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The effectiveness of a new oxygen absorbing packaging technology in modifying the inner atmosphere to very low residual oxygen retarding the growth of spoilage bacteria and mold, biochemical and enzymatic degradation, while minimizing the need for butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), sulfur dioxide, sorbates, benzoates, and other food additives was evaluated. The project addressed the problem of oxygen ingress reducing the quality of packaged products containing high oil content, including MRE hot fill non-retort items such as cheese spread, and mayonnaise (in MRE26, menu # 10).

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STUDY OF THE USE OF OXYGEN-ABSORBING PACKAGING MATERIAL TO PROLONG SHELF-LIFE OF RATIONS

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Summary

The effectiveness of a new oxygen absorbing packaging technology in modifying the inner atmosphere to very low residual oxygen retarding the growth of spoilage bacteria and mold, biochemical and enzymatic degradation, while minimizing the need for butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), sulfur dioxide, sorbates, benzoates, and other food additives was evaluated. The project addressed the problem of oxygen ingress reducing the quality of packaged products containing high oil content, including MRE hot fill non-retort items such as cheese spread, and mayonnaise (in MRE26, menu # 10).

We determined the ability of the proposed films to maintain product shelf-life by conducting studies at 80°F (26.7°C) for 12 months, six months at 100°F (37.8°C) and a 1-month study at 125°F (52°C). Confirmatory testing was performed by a trained panel at the National Soldier Center (NSC) at Natick. In addition, tests on the mechanical integrity of the film were conducted.

The following objectives were completed: (a) Determining the minimum amount of oxygen-absorbing material required to reduce the oxygen level in hermetically sealed packaged products according to product specifications (Phase I); (2) identifying the relationship between food moisture content and activation of oxygen absorber functionality (Phase I); (3) conducting accelerated storage studies, sensory evaluations, microbiological and chemical analyses (e.g., moisture, pH and rancidity) to determine the acceptability of the packaged rations over time (Phase II). In summary, this packaging technology effectively reduces rancidity, preserves vitamin C, and maintains Vitamin A while ensuring required product shelf life of a high-fat content MRE items such as cheese spread. The oxygen absorber quickly reduced the headspace oxygen to below 0.5%.

In Phase III, we explored the possible implementation for the use of the new oxygen absorber technology to all combat ration packages that have head spacing issues, including retort MRE pouches**.** It was also proposed to demonstrate that hydrogenated oils of MREs can be replaced with the more healthful olive oil. Results showed that the packaging technology can be used for retortable items (MRE 28 “Italian” entrée, chicken pesto with noodles) since it maintained the

product shelf-life and oil stability. Our findings support the use of olive oil as a healthy alternative in future formulations.

Introduction

-Background Information:

It has been a long-standing goal to enhance the nutrition of MREs and UGRs by replacing the hydrogenated oils in these rations, which contain trans fats, with non-hydrogenated oils such as olive and canola. Olive and canola oils are known to promote cardiovascular health due their high content of monounsaturated fat and low content of saturated fat. These healthy oils are not currently used in MREs and UGRs because they tend to become rancid over prolonged storage. Rancidity is caused when oxygen combines with fatty acids. The access of oxygen to the food product influences the deterioration of pigments, lipids, proteins and the overall sensory quality thus affecting the shelf life. Our thesis was that this reaction will not occur if the oxygen within the sealed package is absorbed by the packaging material, thus allowing the use of healthy oils in these rations and also providing a three-year shelf life.

The task of packaging technology is to develop the type of packaging that will maintain the low level of oxygen inside the package in a given time. Removal of oxygen, both residual and that entering through the plastic package walls or seals, may be achieved by affixing an oxygen scavenger sachet to the interior of the package wall to extend the quality of the product and suppress aerobic microorganisms. Oxygen scavengers can reduce the amount of oxygen in a package to less than 0.01 percent, as compared to traditional preservation methods such as gas flushing and vacuum packing, which reduce headspace oxygen to only about 0.50 percent.

Oxygen scavenger sachets were introduced in Japan in and are currently available in a wide variety of sizes and fills to ensure adequate oxygen absorber capacity. The sachets are made entirely from food grade materials and can be used by themselves or in conjunction with vacuum/gas flushed packaging to reduce ambient oxygen present at the time of packaging. This approach of inserting a sachet into the package is effective but meets with resistance among food packers. The active ingredients in most systems consist of a non-toxic brown/black powder or aggregate which is visually unappealing if the sachet is broken. A much more attractive approach would be the use of a transparent packaging plastic as the scavenging medium. By incorporating a desiccant in the product contact layer, contamination of a product by leakage from a sachet will not occur. This approach also eliminates the risk of ingestion. Oxygen-scavenging films also offer potential cost savings due to increased production efficiency and convenience. The quality of the packaged food is preserved by modifying the inner atmosphere to very low residual oxygen retarding the growth of spoilage bacteria and mold, biochemical and enzymatic degradation, while minimizing the need for butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), sulfur dioxide, sorbates, benzoates, and other food additives.

Oxygen-absorbing sachets are commonly used in dry bakery products but are impractical in liquid suspensions where the sachet may become immersed into the food product. This complication is eliminated by imbedding the oxygen-absorbing material within the structure of the packaging material. Shelf stability is critical because the military requires that MRE foods be stable for a minimum of three years without refrigeration at 80°F (26.7°C) and for six months at 100°F. The Unitized Group Ration (UGR) requirement is at least 18 months at 80°F (26.7°C). Therefore, it is necessary to determine the ability of the proposed films to maintain the target product shelf life.

-Cost Effectiveness

The primary cost benefit derived from this study was the finding that MRE components formulated with olive oil does not become rancid during three years of storage. This finding allows for a more healthful reformulation of virtually all MRE components, which have added oils as ingredients, particularly those that are partially-hydrogenated and contain trans fats.

The long-term health benefits of MRE reformulation with olive oil could be substantial. There is a large body of clinical data to show that consumption of olive oil can provide heart health benefits such as favorable effects on cholesterol regulation and LDL cholesterol oxidation, and that it exerts anti-inflammatory, antithrombotic and antihypertensive effects.

The FDA allows food products containing olive oil to display the following health claim on the label: "Limited and not conclusive scientific evidence suggests that eating about 2 tbsp. (23 g) of olive oil daily may reduce the risk of coronary heart disease due to the monounsaturated fat in olive oil. To achieve this possible benefit, olive oil is to replace a similar amount of saturated fat and not increase the total number of calories you eat in a day."

Project Plan

The project was separated into three different phases listed below.

Phase I:

To gather information regarding acceptability of the packaged rations and perform necessary basic analysis of the new oxygen absorber containing pouch laminates.

Phase II:

To determine if any component of the oxygen absorber, i.e., Zero-Ox E, migrates into in the product and to identify the effectiveness of the oxygen absorber under various moisture and packing conditions. To study how the presence of the oxygen absorber influences the food quality and safety (appearance, color, flavor, odor, texture, water activity and moisture content, microbial counts, rancidity, and shelf life). To present this information to the government to determine the usefulness of the new oxygen absorber containing laminates for other MRE or UGR packaging applications.

Phase III:

To apply the knowledge gained to study other MRE or UGR food items of interest to CORANET.

Objectives

(1) To determine the minimum amount of oxygen-absorbing material required to reduce the oxygen level in hermetically sealed packaged products according to product specifications.

(2) Identify the relationship between food moisture content and activation of oxygen absorber functionality.

(3) Conduct accelerated storage studies, sensory evaluations, microbiological and chemical analyses (e.g., moisture, pH and rancidity) to determine the acceptability of the packaged rations over time. Products included cheese spread and canola-based mayonnaise.

(4) Explore the possible implementation for the use of the new oxygen absorber technology to all combat ration packages that have head spacing issues (e.g., retort item or those containing olive oil). Products included chicken pest with noodles (retorted entrée) with soybean oil and olive oil reformulation.

Definitions

MRE: Meal Ready to Eat

UGR: Unitized Group Ration

BHA: Butylated hydroxyanisole

BTA: Butylated hydroxytoluene

TBA: 2-Thiobarbituric Acid

Results and Discussion

In summary, the new packaging material did not perform well with the canola-based mayonnaise. There was a problem of migration of the iron compound into the product. Therefore, this report will only present results for the cheese spread and other products. Results from Phase II studies for the cheese spread were published in the ***Journal of Food Science (Gomes, C., Castell-Perez, M.E., Chimbombi, E., Dazhi, S., Jia, L., Sue, H.G., Sherman, P., Dunne, P. and Wright, A.O. 2009. Effect of Oxygen Absorbing Packaging on the Shelf-life of a Liquid-based Component of Military Operational Rations. 74(4), E167-E176, 2009).*** Below is a summary of the findings presented in that publication.

Cheese Spread Study

This study showed that the proposed O_2-absorbing laminate was efficient in reducing headspace oxygen concentration by 67.44% (from 20.4% to 6.82%) within 24 hours. This active packaging material significantly reduced rancidity in cheese spread samples. In addition, the laminate helped delay the vitamin C decay, samples had high acceptable sensory characteristics throughout the whole shelf-life study and rated at par when not above with standard sample with respect to the sensory, physical, chemical and microbiological characteristics. Samples also met shelf-life the requirement of 6 months at 37.8°C (100°F). Therefore, pouches containing O_2 scavenger in the laminate can help retain nutrition and extend shelf-life of high-fat, liquid-like products.

Film Oxygen Absorbing Capability

Prior to the testing of the oxygen absorbing capability of $ABSO_2RB^{TM}$ film, the oxygen absorption kinetics of the oxygen absorber–containing material in pellet form was first characterized at temperatures ranging from 25°C to 65°C (77^{o}F to 149^{o}F) and relative humidity (RH) from 75 to 100%. The results show that both temperature and relative humidity can significantly affect the oxygen absorption rates. At temperatures ranging from 25°C to 45°C (77^{o}F to 113^{o}F), the oxygen absorption rates increase as temperatures increased at fixed RH (0.184 $\%O_2$/hr for 25°C, 0.534 $\%O_2$/hr for 35°C, and 0.948 $\%O_2$/hr for 45°C under 100% RH; 0.711 $\%O_2$/hr for 25°C, 0.890 $\%O_2$/hr for 35°C, and 0.990 $\%O_2$/hr for 45°C under 75% RH;). At RH ranging from 75 to 100%, the oxygen absorption rates decrease as the RH is increased at a fixed temperature. Further increase in temperature to 65°C (149^{o}F) will dramatically inhibit the oxygen absorption rates. It is hypothesized that high temperature leads to high vapor pressure, thus limiting the oxygen absorption reaction.

The activation energy for the oxygen absorption was also estimated at different RH using the Arrhenius equation ($Ln(k) = Ln(k_a) - \frac{E_a}{RT}$, where k is the oxygen absorption rate, k_a is the pre-exponential factor, E_a is activation energy, R is gas constant, and T is absolute temperature). The results show that for 75% and 100% RH, the E_a are 13.1 and 64.8 J/mol, respectively. The above data clearly indicate that lower RH leads to lower activation energy and high absorption rate. Therefore, the oxygen absorbing materials chosen in this study would perform better at lower temperature and lower HR. The optimal condition is found to be at 45°C (113^{o}F) and 75% RH.

The above findings are useful as guidance for better understanding and design of the ABSO$_2$RB^{TM} for pouch laminate applications.

Both packaging materials (ABSO$_2$RB^{TM} and regular MRE pouches) showed an exponential decay of oxygen concentration with time measured with a Mocon O$_2$-analyzer (Figure 1). Major changes in headspace gas composition occurred in the pouches containing the O$_2$ scavenger (ABSO$_2$RB^{TM}) in the first days of storage at room temperature with these pouches reaching equilibration of the atmosphere at a faster rate. Within 11 days of storage, the oxygen concentration in the headspace of the ABSO$_2$RB^{TM} -laminate was below 1.0% and remained below this level throughout the whole storage period. Oxygen concentration in the regular MRE pouches decreased by 50% during the first fifteen days and remained stable down to a concentration of 5%. The oxygen decreased in the regular packaging because the oxygen reacted with the food. Thus the purpose of the oxygen-absorbing packaging is to remove the oxygen before degrading reactions occur**.** This result supports the effectiveness of the O$_2$ absorbing laminated evaluated in this study since we had data that demonstrated that oxygen depletion in the ABSO$_2$RB^{TM} pouches occurred considerably faster than in regular pouches. That is solid evidence that the laminate effectively absorbed oxygen.

Film Properties

- Laminate structure

A TOM image of the cross section of the oxygen absorber-containing film is shown in Figure 2. A total of six layers can be clearly indentified (PE, oxygen absorber-containing sealant, tie-layer, aluminum foil, pigment layer and PET). The dark particles dispersed in the sealant layer are oxygen absorbers.

- Pouch peel testing

The T-peel testing reveals that aging at 51.7^{o}C (125°F) does not deteriorate the integrity of the pouch that contains oxygen absorbers. The samples stored at room temperature and aged at 51.7^{o}C for 60 hours have almost the same T-peel strength values (16.0±0.6 and 16.0±0.8 lbs., respectively). These T-peel strengths values are the same as the reference sample which does not contain any oxygen absorbers.

Shelf Life Studies

Accelerated shelf-life tests of ABSO$_2$RB^{TM} and regular MRE pouches without the O$_2$-absorber were conducted for 3 months at 51.7^{o}C (125^{o}F), and 6 months at 37.8^{o}C (100^{o}F) by measuring microbiological, and physico-chemical quality characteristics, including color, texture, moisture, free fatty acid (FFA), pH, water activity, vitamins C and A. Pouches stored at 26.7^{o}C (80^{o}F) for 12 months served as calibrated controls.

No microbial growth (aerobic, coliforms, yeast and molds) was detected ($P<0.05$) for both packages. Overall, the ABSO$_2$RB^{TM} -pouches indicate an improved reduction in oxygen and Vitamin C retention versus MRE controls and, maintained product quality (physico-chemical and organoleptic). ABSO$_2$RB^{TM} -laminates met the accelerated shelf-life requirement of 1 month at 51.7^{o}C (125^{o}F), and 6 months at 37.8^{o}C (100^{o}F).

The cheese spread samples ($ABSO_2RB^{TM}$ and regular MRE pouches) stored at 26.7°C and 37.8oC were evaluated in terms of color, odor, texture, flavor, and overall quality throughout storage. Two pouches from each treatment were placed in covered glass containers labeled with a random 3-digits number and presented to each panelist at once for a total of 4 samples. A minimum of thirty panelists, consisting of students, staff and faculty at Texas A&M University formed the untrained, consumer test panel. Evaluation was conducted in a well-equipped taste panel booth. Panelists were asked to evaluate the samples and indicate their preferences using a nine-hedonic scale. A score of 1 represented attributes most disliked and a score of 9 represented attributes most liked. Scores higher than or equal to 5 were considered acceptable.

When <u>flavor</u> was scored, all treatments were highly acceptable and only slight changes were observed throughout time. No significant difference ($P > 0.05$) in flavor was detected by the panelists. Similar trend was observed for <u>overall quality scores</u> (Figure 3). For samples stored at 26.7°C, odor, flavor and overall quality sensory attributes did not show ($P>0.05$) significant changes between treatments (control and $ABSO_2RB^{TM}$) throughout the 12-months storage period. These consumer acceptability results indicate that cheese spread samples packed in $ABSO_2RB^{TM}$ pouches were rated at par with those packed in control MRE pouches and for most of the study length consumers could not detect significant differences among treatments.).

A parallel sensory study was conducted at U.S. Army Natick Soldier Center by a trained panel (12 panelists) using a 9-point hedonic scale. The trained panelists evaluated the same parameters as the consumer panelists with the addition of samples stored at 4.4°C (40°F). These results

(Figure 4) confirmed the acceptance of the products packaged in ABSO$_2$RB^{TM} pouches with all samples with scores above acceptability (>5.00) and only a slight difference among treatments throughout storage (1 year). Continued studies (36 months at 80^{o}F and 40^{o}F) showed that the technical panel did not find any significant benefit or detriment from using the oxygen-scavenging pouches.

Shelf life study of MRE applesauce in ABSO$_2$RB^{TM} pouches.

We carried out shelf life studies at 120°F (49^{o}C, 8 weeks), 100°F (37.8^{o}C, 6 months), 80°F (27^{o}C, 12 months) to determine effectiveness (if any) of package to reduce browning.

Experimental Methods: Quality attributes (pH, water activity, moisture content, ^{o}Brix, consistency, color, and weight) were monitored at fixed time intervals throughout the different shelf-life studies. Vitamin C content was also recorded. Consumer testing was also carried out by presenting both samples (regular MRE and ABSO$_2$RB^{TM} MREs at the specified temperatures) to at least 30 members of Texas A&M faculty, staff, and student population. Calibrated controls (80^{o}F, 27^{o}C) were also presented. Panelists scored samples using a 1-9 hedonic scale with 1= dislike extremely and 9 = like extremely).

Results: Although all products met specifications by end of shelf-life (PCR-F-200A), the applesauce samples in both types of packaging showed an undesirable darkening in color after 8 weeks at 120^{o}F (49^{o}C) and 6 months at 100^{o}F (37.8^{o}C) . The samples stored at 80^{o}F (27^{o}C) still show the original yellow color. We decided to test for formation of volatiles responsible for rancidity using gas chromatography. Overall, the formation of such radicals was below detection limits. Consumer panelists consistently gave good scores to both MRE applesauce samples. It is worth to comment that panelists were not as displeased with the darker color – as long as the flavor was acceptable to them. Flavor scores were above 5.00 by the end of shelf-life.

Conclusion: Although the $ABSO_2RB^{TM}$ pouches maintain the shelf-life attributes of the MRE applesauce, they did not prevent the darkening problem. It is suspected that the retort processing step for applesauce manufacture may have a role in this problem.

Parallel studies on the mechanical properties and structural integrity of the pouches.

Experimental Methods: T-peel tests were performed to confirm the mechanical integrity of $ABSO_2RB^{TM}$ containing pouches. Optical microscopy and scanning electron microscopy were undertaken to investigate the structural integrity of the $ABSO_2RB^{TM}$ containing pouches.

Results: It was found that the T-peel strengths of the $ABSO_2RB^{TM}$ containing pouches are at least 30% stronger than the reference samples in all tests. The microscopy observation also shows good structural integrity for all the pouches investigated.

Conclusion: The $ABSO_2RB^{TM}$ pouches have met all the necessary mechanical and structural properties requirements for MRE pouch needs.

Suitability of $ABSO_2RB^{TM}$ in retort packaging and reformulation of one of the MRE 28 "Italian" entrées using olive oil plus $ABSO_2RB^{TM}$ retort packaging

The hypothesis was that olive oil would be a natural oil base for these products. Item chosen was the chicken pesto and noodles entrée. Controls consisted of Olive oil entrees in regular MRE retort packaging and Regular entrees (hydrogenated oils) in regular MRE packaging.

We completed accelerated shelf-life studies at 120°F (49^{o}C, 8 weeks), 100°F (37.8^{o}C, 6 months), and 80°F (27^{o}C, 18 months). We followed the specification requirements for the entrée based on PCR-0-21. Quality attributes (Color, texture, moisture content, Aw, pH, net weight) were monitored at fixed time intervals throughout the different shelf-life studies. We also performed TBARS tests to determine rancidity levels. Consumer testing was also carried out by presenting four samples (regular MRE and ABSO$_2$RB^{TM} MREs and reformulated entrees packaged in regular MRE and ABSO$_2$RB^{TM} MREs at the specified temperatures) to at least 30 members of Texas A&M faculty, staff, and student population. Panelists scored samples using a 1-9 hedonic scale with 1= dislike extremely and 9 = like extremely). Natick R&D conducted sensory test with a trained panel to confirm the results from our consumer panels.

***<u>120^{o}F study</u>*: Accelerated shelf-life study at 120^{o}F (49^{o}C) for 2 months showed no effect of packaging type on acceptability and shelf-life of chicken pesto entrée. All four samples reached the end of shelf-life (by week 4) with acceptable scores from panelists (never < 6.00 for overall quality and flavor attributes) and good physico-chemical quality attributes based on the measured parameters. None of the samples developed rancidity, even by the end of shelf-life (week 4 with TBAR values well below the limit of onsite of rancidity. Consumer panelists (students, faculty, staff, and some members of the CORPS of cadets) were very accepting of the olive oil formulations (Figure 5).

Conclusions: Olive oil is stable over long-term storage.

100°F (37.8°C) and 80°F(27°C) studies: Results confirm the findings from the higher temperature study regarding the stability of the olive oil (no rancidity developed). Sensory scores average values of 7.00 for both flavor and overall quality for both types of packaging and formulations (Figure 6, Table 1). One interesting finding is that by the end of shelf-life (6 months) of the 100°F (37.8°C) study, the ABSO$_2$RB^{TM} package seems to significantly reduce the TBARs of the olive oil formulations compared to the regular MREs.

Conclusion: ABSO$_2$RB^{TM} packaging limited the formation of rancid fatty acids in olive oil compared to the control (80°F study). Soybean formulation in ABSO$_2$RB^{TM} had the lowest TBARs value. Reformulation with healthier olive oil is feasible.

Confirmatory sensory evaluation with trained panel (NSC): Results confirmed that panelists were not able to point out any differences among samples (Table 2). This finding supports the suitability of olive oil as a healthy alternative in formulations.

Fatty acid methyl esther (FAME) analysis: This test measures the composition of fatty acids present on the triglycerides of the samples using GC analysis. Staff at the Chemistry Department at Texas A&M University used a Varian gas chromatograph (model CP-3800 fixed with a CP-8200 autosampler). Separation of fatty acid methyl esters accomplished on a fused silica capillary column CP-Sil 88 (100m x 0·25mm internal diameter) (Chrompack Inc., Middleburg, The Netherlands) with He as the carrier gas (1·2 ml/min). After 32 min at 180°C, oven temperature was increased at 20_{o}C/min to 225°C and held for 14·15 min. Injector and detector temperatures were at 270 and 300°C, respectively. Individual fatty acid methyl esters were identified using genuine standards (Nu-Chek Prep, Inc., Elysian, MN, USA). The preparation of the samples consisted of extraction of total lipids followed by saponification and methylation of lipids.

Fat content of samples was: MRE olive - 8.55%; $ABSO_2RB^{TM}$ Olive - 10.32%; MRE soy - 9.08%; $ABSO_2RB^{TM}$ soy - 9.86%. The standard was Lauric acid – C12.

The main fatty acids present on the triglycerides chain were:

<u>Olive oil</u>: 55% - Oleic acid (C18:1 - c9); 15% - Linoleic acid (C18:2); 2% - Linolenic acid (C18:3); 16.5% - Palmitic acid (C16). <u>Soybean oil</u>: 25% - Oleic acid (C18:1 - c9); 39% - Linoleic acid (C18:2); 5% - Linolenic acid (C18:3); 15% - Palmitic acid (C16).

In summary, both oil samples remained stable throughout the shelf-life study. Soy-based samples packaged in $ABSO_2RB^{TM}$ pouches showed slightly higher content of these fatty acids compared to the MREs samples.

Determination of the Structure and Peel Strength of MRE Pouches Containing $ABSO_2RB^{TM}$

Film samples were sectioned and observed through a laser scanning microscope and an optical microscope in order to determine the structure of the laminate. The standard MRE reference film can be seen in Figure 7, and the $ABSO_2RB^{TM}$ film can be seen in Figure 8, as well as a comparison to a sample aged at 100°F for 6 months. After aging at 100°F and 80°F, the $ABSO_2RB^{TM}$ film maintained its integrity. There was no significant difference between samples prepared with olive oil and those prepared with soy oil.

The T-peel testing reveals that aging at 100°F and 80°F does not significantly deteriorate the integrity of the pouch that contains oxygen absorbers. The samples stored at room temperature and those aged for 6 months at 100°F show similar T-peel strength values (24.3±0.3 and 23.2±1.5 lbs, respectively). Likewise, samples aged at 80°F for 12 months show only slight variation, with T-peel strengths of 21.3±0.5 lbs. These T-peel strengths are higher than those of the reference samples, which do not contain any oxygen absorbers. Compared to the control, which had a T-peel strength of 19.1±0.6 lbs, the samples stored at 100°F for 6 months and the samples stored at 80°F for 12 months had T-peel strengths of 17.2±0.8 lbs and 15.1±0.39 lbs, respectively. There was no significant difference between samples that used olive oil or soy oil. A summary of the T-peel results can be found in Table 3.

Conclusion and Recommendations

Based on the studies conducted in this project, ABSO2RB^{TM} packaging film works well with high fat content MRE items such as cheese spread and it can be made into pouches (hot-fill and retort products) since material maintains integrity and peel strength throughout storage. It is our recommendation that reformulation of entrées (e.g. chicken pesto with noodles) with healthier oils such as olive oil should be seriously considered.

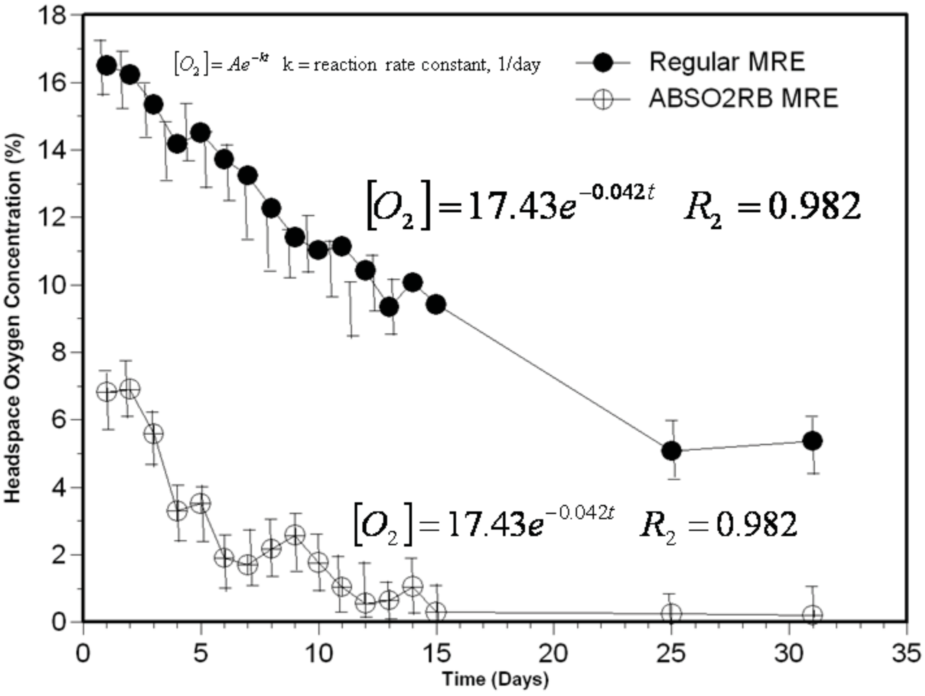

Figure 1: Change in headspace oxygen concentration in control and ABSO$_2$RB$^{®}$ cheese spread pouches stored at room temperature (Gomes et al., 2009).

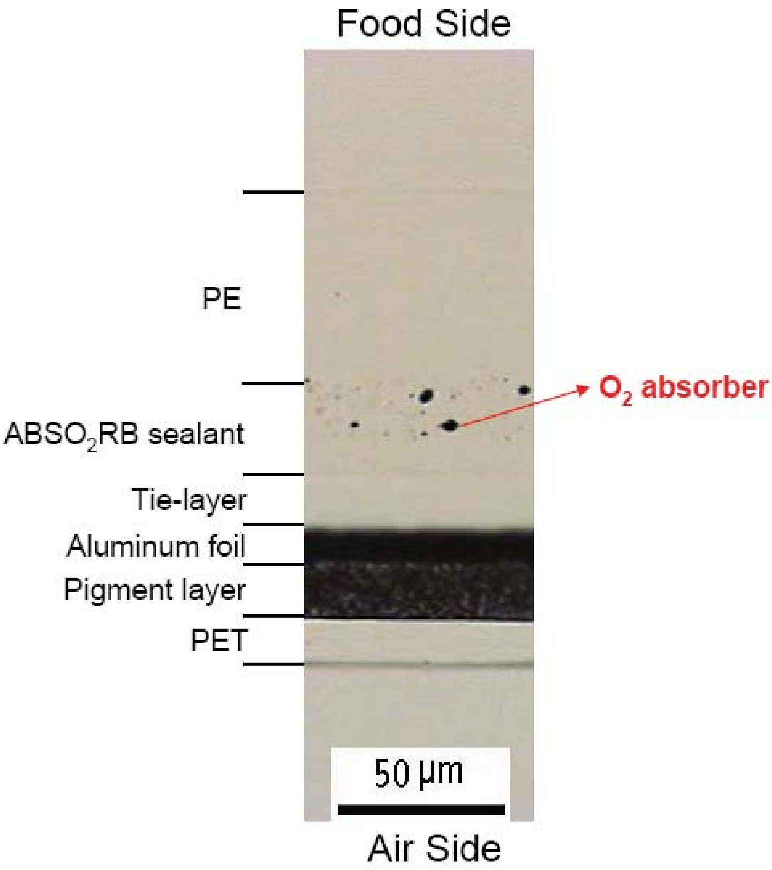

Figure 2: Transmitted Optical Microscopy (TOM) image of the cross section of the oxygen absorber-containing film (Gomes et al., 2009).

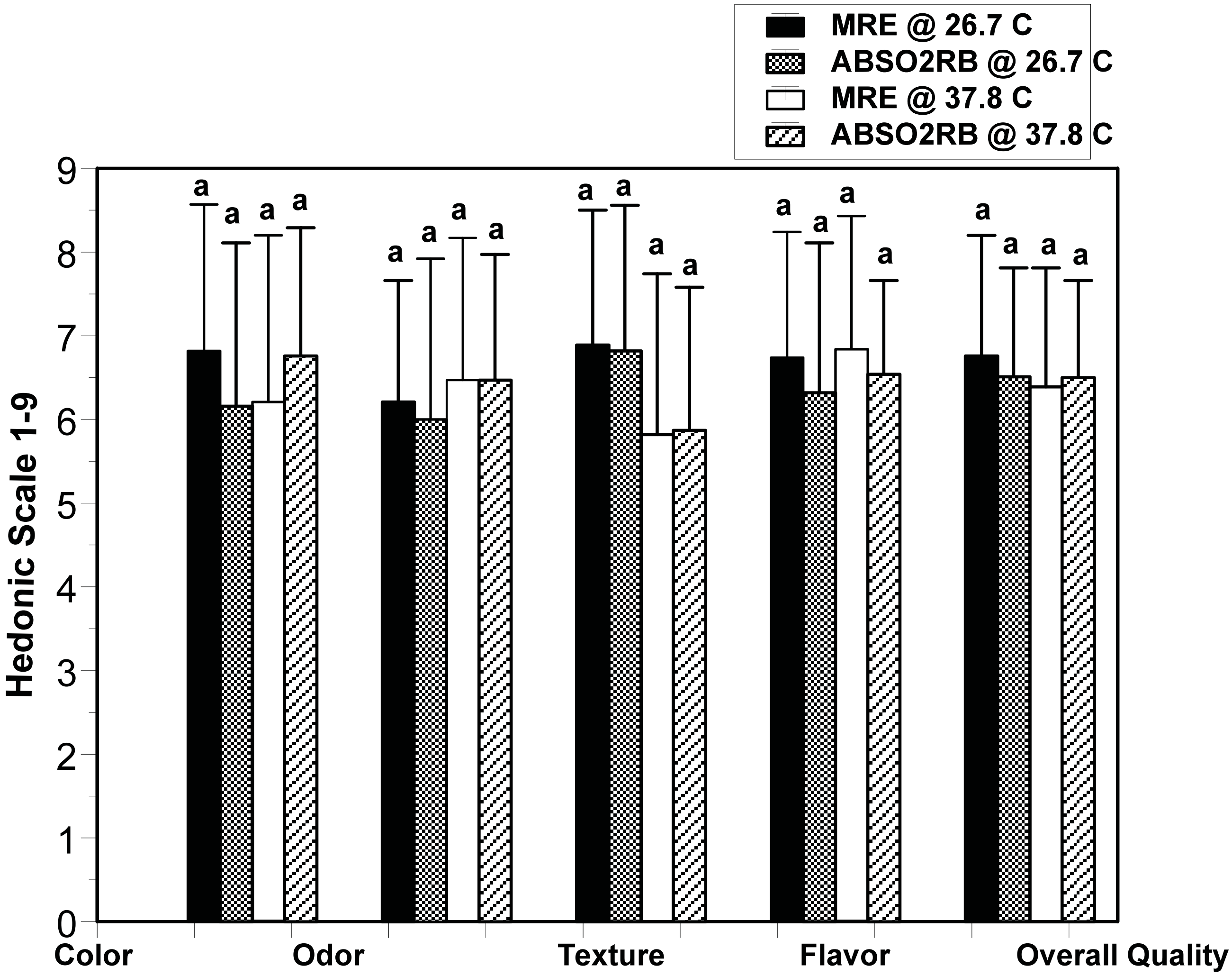

Figure 3: Sensory test results for MRE cheese spread stored at 26.7°C(80°F) and 37.8°C (100°F) for 6 months. Total of 30 consumer panelists was used. Scores were given based on 9-hedonic scale. Error bars represent standard deviation. Calibrated controls at 26.7°C (80°F) for 1 year. ^{a,b} means with different superscript letters are significantly different ($P < 0.05$) (Gomes et al., 2009).

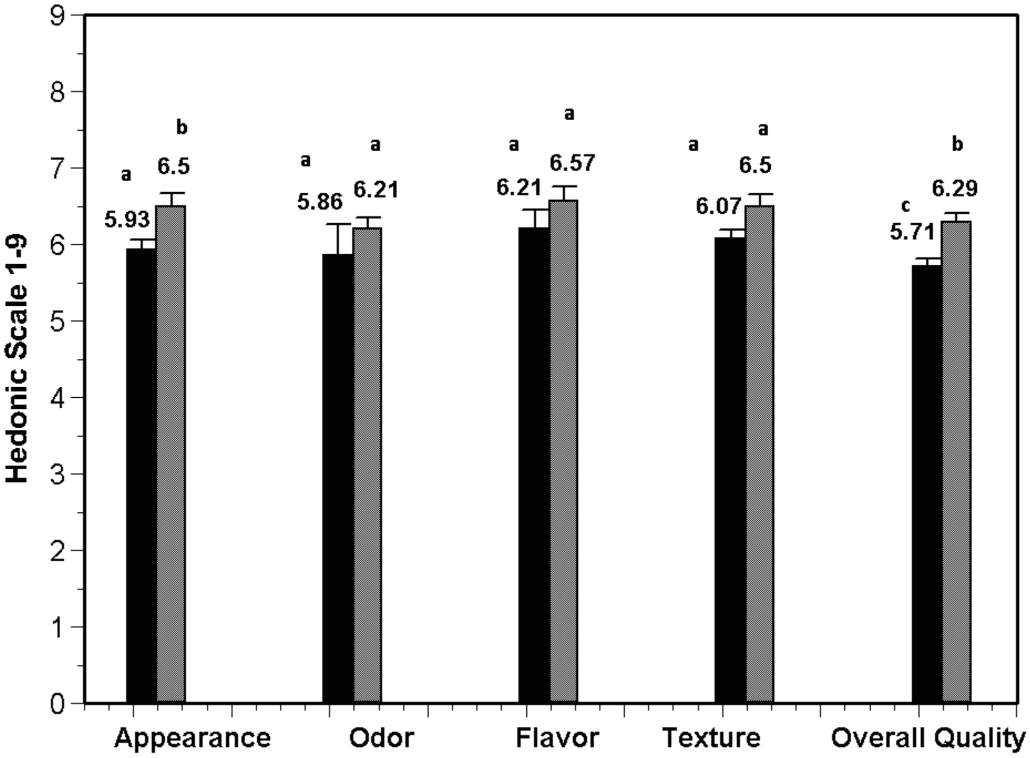

Figure 4: Sensory analysis test results for MRE cheese spreads after one year of storage at 26.7^{o}C(80^{o}F) conducted at the U.S. Army Natick Soldier Center. Total of 12 trained panelists. Scores were given based on 9-hedonic scale. ^{a,c} means with different superscript letters are significantly different ($P < 0.05$) (Gomes et al., 2009).

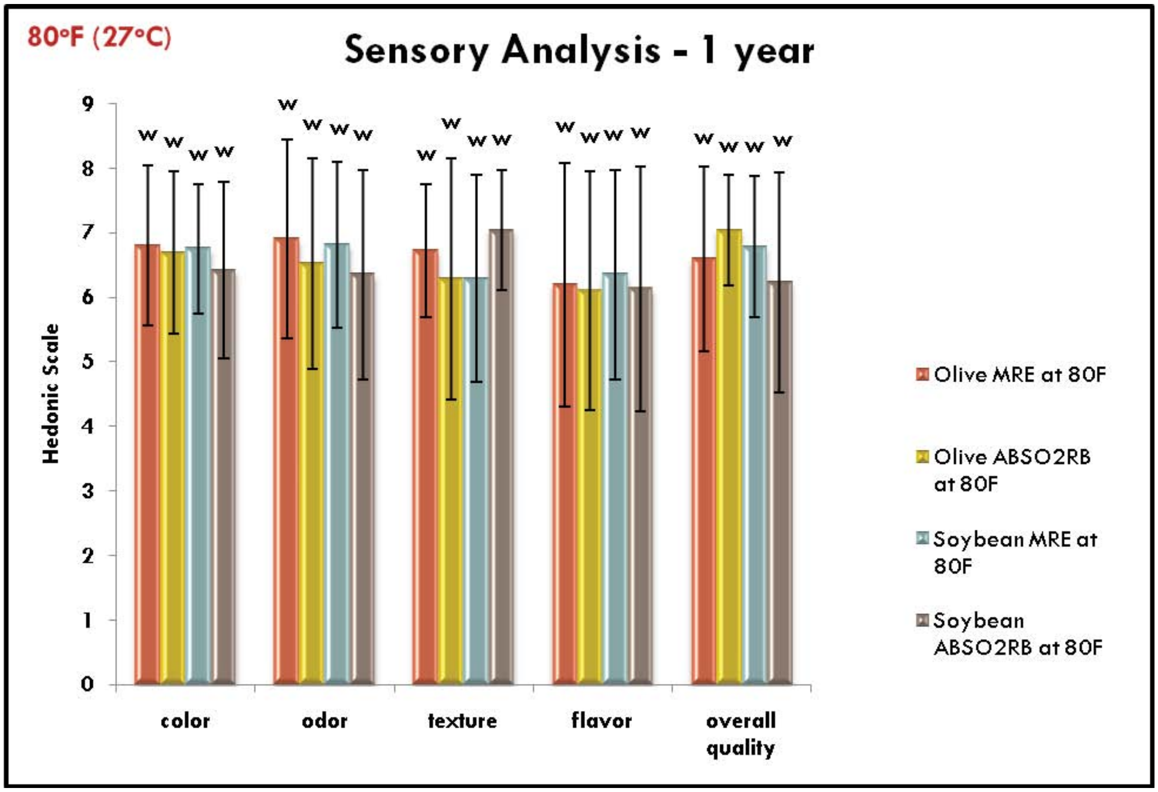

Figure 5: Sensory test results for MRE chicken pesto samples stored at 26.7°C(80°F) for 12 months. Total of 30 consumer panelists. Scores were given based on 9-hedonic scale. Calibrated controls at 26.7°C (80°F) for 1 year.

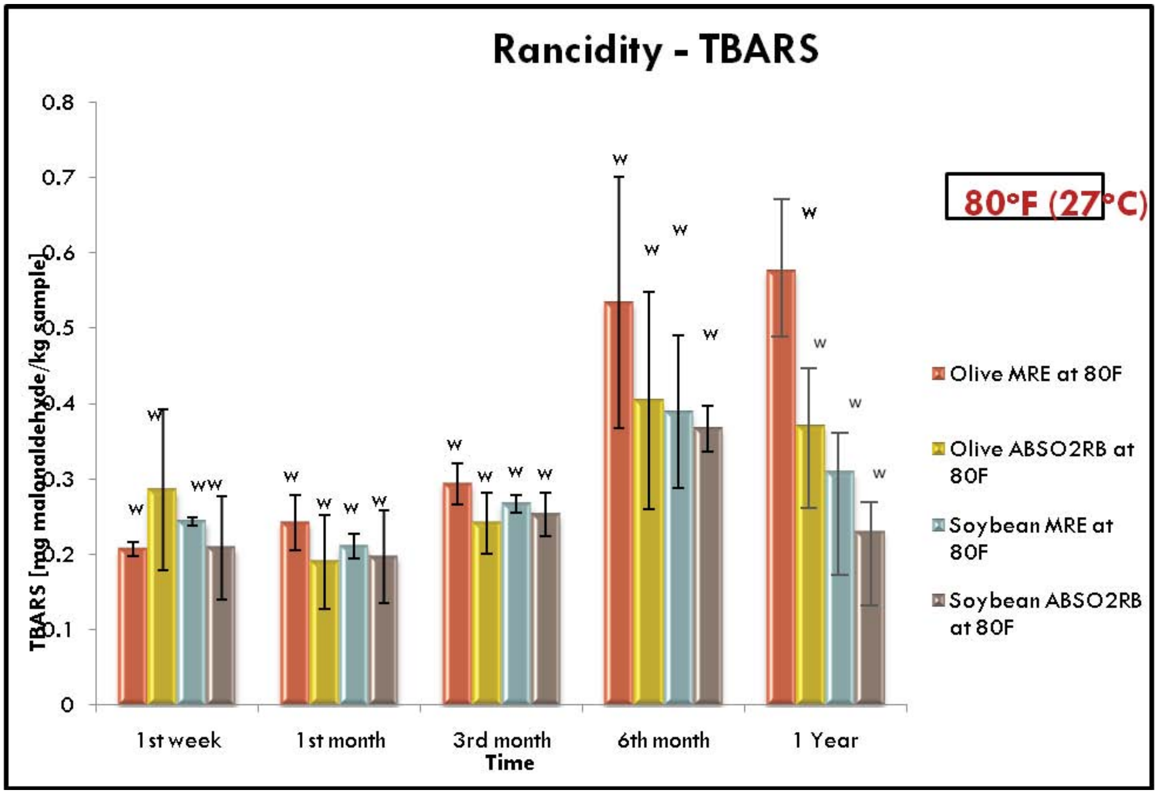

Figure 6: Effect of package type on development of rancidity (free fatty acid as % oleic acid) of MRE chicken pesto entrée in control MRE and ABSO$_2$RB$^{®}$ pouches during accelerated shelf life studies

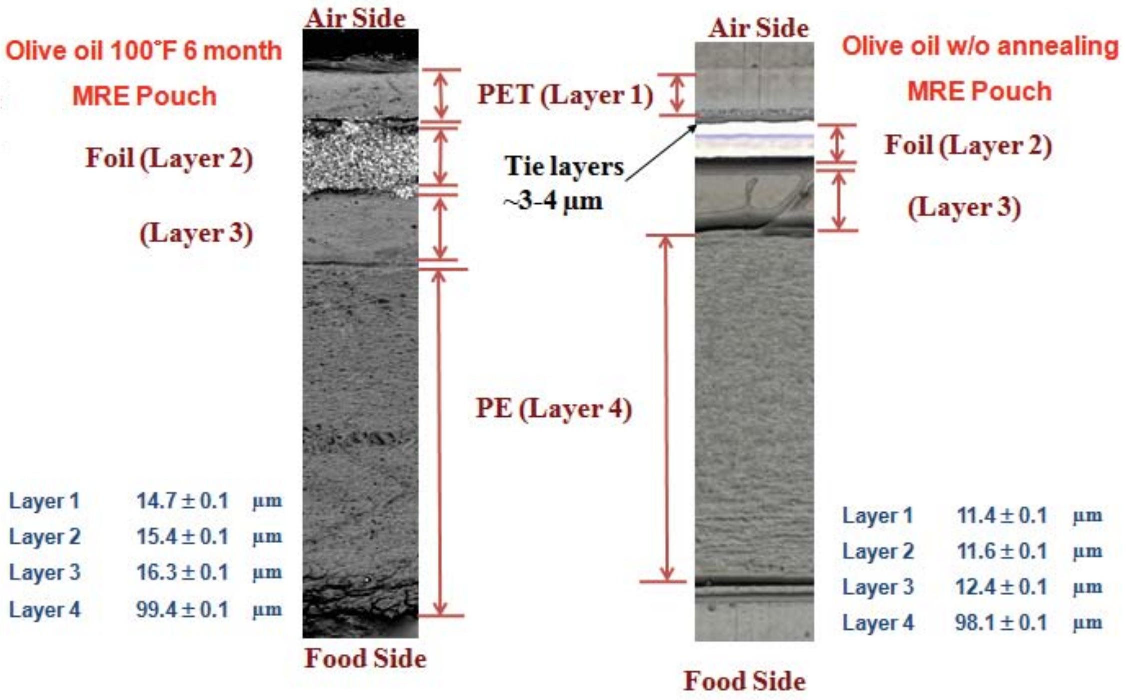

Figure 7: Laser scanning microscopy image of the reference MRE film structure and a comparison to a sample aged at 100°F for 6 months.

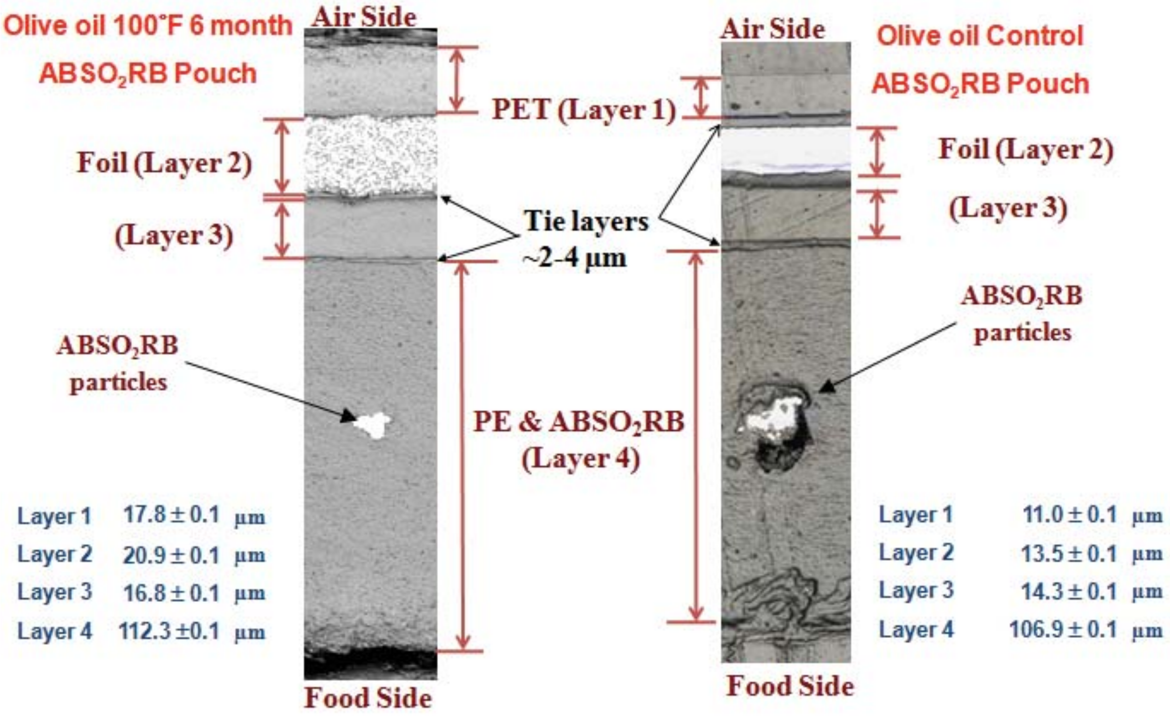

Figure 8: Laser scanning microscopy image of the ABSO$_2$RB^{TM} test MRE film structure and a comparison to a sample aged at 100°F for 6 months.

Table 1: Rancidity (TBARs values)

	TBARS [malonaldehyde mg/kg sample]			
Time	**Olive MRE**	**Olive ABSO$_2$RB**	**Soy MRE at**	**Soybean ABSO$_2$RB**
Day 1	$_{w}$ 0.2060^{a} (0.0431)	$_{w}$ 0.2832^{a} (0.0043)	$_{w}$ 0.2351^{a} (0.0221)	$_{w}$ 0.2081^{a} (0.0281)
Week 1	$_{w}$ 0.2073^{a}	$_{w}$ 0.2853^{a}	$_{w}$ 0.2436^{a,b}	$_{w}$ 0.2088^{a}
	(0.0091)	(0.1067)	(0.0052)	(0.0692)
Month 1	$_{w}$ 0.2422^{a}	$_{w}$ 0.1907^{a}	$_{w}$ 0.2104^{a}	$_{w}$ 0.1973^{a}
	(0.0364)	(0.0623)	(0.0163)	(0.0618)
Month 3	$_{w}$ 0.2933^{a}	$_{w}$ 0.2420^{a}	$_{w}$ 0.2673^{b}	$_{w}$ 0.2525^{a}
	(0.0276)	(0.0405)	(0.0113)	(0.0290)
Month 6	$_{w}$ 0.5343^{a}	$_{w}$ 0.4040^{a}	$_{w}$ 0.3892^{a}	$_{w}$ 0.3670^{a}
	(0.1670)	(0.1445)	(0.0011)	(0.0303)
1 Year	**$_{w}$ 0.5764^{a}**	**$_{w}$ 0.3703^{a}**	**$_{w}$ 0.3085^{a}**	**$_{w}$ 0.2303^{a}**
	(0.4209)	**(0.2177)**	**(0.1962)**	**(0.0858)**

[1] Standard deviation.^{a,b}Means within a column which are not followed by a common superscript letter are significantly different ($P < 0.05$).$_{w,x}$Means within a row, which are not followed by a common superscript letter, are significantly different ($P < 0.05$).

Table 2: Combat Feeding Directorate Trained Panel test – December 2009.

Summary of Mean-Scores, P-Values, and Significance Test Result Code - PATCHIXPES							
This test was performed on 11 panelists.							
Attribute	Chicken Pesto Pasta (Regular); MRE Packaging; 935	Chicken Pesto Pasta (Regular); ABSO2RB Packaging; 8325	Chicken Pesto Pasta (Olive Oil); MRE Packaging; 9325	Chicken Pesto Pasta (Olive Oil); ABSO2RB Packaging; 8325	Chicken Pesto Pasta; Control; 9215C	P-Value	Sig
APPEARANCE Quality	6.48	6.71	6.65	6.67	6.45	0.2275	NS
ODOR Quality	6.68	6.67	6.78	6.74	6.62	0.4761	NS
FLAVOR Quality	6.63	6.58	6.49	6.44	6.15	0.0557	NS
TEXTURE Quality	6.36	6.49	6.42	6.48	6.31	0.5485	NS
OVERALL Quality	6.54	6.53	6.42	6.44	6.19	0.162	NS

Table 3: Summary of T-Peel Results (in lbs.) for Reference and $\text{ABSO}_2\text{RB}^{\text{TM}}$ Films.

	Control	100°F, 6 mo	80°F, 12 mo
Olive Oil, Reference	19.09±0.62	17.24±0.75	15.1±0.39
Soy Oil, Reference	17.73±0.54	18.92±1.20	15.82±0.81
Olive Oil, $\text{ABSO}_2\text{RB}^{\text{TM}}$	24.34±0.32	23.22±1.48	21.27±0.48
Soy Oil, $\text{ABSO}_2\text{RB}^{\text{TM}}$	25.31±1.83	23.01±1.27	21.48±0.42