The Challenges of Incorporation of Omega-3 Fatty Acids Into Ration Components and Their Prevalence in Garrison Feeding

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ABSTRACT  Increasingly, private and military consumers are becoming aware of the positive benefits of a diet rich in omega-3 fatty acids (FAs) as health claims range from reducing inflammation to improving mood. The number of positive scientific articles supporting these claims is rapidly increasing, leading the military to examine the possibility of omega-3 supplementation for personnel. A variety of menus used either in shipboard or garrison feeding include fatty fishes that are rich in omega-3 FAs. However, omega-3 FAs have shelf-stability issues because of their susceptibility to oxidize; therefore, they create a challenge in terms of incorporation into ration components in nutritionally significant amounts. As a result, the Department of Defense Combat Feeding Directorate is investigating methods, technologies, and emerging products for incorporation of omega-3s into ration components. Based on existing research, fortification of foods with omega-3 FAs would improve nutritional quality as well as provide added benefit to the Warfighters.

INTRODUCTION

The health benefits of omega-3 fatty acids (FAs) are being increasingly researched and highly publicized as a growing collection of science has provided evidence that regular intake of omega-3s may provide a number of health benefits.1 Polyunsaturated fatty acids (PUFAs) are generally classified by their structures as either omega-3 or omega-6 FAs.2,3 These FAs are essential because humans lack enzymes called desaturases, and therefore, must receive them through dietary supplementation.4

Alpha-linoleic acid is an omega-3 FA that is enzymatically converted to both eicosapentaenoic acid and docosahexaenoic acid, which are precursors for various prostaglandins, thromboxanes, and leukotrienes.5 Conversely, omega-6 FAs, such as linoleic acid and arachidonic acid, lead to the production of eicosanoids that propagate both proinflammatory and prothrombic effects.5

During the Paleolithic era, humans consumed a 1 to 2:1 proportion of omega-6 to omega-3.5,7 Today, the typical modern western diet contains a 20:1 proportion of omega-6 to omega-3, with an average intake of alpha-linoleic acid of less than 1 g/d.8 Changes in both agriculture and cooking practices as well as a reduction in the consumption of fish, fruits, and vegetables have contributed to a drastic increase in the amount of omega-6 FAs in the western diet in relation to omega-3 FAs.9 For example, cattle feed switched from the traditional “grass-feeding” to high-energy grains to increase the growth rate and the intramuscular fat of the meat.10 However, these high-energy grains contain mostly omega-6 FAs, contributing to a higher dietary intake of omega-6 FAs.11 Modern diets also include a high quantity of oils (corn, safflower, cottonseed, peanut, and soybean), which primarily contain omega-6 FAs, due to the methods used in food preparation.12

With this information, numerous health claims have escalated in recent years concerning the proportion of omega-6 to omega-3 FAs. For example, dietary proportion of omega-6 to omega-3 may influence the magnitude of inflammatory responses to depression and stressful events in humans. Several studies have found behavioral links with low omega-3 intake and depression, anger, and anxiety.13–16 Others have demonstrated that omega-3 PUFAs assist in prevention of oxidative damage and regulation of brain-derived neurotrophic factor levels after traumatic brain injury, and countering learning disabilities typically associated with traumatic brain injury in rats.17 Other studies have reported that omega-3 FAs can lower the risk for coronary heart disease, atherosclerosis, sudden cardiac death, and atrial fibrillation.18–23 all of which could serve to benefit members of the armed forces.

MILITARY APPLICATIONS—CONCERNS AND CHALLENGES WITH RATION FEEDING

The Combat Feeding Program is positioning itself to respond to potential changes in the Military Required Daily Intake as it translates to omega-3s in response to the emerging concerns with mood and stress as evidenced amongst the United States Military Services (USMS).24–26 Although the USMS have taken interest in research involving omega-3 PUFAs, as well as incorporation of omega-3 PUFAs into standard military rations, many challenges exist in supplementing ration components with sufficient omega-3 PUFAs, such as acceptability, long-term stability, and differing recommended daily intakes.

In addition to conducting in-house research on products or compounds of interest to the military, the Department of Defense (DoD), the Combat Feeding Directorate (CFD) also evaluates commercial products to ascertain if these products can be used for military applications. The potential ration
components are received directly from vendors and the stability of the nutrient content is assessed over time. In the past, CFD did not include omega-3 FA content in its nutritional evaluations; however, because of recent concerns with inflammation and omega-3s potential impact on mood, it was added to the list of vitamins and mineral studied.

Taste and acceptability are major components that are considered when developing new product formulations. Because of oxidative rancidity and instability, omega-3 FAs can produce an “off-taste” or “fishy-taste,” which decrease the acceptability and voluntary consumption. To prevent oxidation of the omega-3 FA, exposures to air, light, and elevated temperature must be tightly controlled. Often during storage and transport, rations experience cycling in terms of hot and cold temperatures, which will have a detrimental effect on the omega-3 FAs. In addition, multiple sources for omega-3 FAs incorporation must be identified to provide a variety of food options to prevent long-term monotony, which may lower acceptance or feeding and may negatively impact soldier performance.

Omega-3’s supplementation has drawbacks mainly because of the unappealing taste associated with oxidation. The stability of omega-3 FAs is dictated not only by the number of double bonds present in the molecules but also by the antioxidants used in addition to the system in which they are incorporated. Emulsification and/or encapsulation are two approaches for adding a relatively high load of omega-3 FAs into food components. However, these emulsified or encapsulated oils need to be mixed with an appropriate antioxidant such as Vitamin E, mixed tocopherols, or rosemary derivatives to reduce oxidation in the oils/emulsion system.

**MILITARY RATION DEVELOPMENT AND AUTHORIZATION**

The Combat Feeding Program was established to foster synergy among the military services in terms of developing ration platforms and systems. U.S. Army Natick Soldier Research, Development and Engineering Center—DoD CFD, under the auspices of the Office of the Secretary of Defense, is responsible for the research, development, engineering, integration, and technical support for the entire family of military combat rations. The Program is driven by Warfighter recommendations and feedback that is obtained by focus groups and annual ration field tests. The CFD works collaboratively with academia, the commercial sector, other government agencies, and the U.S. Army Research Institute of Environmental Medicine (USARIEM) to produce and test new ration components using product designs based on Warfighter feedback and nutrient composition, thus providing technological solutions for the Warfighter (Fig. 1). Another role of the CFD is to use food as a vehicle to deliver proven performance optimizers, with metabolic and physiological testing performed by USARIEM. CFD and USARIEM work hand-in-hand in terms of field tests to evaluate if the compound in the food component delivers the intended nutritional benefit.

All newly designed ration components must pass stringent requirements before they can seek approval for inclusion into rations. All ration components must have shelf stability (time frame is dependent on the ration), be fully processed, achieve microbial sterility, and be acceptable by a variety of consumers. Ration components must also undergo nutrition and shelf stability evaluations as well as trained sensory panels, performed by CFD, to determine overall palatability and Warfighter acceptance. The Office of the Surgeon General (OTSG), Chief Dietician for the Army, approves all menu changes made to the rations. The Joint Services Operational Ration Forum, which meets annually, approves all changes made to individual components within the rations.

**CURRENT OPERATIONAL RATION PLATFORMS**

The CFD has developed a family of operational rations that are designed to provide the necessary nutrition regardless of the tactical situation (Table I). The First Strike Ration (FSR) was fielded in 2007 as an assault ration intended to be consumed during the first 72 hours of intense conflict. The FSR components are compact and designed to be eaten entirely on the move while increasing Warfighter caloric consumption and nutritional intake during highly mobile, highly intense operations.

The Meal, Ready to Eat (MRE) is the cornerstone individual combat ration and is used by all Military Services to sustain personnel during operations where food service facilities are not available. They are intended to provide a Warfighter’s sole subsistence (3 MREs per day) for up to 21 days of deployment (in accordance with AR 40–25). The MREs are nutritionally adequate in accordance with the OTSG’s dietary requirements and are composed of 24 menus to provide variety. Under a Continuous Product Improvement Project, the menu changes each and every year in response to Warfighter’s requests, consisting of commercial items as well as in-house developed items.

A large part of each component’s shelf stability is because of the packaging in which the food is contained. All MRE entrees are composed of a quad-laminate material. This material has four layers: polyester, nylon, foil, and polyelefin that work together to produce extremely high barrier properties to protect the food against microbial, chemical, and physical deterioration under extreme environments. This is integral to help protect the ration components and ensure that the required 3-year shelf life at 80°F is achieved. The MRE is the only ration that is prepositioned which is the primary reason why a 3-year shelf life is required. Therefore, the MRE may be an ideal ration to incorporate additional omega-3 containing components because of the fact that it is the primary individual ration consumed by all Warfighters and it is approved to be consumed for up to 30 days. All other ration platforms have a niche or limited user population and are consumed for short periods of time.

The Unitized Group Ration (UGR) is a family of group rations, consisting of the UGR-Heat & Serve (UGR-HS), UGR-A, UGR-B, and the UGR-Express (UGR-E). The UGRs...
streamlines the process of providing the highest quality group feeding to Warfighters in the field. The UGR-A consists of frozen, refrigerated, and shelf stable food items, which require a field kitchen and military cooks to prepare the UGR. It is designed to provide high-quality, “fresh-like” group meals to the Warfighter in the field and is the most highly accepted ration. The UGR-H&S is usually the first group ration that is made available to Warfighters in theater and is used in combination with the MRE for daily feeding. The UGR-H&S is used early in deployment when a full complement of military cooks is not available and field kitchens do not have refrigeration capability. The UGR-Express (UGR-E) is designed to provide a complete, hot meal for up to 18 Warfighters in remote locations where field feeding facilities would not be possible.

CFD also has dedicated programs for the Navy Afloat community. Under the auspices of this program, CFD, in collaboration with the Navy, developed the Navy Standard Core Menu (NSCM) Continuous Improvement Project designed to provide continuous advanced food improvements and product recommendations to support the Navy. The NSCM is a 21 menu cycle designed to enhance acceptability and improve nutrition while maintaining peak physical performance. The Armed Forces Recipe Service develops recipes and menu cards that are used in garrison. On the menus, there are several seafood items, both appetizers and entrees, which are offered. Unfortunately, how the fish is prepared (fried vs. baked) will have an impact on the amount of omega-3 FAs that are available.

PRACTICALITY OF OMEGA-3 SUPPLEMENTATION IN EXISTING RATION PLATFORMS

Because the FSR is designed for and is generally consumed for up to 72 hours, it may not serve as the ideal platform for increasing omega-3 FA levels of the Warfighter, as consumption of this ration is only temporary and periodic. Fortification of omega-3s within MREs would be more effective, as they are to be consumed more often. However, consideration must be given to which ration components would be fortified with omega-3s. The UGR is composed of numerous commercial items which could be targeted for supplementation with omega-3s. In addition, the type of cooking oil could be replaced with a high oleic acid oil to reduce the quantity of omega-6s and increase omega-3s. As previously stated, the NSCM is a 21-day cycle with 96 items appearing in the menu.
Challenges of Incorporation of Omega-3 Fatty Acids Into Ration Components

Table I. Operational Ration Platforms Nutritional Data, Usage, and Shelf Stability

<table>
<thead>
<tr>
<th>Name of Ration</th>
<th>Average Energy (kcal)/Meal</th>
<th>Purpose of Ration</th>
<th>Shelf Stability</th>
<th>Duration of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRE™</td>
<td>1300</td>
<td>Individual Meal in the Absence of Formal Dining</td>
<td>36 Months</td>
<td>Up to 21 Days (Can Be Longer)</td>
</tr>
<tr>
<td>UGR-Heat and Serve™</td>
<td>1450</td>
<td>First Group Meal, Before Base Refrigeration</td>
<td>18 Months</td>
<td>Until Refrigeration</td>
</tr>
<tr>
<td>UGR-A™</td>
<td>1450</td>
<td>Highest Approval, Cooking Facilities Needed</td>
<td>18 Months</td>
<td>Throughout Deployment</td>
</tr>
<tr>
<td>UGR-B™</td>
<td>1300</td>
<td>Primarily Marine Corps, Cooking Facilities Needed</td>
<td>18 Months</td>
<td>Throughout Deployment</td>
</tr>
<tr>
<td>UGR-E™</td>
<td>1300</td>
<td>Compact Module, Self-Heating, No Facilities Needed</td>
<td>18 Months</td>
<td>When Other UGRs Are Unavailable</td>
</tr>
<tr>
<td>UGR-Artic Supplement™</td>
<td>914</td>
<td>Used With UGR, Additional kcal/Beverage For Arctic Weather</td>
<td>18 Months</td>
<td>Supplementation for Cold Weather Only</td>
</tr>
<tr>
<td>Navy Standard Core Menu</td>
<td>Varies</td>
<td>Standard Feeding for Navy Personnel, Balanced Nutritionally</td>
<td>Varies</td>
<td>Throughout Deployment</td>
</tr>
<tr>
<td>First Strike Ration™</td>
<td>2900</td>
<td>One Ration Per Day, Meant to be Consumed on-the-Move</td>
<td>24 Months</td>
<td>First 72 Hours of Intense Conflict</td>
</tr>
<tr>
<td>MCW/LRP</td>
<td>1540</td>
<td>Additional Calories for Cold Weather, Reduced Sodium/Protein</td>
<td>36 Months</td>
<td>In Cold Environment</td>
</tr>
<tr>
<td>Kosher/Halal Rations</td>
<td>1200</td>
<td>Used to Serve Individuals Maintaining a Strict Religious Diet</td>
<td>10 Months</td>
<td>Throughout Deployment</td>
</tr>
<tr>
<td>Kosher for Passover Rations</td>
<td>1200</td>
<td>Kosher Diet, Not More Than 8 Days Around Passover</td>
<td>9 Months</td>
<td>Only Available Leading up to Passover</td>
</tr>
<tr>
<td>Go-To-War Ration™</td>
<td>1300</td>
<td>UGR, Supplement for Combat Rations, Commercial Products</td>
<td>12 Months</td>
<td>Used Until Industry</td>
</tr>
<tr>
<td>Survival Ration, General Purpose</td>
<td>1435</td>
<td>Designed for 3–5 day survival situation</td>
<td>60 Months</td>
<td>Emergency Use Only</td>
</tr>
<tr>
<td>Survival Ration, Abandon Ship</td>
<td>2400</td>
<td>Low Salt Content, Designed for 3–5 Day Scenario</td>
<td>60 Months</td>
<td>Emergency Use Only</td>
</tr>
<tr>
<td>Survival Ration, Aircraft/Life Raft</td>
<td>300–400</td>
<td>Sustains Personnel That Survive Aircraft Disasters</td>
<td>120 Months</td>
<td>Emergency Use Only</td>
</tr>
</tbody>
</table>

MRE, Meal, Ready to Eat; UGR, Unitized Group Ration; MCW/LRP, Meal Cold Weather/Long-Range Patrol.

Cycle. Of the 680 items that are rotated in the 21-day cycles, a little over 9% is fish, and approximately 5% is shellfish and lobster—which are not as high in omega-3 FAs.

In operational rations, the current percentage of components containing omega-3s is minimal. In the MRE, there is tuna fish and raisin–nut mix (8% of menus contain omega-3s). The FSR also contains tuna fish and raisin–nut mix (33% of menus contain omega-3s) and CFD has plans to introduce three additional fish entrees. The UGR-A has only one fish item, boil-in-the-bag shrimp scampi. Historically, there was as an additional fish item (catfish) in the UGR, but it was removed because of low consumption and poor feedback from Warfighters. The UGR-A also has raisin–nut mix in addition to the shrimp scampi (4.3% of menus contain omega-3s).

Military Applications: Concerns and Challenges Into Dining Hall Feeding

In garrison or dining hall, feeding incorporation of omega-3 FAs is a very different challenge than incorporation into ration components. Although fish, rich in omega-3s, is being provided to the Armed Forces, most military personnel who eat in garrison choose to consume a more traditional diet of meat and potatoes diet (unpublished data). Dining facilities in theater are not supported by the menu planning of Natick. Instead, this is accomplished by commercial vendors with input from the Military department procuring their services. One approach to improve the ratio of FAs in these facilities would be to change the type of cooking oils being used by the commercial contractors.

Education that informs the Warfighter of the benefits of consuming foods rich in omega-3 FAs is a separate approach for increasing dietary omega-3 intake. The dining halls contain foods that provide omega-3 FAs. For those Warfighters that don’t eat fish, dietary supplements may be another option. The available data suggest that many Warfighters lack sufficient nutritional knowledge to make wise food decisions. For example, in a recent study, elite U.S. Army Soldiers incorrectly defined the roles of protein and vitamins. Therefore, educational efforts targeted at increasing dietary omega-3 intake might be a complimentary tool for increasing dietary intake of omega-3 FA.

DoD CFD Project to Assess Incorporation of Fish and Flaxseed Oil into a Ration Component

Previously, a CFD project was focused on incorporating flaxseed and fish oil into the military’s First Strike Bar. The First Strike Bar was not only developed as an energy bar but also a carrier for other nutrients or bioactive components, such as omega-3 FAs to attempt to increase the levels within the Warfighter’s diet. Approximately, 20% of either encapsulated fish oil or encapsulated flaxseed oil was incorporated.
into the formulation of the bar. However, this effort failed as a trained sensory panel reported that there were off-odors and off-flavors in both the encapsulated fish oil and encapsulated flaxseed oil samples.

As part of this research project, we evaluated if incorporation of antioxidants would decrease the oxidation that is prevalent with omega-3s. CFD examined the oils in both encapsulated and unencapsulated forms. Overall the data indicated that the fish oil was less stable than the flaxseed oil, but the flaxseed oil tended to be pro-oxidant as opposed to antioxidant (unpublished data). This is an issue that will have to be further evaluated before flaxseed oil can be incorporated into military rations.36

CFD is currently evaluating chia (Salvia hispanica) seeds that were submitted by a commercial vendor as a proprietary blend to increase omega-3 FAs in the ration. This proprietary blend has been cleared by Food and Drug Administration as a food and it contains both omega-3 as well as omega-6 FAs.37 Working with the product is challenging as the product formulation is very, very fine, and with 13 g, there is considerable mass to blend into food components. Two food matrices (bar and cookie) were used to develop the prototypes. Both the First Strike Bar and oatmeal raisin cookie were fortified and subjected to sensory testing before and after accelerated shelf life testing (6 months at 100°F and/or 4 weeks at 120°F is used to correlate to the required shelf life of 3 years at 80°F). The products were then pulled at the designated time frame and repaneled to obtain sensory data from the heat stressed product. If the item does not pass acceptability (obtains a score of 5 or below on a 9-point hedonic scale)38 testing typically will not proceed further. The cookies held up better than the First Strike Bars, which darkened and hardened after 4 weeks at 120°F, however, sensory data scores indicated that additional product development is required, as the acceptability scores were below the acceptable threshold value of 6 on a 9-point hedonic scale (unpublished data). Further research and development will be required to optimize incorporation and test other sources of omega-3 FAs within ration components.

CONCLUSIONS
The primary focus within the CFD is to ensure that Warfighters are the best fed in the world and that they are provided the fuel to outlast and outmaneuver other fighting forces. Part of the solution is to provide, through food components, those nutrients to optimize Warfighter cognitive and physical performance. Based on emerging concerns with mood and stress, the Combat Feeding Program is positioning itself to respond to potential changes in the Military Required Daily Intake as it translates to omega-3s.

However, because of Warfighter food preferences (e.g., fried food), it is difficult to get adequate integration of these FAs into the Warfighter’s diet. Even when the Warfighter is provided omega-3 FAs via some ration components, it is up to individual preference whether those components will be consumed. The Warfighter requires better education on the benefits of consuming products that are high in omega-3 FAs. There are opportunities, whether it is through literature in the dining facility on the food line or information on ration packaging, to promote omega-3s and tout their benefits.

There has to be a multidisciplined approach that is driven by the Medical Command, OTSG, the DoD Nutrition Committee, and military leadership. Further research is needed to quantify, based on science, the precise dosage of omega-3s thus providing clear direction to food developers in both the military and commercial sectors. Group feeding scenarios may be the easiest way to increase omega-3 consumption, first by targeting some of the items that may be higher in omega-6 and just decreasing or replacing those ration items. In addition, if tasked, CFD could look at ration components that would be potential carriers for omega-3 FAs and evaluate emerging and existing technologies/strategies for their incorporation (e.g., encapsulation, non-fish sources), but that has to be driven by policy. If omega-3 FAs are part of the nutritional armor that CFD needs to provide for the Warfighter, then that is our duty, as well as our mission.

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