7.2	7.4	7	6.8	7.1	-4	1	Steak

Breakfast Steak (Sample); 1week	6.9	6.8	6.7	6.5	6.6	-4	1	Steak
Breakfast Steak (Sample); 1week	6.6	6.8	6.7	6.6	6.6	-4	1	Steak
Breakfast Steak (Sample); 1week	6.8	6.7	6.6	6.4	6.7	-4	1	Steak
Breakfast Steak (Sample); 1week	6.8	6.8	6.9	6.9	6.9	-4	1	Steak
Breakfast Steak (Sample); 1week	6.5	6.2	7.6	7.2	7	-4	1	Steak
Breakfast Steak (Sample); 1week	6.5	6.5	6.7	6.7	6.6	-4	1	Steak
Chicken Cordon Bleu (Control); 1 week	7	7	7	7	7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	8	7.3	6.5	6.5	6.5	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	7.5	7	7	7	7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	7.5	7.4	7.3	7.3	7.3	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	8	7.8	8	7.7	7.7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.7	7	7.2	6.8	7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.9	6.9	6.9	6.9	6.9	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.8	6.8	6.9	7	7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.5	6.8	6.9	6.8	6.7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.7	6.7	6.7	6.8	6.7	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	7.4	7.5	7.2	7.4	7.3	Control	1	Chicken
Chicken Cordon Bleu (Control); 1 week	6.7	6.6	6.6	6.6	6.6	Control	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7	7	7	7	7	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	8	7.5	7	7	7.3	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7.5	7	7	7	7	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7.2	7	7.1	7	7	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	8	7.8	8	7.7	7.7	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7.5	7.5	7.5	7.2	7.3	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	6.8	6.8	6.9	6.8	6.9	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	6.8	6.8	6.9	6.9	6.9	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7.2	7.2	7.2	7.1	7.2	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	6.8	6.9	6.9	6.9	7	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	7.7	7.7	7.6	7.7	7.6	-4	1	Chicken
Chicken Cordon Bleu (Sample); 1week	6.7	6.7	6.7	6.7	6.7	-4	1	Chicken
Shrimp Scampi (Control); 1week	6.3	6.8	6.8	6.5	6.4	Control	1	Shrimp

Shrimp Scampi (Control); 1week	8	8	8	7.2	7.5	Control	1	Shrimp
Shrimp Scampi (Control); 1week	7	7.5	7.5	7	7	Control	1	Shrimp
Shrimp Scampi (Control); 1week	7	7	7.1	7.1	6.9	Control	1	Shrimp
Shrimp Scampi (Control); 1week	7.5	7.5	7.4	7.5	7.4	Control	1	Shrimp
Shrimp Scampi (Control); 1week	7.4	7.2	7	6.9	7.1	Control	1	Shrimp
Shrimp Scampi (Control); 1week	6.8	6.8	6.8	6.5	6.7	Control	1	Shrimp
Shrimp Scampi (Control); 1week	6.8	6.8	6.8	6.8	6.9	Control	1	Shrimp
Shrimp Scampi (Control); 1week	6.8	7	7	7	7	Control	1	Shrimp
Shrimp Scampi (Control); 1week	6.6	6.4	6.4	6.6	6.4	Control	1	Shrimp
Shrimp Scampi (Control); 1week	7.3	6.5	7.6	7.6	7.5	Control	1	Shrimp
Shrimp Scampi (Control); 1week	6.8	6.8	6.9	6.8	6.8	Control	1	Shrimp
Shrimp Scampi (Sample); 1week	7	7	7	7	7	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	8	8	8	8	8	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	7.4	7.5	7.5	7.5	7.5	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	7	7.2	7.3	7	7.1	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	7.7	7.5	7.5	7.5	7.5	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	7.4	7.2	7	6.8	7.1	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	6.9	6.9	6.8	6.8	6.8	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	6.8	6.7	6.7	6.8	6.8	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	6.5	6.8	6.8	6.6	6.7	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	6.6	6.4	6.4	6.7	6.4	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	7.3	6.5	7.5	7.5	7.4	-4	1	Shrimp
Shrimp Scampi (Sample); 1week	6.7	6.7	6.8	6.7	6.7	-4	1	Shrimp
Breakfast Steak (Control); 2week	5.5	6	6	6	6	Control	2	Steak
Breakfast Steak (Control); 2week	7	7	6.5	6.8	6.8	Control	2	Steak
Breakfast Steak (Control); 2week	7.1	7.1	7.2	7.1	7.1	Control	2	Steak
Breakfast Steak (Control); 2week	7.5	7.5	7.5	7.5	7.5	Control	2	Steak
Breakfast Steak (Control); 2week	7	7.3	7.3	7.3	7.1	Control	2	Steak
Breakfast Steak (Control); 2week	6.8	6.8	6.8	6.8	6.8	Control	2	Steak
Breakfast Steak (Control); 2week	6.8	6.9	6.9	6.9	6.9	Control	2	Steak
Breakfast Steak (Control); 2week	7.5	7	7	7	7	Control	2	Steak

Breakfast Steak (Control); 2week	6	6.2	5.8	5.5	5.9	Control	2	Steak
Breakfast Steak (Control); 2week	7	7	7	6	6.7	Control	2	Steak
Breakfast Steak (Control); 2week	6.5	6.5	6.5	6.5	6.5	Control	2	Steak
Breakfast Steak (Control); 2week	6.7	6.5	6.6	6.6	6.6	Control	2	Steak
Breakfast Steak (Sample); 2week	6.5	6.5	6.5	6.5	6.5	-4	2	Steak
Breakfast Steak (Sample); 2week	6.5	6.5	6.5	6.6	6.5	-4	2	Steak
Breakfast Steak (Sample); 2week	6.9	6.8	6.9	6.7	6.7	-4	2	Steak
Breakfast Steak (Sample); 2week	7.5	7.5	7.5	7.4	7.5	-4	2	Steak
Breakfast Steak (Sample); 2week	7	7.3	7.3	7.3	7.2	-4	2	Steak
Breakfast Steak (Sample); 2week	6.8	6.7	6.8	6.7	6.8	-4	2	Steak
Breakfast Steak (Sample); 2week	6.9	6.9	7	6.9	6.9	-4	2	Steak
Breakfast Steak (Sample); 2week	7	7	6.5	6.5	6.5	-4	2	Steak
Breakfast Steak (Sample); 2week	5.5	6	6	6	6	-4	2	Steak
Breakfast Steak (Sample); 2week	7	7.2	7	6.2	6.8	-4	2	Steak
Breakfast Steak (Sample); 2week	7	7	7	6.5	6.5	-4	2	Steak
Breakfast Steak (Sample); 2week	6.6	6.7	6.7	6.5	6.7	-4	2	Steak
Chicken Cordon Bleu (Control); 2week	7	7	6.5	7	6.5	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	6.8	6.8	6.7	6.5	6.7	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7	7	7.1	7.1	7	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7.5	7.5	7.5	7.5	7.5	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	6.5	6.5	6.4	6.3	6.4	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7	7	7	7	7	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	6.6	6.7	6.7	6.7	6.7	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7.5	7.2	7.2	7.2	7.2	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	6.5	6.2	6.5	6.2	6.5	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7	6.7	6.9	6.8	6.8	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	7	7	7	7	7	Control	2	Chicken
Chicken Cordon Bleu (Control); 2week	6.7	6.5	6.5	6.5	6.5	Control	2	Chicken
Chicken Cordon Bleu (Sample); 2week	7	7	7	7	7	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6.5	6	5.8	6	6	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6.9	6.8	6.7	6.7	6.8	-4	2	Chicken

Chicken Cordon Bleu (Sample); 2week	7.5	7.5	7.6	7.5	7.5	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	7	7.3	7.3	7.2	7.2	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	7	7	7	7	7	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6.7	6.7	6.8	6.7	6.7	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	7.5	7	6.7	7	7	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6	6	6	6.2	6.2	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6	6.7	6	6	6.2	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	7	7	7	7	7	-4	2	Chicken
Chicken Cordon Bleu (Sample); 2week	6.7	6.5	6.5	6.5	6.5	-4	2	Chicken
Shrimp Scampi (Control); 2week	7	7	7	7	7	Control	2	Shrimp
Shrimp Scampi (Control); 2week	5.8	6.2	6	6	6	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6.7	6.6	6.7	6.7	6.7	Control	2	Shrimp
Shrimp Scampi (Control); 2week	7.5	7.5	7.5	7.5	7.5	Control	2	Shrimp
Shrimp Scampi (Control); 2week	7	6.8	6.3	6.5	6.5	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6.7	6.8	6.7	6.8	6.8	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6.6	6.6	6.6	6.7	6.6	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6.7	6.7	6.7	6.7	6.7	Control	2	Shrimp
Shrimp Scampi (Control); 2week	7	6.5	6.5	6.5	6.8	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6	7	7	7	6.9	Control	2	Shrimp
Shrimp Scampi (Control); 2week	7	7	5.5	6	5.5	Control	2	Shrimp
Shrimp Scampi (Control); 2week	6.8	6.8	6.8	6.8	6.8	Control	2	Shrimp
Shrimp Scampi (Sample); 2week	7.1	7	7	7	7	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	7	6.7	6.7	6.2	6.6	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6.7	6.9	6.6	6.5	6.6	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	7.5	7.5	7.5	7.5	7.5	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	7	7	6.5	6.7	6.8	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6.4	6.5	6.5	6.3	6.4	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6.5	6.4	6.5	6.4	6.4	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	7	7	7	7	7	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6	6.5	6.7	6.7	7	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6.6	6.6	6.5	6.7	6.9	-4	2	Shrimp

Shrimp Scampi (Sample); 2week	7.1	7	5.5	6	5.5	-4	2	Shrimp
Shrimp Scampi (Sample); 2week	6.7	6.7	6.8	6.7	6.7	-4	2	Shrimp
Breakfast Steak (Control); 4week	6.8	6.8	6.8	6.7	6.8	Control	4	Steak
Breakfast Steak (Control); 4week	7	7	7	7	7	Control	4	Steak
Breakfast Steak (Control); 4week	7.9	7.5	8	7	7.7	Control	4	Steak
Breakfast Steak (Control); 4week	7.5	7	6.8	6.5	6.9	Control	4	Steak
Breakfast Steak (Control); 4week	7	7	7	7	7	Control	4	Steak
Breakfast Steak (Control); 4week	4.9	6.3	6.1	5.7	6	Control	4	Steak
Breakfast Steak (Control); 4week	7.2	7.5	7.5	7.3	7.3	Control	4	Steak
Breakfast Steak (Control); 4week	6.9	6.9	6.9	6.7	6.8	Control	4	Steak
Breakfast Steak (Control); 4week	7	7	7	6.7	6.9	Control	4	Steak
Breakfast Steak (Control); 4week	6.7	6.7	6.8	6.8	6.8	Control	4	Steak
Breakfast Steak (Control); 4week	7	7	7	7.2	7	Control	4	Steak
Breakfast Steak (Control); 4week	7.2	7.2	7.2	6.8	7.1	Control	4	Steak
Breakfast Steak (Sample); 4week	7	7	7	7	7	-4	4	Steak
Breakfast Steak (Sample); 4week	5.6	7	7.2	6	6.4	-4	4	Steak
Breakfast Steak (Sample); 4week	7.9	7.5	8	7.5	7.9	-4	4	Steak
Breakfast Steak (Sample); 4week	4	6.2	7	6.3	5	-4	4	Steak
Breakfast Steak (Sample); 4week	7	7	7	7	7	-4	4	Steak
Breakfast Steak (Sample); 4week	5.8	6	6.3	5.7	6	-4	4	Steak
Breakfast Steak (Sample); 4week	7.2	7.5	7.6	7.2	7.2	-4	4	Steak
Breakfast Steak (Sample); 4week	6.9	6.9	6.9	6.8	6.8	-4	4	Steak
Breakfast Steak (Sample); 4week	7	7	7	7	7	-4	4	Steak
Breakfast Steak (Sample); 4week	6.7	6.5	6.4	6.5	6.4	-4	4	Steak
Breakfast Steak (Sample); 4week	7	6.7	6.5	6	6.3	-4	4	Steak
Breakfast Steak (Sample); 4week	7.5	7.5	7.7	7.4	7.7	-4	4	Steak
Chicken Cordon Bleu (Control); 4week	7	7	7	7	7	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7	7	7	6.5	6.8	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	8	7.8	8	8	8	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7	6.8	6.8	6.7	6.8	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7	7	7	6.8	6.8	Control	4	Chicken

Chicken Cordon Bleu (Control); 4week	6.4	6.4	7	7	7.1	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	8	7.5	7.5	7.9	7.7	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7	7	7	7	7	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7	7	7.1	7.1	7.1	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	6.9	6.5	6.4	6.7	6.5	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7.5	7.5	7.5	7.5	7.5	Control	4	Chicken
Chicken Cordon Bleu (Control); 4week	7.6	6.9	7.2	6.9	6.9	Control	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7	7	7	7	7	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7	7	7	7	7	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	8	7.5	7.5	8	7.7	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	6.5	6.5	6.2	6.5	6.3	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7	7	7	7	7	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7	6.5	6.5	6.7	6.6	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	8	7.5	7.5	7.5	7.5	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7	7	7	7	7	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	6.7	7	7.2	6.7	6.8	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	6.9	6.6	6.5	6.9	6.6	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7.5	7.5	7.5	7.5	7.5	-4	4	Chicken
Chicken Cordon Bleu (Sample); 4week	7.7	7.6	7.6	7.7	7.7	-4	4	Chicken
Shrimp Scampi (Control); 4week	7	7	7	7	7	Control	4	Shrimp
Shrimp Scampi (Control); 4week	7	7	7	7	7	Control	4	Shrimp
Shrimp Scampi (Control); 4week	8	7	7	8	7.4	Control	4	Shrimp
Shrimp Scampi (Control); 4week	6	6.4	6.3	6.2	6.2	Control	4	Shrimp
Shrimp Scampi (Control); 4week	7	7	7	7	7	Control	4	Shrimp
Shrimp Scampi (Control); 4week	6.3	6.4	6.9	6.4	6.3	Control	4	Shrimp
Shrimp Scampi (Control); 4week	8	7.7	7.5	7.9	7.8	Control	4	Shrimp
Shrimp Scampi (Control); 4week	6.8	6.8	6.7	6.8	6.8	Control	4	Shrimp
Shrimp Scampi (Control); 4week	7	7	7.1	7	7	Control	4	Shrimp
Shrimp Scampi (Control); 4week	6.9	6.9	6.9	7	6.9	Control	4	Shrimp
Shrimp Scampi (Control); 4week	6.3	6.7	6.5	7	6.7	Control	4	Shrimp
Shrimp Scampi (Control); 4week	7.5	7.6	7.6	7.6	7.7	Control	4	Shrimp

Shrimp Scampi (Sample); 4week	7	6.7	6.5	6.5	6.4	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	7	7	7	7	7	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	8	7.5	7.5	8	7.7	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.2	6.7	6.7	6.2	6.4	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	7	7	7	7	7	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.2	6.4	6.9	6.2	6.3	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	8	7.7	7.5	7.8	7.8	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.7	6.8	6.7	6.7	6.7	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.5	7	7	6.8	6.9	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.9	6.7	6.8	6.8	6.7	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	6.5	7	6.5	7	6.9	-4	4	Shrimp
Shrimp Scampi (Sample); 4week	7.6	7.5	7.5	7	7.4	-4	4	Shrimp
Chicken Cordon Bleu - Control	7.5	7.2	7.2	7	7.1	Control	16	Chicken
Chicken Cordon Bleu - Control	6.5	6.4	6.5	6.5	6.5	Control	16	Chicken
Chicken Cordon Bleu - Control	7.5	7.5	7.5	7.5	7.5	Control	16	Chicken
Chicken Cordon Bleu - Control	8	8	8	8	8	Control	16	Chicken
Chicken Cordon Bleu - Control	7.5	7.3	7.3	7.5	7.4	Control	16	Chicken
Chicken Cordon Bleu - Control	7	7.1	7.2	7	7	Control	16	Chicken
Chicken Cordon Bleu - Control	7	7	7	7.1	7	Control	16	Chicken
Chicken Cordon Bleu - Control	7	7.1	7.2	7.1	7.2	Control	16	Chicken
Chicken Cordon Bleu - Control	7	7	7	7	7	Control	16	Chicken
Chicken Cordon Bleu - Control	7.4	7.4	7.5	7.4	7.4	Control	16	Chicken
Chicken Cordon Bleu - Control	6.5	6.5	6.5	6.6	6.5	Control	16	Chicken
Chicken Cordon Bleu - Control	8	8	8	8	8	Control	16	Chicken
Chicken Cordon Bleu - -4C	7.5	7.4	7.3	7	7.1	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.5	6.4	6.2	6	6.1	-4	16	Chicken
Chicken Cordon Bleu - -4C	7.4	7.4	7.4	7.4	7.4	-4	16	Chicken
Chicken Cordon Bleu - -4C	7.6	7.5	7.5	6.5	6.5	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.8	7	6.9	6.8	6.9	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.9	7.1	7.1	7.2	7	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.5	7	6.8	7.7	6.8	-4	16	Chicken

Chicken Cordon Bleu - -4C	7.1	7.1	7.2	7.2	7.2	-4	16	Chicken
Chicken Cordon Bleu - -4C	7.1	7	7	6.7	6.9	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.4	6.8	6.8	6.4	6.5	-4	16	Chicken
Chicken Cordon Bleu - -4C	6.5	6	6.2	5.7	5.8	-4	16	Chicken
Chicken Cordon Bleu - -4C	7.8	7.8	7.7	7.7	7.7	-4	16	Chicken
Steak- Control	7.2	7	7.5	7.4	7.5	Control	16	Steak
Steak- Control	6.5	6.5	6.5	6	6.1	Control	16	Steak
Steak- Control	6.5	7	7	6.5	6.8	Control	16	Steak
Steak- Control	6.8	7	7	7	7	Control	16	Steak
Steak- Control	7.5	7.2	7.4	7.3	7.3	Control	16	Steak
Steak- Control	7.1	7.2	7.5	7.4	7.3	Control	16	Steak
Steak- Control	7	7	7	6.8	7	Control	16	Steak
Steak- Control	7	6.9	6.7	6.6	6.8	Control	16	Steak
Steak- Control	7	7	7	6.7	6.8	Control	16	Steak
Steak- Control	7.1	7	7.4	6.6	7.1	Control	16	Steak
Steak- Control	7	7	7	7	7	Control	16	Steak
Steak- Control	7.8	7.8	8	7.7	7.8	Control	16	Steak
Steak - -4C	7.2	7.2	7.5	7.4	7.5	-4	16	Steak
Steak - -4C	6.3	6.3	6.5	6.4	6.4	-4	16	Steak
Steak - -4C	7	7	7	7	7	-4	16	Steak
Steak - -4C	7.2	7.3	7.3	7.2	7.2	-4	16	Steak
Steak - -4C	7.4	6.7	6.7	7.2	6.8	-4	16	Steak
Steak - -4C	7.2	7.3	7.6	7.3	7.3	-4	16	Steak
Steak - -4C	7	7	7	7	7	-4	16	Steak
Steak - -4C	6.7	7	6.9	7	6.9	-4	16	Steak
Steak - -4C	7	7	7	7	7	-4	16	Steak
Steak - -4C	6.6	6.7	6.6	6.4	6.6	-4	16	Steak
Steak - -4C	7	7	7	7	7	-4	16	Steak
Steak - -4C	7.9	7.7	8.2	8	8	-4	16	Steak
Shrimp Scampi - Control	7.6	7.4	7.5	7.4	7.5	Control	16	Shrimp
Shrimp Scampi - Control	6.5	6.5	6.3	6.2	6.2	Control	16	Shrimp

Shrimp Scampi - Control	7.5	7.5	7.5	7.5	7.5	Control	16	Shrimp
Shrimp Scampi - Control	7.3	7.3	7.3	7.2	7.3	Control	16	Shrimp
Shrimp Scampi - Control	7	7.1	7.1	7	7	Control	16	Shrimp
Shrimp Scampi - Control	7.2	7.2	7.5	6.9	7.1	Control	16	Shrimp
Shrimp Scampi - Control	7	7	7	6.8	6.9	Control	16	Shrimp
Shrimp Scampi - Control	7	7	7.2	7.2	7.1	Control	16	Shrimp
Shrimp Scampi - Control	7	7	7	7	7	Control	16	Shrimp
Shrimp Scampi - Control	7.1	7.4	7.4	7.2	7.3	Control	16	Shrimp
Shrimp Scampi - Control	6.5	6.5	6.5	6.5	6.5	Control	16	Shrimp
Shrimp Scampi - Control	7.7	7.7	7.7	7.4	7.6	Control	16	Shrimp
Shrimp Scampi - -4C	7.3	7.1	6.8	7.2	6.9	-4	16	Shrimp
Shrimp Scampi - -4C	6	6.2	5.9	6	6	-4	16	Shrimp
Shrimp Scampi - -4C	7.5	6	4.5	7	4.8	-4	16	Shrimp
Shrimp Scampi - -4C	7.2	7.3	7	7	7	-4	16	Shrimp
Shrimp Scampi - -4C	6.8	6.8	6.5	6.5	6.6	-4	16	Shrimp
Shrimp Scampi - -4C	6.8	7	7.1	6.9	6.9	-4	16	Shrimp
Shrimp Scampi - -4C	6.6	6.9	6.4	6.3	6.5	-4	16	Shrimp
Shrimp Scampi - -4C	6.7	6.7	6	7	6	-4	16	Shrimp
Shrimp Scampi - -4C	6.8	6.8	6.8	6.9	6.8	-4	16	Shrimp
Shrimp Scampi - -4C	7	7.3	7.2	7	7	-4	16	Shrimp
Shrimp Scampi - -4C	6	6	5.5	6	5.5	-4	16	Shrimp
Shrimp Scampi - -4C	7.5	7.8	7.5	7.2	7.4	-4	16	Shrimp
Chicken Cordon Bleu; -12; 24 weeks	7.7	7.6	7.5	7.6	7.5	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	6	6	6	6	6	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7	6	6	5.5	5.8	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7.5	7.5	7.5	7.5	7.5	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	6.3	5.8	5.5	6.2	5.6	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7	6.8	6.5	6.5	6.6	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7.5	7	7.2	7.2	7.2	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	6.8	6.8	6.9	6.8	6.8	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	6.8	7.3	7	7	6.9	-12	24	Chicken

Chicken Cordon Bleu; -12; 24 weeks	6.7	6.7	6.8	6.7	6.7	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7.3	7.5	6.2	7	6.5	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7.6	7.5	7.6	7.6	7.6	-12	24	Chicken
Chicken Cordon Bleu; -12; 24 weeks	7	6.8	6.7	6.7	6.7	-12	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7.5	7.7	7.5	6.6	7	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6	6	6	6	6	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7	7	7	7	7	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7.5	7.5	7.5	7.5	7.5	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6.5	6	6	6.3	6	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6.1	6.4	6.1	6.1	6.1	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7.5	7.5	7.5	7.5	7.5	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6.6	6.8	6.9	6.9	6.9	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7.5	7.5	7.5	7.4	7.5	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6.6	6.7	6.7	6.8	6.7	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	6.6	6.5	5.9	7	6.3	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7.6	7.4	7.5	7.5	7.5	-18	24	Chicken
Chicken Cordon Bleu; -18; 24 weeks	7	6.7	6.7	6.7	6.7	-18	24	Chicken
Chicken Cordon Bleu; Control	7.6	7.5	7.2	7.5	7.2	Control	24	Chicken
Chicken Cordon Bleu; Control	5.9	6	6	6	6	Control	24	Chicken
Chicken Cordon Bleu; Control	6.5	6.5	6.5	6.5	6.5	Control	24	Chicken
Chicken Cordon Bleu; Control	7.5	7.5	7.5	7.5	7.5	Control	24	Chicken
Chicken Cordon Bleu; Control	6.4	5.7	5	6.3	5.2	Control	24	Chicken
Chicken Cordon Bleu; Control	7	6.8	6.6	6.7	6.7	Control	24	Chicken
Chicken Cordon Bleu; Control	7.5	7	7	7.2	7.2	Control	24	Chicken
Chicken Cordon Bleu; Control	6.8	6.7	6.6	6.8	6.7	Control	24	Chicken
Chicken Cordon Bleu; Control	7.2	7.5	7.3	7.3	7.3	Control	24	Chicken
Chicken Cordon Bleu; Control	6.7	6.7	6.7	6.7	6.7	Control	24	Chicken
Chicken Cordon Bleu; Control	7	7.2	6.5	6.7	6.5	Control	24	Chicken
Chicken Cordon Bleu; Control	7.7	7.4	7.4	7.5	7.4	Control	24	Chicken
Chicken Cordon Bleu; Control	7	6.8	6.8	6.7	6.8	Control	24	Chicken
Shrimp Scampi; -12; 24 weeks	6.8	7	7.5	7.5	7.5	-12	24	Shrimp

Shrimp Scampi; -12; 24 weeks	6	5.8	5.7	6	5.8	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7	7	7	7	7	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7.5	7.5	7.5	7.5	7.5	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	6.7	6.8	6.8	6.8	6.8	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	6.3	6.5	6.4	6	6	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7.3	7.3	7.3	7.3	7.3	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	6.9	6.9	6.9	6.9	6.9	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	6.9	7.4	7	7	7	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	6.6	6.5	6.5	6.6	6.5	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7.2	7.3	6.5	6.5	6.6	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7.6	7.5	7.4	7.5	7.4	-12	24	Shrimp
Shrimp Scampi; -12; 24 weeks	7	7.2	7.2	7	7.1	-12	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.8	7.3	7.5	7.5	7.4	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6	5.8	5.8	5.7	5.7	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	7	7	7	7	7	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	7.5	7.5	7	7.5	7.2	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.7	6.2	5.8	6.6	5.8	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.5	6.5	6.4	6.5	6.5	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	7.2	7.3	7.2	7.2	7.3	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.5	6.9	6.8	6.7	6.8	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.8	7.4	6.9	7	6.9	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	6.6	6.6	6.5	6.3	6.4	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	5.5	6.7	7.4	7	7	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	7.6	7.4	7.3	7.4	7.3	-18	24	Shrimp
Shrimp Scampi; -18; 24 weeks	7	7.2	7.2	7	7.1	-18	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6.7	7.3	7.5	7.5	7.4	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6	6	6	6	6	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7.5	7.5	7.5	7.5	7.5	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7.5	7.5	7.5	7.5	7.5	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6.7	6.7	6.5	6.6	6.6	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6.5	6.5	6.5	6.6	6.5	Control	24	Shrimp

Shrimp Scampi; Control; 24 weeks	7.3	7.3	7.3	7.2	7.3	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6.5	6.7	6.7	6.7	6.8	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7.6	7.5	7.5	7.4	7.5	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	6.5	6.6	6.6	6.7	6.6	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7.8	7.5	7.2	7.5	7.7	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7.7	7.5	7.6	7.7	7.6	Control	24	Shrimp
Shrimp Scampi; Control; 24 weeks	7	7.2	7.3	7.2	7.2	Control	24	Shrimp
Steak; -12; 24 weeks	6.6	7.4	7.6	7.6	7.6	-12	24	Steak
Steak; -12; 24 weeks	6	6.2	6.5	6.2	6.2	-12	24	Steak
Steak; -12; 24 weeks	4	7	5.5	4.5	4.8	-12	24	Steak
Steak; -12; 24 weeks	7.5	7.4	7.1	7.4	7.3	-12	24	Steak
Steak; -12; 24 weeks	6.5	5.7	5.5	6.5	5.5	-12	24	Steak
Steak; -12; 24 weeks	6.4	6.5	6.5	6.4	6.5	-12	24	Steak
Steak; -12; 24 weeks	7.5	7.5	7.2	7.2	7.4	-12	24	Steak
Steak; -12; 24 weeks	6.6	6.5	6.6	6.4	6.3	-12	24	Steak
Steak; -12; 24 weeks	6.9	7.4	7.4	6.7	7.1	-12	24	Steak
Steak; -12; 24 weeks	6.8	6.7	6.7	6.6	6.8	-12	24	Steak
Steak; -12; 24 weeks	6.7	7.2	7.2	7.2	7.3	-12	24	Steak
Steak; -12; 24 weeks	6.9	7.1	7.6	7.5	7.5	-12	24	Steak
Steak; -12; 24 weeks	7.3	7.3	7.4	7	7.2	-12	24	Steak
Steak; -18; 24 weeks	6.7	6.9	7	6.9	6.9	-18	24	Steak
Steak; -18; 24 weeks	4	5	4.4	4.5	4.5	-18	24	Steak
Steak; -18; 24 weeks	6.5	6.5	6	6	6	-18	24	Steak
Steak; -18; 24 weeks	7.4	7.4	7.1	7.5	7.3	-18	24	Steak
Steak; -18; 24 weeks	6.2	6.3	6.3	6.2	6.3	-18	24	Steak
Steak; -18; 24 weeks	6.3	6.4	6.5	6.3	6.5	-18	24	Steak
Steak; -18; 24 weeks	7.5	7.5	7.3	7.2	7.5	-18	24	Steak
Steak; -18; 24 weeks	6.9	6.8	6.9	6.9	6.9	-18	24	Steak
Steak; -18; 24 weeks	6.7	6.8	6.7	6.7	6.7	-18	24	Steak
Steak; -18; 24 weeks	6.8	6.8	6.7	6.5	6.7	-18	24	Steak
Steak; -18; 24 weeks	5.8	7.2	6.8	6.3	6.2	-18	24	Steak

Steak; -18; 24 weeks	7.2	6.9	7.4	7.3	7.3	-18	24	Steak
Steak; -18; 24 weeks	6.7	6.8	6.8	6.6	6.7	-18	24	Steak
Steak; Control; 24 weeks	7	7.8	7.8	7.6	7.7	Control	24	Steak
Steak; Control; 24 weeks	5	6	6	5.5	5.5	Control	24	Steak
Steak; Control; 24 weeks	8	7.5	7.5	6.8	7.5	Control	24	Steak
Steak; Control; 24 weeks	7.5	7.5	7.2	7.5	7.4	Control	24	Steak
Steak; Control; 24 weeks	7.2	6.7	6.8	7	7	Control	24	Steak
Steak; Control; 24 weeks	6.9	6.5	6.6	6.5	6.6	Control	24	Steak
Steak; Control; 24 weeks	7.5	7.5	7.5	7.2	7.5	Control	24	Steak
Steak; Control; 24 weeks	6.9	6.8	6.8	6.9	6.8	Control	24	Steak
Steak; Control; 24 weeks	7.5	7.5	7.5	7.4	7.5	Control	24	Steak
Steak; Control; 24 weeks	6.6	6.7	6.7	6.6	6.7	Control	24	Steak
Steak; Control; 24 weeks	7.5	7.5	7.5	7.5	7.7	Control	24	Steak
Steak; Control; 24 weeks	7.4	7.4	7.8	8	7.8	Control	24	Steak
Steak; Control; 24 weeks	7	7	7.2	7.2	6.8	Control	24	Steak
Chicken Cordon Blue; 40wks; -12	6.5	7.1	7	7	7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	6.5	6.5	6.5	6.5	6.5	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	6.5	7	7	7	7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7.2	6.8	6.8	6.8	6.8	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	6.4	6.7	6.5	6.5	6.5	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7.3	7.2	7.1	7.5	7.5	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7	6.9	7	7	7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7	6.8	6.8	6.8	6.7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7	7	6.5	6.9	6.7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	6.9	6.9	6.8	6.6	6.7	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	6.5	6.5	6.2	6.3	6.3	-12	40	Chicken
Chicken Cordon Blue; 40wks; -12	7.7	7.5	7.6	7.4	7.5	-12	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.2	7.1	6.9	6.9	6.7	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.5	6.5	6.5	6.5	6.5	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.5	6.5	6.5	6	6.3	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	7.1	6.7	6.7	6.7	6.7	Control	40	Chicken

Chicken Cordon Blue; 40wks; Control	6.7	6.4	6.3	6.5	6.4	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	7.3	7.2	7	7.2	7.3	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.9	6.9	6.5	6.7	6.7	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	7	6.9	6.9	6.7	6.9	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	7	7	6.5	6.9	6.7	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.9	6.9	6.9	6.8	6.9	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	6.5	6.5	6.5	6.5	6.5	Control	40	Chicken
Chicken Cordon Blue; 40wks; Control	7.5	7.4	7.1	7	7	Control	40	Chicken
Shrimp Scampi; 40wks; -12	6.1	7.5	7.4	7	7.4	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6	6	6	6.2	6	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	7	6.7	6.8	5.8	6	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	7.2	6.6	6.6	6.5	6.5	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6.3	6.5	6.4	6.5	6.5	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	7.5	7	6.8	6	6.5	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6.3	6.1	6.1	6.2	6.1	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6.7	6.6	6.4	6.4	6.4	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	7	7	6.8	6.9	6.9	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6.8	6.7	6.7	6.7	6.7	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	6.7	6.5	6.5	6.5	6.5	-12	40	Shrimp
Shrimp Scampi; 40wks; -12	7.4	6.9	6.2	7.3	6.4	-12	40	Shrimp
Shrimp Scampi; 40wks; Control	6.1	7	7	7	7	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	6.5	6.5	6.5	6.5	6.5	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7	7	7	7	7	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7.2	7	6.7	6.7	6.7	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7	6.5	6.5	6.5	6.5	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7.5	7.5	7.5	7.5	7.5	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7	7	6.7	6.9	6.7	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	6.8	6.7	6.7	6.8	6.8	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	7	7	6.8	6.8	6.8	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	6.9	6.8	6.7	6.7	6.7	Control	40	Shrimp
Shrimp Scampi; 40wks; Control	6.8	6.8	6.8	6.7	6.7	Control	40	Shrimp

Shrimp Scampi; 40wks; Control	7.5	7.3	7.5	7.7	7.6	Control	40	Shrimp
Steak; 40wks; -12	7.1	7.4	7.4	7	7.2	-12	40	Steak
Steak; 40wks; -12	6.5	6.5	6.3	6.3	6.2	-12	40	Steak
Steak; 40wks; -12	7	7	7	6.8	7	-12	40	Steak
Steak; 40wks; -12	7.3	7	7.4	7	7	-12	40	Steak
Steak; 40wks; -12	6.5	6.7	6.6	6.5	6.5	-12	40	Steak
Steak; 40wks; -12	7.5	6.9	7.2	7	7.2	-12	40	Steak
Steak; 40wks; -12	6.9	6.9	6.7	6.9	6.9	-12	40	Steak
Steak; 40wks; -12	7	7	6.8	6.6	6.9	-12	40	Steak
Steak; 40wks; -12	6.8	7	7	6.5	6.7	-12	40	Steak
Steak; 40wks; -12	6.7	6.8	6.7	6.4	6.6	-12	40	Steak
Steak; 40wks; -12	6.5	6.2	6.2	6.2	6.3	-12	40	Steak
Steak; 40wks; -12	7.3	7.3	7.8	7.7	7.7	-12	40	Steak
Steak; 40wks; Control	6.5	7.3	7.2	6.8	6.9	Control	40	Steak
Steak; 40wks; Control	6.5	6.6	6.5	6.5	6.5	Control	40	Steak
Steak; 40wks; Control	7	6.5	5.7	6.5	6.2	Control	40	Steak
Steak; 40wks; Control	7.2	7	6.7	6.8	6.8	Control	40	Steak
Steak; 40wks; Control	7	6.6	6.7	7	6.9	Control	40	Steak
Steak; 40wks; Control	7.5	7	7.2	7	7.2	Control	40	Steak
Steak; 40wks; Control	6.5	6.9	6.9	6.9	6.9	Control	40	Steak
Steak; 40wks; Control	7	7	6.9	6.6	6.8	Control	40	Steak
Steak; 40wks; Control	7	7	7	7	7	Control	40	Steak
Steak; 40wks; Control	6.7	6.7	6.7	6.4	6.6	Control	40	Steak
Steak; 40wks; Control	6.5	6.2	6.2	6.2	6.2	Control	40	Steak
Steak; 40wks; Control	6.7	6.7	7.3	7.2	7.1	Control	40	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.4	6.7	6.5	6.4	6.5	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7.5	7.5	7.5	7.5	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7.2	7	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7.5	7.6	7.5	7.5	7.5	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.2	6.5	6.5	6.2	6.3	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	5.8	7	7	6	6	-4	0	Steak

Breakfast Steak 6oz; Initial Panel Controls	6	7.2	7.2	6.7	7.1	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	7.4	7.3	6.4	6.6	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7.5	6.7	7.1	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.6	6.9	6.8	6.4	6.7	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.8	6.9	6.6	6.9	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7	7	-4	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.7	6.8	6.7	6.8	-4	0	Steak
Chicken Cordon Bleu; Initial Panel Controls	6.6	7.5	6.8	6.7	6.8	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7	6.7	6.8	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	6.7	6.7	6.7	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6.7	6.7	6.8	6.7	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6	6	6.5	6.1	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.5	6.8	6.5	6.7	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	6.6	6.5	6.5	6.7	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.5	7.4	7.5	7.1	7.5	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7.5	7.5	7.5	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.2	7.3	7.3	7.2	7.3	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.7	6.7	6.7	6.8	6.8	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	7	6.7	6.7	6.7	-4	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.6	6.6	6.6	6.6	-4	0	Chicken
Shrimp Scampi; Initial Panel Controls	7.3	7.3	7.2	7.1	7.1	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.7	7	7	6.9	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.8	6.8	6.8	6.8	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.5	7.2	7	7	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.7	6.5	6.2	6.2	6.4	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.5	6.8	7	6.7	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	7	6.3	6.4	6.6	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7.2	6.7	6.9	7	7	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7	7.5	7	7.5	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.3	7.4	7.2	7.3	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.5	6.6	6.6	6.6	-4	0	Shrimp

Shrimp Scampi; Initial Panel Controls	6.5	6.5	6.7	6.7	6.7	-4	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.9	7	6.9	6.9	-4	0	Shrimp
Breakfast Steak 6oz; Initial Panel Controls	6.4	6.7	6.5	6.4	6.5	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7.5	7.5	7.5	7.5	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7.2	7	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7.5	7.6	7.5	7.5	7.5	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.2	6.5	6.5	6.2	6.3	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	5.8	7	7	6	6	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6	7.2	7.2	6.7	7.1	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	7.4	7.3	6.4	6.6	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7.5	6.7	7.1	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.6	6.9	6.8	6.4	6.7	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.8	6.9	6.6	6.9	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7	7	-12	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.7	6.8	6.7	6.8	-12	0	Steak
Chicken Cordon Bleu; Initial Panel Controls	6.6	7.5	6.8	6.7	6.8	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7	6.7	6.8	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	6.7	6.7	6.7	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6.7	6.7	6.8	6.7	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6	6	6.5	6.1	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.5	6.8	6.5	6.7	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	6.6	6.5	6.5	6.7	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.5	7.4	7.5	7.1	7.5	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7.5	7.5	7.5	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.2	7.3	7.3	7.2	7.3	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.7	6.7	6.7	6.8	6.8	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	7	6.7	6.7	6.7	-12	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.6	6.6	6.6	6.6	-12	0	Chicken
Shrimp Scampi; Initial Panel Controls	7.3	7.3	7.2	7.1	7.1	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.7	7	7	6.9	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.8	6.8	6.8	6.8	-12	0	Shrimp

Shrimp Scampi; Initial Panel Controls	7	7.5	7.2	7	7	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.7	6.5	6.2	6.2	6.4	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.5	6.8	7	6.7	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	7	6.3	6.4	6.6	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7.2	6.7	6.9	7	7	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7	7.5	7	7.5	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.3	7.4	7.2	7.3	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.5	6.6	6.6	6.6	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	6.5	6.7	6.7	6.7	-12	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.9	7	6.9	6.9	-12	0	Shrimp
Breakfast Steak 6oz; Initial Panel Controls	6.4	6.7	6.5	6.4	6.5	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7.5	7.5	7.5	7.5	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7.2	7	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7.5	7.6	7.5	7.5	7.5	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.2	6.5	6.5	6.2	6.3	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	5.8	7	7	6	6	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6	7.2	7.2	6.7	7.1	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	7.4	7.3	6.4	6.6	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7.5	6.7	7.1	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.6	6.9	6.8	6.4	6.7	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.8	6.9	6.6	6.9	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	7	7	7	7	7	-18	0	Steak
Breakfast Steak 6oz; Initial Panel Controls	6.8	6.7	6.8	6.7	6.8	-18	0	Steak
Chicken Cordon Bleu; Initial Panel Controls	6.6	7.5	6.8	6.7	6.8	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	7	6.7	6.8	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	7	6.7	6.7	6.7	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6.7	6.7	6.8	6.7	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7	6	6	6.5	6.1	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.5	6.8	6.5	6.7	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	6.6	6.5	6.5	6.7	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.5	7.4	7.5	7.1	7.5	-18	0	Chicken

Chicken Cordon Bleu; Initial Panel Controls	7	7	7.5	7.5	7.5	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	7.2	7.3	7.3	7.2	7.3	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.7	6.7	6.7	6.8	6.8	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.5	7	6.7	6.7	6.7	-18	0	Chicken
Chicken Cordon Bleu; Initial Panel Controls	6.8	6.6	6.6	6.6	6.6	-18	0	Chicken
Shrimp Scampi; Initial Panel Controls	7.3	7.3	7.2	7.1	7.1	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.7	7	7	6.9	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.8	6.8	6.8	6.8	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.5	7.2	7	7	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.7	6.5	6.2	6.2	6.4	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.5	6.8	7	6.7	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	7	6.3	6.4	6.6	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7.2	6.7	6.9	7	7	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7	7.5	7	7.5	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	7.3	7.4	7.2	7.3	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.8	6.5	6.6	6.6	6.6	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	6.5	6.5	6.7	6.7	6.7	-18	0	Shrimp
Shrimp Scampi; Initial Panel Controls	7	6.9	7	6.9	6.9	-18	0	Shrimp
Breakfast Steak; 48wks@-18	6	6.1	6.5	6	6	-18	48	Steak
Breakfast Steak; 48wks@-18	7	7	6.4	6	6.3	-18	48	Steak
Breakfast Steak; 48wks@-18	6	5.5	5.3	5.3	5.3	-18	48	Steak
Breakfast Steak; 48wks@-18	6.7	6.6	6.2	6.3	6.4	-18	48	Steak
Breakfast Steak; 48wks@-18	6.7	6.5	6.9	6.9	7	-18	48	Steak
Breakfast Steak; 48wks@-18	7	7	7	6.9	7	-18	48	Steak
Breakfast Steak; 48wks@-18	6.8	6.7	6.7	6	6	-18	48	Steak
Breakfast Steak; 48wks@-18	7	6.9	7.2	6.7	7.2	-18	48	Steak
Breakfast Steak; 48wks@-18	7	7	7	6.8	6.9	-18	48	Steak
Breakfast Steak; 48wks@-18	6.5	7	6.7	6.5	6.7	-18	48	Steak
Breakfast Steak; 48wks@-18	6.5	6.6	6.5	6.4	6.5	-18	48	Steak
Breakfast Steak; 48wks@-18	7.5	7.3	7	6.7	7.1	-18	48	Steak
Breakfast Steak; 48wks@-20	6	6	6.2	6.2	6.2	-20	48	Steak

Breakfast Steak; 48wks@-20	7	7	6.4	6.1	6.4	-20	48	Steak
Breakfast Steak; 48wks@-20	7	6.5	6.5	5.5	6.2	-20	48	Steak
Breakfast Steak; 48wks@-20	6.9	6.7	6.5	6.5	6.6	-20	48	Steak
Breakfast Steak; 48wks@-20	6.7	6.6	6.7	6.5	6.8	-20	48	Steak
Breakfast Steak; 48wks@-20	7	7	7.2	7	7	-20	48	Steak
Breakfast Steak; 48wks@-20	6.8	6.8	6.8	6.8	6.8	-20	48	Steak
Breakfast Steak; 48wks@-20	7	6.7	7.5	6.5	7	-20	48	Steak
Breakfast Steak; 48wks@-20	7	7	7	6.8	6.9	-20	48	Steak
Breakfast Steak; 48wks@-20	6.6	6.7	6.7	6.2	6.5	-20	48	Steak
Breakfast Steak; 48wks@-20	6.2	6.2	6.3	6.2	6.2	-20	48	Steak
Breakfast Steak; 48wks@-20	7.5	7.4	7.4	6.7	7.4	-20	48	Steak
Shrimp Scampi; 48wks@-18	5.9	6.9	6.2	6.1	6.5	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	7	7	7	7	7	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.3	6.5	6.5	6.5	6.5	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.6	6.3	6.3	6.3	6.3	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.2	6.4	6.4	6.4	6.4	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.7	7	7	7	6.9	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.8	6.7	6.8	6.7	6.7	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.4	7.5	7.7	7.5	7.2	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.5	6.6	6.6	6.7	6.6	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.8	7	7	6.4	6.4	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	6.6	6.5	6.5	6.5	6.5	-18	48	Shrimp
Shrimp Scampi; 48wks@-18	7.8	7.7	7.7	7.6	7.7	-18	48	Shrimp
Shrimp Scampi; 48wks@-20	5.9	6.7	6.2	6.1	6.5	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	7	7	7	7	7	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6	6	6	5.5	5.5	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.6	6.2	6.2	6.2	6.2	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.2	6.4	6.3	6.3	6.4	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	7	7	6.9	7	6.9	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.7	6.7	6.7	6.8	6.8	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.5	7	7.5	7.2	7.2	Control	48	Shrimp

Shrimp Scampi; 48wks@-20	6.6	6.6	6.6	6.6	6.6	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.7	6.9	7	6.6	6.7	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	6.5	6.5	6.5	6.5	6.5	Control	48	Shrimp
Shrimp Scampi; 48wks@-20	7.1	7	7.1	6.5	6.8	Control	48	Shrimp
Chicken Cordon Bleu; 48wks@-18	6.7	6.7	6.2	6.1	6.5	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7	7	7	7	7	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	6.5	5.8	5.8	6	6	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	6.6	6.4	6.2	6.5	6.3	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7	6.4	6.5	6.4	6.5	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	8	7.5	7.5	7.5	7.5	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	6.7	6.8	6.8	6.8	6.8	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7	7	6.7	7	6.7	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7	7	7	7.1	7	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	6.5	7	7	6.9	6.8	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7	7	7	7	7	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-18	7.7	7.3	7.4	7.4	7.4	-18	48	Chicken
Chicken Cordon Bleu; 48wks@-20	6.3	6.4	6.2	6	6.4	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	7	6	6	6.5	6.5	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	4.8	5	4.8	5.5	5.5	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	6.6	6.1	5.7	6.3	5.8	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	6.8	6.4	6.5	6.4	6.5	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	8	7.4	7.5	7.4	7.5	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	6.8	6.7	6.8	6.7	6.8	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	7	6.7	7	6.5	6.7	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	7	7	7	6.7	6.9	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	6.3	6.6	6.2	6.3	6.5	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	7	7	6.5	6.7	6.6	Control	48	Chicken
Chicken Cordon Bleu; 48wks@-20	7.6	7.4	7.6	7.6	7.6	Control	48	Chicken
Steak; 18mos; -12	6.1	6.7	6.4	5.2	6	-12	72	Steak
Steak; 18mos; -12	6.2	5.7	5.8	6	5.8	-12	72	Steak
Steak; 18mos; -12	5	6	5	5	5	-12	72	Steak

Steak; 18mos; -12	6.7	6.7	6.8	6.7	6.7	-12	72	Steak
Steak; 18mos; -12	6.5	5.5	4.5	6.2	4.8	-12	72	Steak
Steak; 18mos; -12	6.5	6.5	6.7	6.3	6.5	-12	72	Steak
Steak; 18mos; -12	6.3	6.7	6.7	6.3	6.4	-12	72	Steak
Steak; 18mos; -12	7	7	7	6.5	6.8	-12	72	Steak
Steak; 18mos; -12	6.5	7	6.8	5	6	-12	72	Steak
Steak; 18mos; -12	8	7.9	7.7	7.9	7.9	-12	72	Steak
Steak; 18mos; -12	7	6.9	6.7	6.7	6.7	-12	72	Steak
Steak; 18mos; -12	6.3	6.6	6.7	6.3	6.4	-12	72	Steak
Steak; 18mos; -18	7.2	7.2	7.5	7.5	7.5	-18	72	Steak
Steak; 18mos; -18	6.3	6.4	6.5	6.3	6.5	-18	72	Steak
Steak; 18mos; -18	5.5	6.3	6	6	6	-18	72	Steak
Steak; 18mos; -18	6.8	6.7	6.7	6	6.2	-18	72	Steak
Steak; 18mos; -18	6.7	6.3	6	3.5	4	-18	72	Steak
Steak; 18mos; -18	6.5	6.4	6.5	6.2	6.4	-18	72	Steak
Steak; 18mos; -18	6.5	6.7	6.7	6.5	6.6	-18	72	Steak
Steak; 18mos; -18	7	6.8	6.6	6.7	6.6	-18	72	Steak
Steak; 18mos; -18	7	7.2	7	6.5	6.7	-18	72	Steak
Steak; 18mos; -18	8	8	8.2	7.4	8.1	-18	72	Steak
Steak; 18mos; -18	6.8	6.9	6.8	6.7	6.7	-18	72	Steak
Steak; 18mos; -18	6.4	6.6	6.7	6.4	6.5	-18	72	Steak
Steak; 18mos; -20	7.2	7	7.2	7.5	7.4	Control	72	Steak
Steak; 18mos; -20	6.8	6.8	7	6.7	6.8	Control	72	Steak
Steak; 18mos; -20	5.7	6.3	6.3	6.1	6.5	Control	72	Steak
Steak; 18mos; -20	6.8	6.7	6.7	6.4	6.5	Control	72	Steak
Steak; 18mos; -20	6.8	6.4	6.5	6.5	6.5	Control	72	Steak
Steak; 18mos; -20	6.7	6.7	7	7	7	Control	72	Steak
Steak; 18mos; -20	7.4	6.9	7.3	7.2	7.3	Control	72	Steak
Steak; 18mos; -20	7	7	7	6.8	6.9	Control	72	Steak
Steak; 18mos; -20	7.3	7.2	7.3	6.8	7	Control	72	Steak
Steak; 18mos; -20	8.5	8.5	8.7	7	8.5	Control	72	Steak

Steak; 18mos; -20	6.6	6.8	6.7	6.5	6.6	Control	72	Steak
Steak; 18mos; -20	6.4	6.6	6.7	6.3	6.4	Control	72	Steak
Chicken Cordon Bleu; 18mos; -12	6.8	6.6	6.6	6.6	6.6	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	7.2	7.2	7.2	7.2	7.2	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	7	7	7	7	7	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	7	7.1	7.1	7	7	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	6.9	7	7	6.9	7	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	6.5	6.2	6.2	6	6.3	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	6.7	6.6	6.6	6.6	6.6	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	6.5	6.3	6.5	6.2	6.3	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	7	7	7	7	7	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	7	7	7	6.5	6.7	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -12	6.5	6.4	6.7	6.4	6.5	-12	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.5	6.3	6	6.1	6	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.6	6.5	6.4	5.9	6.1	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	7	7	6.9	6.9	6.9	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	7	6	6	6	5.7	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.6	6.6	6.4	6.4	6.4	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.5	6.5	6.5	6.3	6.5	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.7	6.6	6.5	6.5	6.5	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	5.8	6	6	5.8	6	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	7	7	7	7	7	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	7	6.7	6.9	7	7	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -18	6.5	6.5	6.7	6.6	6.7	-18	72	Chicken
Chicken Cordon Bleu; 18mos; -20	6.7	6.7	6.5	6.6	6.6	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	7	7	6.8	6.8	6.8	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	7	7	7.3	7.2	7.2	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	7	7.1	7	7	7	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	6.8	7.1	7.2	7	7.1	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	6.6	6.5	6.5	6.9	6.6	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	6.8	6.7	6.7	6.7	6.7	Control	72	Chicken

Chicken Cordon Bleu; 18mos; -20	6.8	6.5	6.8	7	6.8	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	7	7	7	7	7	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	7	6.9	7	7	6.9	Control	72	Chicken
Chicken Cordon Bleu; 18mos; -20	6.3	6.5	6.7	6.7	6.8	Control	72	Chicken
Shrimp Scampi; 18mos; -12	6.6	6.5	6.4	6.5	6.4	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	7	7	7	7	7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.7	6.8	6.7	6.5	6.7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.5	6.5	6.5	6.5	6.5	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.4	6.6	6.7	6.4	6.5	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6	5.7	5.9	6	6	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.5	6.7	6.8	6.7	6.7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.2	7	6	5.4	5.7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	7	6.7	6.6	6.7	6.7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6	7	7	6.8	6.7	-12	72	Shrimp
Shrimp Scampi; 18mos; -12	6.2	6.5	6.5	6	5.9	-12	72	Shrimp
Shrimp Scampi; 18mos; -18	6.4	6.3	6.2	6.2	6.2	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	7	6.9	6.8	6.8	6.8	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	7	6.8	6.7	6.5	6.7	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6	6	5.5	5	5.3	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6.2	6.7	6.6	6.3	6.4	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6	6.1	6	6	6.2	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6.7	6.7	6.8	6.8	6.8	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	5.5	6.8	5.5	5	5.4	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6.6	6.6	6.2	6.7	6.6	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	6.5	6.7	6.8	6.6	6.6	-18	72	Shrimp
Shrimp Scampi; 18mos; -18	5.9	6.5	6.5	6	5.9	-18	72	Shrimp
Shrimp Scampi; 18mos; -20	6.6	6.6	6.6	6.6	6.6	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.9	6.1	6	6.1	6.1	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	7	7	6.9	6.9	6.9	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.2	6.3	6.2	6.2	6.3	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.8	6.9	6.9	6.8	6.8	Control	72	Shrimp

Shrimp Scampi; 18mos; -20	6	5.8	5.9	5.9	5.9	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.7	6.7	6.7	6.7	6.7	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.8	7	7	7	7	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	7	6.7	6.8	6.8	6.8	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.6	7	6.9	6.9	6.7	Control	72	Shrimp
Shrimp Scampi; 18mos; -20	6.7	6.5	6.5	6.5	6.5	Control	72	Shrimp

Appendix 4.8

UGR-A Analytical Quality Data (TWP#230)

COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION

UGR-A Analytical Quality Data

Technical Working Paper (TWP) #230

Neha Bhide

November 8, 2012

Sponsored by:

DEFENSE LOGISTICS AGENCY

8725 John J. Kingman Rd.

Fort Belvoir, VA 22060-6221

Contractor:

Rutgers, The State University of New Jersey

THE CENTER FOR ADVANCED FOOD TECHNOLOGY

School for Environmental and Biological Science

N.J. Agricultural Experiment Station

New Brunswick, New Jersey 08903

Chemical analysis of UGR-A rations:

As a food sample ages, two chemical changes that take place which can be measured ad quantified are oxidation of fatty acids and protein degradation. To quantify these two we chose the measurement of TBARs and TVBN respectively as our choice of methods.

The UGR-A samples for testing were Beef Steak, Chicken cordon Bleu and Shrimp Scampi. All samples were stored at -4, -12 and -18^{o}C, and periodically tested for quality. Since all the three samples were rich in fat content, TBARs assay was performed on all three samples periodically. The shrimp samples being rich in proteins and the most sensitive to degradation were also tested for protein degradation by the TVBN method.

An additional test was done to test the validity of the above-mentioned tests by maintaining a separate batch of fresh shrimp (IQF) vacuum packed in MRE pouches compared to ones packed in normal plastic pouches.

Following is a detailed explaination of the testing methods employed and the results obtained

I) Analysis of TBARs in food samples by distillation method:

Principle:

The oxidized fatty acids from the samples are volatile and obtained in the distillate. These compounds react with Thio barbituric acid to give a pink colored complex, which can be measured and quantified as degree of oxidation in the tested food sample with reference to a TEP standard curve.

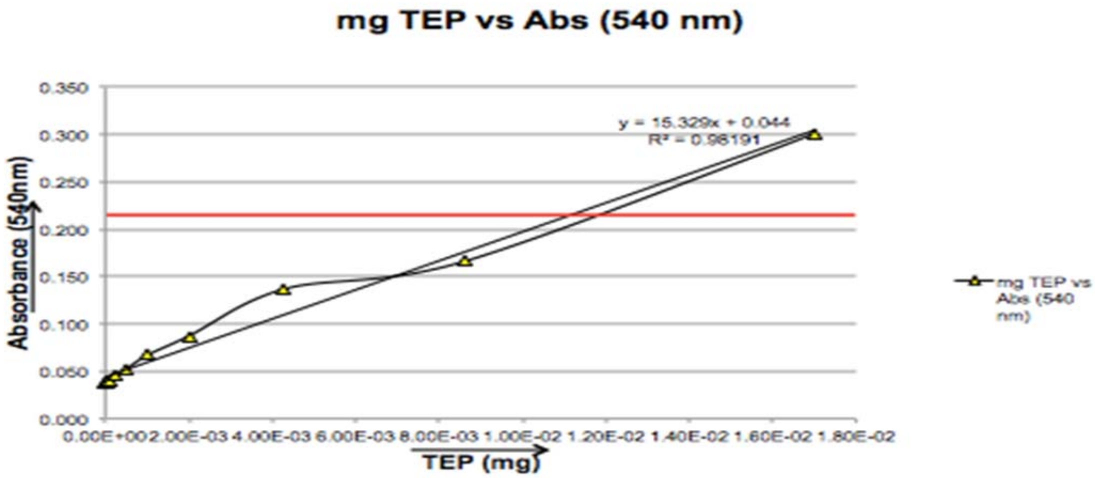
Materials and reagents:

Thawed meat samples, 4mm mesh grinder for meat, 0.02M Thio Barbituric Acid (TBA) in 90% glacial acetic acid, 1X10^{-3}M TEP in distilled water, 4N HCl solution, Butylated Hydroxytoluene (BHT), anti-foaming agent, boiling water bath, distillation apparatus

Procedure:

A) Procedure for standard curve:

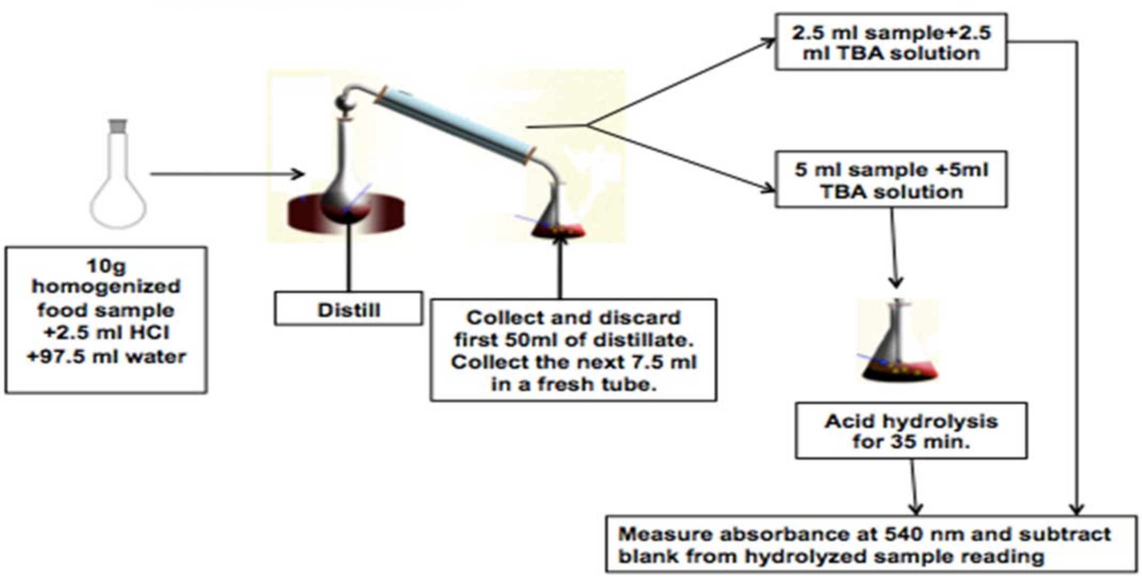
1. Take varying amounts of 1X10^{-3}M TEP with distilled water and make serial dilutions.
2. Take 5ml of these samples and add 5ml of 0.02MTBA.
3. Heat this mixture for 35 minutes in a boiling water bath.
4. Cool for 10 minutes and measure optical density with a spectrophotometer at 540mµ.
5. Plot known concentration against measured optical density to obtain a standard curve.



B) <u>Procedure for food sample:</u>

1. Thaw the frozen meat samples.
2. Grind 100gm meat with 10ml BHT in a mesh grinder of 4mm.
3. Take 10 gm aliquot at a time in a flat-bottom flask and add a drop of anti-foaming agent.
4. Add 2.5ml of 4N HCl and 97.5 ml distilled water to this flask, and distill this mixture.
5. Discard the first 50ml of distillate and take the next 5 ml in a fresh flask.
6. Add 5ml of 0.02M TBA.
7. Heat this mixture for 35 minutes in a boiling water bath.
8. Cool the sample for 10 minutes and measure optical density at 538mµ
9. Take all readings against a blank prepared by distilled water TBA mixture.

TBARS (Thiobarbituric Acid Reactive Substances)



II) Determination of total volatile basic nitrogen (TVB-N) in marine fish

Principle

The volatile basic nitrogen content is liberated by addition of magnesium oxide (MgO), a weak alkali, to the thoroughly homogenized fish, followed by steam distillation. The volatile bases are absorbed in boric acid solution, and determined by titration with 0.1 N acid. Alternatively an extract of fish with 0.6 N perchlorie acid is used for confirmation in cases ofdoubt.

Equipment

Steam distillation unit, Antona apparatus (consisting of 2-1 round-bottom flask with glass side arm and stop cock (steam generator), reaction vessel insert, connecting tube and coil condenser with extended outlet or an appropriate projection from the condenser, electric heating mantle for the 2-1 round bottom flask, receiver support (height adjustable), or Bfichi distillation unit model 315-special with insulating mantle for the reaction vessels, control valve for steam regulation and special condenser or a related unit with adjustable reduced steam flow), Mincer, homogenizer/blender (e.g., top-drive blender), 10- or 25-ml burette for the 0.1 N acid

Reagents

Water, distilled or deionized Magnesium oxide, reagent grade Silicone antifoam emulsion, Approximately 3% aqueous boric acid solution, 0.1 N hydrochloric or sulphuric acid, Tashiro-indicator mixture (methyl red and methylene blue), Perchloric acid, 0.6 N (6%) (for alternative method only)

Procedure:

A) Preparation o f the distillation unit

1. Before analysing samples, carry out a blind distillation of 200 ml water into the receiver (put 50 ml water into the reaction vessel and 100ml water into the receiver), to avoid TVB-N losses in the first distillates.

2.Adjust the distillate flow to 10 ml/min; check the distillate amount occasionally.

3. Pipette approx. 10m] of the boric acid solution into the graduated Erlenmeyer flask (receiver), add approx. 8 drops of the Tashiro indicator and fill up with distilled water to 100 ml.

4. Place the flask on the receiver support, so that the outlet of the condenser is immersed.

B) Preparation of samples

Take a fish flesh sample of at least 100 g (preferably a total fillet) and homogenize thoroughly with a mincer and/or blender Investigate immediately, within 1 h in chilled storage, otherwise quick freeze the minced sample (e.g., in a closed container/ plastic bag) and store at - 18 ° C or lower for a limited period.

C) Separation of TVB-N

-Directly from fish flesh

Weigh 10.0_+0.1 g from the well homogenized fish flesh sample into a suitably sized flat dish. After addition of a small amount of water disperse the sample with a glass rod. Transfer it by means of a powder funnel quantitatively into the reaction vessel. Rinse with a small amount of water to ensure that as far as possible the sample lies on the bottom of the vessel. Shake to ensure proper dispersion and avoid clotting during distillation

1. Bring the water in the round-bottom flask (approx. 1 1) to boiling point with the stopcock open in order to reduce dilution by condensation, which would retard the process of separation: close the cock when boiling starts.

2. Distill for 10 min with the outlet tube from the condenser immersed, and 2 min with it above the surface. (Lower the support with the receiver).

3. When distillation is completed, Open the cock in the steam generator (Antona unit) or switch off distillation (Biichi unit). Rinse the condenser outlet with a small amount of distilled water and then remove the receiver for titration, Preparation of the units for the following sample. Remove the reaction vessel while it is still hot, empty and rinse the reaction vessel well with water, also rinse condenser and connecting tube of the Antona unit a little. It is advantageous to operate with two reaction vessels alternately for preparation and distillation.

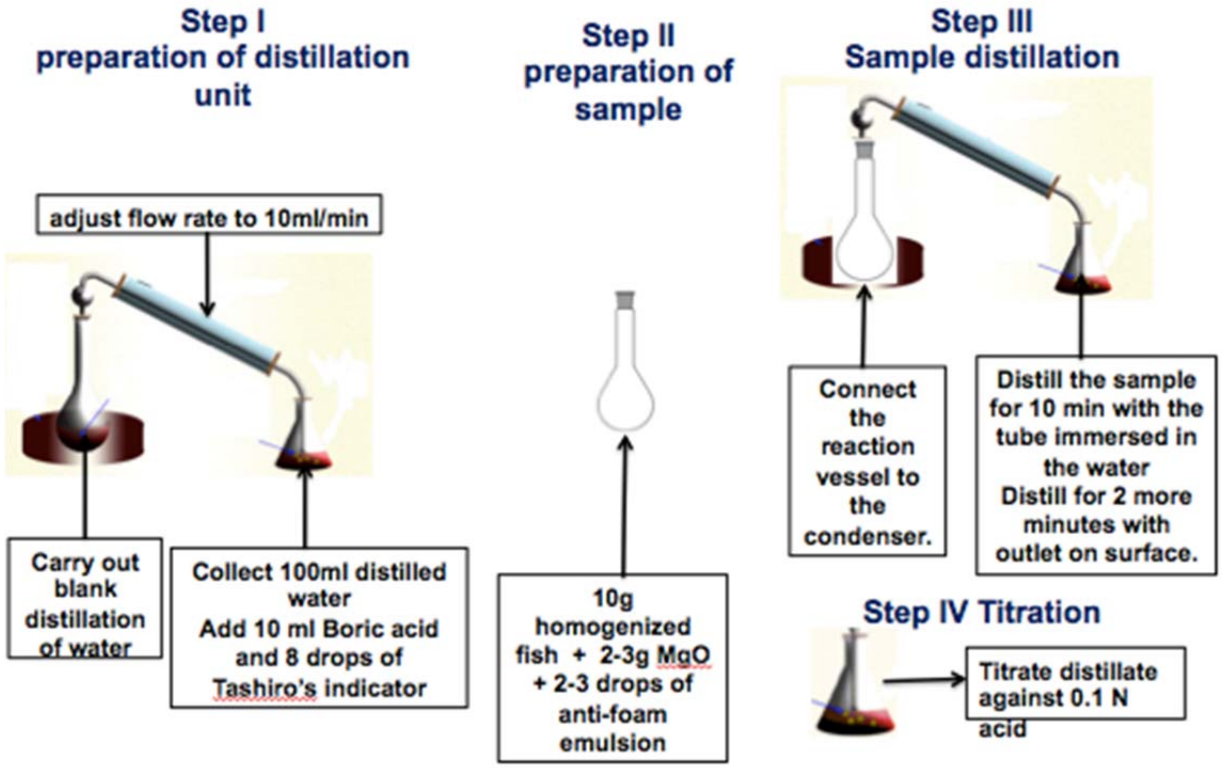
4. After each distillation, with glass stopcock open, fill up the steam generator with hot water and preheat near to the boiling point, before the next reaction vessel is inserted. Grease the joints well to avoid sticking.

Determination of TVB-N

1. Titrate the distillate containing the volatile basic nitrogen against the 0.1 N acid (from a burette) until the neutral point is reached (the colour changes from green to red-violet and is grey at the neutral point).

Calculation

Volume (ml of acid) x 14 = mg TVB-N/100 g or expressed more exactly: ml 0.1 N × 1.4 x 100/sample mass in g (if 25 ml extract is used, sample mass in calculation is 25% of original mass extracted).



Results:

TBARs were measured by measuring the absorbance at 540nm. And TVBN was calculated as mg of Nitrogen per 100g sapmle. The results were compared to standard results and the respective threshold limits for acceptable levels of TBARs and TVBNs.

The threshold for TBARs and TVBN are 0.2 (Absorbance at 540nm) and 25mg TVN/100g sample respectively.

Samples stored at -4, -12 and -18^{o} C were periodically pulled. Tests were performed and results were computed and recorded for amount of TBARs and TVBN as shown in the table.

-4 C					
Wk	Date	TBARS Absorbance at 540nm			TVBN TV mg TVN/100g sample
		shr	chi	bs	
0	3/14/11	0.0016	0.0053	0.012	20
1	3/21/11	0.002	0	0.0086	18.3
2	3/28/11	0.0018	-	0.011	18.8
4	4/11/11	0.0023	0	0.0066	20
6	4/25/11	0.002	0.001	0.001	18.3
12	8/22/11	0.0018	0.0015	0.009	15
16	9/19/11	0.0016	0.001	0.0066	-
24	11/14/11	0.002	0	0.008	-

-12 C					
Wk	Date	TBARS Absorbance at 540nm			TVBN TV mg TVN/100g sample
		shr	chi	bs	
0	3/14/11	0.0016	0.0053	0.012	20
8	5/9/11	0.001	0	0.005	10.825
24	8/29/11	0.0023	0	0.0066	16.25
40	11/28/11	0.0015	0.0015	0.001	-
72	7/30/12	0.0015	0.0015	0.009	7.085

-18 C					
Wk	Date	TBARS Absorbance at 540nm			TVBN TV mg TVN/100g sample
		shr	chi	Bs	
0	3/14/11	0.0016	0.0053	0.012	20
24	8/29/11	0.002	0	0.003	13.75
48	2/13/12	0.001	0.0006	0.03	12.5
72	7/30/12	0.001	0	0.0086	13.862

Conclusion:

For both the tests, at the end of the testing priod, we observe that, there is no significant difference or increase in the levels of TBARs and TVBN. Also, it should be noted that all of the recorded values are below the threshold limits for both and hence the food is chemically fit for consumption. Also, the recorded readings show no specific trend. We can hence conclude that the results are still in the noise region and hold no significance, as there is no degradation in chemical quality.

III) Sensory analysis:

Simultaneously, for every pull, a sensory analysis was done by a panel at Natick. Samples were shipped to Natick every time they were pulled for chemical analysis. This sensory testing helped in validating the chemical tests.

The samples were prepared and tasted. They were then rated on a scale of 1 to 10 for each of the following parameters:

1. Appearance
2. Texture
3. Flavor
4. Odor
5. Overall Quality

A score of 5.0 or less means that the food is unacceptable for consumption. The sensory quality of the samples never went below 6, indicating that the samples were acceptable throughout the considered shelf life. More detailed statistical analysis of the sensory data is being reported in a separate technical working paper.

Appendix 4.9

TTI Technology Survey (TWP#231)

COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION

Technical Working Paper (TWP) #231

TTI Technology Survey

Rieks Bruins

July 10, 2012

Sponsored by:
DEFENSE LOGISTICS AGENCY
8725 John J. Kingman Rd.
Fort Belvoir, VA 22060-6221

Contractor:
Rutgers, The State University of New Jersey
THE CENTER FOR ADVANCED FOOD TECHNOLOGY
School for Environmental and Biological Science
N.J. Agricultural Experiment Station
New Brunswick, New Jersey 08903

TTI Technology Survey

Introduction

UGR-A Distribution System

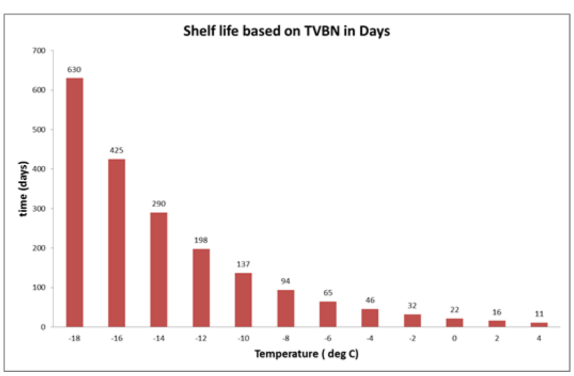
The current UGR-A frozen components are assembled into menu boxes and the menu boxes are then palletized. These pallets are loaded into refrigerated containers (-18 C) and shipped to various locations around the world, involving road, rail and sea transport. At the destination point, the container is unloaded and the palletized product is stored in prime vendor refrigerated warehouse (-18 C). Orders are placed by Forward Operating Bases (FOB) for specific quantity menu items. These orders are filled by the prime vendor who might breakdown the incoming pallet loads and assemble pallets loads with the required product. This product is then loaded into refrigerated trucks and delivered to the FOB.

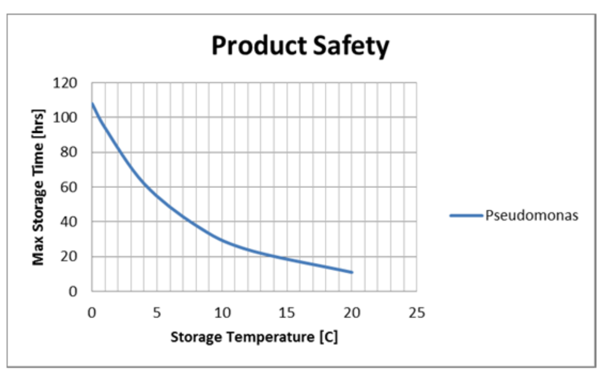
The temperature of the container that is shipped from the United States is being monitored and recorded. This data is down loaded at the destination point. One pallet (the nearest to the container door) has also a temperature recording device attached to it. This data is down loaded at the prime vendor destination point as well. This data is reviewed by the AVI at destination as well as a general inspection of the incoming product. Any out of the ordinary temperature upsets that are noted during the inspection of the temperature records could warrant further inspection of the product for product defrost/refreeze conditions. It should be noted that temperature upsets of several hours (5-10 hrs) during the transport sequence are normal as containers switch from one transport mode to another, the temperature of the container might rise during these transit points to -5 C.

The trucks that transport the product from the Prime Vendor Warehouse to the FOB are presumable equipped with chart recorders, but no additional recorders are attached to the pallet or product. It is not uncommon that temperature upsets occur during this last phase of product distribution due to mechanical breakdowns, excessive environmental temperatures, delays in transport, resulting in distressed product arriving at the FOB. These FOB do not have food inspectors available that can evaluate the quality and safety of the product upon receipt, hence the desire to have a TTI type device on the product that can assist the FOB operator in the decision process to accept/reject the product.

TTI Performance Criteria

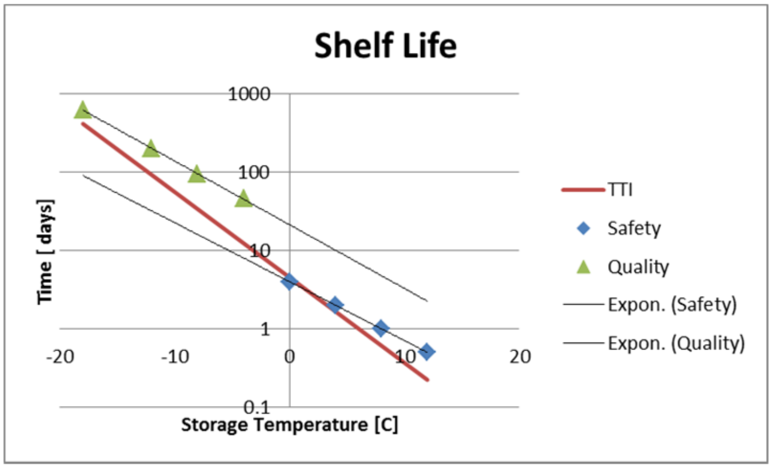
Performance criteria for a candidate TTI technology have been defined in Phase I of the project. Heat transfer models for three different UGR-A menu's have been developed and kinetic degradation values for both quality degradation as well as microbial growth established. Various case studies were evaluated to develop guidelines regarding acceptable time/temperature exposure. The two graphs below depict the shelf life of product for quality characteristics (TVBN) and microbial growth (*Pseudomonas*)





The above are two separate reactions with their own temperature range and their own activation energy as can be seen in the graph and table below.

If we decide to have two TTI's, one for quality and one for safety, we need to realize that the TTI for safety needs to be have a temperature trigger point, meaning that the reaction will not occur unless the temperature exceeds a certain point as microbial growth does not occur in products that are frozen (<-4 C). A TTI without a trigger point would otherwise indicate microbial problems during regular frozen storage (18 C) after about 80 days.



Storage Temp	Quality Shelf Life	Microbial Shelf Life	Desired TTI Response	Compromised Response
-18 C	630 days	>630 days	630 days	416 days
-12 C	198 days	>198 days	198 days	92 days
-8 C	94 days	>94 days	94 days	34 days
-4 C	46 days	>46 days	46 days	12 days
0 C	>4 days	4 days	4 days	4.5 days
+4 C	>2 days	2 days	2 days	1.7 days
+8 C	>1 day	1 day	1 day	0.6 days
+12 C	>0.5 day	0.5 day	0.5 day	0.22 days

We could simulate quality and microbial shelf life with a single TTI if we compromise by overestimating the quality degradation at storage temperatures ranging from -4 C to -18 C and over estimating bacterial growth at temperatures of +8 C and +12 C. This TTI would be able indicate that the product has exceeded storage for more than year at -18 C and/or if it was exposed to high temperatures for short duration that could lead to microbial growth. The key in determining the desired response time of the TTI will be the location of the label. The response time as indicated above would be good for a label that is located inside the shipping case attached to one of the product items. A label that is attached on the outside of the shipping case needs to react slower at higher temperature due to the lag time between shipping case temperature and surface temperature of the product. This lag time will need to be determined in heat transfer simulation studies.

Overview Available Technology

Various time/temperature indicating devices are commercially available, ranging from container security devices to color changing labels.

The most expensive devices are container security devices (CSD). These devises would not only detect if physically the door was opened, but could also monitor the temperature inside the container. These devises can communicate via satellite links to a central point to track the shipment and notify the user if and when the security of the container was breached and/or if the temperature of the container exceeded a threshold value. This technology was researched by the US Army Natick Soldier Development and Engineering Center (NSRDEC) and reported in Technical Report Natick/TR-08/009L

The mid-range devices are temperature recording devices that store data internally. These devices can be used at the container and/or pallet level. The data can be downloaded at the receiving end and evaluated. Based on a heat transfer model, calculations can be made to study the impact of the temperature fluctuations on the product temperature quality and safety. Examples of these systems are the SensiTech recorders (RYAN UTI, RYAN CR-1 and TempTale-4) currently used by the contractors during transport from the assembly location to the prime vendor. These devices are battery powered. Another class of recorders are smart RFID where the RFID tag has the ability to record some temperature data that can then be downloaded wirelessly. The smart RFID's are not fully mature.

The low cost devices have no data storage capability but can integrate the time temperature abuse based on some kind of first order kinetic reaction. These labels are referred to as TTI (Time Temperature Integrators), where the change in color is an indication of time temperature exposure. These devices can be located on each food item, either inside the case or on the outside of the case or be located on the pallet level. There is a variation of this technology that only integrates time once a threshold temperature value has been exceeded.

Container Security Devices (CSD)

The following is a list of companies that market container security devices. These devises are typically proprietary and lack an open standard, meaning that the data is being collected, managed and distributed by that company. The data is collected via satellite links. While these devices were original developed for detecting intrusion, the sensors can be equipped with additional sensors such as temperature.

- Savi Sensor Tag
- Impeva Labs Global Sentinel
- Avery Dennison CSD
- GE Security CSD
- Zenatek

Temperature Recording Devices

Temperature recording devices can be used either at the trailer level or at the pallet level. Both techniques are used in the current transportation system of UGR-A's. Each trailer is equipped with a recording device that measures the temperatures of the compressor, both the incoming as existing air temperature of the compressor air is being measured.
In addition, the military is monitoring the temperature on the last loaded pallet by sticking a temperature recorder to this pallet. Various systems from Sensitech are being used. Most of the shipments to Iraq and Afghanistan use the digital TemTale4 recorder and shipment to Europe use the Ryan UTI or Ryan CR-1 analog strip chart recorders. These recorders are removed once the truck is unloaded at the destination warehouse of the prime vendor and evaluated by the AVI for temperature upsets.

Products are distributed from these prime vendor locations to forward operating bases (FOB) where it then stored and consumed. Severe temperature abuse could happen in this last phase of product distribution. However, no reliable system is in place that monitors the temperature and no inspection agency is available to inspect the product at the receiving point for temperature abuse.

SensiTech Information:
Contact at SensiTech is John Snoke (704-953-5815).
Models:

- TempTale4 2K (1920 data points)
- TempTale4 16K (16,000 data points)
- Ryan UTI
- Ryan CR-1

Some of these units can be recycled

Semi Passive RFID

The following are companies that were marketed semi passive RFID's in 2011. While the main purpose of passive RFID tags is to identify the product via a serial number, a semi passive RFID is equipped with a small battery that allows it to store limited data, such as a maximum temperature or in some cases a calculated first order kinetic value such as a TTI. To read these passive RFID, hardware need to be acquired to interrogate these tags. These systems are still immature and the technology is constant changing. At the time of our survey, most systems were based on LF or HF technology and not compatible with UHF RFID technology (UHF gives extended reading range). Another issue is the accuracy of the temperature and time reading. Once the technology matures and the cost comes down, the use of these tags can be considered on a pallet level if the infrastructure to read these tags are already deployed at Forward Operating Bases.

- Gentag
- KSW (www.ksw-microtec.com)
- iButton from Dallas Semiconductor (www.ibutton.com)
- TurboTag from Sealed Air (www.turbo-tag.com)
- www.alientechnology.com
- www.bioett.com
- www.coronis.com
- www.maxim-ic.com
- www.evidencia.biz
- www.franwell.com
- www.gentag.com
- www.identecsolutions.com
- www.intelleflex.com
- www.motorola.com
- www.nxp.com
- www.savi.com
- www.sealedair
- www.secureerf.com
- www.sensitech.com
- www.sensorlogic.com
- www.syntaxcommerce.com
- www.lifelinestechnology.com
- http://www.evidencia.com/48-thermassure-x2-log-usb-logger.html

TTI

Most TTI's are based on a first order kinetic degradation reactions. The labels change in color based on time temperature exposure. The technology used for color changes in the label varies from microbiological reactions, enzymatic reactions, oxidative reactions, polymerization reactions. The military uses one of these labels on their MRE to indicate when this ration nears the end of its shelf life. This label is made by LifeLine and developed for ambient storage conditions. There are also numerous labels available for refrigerated product distribution (+4 C) which have a relative short shelf life. Not many labels are available for frozen product distribution and its relative long shelf life.

A special type of TTI are threshold indicators that integrate the time that a product is exposed to a temperature above the threshold. These labels are based on the state change of the polymer (solid ➡ liquid) that fills a reservoir over time using capillary flow technology.

Extensive research is being done in Europe on TTI labels under a project "Chill-on" and "FreshLabel". The Chill-on project was a 4 year project that started in 2006 (€ 16 mil) and was partial funded by the European Commission. The consortium of 26 members was tasked to develop and integrate novel technologies to improve safety, transparency and quality assurance of the chilled/frozen food supply chain– test case fish and poultry. FreshPoint, a producer of smart TTI labels was one of the partners. The main focus of this project was on refrigerated foods with a relative short life span. IQ-FRESHLABEL is on on-going research project, partly funded by the European Commission in the 7th Framework programme. The project runs over three years (1st Aug 2010 to 31st July 2013) and has 18 partners from 9 different countries working on various aspects of promoting and development of TTI labels. Under this program, they are tasked to develop novel intelligent labels for indication of temperature abuse of frozen foods. Besides the research organizations and associations that are member of this consortium, FreshPoint Quality Assurance Ltd. and Vitsab International AB, both producers of smart labels are members of this consortium. At our last literature survey (summer 2012), no information was yet made available that could be used in this project.

A literature and web search yielded the following contacts for TTI labels:

- CoolVu http://freshpoint-tti.com/
- OnVu http://www.onvu.com/en/start
- TempTime http://www.temptimecorp.com/publicpages/Home.aspx
- AveryDennison http://www.averydennison.com
- CheckPoint http://www.vitsab.com/index.htm
- Monitor Mark http://www.3m.com/product/index.html
- CoolID http://www.invenview.com/en
- Cryolog http://www.cryolog.com/en/home.html
- Timestrip http://timestrip.com/

In the following section we will discuss each of the labels individually:

CoolVu

CoolVu is a label developed and marketed by FreshPoint: http://www.freshpoint-tti.com/ Freshpoint is an Israel company that has developed two type of labels: CoolVu and OnVu. The OnVu label was a joint development between FreshPoint and BASF and it has been licensed to BASF and will be discussed separately.

CoolVu labels are time-temperature indicators that are based on a temperature dependent dissolution (etching) process of a fine aluminum layer. The CoolVu time-temperature indicators arrive as two separate labels of which one consist of a printed aluminum label while the other is a transparent label bearing the etchant in its adhesive layer. The activation of the label is achieved by adhering the adhesive label to the surface of the aluminum label. At the first phase after activation, the aluminum layer becomes thinner as a function of the time and temperature, still preserving its mirror like appearance, Figure 1a. At more advanced stages of the process the active spot turns from being a metallic mirror into black, Figure 1b. Towards the end of its life, the active spot slowly adopts the color that was printed at its backside and at the end of its life the full color of the background is revealed, Figure-1c.

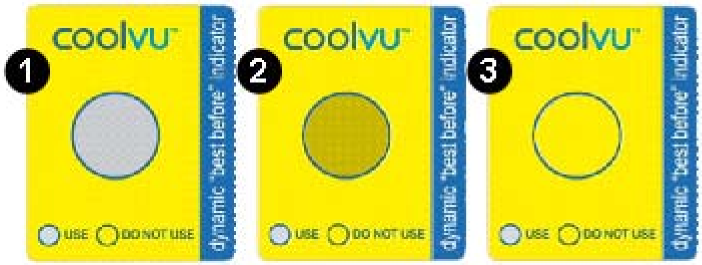


Figure 1: CoolVu labels, a - freshly activated label, b - mid life label, c - expired label.

There are various CoolVu labels

▪ CoolVu Food	Commercial
▪ CoolVu – Thaw and Sell	Commercial
▪ CoolVu Active Barcode	Advanced Development
▪ CoolVu RF Compatible	Under Development
▪ Coolimark Food Rotation	Commercial
▪ Coolicemark thaw indicator	

Detailed description for each of the labels can be found on the FreshPoint website. The CoolVu T&S is suited to products that are stored in a frozen condition, and then dependent on product demand and inventory management, are thawed and sold as fresh. This includes a wide range of baked goods such as pastries, cakes, muffins etc, in addition to pizza's, sausages, seafood, ready to eat meals, fresh fruit and others. CoolVu T&S is designed to eliminate the need to place date codes on products at the point of thawing, and protects brand owners by ensuring that expired products can be identified and removed from display. Contact: 'Yoav Levy' ylevy@freshpoint-tti.com

ONVU.

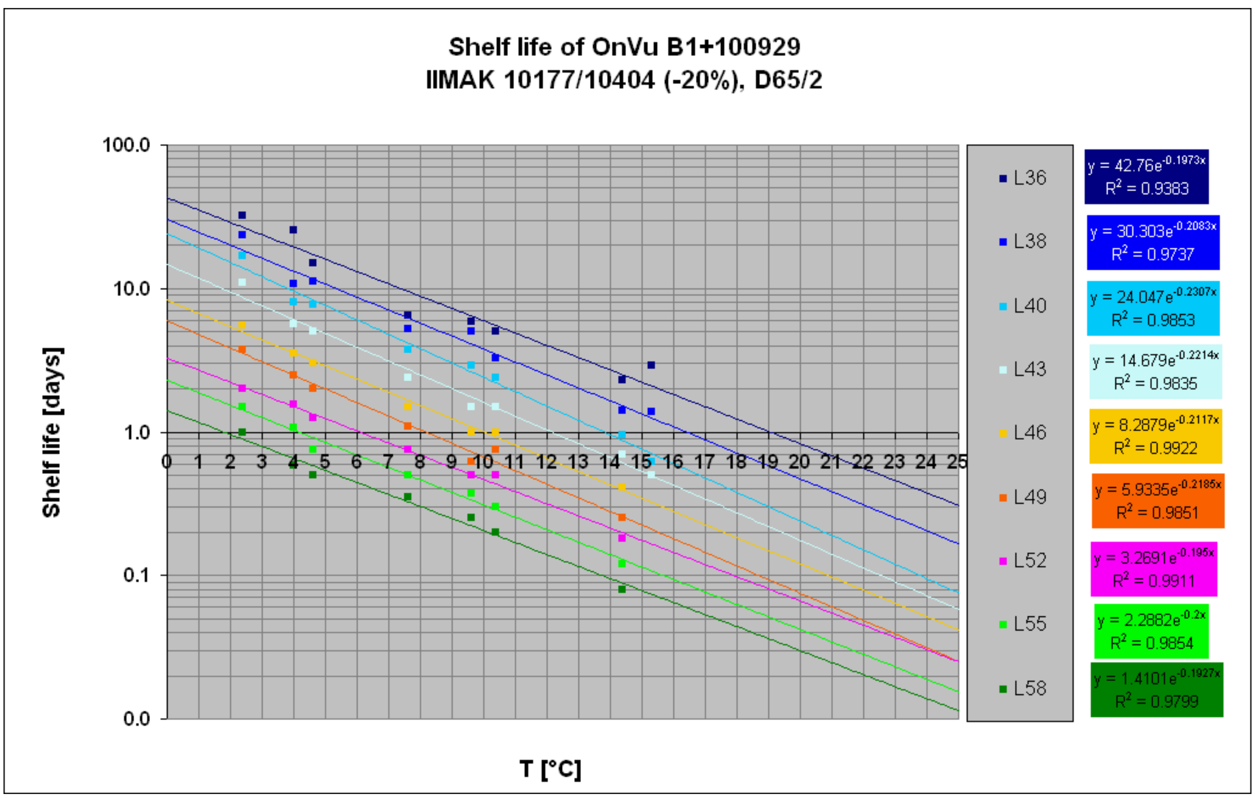
The OnVu label was developed under a joint venture between FreshPoint and BASF. BASF markets the label at this time and is located in Switzerland.

The OnVu label is based on active inks that can be custom charged with a UV light source, to give it its desired shelf life characteristics. OnVu™ indicators can be calibrated to cater for the different spoilage behavior of various foods and beverages. These tailored indicators are highly accurate and consistent in recording and displaying the freshness of the products, based on their time and temperature histories. As the perishable goods are packaged, an OnVu™ TTI is applied and activated using an ultra violet (UV) light source. A filter is then placed over the label to protect it from deliberate or accidental recharging. The label activation and filter placement processes can be carried out automatically by a range of OnVu™-capable label dispensers that have been developed to meet industry needs.

OnVu has different type labels

- OnVu: Commercial
- OnVu Ice: Thaw Indicator Commercial
- OnVu Logistics: Commercial
- SecQstor: Advanced Development

The OnVu and or the OnVu Ice could be applicable to this project. In discussion with BASF, we believe that the OnVu-B1 label can be charged so that it will indicate quality degradation of the UGR-A product. Test data is available in the temperature range of 0 C to +15 C (see chart below). The L52 version would work as an indicator for the microbial safety of the product. However, test data on its behavior at freezer temperatures (-18 C to 0 C) is not known. Work is done in Europe under the IQ Freshlabel program on the OnVu B1 label, but data has not yet been made available. Contact: andre.fuchs@basf.com

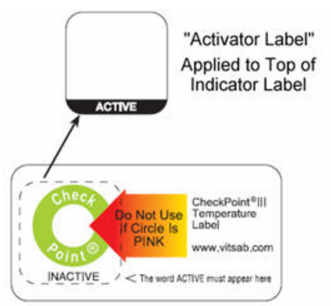


CheckPoint

The CheckPoint Label is developed and marketed by VITSAB, a company that located in Sweden. VITSAB was acquired by Dow Chemical. http://www.vitsab.com/VNCheckPointFreezerTechnical.htm. Vitsab has two different type labels. The Checkpoint I label is based on an enzymatic reaction, while checkpoint III is based on pH shifting chemicals.

The Checkpoint I label is activated by bursting a seal between two pouches that contain fluid. The fluid is mixed together to start a enzyme reaction. The enzyme reaction leads to pH change in contained fluids which leads to color changes: white→green→yellow→orange-red.

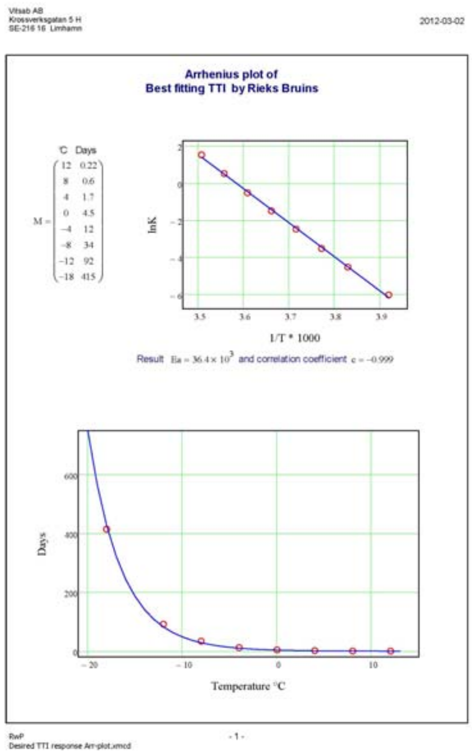
The Checkpoint III label is based on a diffusive reaction that leads to pH change in printed dot on label face. Dual labels are merged into single active label at the activation step

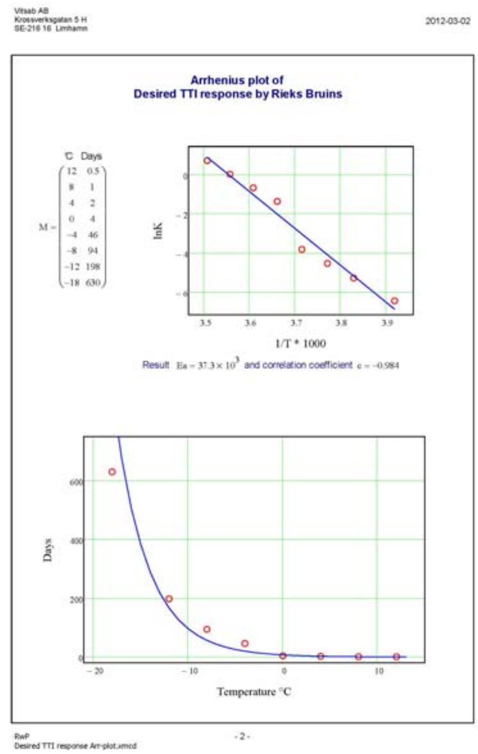


"CheckPoint® III Label"

In discussions with Vitsab, the CheckPoint I labels is most appropriate for our application. They have developed various applications. The flight label for British Airways would be a good candidate for the UGR-A product once it is being defrosted, however the reactions don't stop at temperatures below -4 C and the response time at freezer conditions is too fast. Vitsab felt comfortable that they could develop an enzymatic reaction according to the compromised reaction kinetics as indicated at the beginning of this paper in the TTI Performance Criteria section.

Contact: Peter Rönnow peter.ronnow@vitsab.com





Fresh-Check

Fresh-Check Label is developed and marketed by the TempTime Corporation, formerly also known as LifeLine Technologies, located at Morris Plains New Jersey. Their main website can be accessed via: http://www.temptimecorp.com

The majority of their product line is geared toward the pharmaceutical industry where medications/vaccines need to be monitored for both hot and cold abuse. A specific product line is the “Fresh Check” Label. Fresh-Check Indicators are a convenient tool for compliance with US Hazard Analysis and Critical Control Point (HACCP) standards imposed upon modified atmosphere packaged seafood producers. The indicators are used to monitor modified atmosphere packaged seafood. Fresh-Check indicators are also used for long-term monitoring of all of the US military field-deployable “Meals Ready to Eat.” Based on Mendoza’s paper, this TTI is based on solid state polymerization of an acetylenic monomer that changes to an opaque polymer. TTI is active upon manufacturing and therefore requires cold transport and storage at or below -24C. When we discussed the UGR-A application with a sales rep from Fresh Check, they indicated that none of their labels would be applicable for our product. No performance data are available at temperatures below 0 C

The following FreshCheck labels are commercial available:

Category	0 C	+4 C	+8 C	+20 C
B		6.0	3.4	0.7
M		9.0	5.1	1.0
P		15.0	8.5	1.7
D		24.0	13.6	2.7
H		26.0	14.7	2.9

F		45.0	25.5	5.1
S		56.0	31.7	6.3

Contact Jeffery Gutkind JeffG@temptimecorp.com

TopCryo

Cryolog is a French company located in Nante. Cryolog makes TTI labels that contain a nutrient gel, a dye indicator and a specific strain of lactic acid bacterium determined based on the desired shelf life requirements. In the label, the bacteria use the nutrient to growth, and lactic acid is released as the bacteria multiply. As a result, the pH of the medium decreases according to the time/temperature combination and the dyed indicator turns from green to red, thereby signaling that the food item has reached the end of its shelf life. The labels are “life” when they are manufactured and need to be stored at -18 C. Once the label thaws the bacterium becomes active and grows just as bacteria in the food items will do.

Cryolog markets two labels, one for retail: (eO)® and one for the cold chain distribution: TOPCRYO™. The TopCryo labels comes in different configurations. The table below indicates the required time (hrs) to turn the label red as function of temperature. The TOPCRYO C appears to be closest to what the UGR-A ration needs for detecting if the product is safe as its microbial growth stops when it is in a frozen state. However, no data is available indicating the stability of the label at frozen conditions. Sales literature indicates that the label can be stored for up to 3 month at -18 C w/o performance degradation. Additional experiments are required to study the stability of the label for period up to 1 year at -18 C.

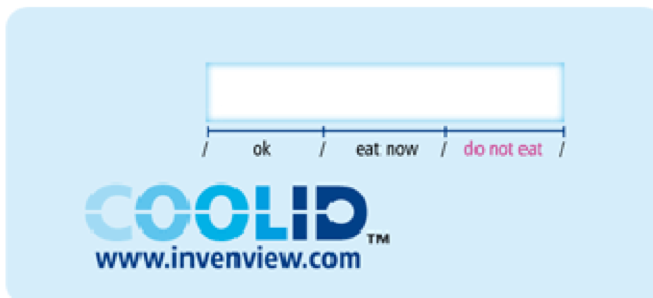
Description	2 C	3 C	4 C	8 C	12 C
TOPCRYO™ B	50 hrs	40	30	20	12
TOPCRYO™ C	76	64	48	30	18
TOPCRYO™ D	112	96	72	44	25
TOPCRYO™ E	142	118	96	56	32
TOPCRYO™ F	184	152	120	70	40
TOPCRYO™ G	216	180	144	82	46
TOPCRYO™ H	254	212	168	98	55
TOPCRYO™ I	292	244	192	114	64

- http://www.cryolog.com/en   send e-mail requesting additional data
- Serge Le Faouder (Responsable.commercial@cryolog.com) <responsable.commercial@cryolog.com>

CoolID

- CoolID is marketed by Invenview Technology, a Polish company. The label was developed by the Gdańsk University of Technology in partnership with the Invenview Company. With the Cooperation of scientists and specialists from the branch of chemistry, food technology and material technology they are working on the implementation of COOLID temperature indicator into mass production.

COOLID indicators work on the basis of enabling certain reagents to join above the critical temperature (indication temperature). These reagents are harmless to the health (accepted to be used in the groceries industry), therefore the contact with the sensor- even damaged- does not lead to any danger. The reaction – which gives the colored product –occurs only in an aqueous solution. Both reagents are diluted and placed in two neighboring beds, where the two solutions are immobilized, which makes impossible for them to mix and create a color. After freezing, the structure that immobilizes the solution is damaged (it should occur in 1 or 2 hours of freezing), but the solutions are still kept in solid state, which still makes the indication impossible.
It means that activation (transforming into the state of indication) of the COOLID indicators occurs automatically, which is one of their biggest advantages. After exceeding the critical temperature, e.g. defrosting, and exposure at the given temperature during suitable time, the solutions are no longer immobilized and they can mix causing reaction, which gives the color (visible in the window). Both beds (in the form of spots, stripes etc.) are placed on the adhesive base enabling their fastening to the package material.



Contact Information: http://www.invenview.com/

Timestrip

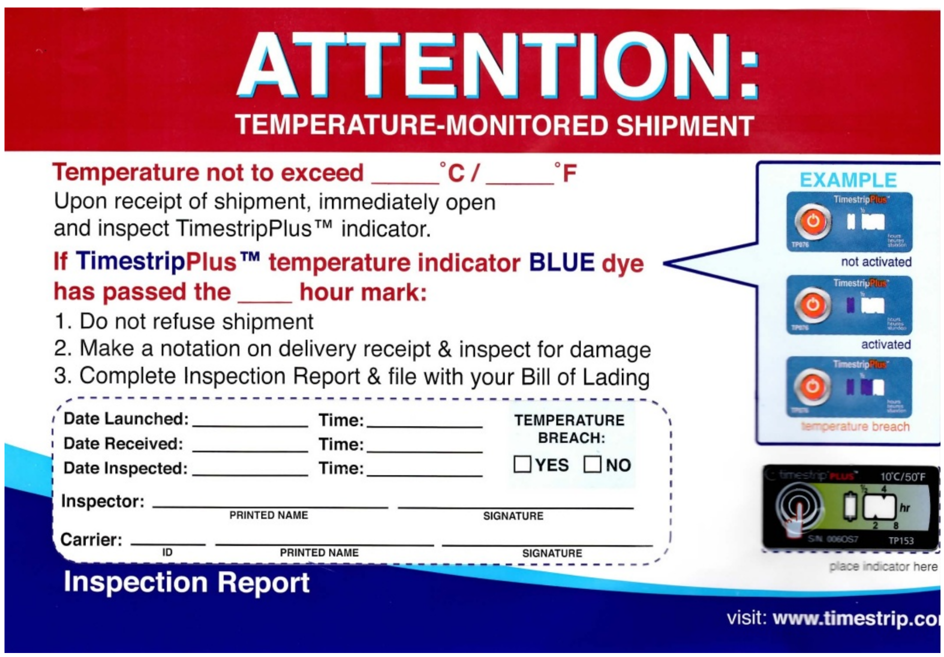
Timestrip UK Limited, is a British company headquartered in London, that makes elapsed time indicators for the Pharmaceutical and Food Industry. They do have a North American authorized distributor ship located in Wyckoff NJ USA. Timestrip markets three types of indicators: Timestrip Plus™; Timestrip Minus™; Timestrip Complete™. The Timestrip Plus™ measures the time excursions above a specific temperature ranging from two minutes to eighteen month. This label is most applicable to the UGR-A

Their label ships in an inactivated state and can be stored at ambient temperatures. To activate the label it needs to be above the freezing point of the dye-polymer. The seal between the storage reservoir and the activation reservoir is broken by mechanical means so that the dye can flow to the activation reservoir. The temperature of the label should then immediately be lowered to freeze the dye. Once the label is exposed to a temperature above the freezing point of the dye, capillary flow of the dye will occur and start filling the timing reservoir. Flow rate is based on the viscosity of the liquid, hence slightly faster at higher temperatures but doesn't work on a kinetic model. Once the temperature drops below the freezing point, the dye refreezes and the flow stops. According to the sales rep, multiple time indicators can be combined on a single label to that the excursion time at 0 C, +4 C and +8 C can be measured individually and each one can have its own time scale, giving this the capability to integrate time. Major food application areas for this label are:

- **Samuels Seafood Co.**, Frozen Seafood
- **Gate Gourmet**, the world's largest independent provider of catering services to airlines and railways

- **Choicelunch,** catering company to schools in CA

The common implementation is to put a time strip label inside the box and adhere a shipping label on the outside of the box. Upon receiving, the clerk will open the box and inspect the indicator and make the appropriate notes on the shipping label, remove the shipping label and make it part of the delivery receipt documentation.



Contact information: Dan Hafen 214-263-5793
http://www.timestrip.com/temperaturemonitoring.php

Monitor Mark

3M™ company is located at St Paul MN. It markets three products for time temperature monitoring. The first one is the 3M™ Monitor Mark™ which will indicate heat abuse. The second product, 3M™ Freeze Watch™ Indicators help alert when products have been exposed to temperatures below a defined threshold. Both markers are used primarily for secondary shipping packaging (case, box) to help monitor temperature-sensitive shipments including food, vaccines, drugs, blood products, implants, diagnostic substances, ophthalmic solutions, intraocular lenses and chemicals, and signal when product quality should be checked due to temperature exposure. A third product (TL30 or TL20) is a small digital recorder similar to the earlier discussed TempTale recorder from SensiTech. The data can be down loaded to a PC.

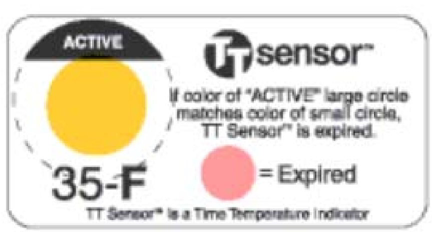
3M™ MonitorMark™ comes in eight different configurations. The label is not active when shipped and can be activated by pulling a tab allowing contact between the dye in the reservoir and the end of a porous wick indicator track. Before the tab is pulled the label needs to be preconditioned at a temperature below the threshold temperature so that the fluid will not immediately wick. There is thus no indication that the label has been activated as is the case with the previous described system. If the temperature drops below the threshold temperature, the wicking of the dye will stop. The 9860B version could be applicable to the UGR-A case as an indicator that the inside of the box has seen temperature above +5 C and if the exposure exceeded 48 hrs

Monitor Mark	Threshold Temp	Recording Time	Stop Moving
9860A	-15 C	48 hrs	-20 C
9860B	+5 C	48 hrs	0 C
9860C	10 C	48 hrs	7 C
9860D	10 C	1 week	7 C
9860E	26 C	48 hrs	24 C
9860H	31 C	1 week	29 C
9861A	TTI 10 C	2 weeks	7 C
9864C	TTI 10 C	24 hrs	7 C

TT Sensor

The TT Sensor active label is marketed by Avery Dennison, a US company head quartered in Cleveland OH. The TT Sensor active labels have a two-piece design comprised of an indicator label and an activator label. This construction makes TT Sensor easy to use in terms of application, activation and readability. Time-temperature monitoring does not begin until the activator label is applied. On most packaging lines the transparent activator label is applied to the indicator label, which is then immediately affixed to the package. No refrigeration of the labels prior to application is required. TT Sensor active labels can be custom printed and cut to meet the package design and branding requirements of food marketers. TT Sensor fulfills compliance requirements for food handling HACCP plans and meets the requirements of FDA Import Alert #16-125 for fresh seafood

The labels are available in a variety of formulations to meet the specific time requirements of processors. Once activated, TT Sensor will change color from yellow to pink at a pre-determined rate based on temperature exposure. Once activated, the indicator dot immediately starts to change color. Currently, there are three standard TT Sensor labels available: 35-F, 35-K and 35-P. However, they can customize a TT Sensor to different parameters to match specific application requirements.



Time	Temperature (°F)						
	35	40	45	50	60	70	80+
< 2 hrs							ALL
5 hrs						35-F	
7 hrs						35-K	
10 hrs					35-F		
12 hrs						35-P	
18 hrs					35-K		
1 day				35-F	35-P		
1.5 days			35-F				
2 days				35-K			
3 days		35-F		35-P			
4 days			35-K				
5 days	35-F		35-P				
6 days		35-K					
9 days		35-P					
10 days	35-K						
15 days	35-P						

Because the activated label reacts also at frozen temperature, the label is not appropriate for the UGR-A product according to a sales representative.

Contact: Nick 440-878-7130 Nicholas.Greco@averydennison.com

Conclusion:

TTI labels for refrigerated products are well established. However, there is little or no information available regarding behavior at prolonged storage at freezer temperatures. It is expected that these labels will expire under frozen conditions well before the end of the shelf life of the product and thus not suitable for application on frozen product. IQ-Freshlabel, an European research program is studying this application area and it is expected that results will become available to the public over the next twelve month. At this point, it appears that a TTI label designed for refrigerated conditions but with a trigger temperature, below which the label is stable will be best suited for the UGR-A ration to alarm for safety concerns. The development of a TTI label that will alarm for quality and safety is feasible but require additional work by the vendor to develop the appropriate kinetic reaction.