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IMPROVED STORAGE STABILITY OF MEAL READY-TO-EAT CHEESE SPREAD UNDER HEAT-STRESSING CONDITIONS

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U.S. Army Natick Soldier Research, Development and Engineering Center
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14. ABSTRACT

This report summarizes testing and results of experimental formulations for Meal, Ready-To-Eat (MRE) cheese spread. A formulation utilizing a new stabilizing and colorizing system in concert with nitrogen flushing was shown to significantly improve the storage stability under heat stressing conditions of 120° F (49° C), 100° F (38° C), and 80° F (26.7° C) and at specific time intervals. The formulation had significantly higher ratings than the current specified control sample and three other experimental samples for all sensory attributes under heat stressing conditions. As a result, the technical performance requirements in product procurement documents have been changed to reflect the ingredients of the new formulation.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This report documents work performed by the Individual Combat Ration Team and the Food and Engineering Services Team of the Department of Defense Combat Feeding Directorate at the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) during the period May 2005 to May 2008. The work involved identification of new formulations and/or packaging designed to extend the shelf life of Meal, Ready-to-Eat™ (MRE™) cheese spread to withstand exposure to heat stress and maintain Warfighter acceptability. It was performed as part of the Operational Ration Accelerated Storage Data Correlations and Validation Project (No. JSN 05-7), under the Fielded Individual Ration Improvement Program (FIRIP).

The authors would like to acknowledge the following individuals for their technical expertise, valued contributions and timely support to this project.

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IMPROVED STORAGE STABILITY OF MEAL, READY-TO-EAT™ CHEESE SPREAD UNDER HEAT STRESSING CONDITIONS

1. INTRODUCTION

The Individual Combat Ration Team (ICRT), Combat Feeding Directorate (CFD), of the Natick Soldier Research, Development and Engineering Center (NSRDEC) has been investigating/identifying alternative formulations and/or packaging changes that will extend the shelf life of Meal, Ready-to-Eat™ (MRE™) cheese spread (shown in Figure 1) to withstand exposure to heat stress and maintain acceptability. In 2004, CFD initiated the Operational Ration Accelerated Storage Data Correlations and Validation Project (No. JSN 05-7), under the Fielded Individual Ration Improvement Program (FIRIP), to improve the shelf life of MRE™ cheese spread. This report covers the period May 2005 to May 2008. The principal objectives of the project were:

- Determine the efficacy of each new formulation/processing method against the original formulation and other formulation/processing methods to improve shelf life as determined by sensory acceptability.
- Determine the maximum time and temperature that the original and experimental formulations can be stored and still retain sensory acceptability.

Figure 1. MRE Cheese Spread

As part of this effort, NSRDEC collaborated with Portion Pac, the sole cheese spread product vendor, to establish experimental protocols for improved stability of the cheese spread under heat-stressed conditions. A development and manufacturing protocol was established to produce five experimental batches at Portion Pac's experimental facility in Stone Mountain, GA, in January 2005.

Beginning in May 2005, product samples were stored under controlled conditions at 80° F (26.7° C), 100° F (38° C), and 120° F (49° C) for intervals of three years, six months, and nine weeks, respectively. Testing was concluded in May 2008.

Each batch was tested for appearance, odor, flavor, texture, and overall sensory quality attributes. In addition to sensory testing, the study consisted of L*a*b* colorimetry, photography, emulsion stability testing, and First Strike Ration™ field testing at Fort Bragg, NC, in July 2006. The sensory testing yielded promising findings. As a result, follow-up sensory testing was performed to verify the findings. Verification was also advised because dairy products vary considerably in their chemical and physical properties from season to season.

Modern battlefield requirements demand ration support systems that adequately provide for the needs of military personnel in extremely intense and highly mobile combat situations. NSRDEC develops and tests individual combat rations for all of the Armed Forces (Army, Air Force, Navy and Marines). The MRE™ (shown in Figure 2) is the standard U.S. military ration developed to support the individual Warfighter. On average, 36 million MREs are purchased annually. The MRE™ is used by the Services to sustain Warfighters during operations that preclude organized food service facilities, but where resupply is established or planned. The MRE™ replaced the Meal, Combat Individual Ration (MCI), also referred to by the name of its predecessor the C - Ration, in the early 1980s. Each meal provides an average of 1300 kilocalories and 13% protein, 34% fat, and 53% carbohydrates. Furthermore, when supplemented with pouch bread, an additional 200 kilocalories are provided (12% protein, 33% fat, 55% carbohydrates). Feedback from Operation Desert Shield / Desert Storm suggested that soldiers would consume more food if their preferences were taken into consideration.

Figure 2. MRE and Components

Since 1993, changes to the MRE™ have focused on user preferences and increased variety. Major customer-driven improvements have been implemented to improve variety, acceptability, consumption and nutritional intake to enhance performance on the battlefield. Since MRE™ 13, the1993 Date-of-Pack (DOP), 189 new items were approved for the MRE™. Fifty-seven of the least acceptable MRE™ items were replaced. The number of menus increased, incrementally, from 12 to 24 and four vegetarian meals are now included (two in each case). In addition a new, easy-open meal bag with commercial-like graphics is included, and nutritional labeling of all ration components is now mandated. Beginning with MRE™ 26, 2006 DOP, the component label must provide trans fat content and list the allergen content if any of the eight major food allergens (milk, egg, peanuts, tree nuts, fish, crustaceans, soybeans, wheat) are in the product, as mandated by the Food and Drug Administration (FDA).[1]

Through the efforts of CFD’s FIRIP, the MRE™ is afforded continuous product improvement to enhance individual rations, increase ration variety, improve quality, and provide state-of-the-art food technology and packaging, thus increasing Warfighter acceptance and ultimately Warfighter performance. Combat feeding personnel work in concert with the FDA, The Office of the Surgeon General (OTSG), the U.S. Army Research Institute for Environmental Medicine (USARIEM), the Joint Service Operational Rations Forum (JSORF), the Combat Feeding Research & Engineering Board (CFREB), and ration developers and assemblers. In addition, international symposiums, Defense Exchange Agreements (DEAs) with Foreign National Governments, and leveraging initiatives with industry and academia ensures our world class commitment to the Warfighter.

2. BACKGROUND

Since its introduction as an individual ration component in 1975, cheese spread has been a highly popular and coveted item by the U.S. Army and Marine Corps Warfighters for use as a spread on crackers and bread and as a seasoning to many entrees, such as spaghetti, raviolis, and hamburgers. The cheese spread was so popular it was adapted and carried over to the MRE™ from the MCI Ration. The cheese spread component is in constant demand and provides inexpensive flavor enhancements to the MRE™.

Cheese spread was procured as a component to the MRE™ under Military Specification (MIL-C-595), which defined the product's requirements including the ingredients, preparation and processing techniques, appearance, flavor and odor characteristics, and analytical tests to be performed on the products. This specification was amended to require fortification with vitamin A, thiamine hydrochloride (vitamin B_1), pyridoxine hydrochloride (vitamin B_6), and ascorbic acid (vitamin C) to help fulfill the Nutritional Standards for Operational Rations (NSORs) of the OTSG in AR 40 to 25, Nutrition Standards and Education. It was determined that this fortification could be achieved without significant detriment to product acceptability (Eames et al. 83). In 2005 MIL-C-595 was converted to a performance document (PCR-C-039). One of the performance requirements cited for all MRE™ components, including the cheese spread, is to have a minimum shelf life of three years at 80° F (26.7° C) and six months at 100° F (38° C).

Despite its popularity, however, the MRE™ cheese spread has been the subject of several complaints over the past 27 years pertaining to browning/discoloration, loss of color, and texture and flavor irregularities. In recent years, the U.S. Marine Corps, Army, and Defense Logistics Agency personnel have asked CFD personnel to evaluate heat-stressed MRE™ cheese spread to determine serviceability, provide substitute components, and identify procedures to determine product acceptability based on appearance.

2.1 Environmental Heat Stress

During pre-position storage throughout the world, operational rations are often exposed to environmental heat-stress. Adverse effects of heat-stress exposure on cheese spreads include oil separation and darkening, often rendering the product unacceptable for use. Operational rations are often subjected to temperatures as high as 120° F and as low as subfreezing conditions. Unfortunately, no database exists for ration inspections conducted during Operation Iraqi Freedom (OIF); however, it has been estimated by the Army G-4 that rations valued at $50-80 million were condemned due to heat-related deterioration during the first three years of OIF. To ascertain the cause and extent of this problem, NSRDEC and the U.S. Army Veterinary Command (VETCOM) conducted a joint study of storage temperatures in the Central Command (CENTCOM) Area of Responsibility. In the summer of 2005, several temperature recording devices were deployed to ration storage areas in Kuwait and Iraq. In Kuwait from 21 June 2005 to 19 September 2005, the overall average storage temperature was found to be 101.3º F (38.5° C), with an average daytime temperature of 112.2 º F (44.6° C) and an average night time temperature of 91º F (32.8° C). In Iraq, the average storage temperature was found to be 104.3º F (40.2° C), ranging from 82º F (27.8° C) to 138º F (59° C). These harsh environmental conditions lead to the rapid deterioration of operational rations, which reinforces the need to improve the heat stability of the more heat sensitive ration components such as cheese spreads. In March 2005, at an Operational Ration Quality Summit Meeting, a VETCOM representative presented a picture of dark orange-brown, curdled MRE™ cheese spread, which is indicative of heat-stressed rations that inspectors have seen in the field.

The mission of VETCOM includes surveillance inspection of operational rations. Those inspections are performed periodically throughout the life cycle of the rations and are documented in a database (except those inspections performed by deployed veterinary units). From October 2005 through December 2006, there were 791 recorded surveillance inspections of MREs™ in the continental United States (CONUS). These records clearly reveal that the cheese spread is among the MRE™ components most susceptible to product deterioration, especially when ambient storage temperatures exceed 80º F (26.7º C). Further, 100 of the 791 inspections resulted in downgrading the condition code of the rations. The recommended disposition of those rations ranged from issue with qualifications (condition codes B and C) to destroy-unfit for intended use (condition code H). The cheese spread components were found defective in a high percentage of those inspections. For condition code B, C, and H, 33%, 69%, and 97%, respectively, of the inspections addressed defective cheese spread. The conclusion reached is that as the quality of an MRE™ degrades, the cheese spread will be among those components most likely to be defective. The defects identified on the inspection reports were associated with the appearance and texture of the product. For regular cheese spread there were 30 instances of curdling, 28 instances of darkening, and 18 instances of oiling off. For jalapeno cheese spread the number of defects were 28 curdling, 22 darkening, and 19 oiling off. All of these defects are either caused by or exacerbated by elevated storage temperatures. Improving the cheese spread and other susceptible components to decrease their heat sensitivity would result in both increased consumption and less waste, especially for those rations shipped to areas with hot climates.

VETCOM food inspectors have learned to look for key components that would be indicators of potential quality problems within a particular inspection lot. The time-temperature indicator labels on the exterior of each case (shown in Figure 3) are the first visual warning that a lot may have been subjected to high temperature storage. These labels work well in revealing aggregate storage temperatures over a prolonged period; however, they may not reveal when products have been subjected to short duration spikes in temperature. In those instances, certain deteriorative biochemical reactions are accelerated and can result in premature degradation of some heat-sensitive components. Based on experience, inspectors pay particular attention to the fruit components, spreads, and freeze dried coffee as the initial indicators of heat-induced deterioration.

Figure 3. TTI Bull's Eye Label on Unopened MRE Case

2.2 Shelf Life Requirements and Testing

The shelf life of MREs™ and their components is a minimum of three years at 80° F (26.7° C) (long-term storage) and six months at 100° F (38° C) (accelerated storage), and the packaging must be able to withstand airdrop, rough handling, and extremes of temperature. Long-term and accelerated storage studies are used to determine the shelf life of ration components. At NSRDEC, products are placed in storage under controlled conditions (temperature, humidity, and light), removed from storage for evaluation at pre-determined times, and rated for acceptability by technical and/or consumer panel groups under individual light and climate controlled sensory testing booths. A technical panel typically consists of a minimum of 12 trained panelists who evaluate the product for specific attributes (e.g., flavor, texture). Consumer panels typically consist of 35 to 40 untrained respondents from a random pool of military and civilian employees. Analysis of both panels is performed utilizing a fully computerized, on-line sensory and consumer data acquisition and management system. Under long-term storage and accelerated storage conditions, a product is considered acceptable if it achieves a score of 5.0 or greater on the nine-point quality scale for each sensory attribute.

2.3 Results of Previous Testing

In a 1983 study conducted by Eames et al., fortified MRE™ cheese spread had a consumer acceptability score of 5.9, standard deviation (SD) 1.78, after six months of storage at 100° F (38° C). Because the shelf life requirement for the MRE™ at that time was three years at 70° F (21° C), the fortified cheese spread was evaluated under those conditions, and an acceptable score of 6.5 (1.44 SD) was recorded.

Sensory scores from a May 1991storage study (Alan Bennett) suggest, however, that the quality of the MRE cheese spread may have decreased since the Eames study. After six months at 100° F (38° C), three years at 70° F (21° C), and three years at 85° F (29.4° C), the cheese spread had acceptability scores of only 4.5, 5.8, and 4.3, respectively (SDs not reported).

In 1997, fortified cheese spread was again evaluated after six months of storage at 100° F (38° C) (Ross et al. 1997). The product was found to have a consumer acceptability score of 5.38 (SD not reported). At that time, the shelf life requirement for the MRE™ was changed to three years at 80°F (26.7°C). Accordingly, after three years of storage at that temperature, fortified cheese spread was tested and evaluated. It was found to have a consumer acceptability score of 4.56 (SD not reported), which reiterates the decrease in quality of the cheese spread since the original 1983 storage study. The results of the three aforementioned storage studies are summarized in Table 1.

Table 1. Results of Previous Cheese Spread Storage Studies

Reference	Time in Storage	Temperature	Consumer Score	Standard Deviation
Eames et al. 83	6 months	100° F (38° C)	5.9	1.78
Bennett 91	6 months	100° F (38° C)	4.5	Not reported
Ross et al. 97	182 days	100° F (38° C)	5.38	Not reported
Eames et al. 83	3 years	70° F (21° C)	6.5	1.44
Bennett 91	36 months	70° F (21° C)	5.8	Not reported
Bennett 91	36 months	85° F (29.4° C)	4.3	Not reported
Ross et al. 97	1095 days	80° F (26.7° C)	4.56	Not reported

2.4 Identification of Experimental Formulations

Utilizing past data on heat-stressed rations (NATICK Tech Report, Occurrence and Effects of High Temperature Storage on Rations Stored in Container Vans at Yuma, AZ 1992-1995, Shaw, 1996) from Operation Desert Storm (ODS) and data obtained from analysis of project JSN 00-7, NSRDEC has targeted three areas to study for cheese stabilization improvements:

- Emulsifier/stabilizer system change
- Addition of a nitrogen flush
- Color change

For proprietary reasons it is inappropriate to discuss the specifics of these improvements in this context. However, general explanations are provided.

NSRDEC met with Portion Pac, at its processing facility in Stone Mountain, GA, in September 2004. The objective of the meeting was to establish experimental protocols for improved shelf stability of the MRE™ cheese spread under heat-stressed conditions. Results of that meeting and subsequent correspondence led to the development of a manufacturing protocol and preparation of five experimental cheese spread batches at the Stone Mountain facility in January 2005:

- Batch 1- Control produced according to MIL-C-595C.
- Batch 2 - Identical to batch 1 with the addition of a nitrogen flush used to remove residual air.
- Batch 3 - Produced with an experimental stabilizer. The exact stabilizer is considered proprietary, but was essentially a new “super” mono and diglyceride mixture which replaced the existing stabilizing system.
- Batch 4 - Produced using a new colorizing carotenoid based system. The exact coloring system was also considered proprietary.
- Batch 5 - All-inclusive batch with the nitrogen flush, new stabilizing system and new colorizing system all together.

2.5 Processing and Packaging

All formulations were produced using a hot-fill method. Ingredients were combined in a commercial mixing tank, heated to obtain commercial sterility in a heat exchanger, filled, and sealed in tri-laminate flexible pouches. The 1.5 ounce pouches were constructed of high barrier aluminum foil sandwiched between a polypropylene film and a polyethylene film.

3. TEST METHODS

Product samples were stored in individual pouches under controlled conditions at 80° F (26.7° C), 100° F (38° C), and 120° F (49° C) for intervals of three years (ongoing), six months, and nine weeks, respectively, for each of the five batches.

3.1 Sensory Testing

Six of the storage samples in each batch were sensory tested and evaluated by a trained technical panel for appearance, odor, flavor, texture, and overall quality. Each sample was allowed to equilibrate to ambient temperatures for at least 24 hours. Samples were rated on a 9-point quality scale, with 9 being excellent quality. A serving of approximately 1/3 ounce per sample was served to the panelists for evaluation in the NSRDEC sensory testing room. The minimum panel size was 12 technical panelists. Sensory evaluation ratings were analyzed for statistical significance using Duncan's New Multiple Range Test. The significance level was set at P = 0.05.

3.1.1 Original Study. In addition to the initial individual pouch samples, highly accelerated 120° F (49° C) storage samples (10 pouches per batch) were pulled each week for seven weeks, except a two week sample was not tested since the original protocol (biweekly) was modified. Ten samples per batch were pulled every month for six months for the accelerated 100° F (38° C) storage, and ten samples per batch were pulled every six months for the 80° F (26.7° C) long-term storage three-year study.

3.1.2 Re-Test (Verification) Study. After promising results had been obtained, particularly on the all-inclusive batch 5 variable, a follow-on production protocol was established to verify the findings, as well as look at the necessity for the nitrogen flush. The verification was considered necessary because dairy products have considerable variation from season to season. The residual air space in the tri-laminate foil pouch for the cheese spread was very small and could not be accurately measured with several attempts. The follow-on production cheese spread batches were:

- Batch 1 - control
- Batch 5 - all-inclusive as described above
- Batch 6 - new colorizing system and new stabilizing system, but no nitrogen flushing.

In addition to the initial samples, six samples of highly accelerated 120° F (49° C) storage were pulled at three, six and nine weeks. Accelerated 100° F (38° C) storage samples (six each) were pulled at three and six months, and the 80° F (26.7° C) samples were pulled every six months for three years (ongoing). The sample size per interval was reduced because only technical sensory testing was performed for the verification study.

3.2 Hunter L*a*b* Colorimetry

L*a*b* color space is one of the most popular color spaces for measuring object color and is widely used in all fields. L* indicates lightness, and a* and b* are the chromaticity coordinates.[1] One sample from each storage withdrawal at 100° F (38° C) and 120° F (49° C) was used as an objective means of appearance evaluation utilizing Hunter Colorimetry testing. Samples were held at 40° F (4.4° C) after withdrawal until the colorimetry was performed.

3.3 Photography

One sample from each storage withdrawal at 100° F (38° C) and 120° F (49° C) during the original study was saved and digitally photographed by NSRDEC audio-visual personnel. Additional samples from each batch were photographed during emulsion stability testing. Samples were held at 40° F (4.4° C) after withdrawal until the storage temperature block was completed so that photography could be done on all of the pulled samples at once.

3.4 Emulsion Stability

Eight filled and sealed pouches were randomly selected from each lot and individually tested for emulsion stability. The samples were not kneaded any time during the temperature cycle test. Any non-conforming result was deemed to be cause for rejection of the lot. The filled and sealed pouches were tested as follows:

- Hold for two days at a temperature of -20° F ± 5° F (-29° C ± 2.8° C).
- Remove from -20° F (-29° C), and hold for 2 days at 70° F ± 5° F (21° C ± 2.8° C).
- Remove from 70° F (21° C), and hold for 2 days at 100° F ± 5° F (38° C ± 2.8° C).
- Cool to 70° F ± 5° F (21° C ± 2.8° C), and examine for emulsion separation on samples that were not kneaded.

3.5 First Strike Ration™ Field Test

Samples of the batch 5 cheese spread formulation (all-inclusive: nitrogen flush, new stabilizing system, and new colorizing system) were field tested at Fort Bragg, NC, by the 4th Battalion, 82nd Airborne Division, July 17-28, 2006, along with other components of the First Strike Ration™.

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[1] Konica Minolta Precise Color Communication, L*a*b* color space, page 18.

4. RESULTS

4.1 Sensory Testing

4.1.1 Highly Accelerated Storage 120° F (49° C) – Original Study. Batch 5 (nitrogen flush, new stabilizer and new color combined) received significantly higher ratings (P = 0.0001) for the sensory categories of appearance, flavor, odor, texture, and overall quality than batch 1 (control) throughout storage after the initial un-stored analysis. This greater statistical significance for sensory attributes started at the second week of storage at 120° F (49° C) and continued on through the conclusion of storage at six weeks. In most cases, batch 5 also had significantly higher ratings than batch 2 (nitrogen flush), batch 3 (new stabilizer), and batch 4 (new color). See Appendix A (Figure A-1) for graphs and Appendix B (Table B-2) for statistical data.

4.1.2 Highly Accelerated Storage 120° F (49° C) – Re-Test. Both batch 5 and batch 6 (new stabilizer, new color, no nitrogen flush) had significantly higher ratings for sensory appearance, texture, and overall quality than the batch 1 control. Batch 5 was significantly greater than batch 6 for sensory texture and overall quality after six weeks, and for appearance, flavor, texture and overall quality after nine weeks of storage. The re-test confirmed that the batch 5 treatment (nitrogen flush, new stabilizer, and new color) had a significant effect in improving storage stability over the control batch. These results also indicate that, although residual air in the packets was small (batch 5 results vs. batch 6), removal by nitrogen flushing resulted in improved shelf stability under highly accelerated storage conditions. See Appendix A (Figure A-2) for graphs and Appendix B (Table B-4) for statistical data.

4.1.3 Accelerated Storage 100° F (38° C) – Original Study. The results were very similar to those obtained from the highly accelerated storage. Batch 5 had significantly higher ratings (P= 0.0001) for sensory appearance, flavor, texture and overall quality than batch 1, and in many cases had significantly higher ratings than batches 2, 3, and 4 throughout storage after the initial un-stored analysis. The significant difference between batch 5 and batch 1 was first detected at one month of storage and was still detected after six months storage. See Appendix A (Figure A-3) for graphs and Appendix B (Table B-1) for statistical data.

4.1.4 Accelerated Storage 100° F (38° C) – Re-Test. Batch 5 and batch 6 had significantly higher ratings than batch 1 for sensory appearance and for sensory overall quality after three months of storage (P= 0.0033 or less). Batch 5 had significantly higher ratings than batch 6 for sensory odor, texture, and overall quality after three months, and for appearance after six months of storage. As with the highly accelerated storage, the 100° F (38° C) re-test (verification) data confirms that the batch 5 treatment (nitrogen flush, new stabilizer, new colorizing system) had a significant effect in improving storage stability over batch 1. Although not as significant as the accelerated storage conditions (120° F, 49° C), these results appear to indicate that removal of residual air (batch 5 vs. batch 6) resulted in improved shelf stability under accelerated storage conditions (100° F, 38° C). See Appendix A (Figure A-4) for graphs and Appendix B (Table B-3) for statistical data.

4.1.5 Normal Storage 80° F (26.7° C) – Original Study. Statistical data for the 80° F (26.7° C) results after 36 months of storage indicated no significant differences between batches 4 and 5 for flavor, and overall quality, while batches 1, 2 and 3 were significantly lower for both sensory attributes. Batch 4 was superior for appearance than batch 5. Batch 1 was significantly worse than batches 2, 3, 4 and 5 for texture. There were no significant differences for odor. See Appendix A (Figure A-5) for graphs and Appendix B (Table B-3) for statistical data.

4.1.6 Normal Storage 80° F (26.7° C) – Re-Test. Statistical data for the 80° F (26.7° C) results indicated no significant differences in any sensory attribute after 36 months of storage. See Appendix A (Figure A-6) for graphs and Appendix B (Table B-6) for statistical data.

4.2 Hunter L*a*b* Colorimetry

The Hunter Colorimetry results confirmed the sensory appearance results for highly accelerated storage and accelerated storage conditions. The Hunter "L" (lightness-darkness) and Hunter "a" (red-green tint) results both correlated strongly positive with sensory appearance.

Differences in "lightness" were seen in the Hunter "L" scores after one week of highly accelerated storage and one month of accelerated storage. This continued throughout storage, and was more pronounced in the highly accelerated samples. Lighter samples were preferred by the sensory panelists. Batch 5 was significantly lighter than all other experimental batches.

Differences in Hunter "a" were detected in the variables which contained the new colorizing system (batches 4 and 5) even in initial sample testing. These samples were more "greenish" as compared with batches with the original coloring system. Generally, the greenish tint was the preferred hue in our study. After one week of highly accelerated storage and one month of accelerated storage, batch 5 was "greener" than batch 4. This trend continued through the remainder of storage testing.

4.3 Emulsion Stability Testing

Results of the emulsion stability testing showed all test batches had difficulty maintaining a stable emulsion under freeze-thaw conditions. See appendix D for photographic results. Batch 4 showed the least amount of emulsion instability with only slight oiling off and grainy texture. All other batches showed advanced oiling off and a marked grainy or gritty texture. CORANET (a Defense Logistics Agency MANTECH program) will be investigating the use of a centrifugation method to determine emulsion stability of MRE™ cheese spread [8].

4.4 First Strike Ration™ Field Test

The field test confirmed laboratory storage results where the item was verified as acceptable by the Warfighter. Mean results from 62 Warfighter respondents resulted in a 6.45 (SD 1.82) rating utilizing a nine-point Hedonic scale.

5. CONCLUSIONS

Both the original and verification accelerated storage study results indicate that the batch 5 formulation had significantly higher ratings than the Military Specification (MIL-C-595) control samples for all sensory attributes and that the combined nitrogen flush, new stabilizer, and new colorizing system had a significant effect in improving storage stability over the MIL-C-595 batch. Warfighter field testing also confirmed these findings. Recommendations for product changes were briefed to The Joint Service Operational Rations Forum (JSORF) and approved by the military service representatives. The technical data changes are being made to the procurement documents and have been transitioned to the Defense Supply Center, Philadelphia, PA, for procurement as a component item of the MRE™ and First Strike Ration™.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 10/ 003 in a series of reports approved for publication.

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APPENDIX A
TECHNICAL SENSORY EVALUATION

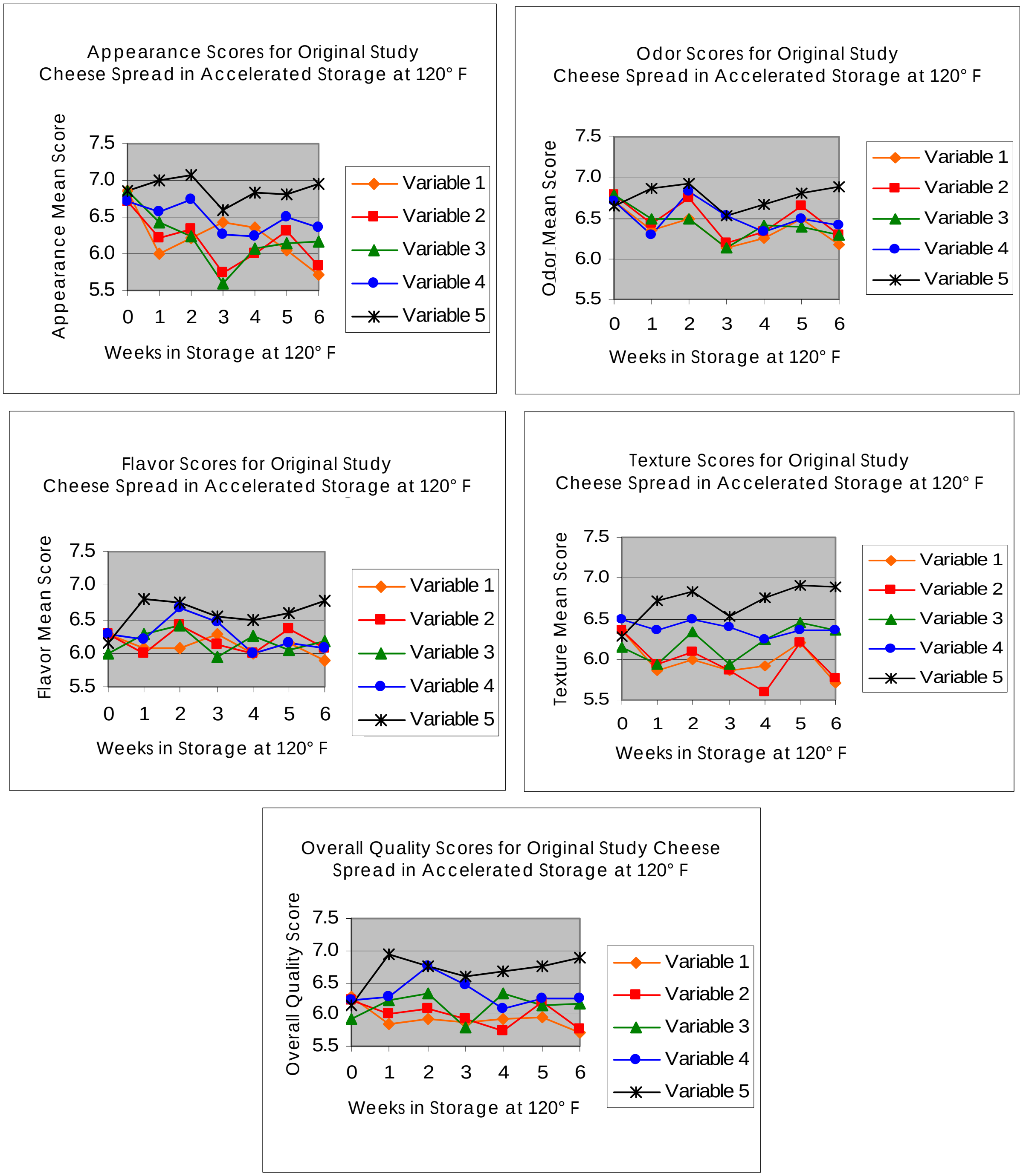

Figure A-1. Original Study Scores at 120° F (49° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

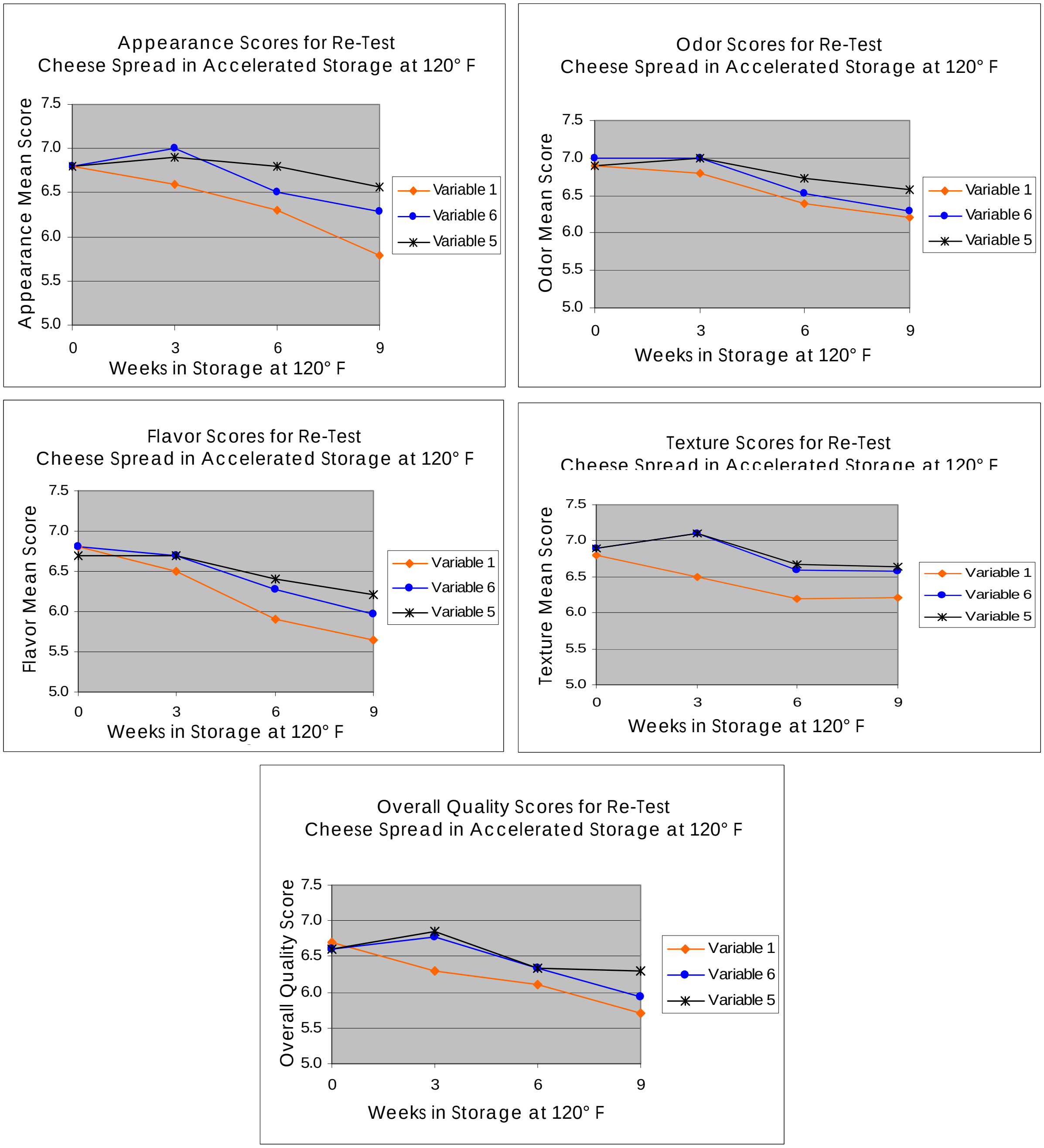

Figure A-2. Re-Test Scores at 120° F (49° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

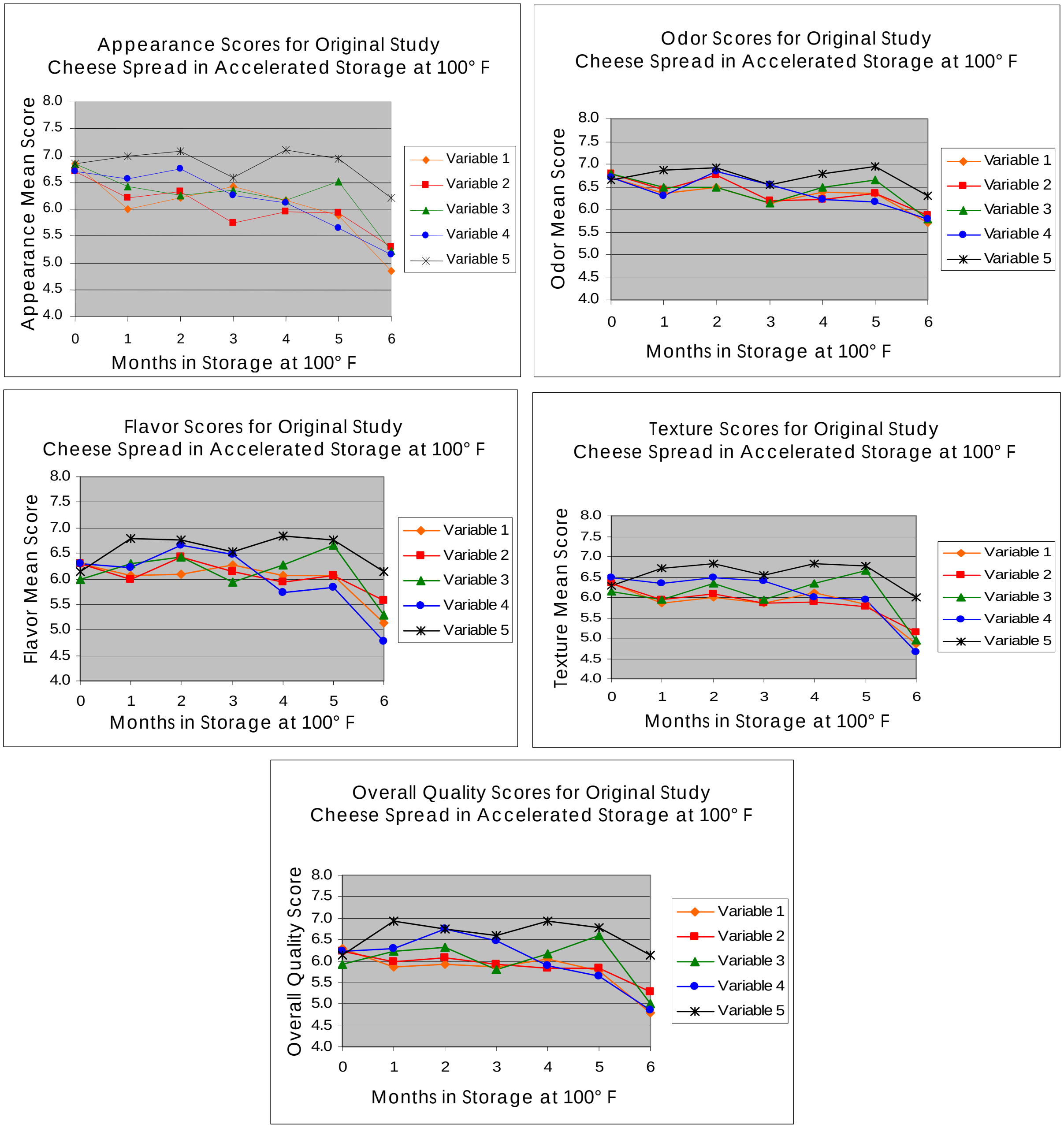

Figure A-3. Original Study Scores at 100° F (38° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

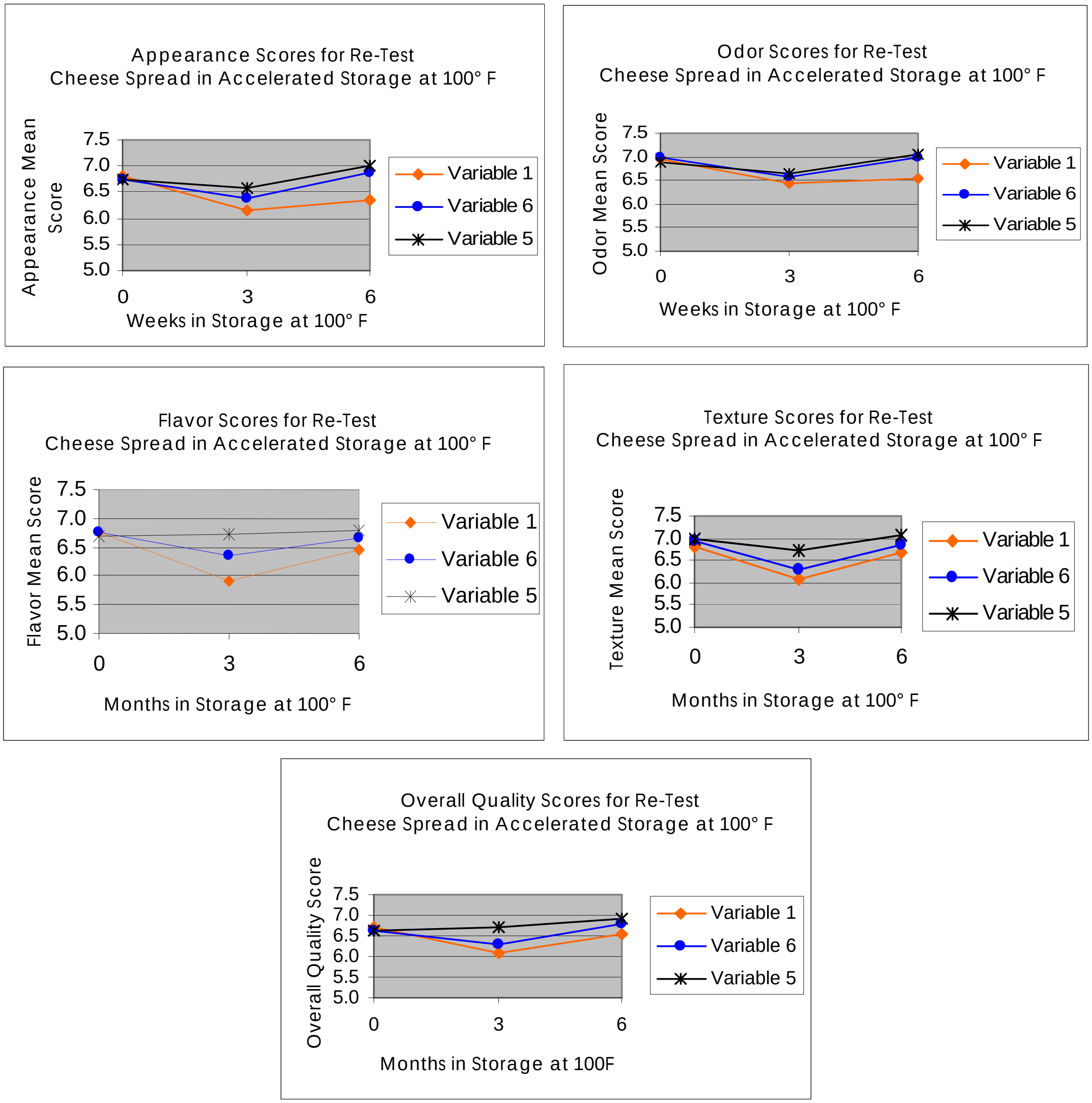

Figure A-4. Re-Test Study Scores at 100° F (38° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

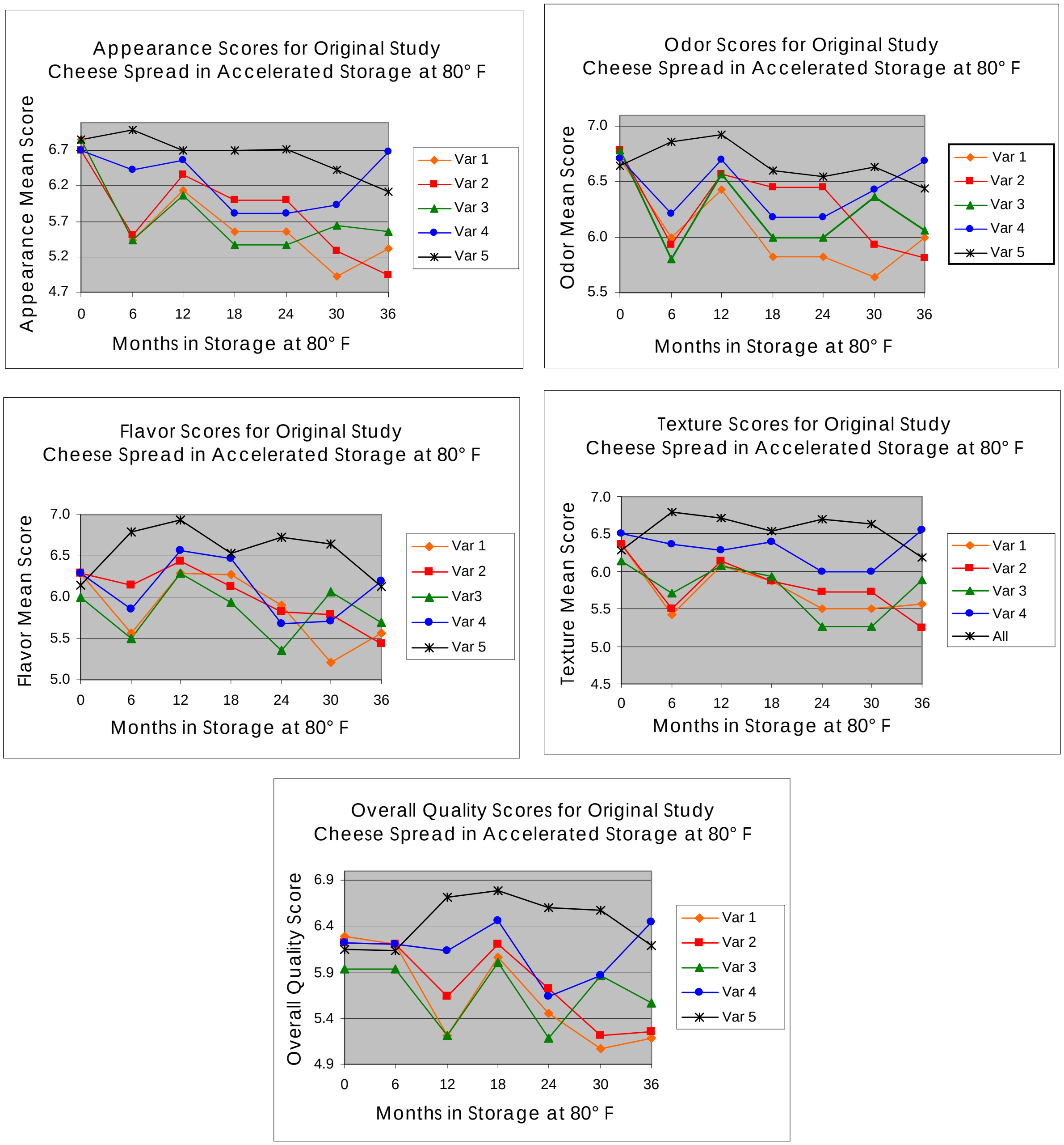

Figure A-5. Original Study Scores at 80° F (27° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

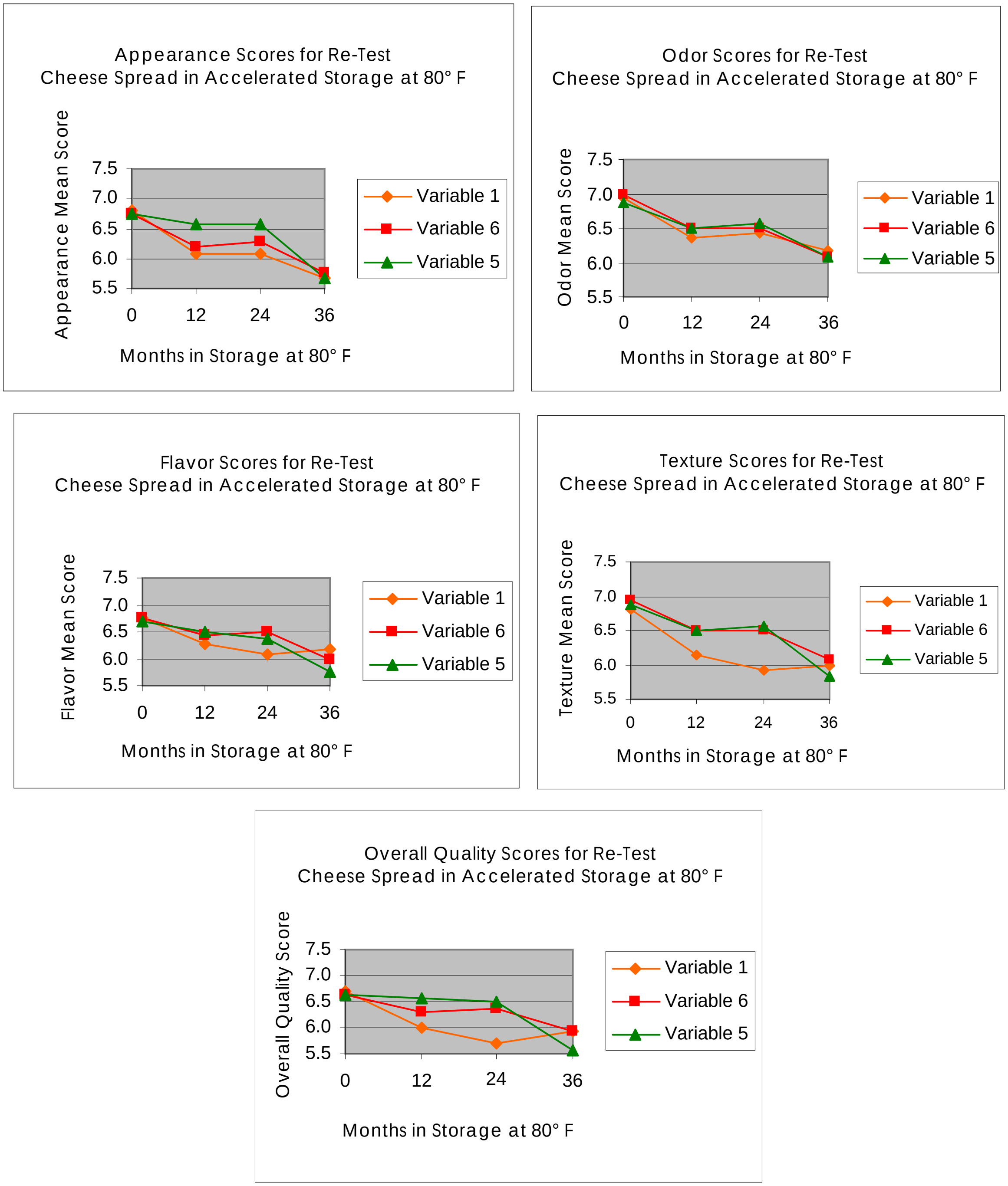

Figure A-6. Re-Test Study Scores at 80° F (27° C)
Top Left. Appearance
Top Right. Odor
Center Left. Flavor
Center Right. Texture
Bottom. Overall Quality

APPENDIX B
DUNCAN'S NEW MULTIPLE RANGE TEST MEAN SCORES AND P-VALUES

Table B-1. Original Study at 100° F (38° C)

Attribute	Initial					1 month					2 months					3 months		
	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3
Appear	cab	cdb	cab	cdb	cab	ghfe	cde	gdfe	cde	a	Hi	ghfi	gdfe	gfe	ab	m	k	kl
	6.86	6.71	6.86	6.71	6.86	6.29	6.59	6.41	6.59	7.06	6	6.21	6.43	6.36	7	4.71	5.21	5.14
Odor	cadb	ab	ab	cadb	cedb	edgf	cadb	cedbf	cadb	cab	Hgf	hegf	cedgf	hg	ab	j	i	i
	6.71	6.79	6.79	6.71	6.64	6.47	6.71	6.59	6.71	6.76	6.36	6.43	6.5	6.29	6.86	5.36	5.71	5.71
Flavor	dbc	dbc	dgecf	dbc	dbecf	dbc	bc	dbc	b	a	Dbecf	dgecf	dbc	dbec	a	l	kjl	kjl
	6.29	6.29	6	6.29	6.14	6.24	6.29	6.24	6.35	6.71	6.07	6	6.29	6.21	6.79	5.14	5.43	5.43
Text	de	de	gehf	dc	def	gef	dbc	bc	dbc	a	Gih	gih	gih	de	bc	k	j	i
	6.36	6.36	6.14	6.5	6.29	6.18	6.53	6.76	6.59	7.18	5.86	5.93	5.93	6.36	6.71	5.07	5.36	5.71
Overall	ecd	efd	iefgh	efd	efgd	iefgdh	ecd	ecd	cd	ab	Ifgh	iefgdh	efd	ecd	ab	mlk	lk	jk
	6.29	6.21	5.93	6.21	6.14	6	6.29	6.29	6.35	6.82	5.86	6	6.21	6.29	6.93	5.14	5.29	5.43

Attribute	3 months		4 months					5 months					6 months					P-Value
	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	
Appear	Hi	gfe	ghi	ji	ghi	ghi	a	ji	ji	cdfe	J	ab	ml	k	k	kl	ghfi	
	6	6.36	6.17	5.94	6.17	6.11	7.11	5.88	5.94	6.53	5.65	6.94	4.86	5.29	5.21	5.14	6.21	0.0001
Odor	hgf	hgf	hedgf	hg	cedgf	hg	ab	hgf	hgf	cedb	H	a	i	i	i	i	i	
	6.36	6.36	6.44	6.22	6.5	6.22	6.78	6.35	6.35	6.65	6.18	6.94	5.71	5.86	5.79	5.79	5.79	0.0001
Flavor	kl	ijh	dbecf	dgehf	dbc	igjh	a	dbecf	dbecf	igehf	Ighf	a	l	ikj	kl	m	dbecf	
	5.29	5.64	6.06	5.94	6.28	5.72	6.83	6.06	6.06	5.88	5.82	6.76	5.14	5.57	5.29	4.79	6.14	0.0001
Text	gihf	dc	gehf	gih	de	gihf	b	ih	i	bc	Gihf	bc	lk	jk	k	l	gihf	
	6	6.5	6.11	5.89	6.33	6	6.83	5.82	5.76	6.71	6	6.76	4.86	5.14	4.93	4.64	6	0.0001
Overall	jk	iefgdh	efgdh	igh	efgd	ifgh	a	ijh	igh	cb	Ij	ab	n	lk	mln	mn	efgd	
	5.43	6	6.06	5.83	6.17	5.89	6.94	5.76	5.82	6.59	5.65	6.76	4.79	5.29	5	4.86	6.14	0.0001

Table B-2. Original Study at 120° F (49° C)

Attribute	Initial					1 week					2 weeks					3 weeks		
	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3
Appear	cadb	cdbe	cadb	cdbe	cadb	hi	hfg	hi	fde	Ab	hfg	hfg	hfg	cadbe	a	l	lkj	l
	6.86	6.71	6.86	6.71	6.86	6.13	6.33	6.07	6.53	7.07	6.33	6.33	6.25	6.75	7.08	5.6	5.73	5.53
Odor	cadbe	cadb	cadb	cadbe	fcadbe	fcgdbe	fighe	igjh	fcgdhe	Ab	fgdhe	cadbe	fgdhe	ab	a	j	ij	j
	6.71	6.79	6.79	6.71	6.64	6.6	6.47	6.33	6.53	6.87	6.5	6.75	6.5	6.83	6.92	6.13	6.2	6.13
Flavor	gkiejdhf	gkiejdhf	kml	gkiejdhf	gkimjlh	cedb	gciedhf	gciedhf	gcedbf	A	kimjlh	gcedhf	gcedhf	cab	ab	gkiejdlhf	gkimjlh	ml
	6.29	6.29	6	6.29	6.14	6.53	6.4	6.4	6.47	6.87	6.08	6.42	6.42	6.67	6.75	6.27	6.13	5.93
Text	dcfe	dcfe	hjifeg	dcb	dcfeg	hdifeg	hjik	dcfe	dcfeg	A	hjikg	hjifg	dcfe	dcb	a	jk	jk	hjik
	6.36	6.36	6.14	6.5	6.29	6.2	5.93	6.4	6.27	7	6	6.08	6.33	6.5	6.83	5.87	5.87	5.93
Overall	cdfeg	hidfeg	hijlkmg	hidfeg	hijdkfeg	hcdfeg	hidfeg	hijdkfeg	cde	A	jlkm	hijlkfeg	cde	ab	ab	ijlkm	hijlkmg	lkm
	6.29	6.21	5.93	6.21	6.14	6.27	6.2	6.13	6.4	6.93	5.83	6.08	6.33	6.75	6.75	5.87	5.93	5.8

Attribute	3 weeks		4 weeks					5 weeks					6 weeks					P-Value
	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	V 1	V 2	V 3	V 4	V 5	
Appear	hfg	cfde	l	hikj	hi	hfg	cadbe	hij	hfg	Hig	fge	cadbe	lk	likj	hg	hfg	cab	
	6.27	6.6	5.67	6	6.08	6.25	6.83	6.05	6.3	6.15	6.5	6.8	5.71	5.82	6.18	6.35	6.94	0.0001
Odor	fcgdhe	fcgdhe	ijh	igjh	figjh	igjh	fcadbe	fgdhe	fcadbe	Figjh	fgdhe	cab	j	ijh	ijh	figjh	ab	
	6.53	6.53	6.25	6.33	6.42	6.33	6.67	6.5	6.65	6.4	6.5	6.8	6.18	6.29	6.29	6.41	6.88	0.0001
Flavor	gcedbf	cedb	kml	kml	gkiejlhf	kml	cedbf	gkimjlh	gciejdhf	Kmjl	gkimjlh	cadb	m	kimjl	gkimjlhf	kimjl	ab	
	6.47	6.53	6	6	6.25	6	6.5	6.15	6.35	6.05	6.15	6.6	5.88	6.06	6.18	6.06	6.76	0.0001
Texture	dcfe	cb	jik	l	hdcfeg	hdcfeg	ab	hdifeg	hdifeg	Dce	dcfe	a	lk	lk	dcfe	dcfe	a	
	6.4	6.53	5.92	5.5	6.25	6.25	6.75	6.2	6.2	6.45	6.35	6.9	5.71	5.76	6.35	6.35	6.88	0.0001
Overall	cdb	cab	hijlkm	lm	cde	hijlkfeg	ab	hijlkfmg	hidfeg	Hijdkfeg	hdfeg	ab	m	lm	hijdfeg	cdfe	a	
	6.47	6.6	5.92	5.75	6.33	6.08	6.75	5.95	6.2	6.15	6.25	6.75	5.71	5.76	6.18	6.29	6.88	0.0001

Table B-3. Original Study at 80° F (27° C)

Attribute	Initial					6 months					12 months				
	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Appearance	a	ab	a	ab	a	higf	hiegf	higf	cadb	a	cedb	cadb	cedbf	cab	ab
	6.86	6.71	6.86	6.71	6.86	5.43	5.5	5.43	6.43	7	6.14	6.36	6.07	6.57	6.71
Odor	cab	ab	ab	cab	cadb	fghe	fgh	gh	fcghdbe	a	fcadbe	cadbe	cadbe	cab	a
	6.71	6.79	6.79	6.71	6.64	6	5.93	5.79	6.21	6.86	6.43	6.57	6.57	6.71	6.93
Flavor	fcgadbe	fcgadbe	fcgihde	fcgadbe	fcghdbe	gihj	fcghdbe	gihj	fgihje	ab	fcgadbe	fcadbe	fcgadbe	cadbe	a
	6.29	6.29	6	6.29	6.14	5.57	6.14	5.5	5.86	6.79	6.29	6.43	6.29	6.57	6.93
Texture	cadbe	cadbe	fcgadbe	cadb	cadbe	jhi	jghi	fjghie	cadbe	a	fcghdbe	fcgadbe	fcghdbe	cadbe	ab
	6.36	6.36	6.14	6.5	6.29	5.43	5.5	5.71	6.36	6.79	6.07	6.14	6.07	6.29	6.71
Overall	fcadbe	fcadbe	fcghde	fcadbe	fcgadbe	jhi	fjghi	jhi	fcgadbe	ab	fcgadbe	fcadbe	fcgdbe	cadb	a
	6.29	6.21	5.93	6.21	6.14	5.21	5.64	5.21	6.14	6.71	6.07	6.21	6	6.5	6.79

Attribute	18 months					24 months					36 months				
	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Appearance	hiegf	cedgf	hig	hedgf	ab	i	hi	hegf	hcedgf	cadb	hig	i	hiegf	ab	cedbf
	5.55	6	5.36	5.82	6.73	4.93	5.29	5.64	5.93	6.43	5.31	4.94	5.56	6.69	6.13
Odor	gh	fcadbe	fghe	fcghde	cadbe	h	fgh	fcgadbe	fcadbe	cadb	fghe	gh	fghde	cab	fcadbe
	5.82	6.45	6	6.18	6.55	5.64	5.93	6.36	6.43	6.64	6	5.81	6.06	6.69	6.44
Flavor	fgihdje	fgihje	ij	gihj	cab	j	fgihj	fcgihdbe	fgihj	cadb	gihj	ihj	fgihj	fcgahdbe	fcgihdbe
	5.91	5.82	5.36	5.64	6.73	5.21	5.79	6.07	5.71	6.64	5.56	5.44	5.69	6.19	6.13
Texture	fjghi	fjghie	ji	fcghde	cab	j	fjghie	fcgadbe	fcghde	cab	fjghi	ji	fghdie	cadb	fcadbe
	5.55	5.73	5.27	6	6.64	5.14	5.71	6.14	6	6.57	5.56	5.25	5.88	6.56	6.19
Overall	jghi	fjghie	ji	fjghi	cab	j	jhi	fghdie	fghdie	cadb	ji	jhi	fjghi	cadbe	fcadbe
	5.45	5.73	5.18	5.64	6.64	5.07	5.21	5.86	5.86	6.57	5.19	5.25	5.56	6.44	6.19

Table B-4. Retest at 100° F (38° C) - Test Result Code: MT006_02D1

Attribute	Initial			3 Months			6 Months			P-Value
	V 1	V 6	V 5	V 1	V 6	V 5	V 1	V 6	V 5	
Appearance	ab	ab	ab	d	cd	cb	cd	ab	a	
	6.81	6.75	6.75	6.14	6.36	6.57	6.33	6.87	7	0.0001
Odor	a	a	ab	c	c	cb	c	a	a	
	6.94	7	6.88	6.43	6.57	6.64	6.53	7	7.07	0.0033
Flavor	ab	ab	ab	d	c	ab	cb	ab	a	
	6.75	6.75	6.69	5.93	6.36	6.71	6.47	6.67	6.8	0.0001
Texture	ab	ab	ab	c	c	ab	b	ab	a	
	6.81	6.94	6.88	6.07	6.29	6.71	6.67	6.87	7.07	0.0073
Overall	ab	ab	ab	d	cd	ab	cb	ab	a	
	6.69	6.63	6.63	6.07	6.29	6.71	6.53	6.8	6.93	0.0004

Table B-5. Retest at 120° F (49° C) - Test Result Code: MT006_02D1

Attribute	Initial			3 Weeks			6 Weeks			9 Weeks			P-Value
	V 1	V 6	V 5	V 1	V 6	V 5	V 1	V 6	V 5	V 1	V 6	V 5	
Appearance	ab	cab	cab	cdb	a	cab	d	cab	cd	e	d	cdb	
	6.94	6.75	6.75	6.57	7	6.86	6.33	6.8	6.47	5.79	6.29	6.57	0.0003
Odor	a	a	a	ab	a	a	de	cab	cde	e	de	cdb	
	6.88	7	7	6.79	7	7	6.4	6.73	6.47	6.21	6.29	6.57	0.0227
Flavor	ab	cab	cab	cde	a	a	fde	cdb	cdb	f	fe	cdb	
	6.81	6.75	6.69	6.5	6.71	6.71	6.4	6.73	6.53	5.64	5.86	6.21	0.3735
Texture	cab	cab	ab	cde	a	a	e	cadbe	cadb	de	cdbe	cadbe	
	6.81	6.94	7	6.5	7.07	7.07	6.2	6.6	6.67	6.21	6.57	6.64	0.0089
Overall	ab	cab	cab	cde	a	a	fde	cdb	cdb	f	fe	cde	
	6.69	6.63	6.63	6.29	6.79	6.86	6.07	6.33	6.33	5.71	5.93	6.29	0.0016

Table B-6. Retest at 80° F (27° C) - Test Result Code: MT006_02D1

Attribute	Initial			12 months			24 months			36 months			P-Value
	V1	V6	V5	V1	V6	V5	V1	V6	V5	V1	V6	V5	
	a	ab	ab	ced	cedb	cab	ced	cadb	cab	e	ed	e	
Appearance	6.81	6.75	6.75	6.07	6.21	6.57	6.07	6.29	6.57	5.67	5.75	5.67	0.001
	a	a	ab	ecd	cd	cd	ecd	cd	cb	ed	e	e	
Odor	6.94	7	6.88	6.36	6.5	6.5	6.43	6.5	6.57	6.17	6.08	6.08	0.0002
	a	a	a	cdb	cab	a	d	cab	ab	cd	cd	d	
Flavor	6.75	6.75	6.69	6.29	6.43	6.5	6.07	6.5	6.36	6.17	6	5.75	0.0825
	a	a	a	cdb	cab	cab	d	cab	ab	cd	cdb	d	
Texture	6.81	6.94	6.88	6.14	6.5	6.5	5.93	6.5	6.57	6	6.08	5.83	0.0013
	a	a	a	cdb	cab	a	d	cab	ab	cd	cd	d	
Overall	6.69	6.63	6.63	6	6.29	6.57	5.71	6.36	6.5	5.92	5.92	5.58	0.0007

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APPENDIX C
HUNTER L*a*b*

Table C-1. Storage at 120° F (49° C)

Batch 1 – CONTROL							
Weeks storage at 120F	**0**	**1**	**2**	**3**	**4**	**5**	**6**
L*	71.51	72.33	70.63	69.47	68.47	67.39	70.37
a*	11.80	9.91	10.17	10.43	10.62	10.78	11.44
b*	35.54	33.77	33.01	32.58	32.00	31.44	33.28
Batch 2 - NITROGEN FLUSH							
Weeks storage at 120F	**0**	**1**	**2**	**3**	**4**	**5**	**6**
L*	71.20	71.43	70.60	69.57	68.64	67.58	69.35
a*	10.45	10.02	10.50	11.00	10.89	10.89	11.58
b*	33.67	33.47	32.79	32.88	32.09	31.68	32.91
Batch 3 - STABILIZER							
Weeks storage at 120F	**0**	**1**	**2**	**3**	**4**	**5**	**6**
L*	73.25	70.28	68.17	66.47	65.07	67.36	68.94
a*	10.56	9.38	9.72	10.44	9.78	10.80	11.20
b*	34.53	32.79	31.56	31.10	29.91	31.53	32.40
Batch 4 - NEW COLOR							
Weeks storage at 120F	**0**	**1**	**2**	**3**	**4**	**5**	**6**
L*	74.28	74.91	71.09	73.64	67.62	71.19	69.11
a*	6.87	7.56	7.55	8.00	7.90	8.17	8.34
b*	32.01	32.99	30.53	32.40	29.03	31.15	30.03
Batch 5 - ALL NEW VARIABLES W/ NITROGEN FLUSH							
Weeks storage at 120F	**0**	**1**	**2**	**3**	**4**	**5**	**6**
L*	75.13	74.26	73.92	73.80	73.35	72.28	72.50
a*	7.74	7.26	7.51	8.08	8.14	8.31	8.54
b*	33.50	32.51	32.22	33.11	32.48	32.11	31.50

Table C-2. Storage at 100° F (38° C)

Batch 1 - CONTROL				
Months in storage at 100F	**0**	**2**	**4**	**6**
L*	71.51	66.55	66.10	64.43
a*	11.80	10.66	11.08	11.44
b*	35.54	30.09	31.03	30.50
Batch 2 - NITROGEN FLUSH				
Months in storage at 100F	**0**	**2**	**4**	**6**
L*	71.20	65.89	65.20	63.88
a*	10.45	10.46	11.08	11.21
b*	33.67	30.41	30.72	30.03
Batch 3 - STABILIZER				
Months in storage at 100F	**0**	**2**	**4**	**6**
L*	73.25	67.23	66.26	65.06
a*	10.56	10.29	10.75	11.10
b*	34.53	31.13	30.69	30.03
Batch 4 - NEW COLOR				
Months in storage at 100F	**0**	**2**	**4**	**6**
L*	74.28	70.06	66.44	67.72
a*	6.87	7.87	7.90	8.44
b*	32.01	31.21	28.92	28.71
Batch 5 - ALL NEW VARIABLES W/ NITROGEN FLUSH				
Months in storage at 100F	**0**	**2**	**4**	**6**
L*	75.13	74.26	69.55	69.21
a*	7.74	7.26	8.21	8.55
b*	33.50	32.51	31.00	30.83

APPENDIX D
EMULSION STABILITY PHOTOGRAPHY