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Nutritional Strategies and Innovative Technologies for Maintaining the Operational Readiness of Military Personnel in Extreme Conditions

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***Abstract*—Executing special missions in extreme conditions requires military personnel to maintain optimal physical and mental performance. This necessitates meticulous planning of rations and beverages to provide sufficient energy, hydration, and immune system support. To enhance interoperability among NATO member states, STANAG 2937 was introduced, standardizing the minimum characteristics and quality assurance of individual operational rations for military use. Key requirements defined in STANAG 2937 include nutritional adequacy, stability, durability, and tailored rations for specific conditions. Rations must provide 4000–6000 calories per day in extreme environments, prioritizing carbohydrates for quick energy, followed by fats and proteins. Packaging must ensure durability, ease of transport, and content preservation. Nutritional supplements, such as energy bars, vitamins, and isotonic drinks, are vital for sustaining energy and overall health. Extreme temperatures significantly influence macronutrient needs. In cold climates, higher fat intake (35–40%) supports energy reserves, while proteins preserve muscle mass and aid thermoregulation. Conversely, in hot climates, increased carbohydrate consumption (55–65%) replenishes glycogen and mitigates energy loss. Vitamins and minerals, such as B-complex, vitamin C, and magnesium, are essential for metabolic functions, immune health, and physical endurance.**

Keywords*— *STANAG 2937, operational rations, military nutrition, extreme conditions, macronutrient requirements.

I. INTRODUCTION

Military operations are often conducted in environments where soldiers are exposed to extreme ecological conditions, such as deserts, the Arctic, and high altitudes. Gradual adaptation to these environments facilitates physiological acclimatization. However, military missions are rarely planned with extended acclimatization periods in mind. Recreational mountaineers, outdoor workers in seasonal cold climates, and residents of cold or high-altitude regions have the advantage of planning their activities in such environments. Those accustomed to cold or high-altitude conditions learn how to adjust their clothing and activities to maintain a sustainable lifestyle, regardless of external conditions.

Regardless of climatic challenges, military forces must be supplied with food, weapons, housing, and other logistical support to enable the immediate execution of their missions [1]. Carrying out special missions in extreme environments requires military personnel to maintain optimal physical and mental states. This necessitates precise planning of rations and beverages that provide adequate energy, hydration, and immune system support. To enhance interoperability among NATO member states and standardize the minimum characteristics and quality assurance of individual operational rations, STANAG 2937 was introduced [2]. This standard defines the requirements for operational rations designed for military use.

The article aims to present the regulatory framework described by NATO strategic documents, as well as the requirements for providing food rations for military personnel in a temperate continental climate and extreme conditions.

II. MATERIALS AND METHODS

Nutritional Values: Rations must provide adequate energy intake and a balanced composition of macro- and

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micronutrients tailored to the needs of military personnel under various operational conditions. In situations of intense physical exertion or extreme climatic conditions, energy requirements can reach 4000–6000 calories per day. Priority is given to carbohydrates as the primary source of quick energy, followed by fats and proteins [4], [5].

Stability and Shelf Life: The products in the rations must be resistant to various climatic conditions and have a long shelf life to ensure food safety and quality during missions [10].

Packaging: Packaging must be durable, easy to open, and suitable for transportation while protecting the contents from contamination and damage.

Specialized Rations: The standard also describes specialized rations for specific conditions, such as extreme climatic environments or prolonged operations, to meet the diverse requirements of different missions.

Quality and Safety: Ensuring the quality and safety of the food is essential, with adherence to established food safety and hygiene standards strongly recommended [3], [10].

Operational Interoperability: The standardization of rations facilitates joint operations among nations, ensuring that military personnel can use and accept rations from other countries without issues [3].

Related documents, such as Allied Medical Publication-1.11 (AMedP-1.11), provide detailed guidelines and information supporting STANAG 2937 to enhance the effective interoperability of individual operational rations during military deployments, exercises, or operations [3].

The above-mentioned requirements and recommendations are designed to ensure that military personnel receive the necessary nutritional support to maintain their effectiveness and health during operations in various environments and conditions.

A. Combat Rations Include the Following Main Components

a) Ready-to-eat foods and beverages – canned meals (with pork, beef, chicken, or lamb, spaghetti, vegetarian menus, meals for individuals of different religious beliefs, etc.), meat and fish preserves, pâtés, packaged confectionery, spices, sauces, powdered drinks, dragees, chewing gum, and more.
- Disposable tableware – plastic spoons, forks, knives, napkins, wet wipes, toothpicks.
- Means for heating food – through chemical reactions or open fire (e.g., solid fuel).
- Water disinfection agents – in liquid or tablet form.

Disposable tableware, food heating means, and water disinfection components may either be included in the combat ration or provided separately.

B. Combat Ration Packaging Types:

- Primary (protective) packaging – in direct contact with food products, protecting them from environmental influences.
- Secondary (grouping) packaging – used to group individual food and non-food components into a single set.
- Tertiary (transport) packaging – used to group individual sets into larger cargo units (boxes, pallets, containers) for easier transport and storage.

C. Classification of Combat Rations

Combat rations can be categorized based on their intended use:

Individual combat rations are designed to provide food for a single soldier and may include food products for one meal (separately for breakfast, lunch, or dinner) or for an entire day (breakfast, lunch, and dinner, packed in one package). They are further divided into general-purpose rations and those for specific situations. General-purpose individual combat rations are the main rations used in a wide range of missions and operations, typically involving moderate physical activity and moderate climatic conditions. The food components of these rations can be consumed cold or hot, with some requiring water for rehydration or heating [2,3].

Table 1 provides information about the main combat rations used by NATO member countries, including the names of different rations and the number of menus within them. Some countries, such as Albania, Iceland, Luxembourg, Montenegro, and others, do not have available information about their combat rations.

TABLE 1. BASIC COMBAT RATIONS IN NATO MEMBER COUNTRIES [2]

No.	Country	Name of Combat Ration	Number of Menus
1.	Albania	No information	
2.	Belgium	Ration de Combat Individuelle Rechauffable, France	14 menus
3.	Bulgaria	Not used	
4.	United Kingdom	12 Hour Operational Ration Pack, 24 Hour Operational Ration Pack	10 menus, 7 menus
5.	Germany	Einmann Packung (EPa)	19 menus
6.	Greece	Special Forces' Ration	
7.	Denmark	Danish Combat Ration (DCR)	1 version
8.	Estonia	24 Hour Combat Ration Pack	14 menus
9.	Iceland	No information	
10.	Spain	Individual Meal Pack (IMP)	6 menus
11.	Italy	Razione Viveri Specialida Combattimento	7 menus
12.	Canada	Individual Meal Pack (IMP)	6 menus
13.	Latvia	Latvia Armed Forces Combat Ration	9 menus
14.	Lithuania	Field ration based on the US Army MRE	10 menus
15.	Luxembourg	No information	
16.	Norway	Feltrasjon	2 types; 7 menus

No.	Country	Name of Combat Ration	Number of Menus
17.	Poland	Zestaw Żywnościowy Indywidualnej Racji Suchej	3 menus
18.	Portugal	Ração Individual de Combate (RIC)	
19.	Romania	Romanian Ration Prototype	
20.	USA	Meal, Ready-to-Eat (MRE)	24 menus
21.	Slovakia	24 Hour Combat Meal, Ready to Eat (PODAP)	5 menus
22.	Slovenia	24 Hour Combat Ration Pack	3 menus
23.	Turkey	Turkish Outdoors 24 Hour Meal	5 menus
24.	Hungary	24 Hour Meal, Ready to Eat	5 menus
25.	France	Ration De Combat Individuelle Réchauffable	14 menus
26.	Netherlands	Gevechtsrantsoen	
27.	Croatia	Croatia Armed Forces 24 Hour Combat Ration	7 menus
28.	Montenegro	No information	
29.	Czech Republic	Bojová Dávka Potravin (BDP)	2 menus

The need for individual meal packs: Individual meal packs for extreme conditions are specifically designed to provide comprehensive nutrition to military personnel in various situations. According to the requirements of STANAG 2937, each pack must contain:

Main Meal: Freeze-dried or dehydrated foods that are easy to prepare and provide sufficient energy [6], [8].

Energy Bars: High-energy foods that quickly replenish energy [8], [9].

Liquid Foods: Packaged in compact and user-friendly containers.

Vitamins and Minerals: Supplements providing essential micronutrients [9].

Beverages: Isotonic or dehydrated powdered drinks [7], [8].

Utensils: Compact and lightweight for convenience.

Disinfectants: Wet wipes or tablets for cleaning hands and surfaces [11].

TABLE 2. NATO STANDARD FOR THE MINIMUM ENERGY VALUE AND NUTRITIONAL COMPOSITION OF THE GENERAL-PURPOSE COMBAT RATION [3]

№	Nutritional l composition of the general-purpose		
	Nutritional Ingredients	*Measure*	*Quantity*
1.	Energy value	kcal	3600
2.	Carbohydrates	g	404
3.	Proteins	g	118
4.	Fats	no more than 35%	
5.	Vitamin A	µg	900
6.	Vitamin B1	mg	1.2
7.	Vitamin B2	mg	1.3
8.	Vitamin B5	mg	6
9.	Vitamin B6	mg	1.3
10.	Vitamin B9	µg	400
11.	Vitamin B12	µg	2.4
12.	Vitamin C	mg	45
13.	Vitamin D	µg	5
14.	Vitamin E	mg	10
15.	Vitamin K	µg	70
16.	Vitamin PP	mg	16
17.	Calcium	mg	1000
18.	Zinc	mg	14
19.	Iron	mg	8
20.	Magnesium	mg	410
21.	Potassium	mg	3800
22.	Sodium	mg	2300
23.	Phosphorus	mg	700
24.	Iodine	µg	150
25.	Selenium	µg	55
26.	Fluoride	mg	4

It is considered that continuous consumption of combat rations meeting the above minimum standards for up to 30 days will not cause nutritional imbalance in the body of soldiers who must be in good physical health at the beginning of the operation. If consumption exceeds 30 days, it is recommended to diversify the daily menu with fresh food products and increase medical monitoring of the soldiers' health condition. According to data from the report "Nutrition Science and Nutritional Standards for Military Operations" by NATO's Research and Technology Organization, of the twelve combat rations studied from NATO member countries, nine have a maximum recommended continuous use period of 30 days. For the combat rations of Australia, the USA, and Slovenia, the recommended periods are 20, 21, and 10 days, respectively. The main reasons for the shorter periods of continuous consumption are the low approval levels of the rations among soldiers and the lack of variety in the menus.

Additionally, Australia points out the reduction of certain valuable vitamins in the rations due to prolonged storage as an important reason [2, 3].

These packs must be lightweight and compact while providing all necessary nutrients and calories to sustain physical and mental endurance.

C. Impact of extreme temperatures on macronutrient requirements for military personnel

Extreme temperatures—both cold and hot—significantly influence metabolic processes and macronutrient needs for military personnel. In cold conditions, the primary priority is maintaining body heat and adequate energy supply. This necessitates increased energy consumption, with diets requiring higher fat content to provide long-term energy reserves. According to Young and Pasiakos (2013), fats should account for up to 35–40% of total energy intake in cold climates, with a preference for sources rich in omega-3 fatty acids due to their anti-inflammatory properties [4]. Meanwhile, proteins play a critical role in preserving muscle mass, essential for thermoregulation and physical performance [5].

In hot climates, military personnel require increased carbohydrate intake, which serves as the primary source of readily available energy. Young and Deuster (2001) note that carbohydrates should constitute 55–65% of daily energy intake in high temperatures to compensate for significant energy expenditure and prevent glycogen depletion [5]. Additionally, proteins should be moderately increased (around 15–20% of energy intake) to support muscle tissue recovery and prevent catabolism.

The importance of a balanced diet adapted to specific climatic conditions is strongly emphasized in the literature. As Young and Pasiakos (2013) state, "Optimizing macronutrient balance is crucial for maintaining physical endurance, cognitive functions, and the health of military personnel in extreme environments" [4].

D. The role of supplements and energy bars

Supplements in military rations, such as energy bars and dehydrated foods, are crucial for reducing load and providing essential energy reserves. Freeze-drying and dehydration are methods that extend shelf life while preserving nutrients. For example, freeze-drying retains 97% of the nutritional value of products while minimizing changes in structure and taste [7]. Additionally, the process simplifies food digestion and preparation [8], [9].

Hydration Beverages: Hydration is essential for military personnel in extreme conditions. The use of isotonic beverages is recommended to replenish electrolyte levels and prevent dehydration. Advanced drying technologies, such as freeze-drying, enable easy storage and use of beverages with high nutritional value [7], [8].

E. The need for water purification systems

In extreme conditions, ensuring access to clean drinking water is critical for the health and operational capabilities of military personnel. Water purification systems, such as ultrafiltration and reverse osmosis, effectively remove contaminants and pathogens. Research highlights that the use of portable water purification systems significantly reduces the risk of waterborne illnesses and ensures a sustainable supply even in the most adverse conditions [11].

These systems incorporate key technologies such as activated carbon, UV sterilization, and integrated portable pumps. Advanced filtration membranes help eliminate bacteria, viruses, and chemical pollutants, ensuring compliance with military-grade water safety standards. Models described by Taylor and Brown (2022) demonstrate how combining efficient filtration technologies with compact designs can provide safe water for drinking and cooking, even under resource-constrained circumstances [12].

Furthermore, modern purification units integrate real-time water quality monitoring sensors, enabling personnel to assess contamination levels and system performance in the field. The development of nanostructured filtration materials has further improved efficiency, enhancing the removal of heavy metals, toxins, and microscopic contaminants. Some advanced military-grade systems also utilize electrochemical disinfection methods, ensuring prolonged water safety without the need for frequent maintenance.

Recent studies emphasize the effectiveness of advanced nanomaterials in water purification. Research published in the *Journal of Water Process Engineering* highlights that nanostructured membranes improve filtration efficiency and enhance the removal of bacteria, viruses, and heavy metals [13].

Ensuring the availability of potable water has long been a critical challenge for military operations, directly impacting the performance of soldiers. Currently, the U.S. Armed Forces rely on large, centralized reverse osmosis (RO) water treatment systems to produce potable water, which must then be distributed to the points of use. However, the logistics of delivering water to remote expeditionary operations are costly, dangerous, and complex. While the Navy and the Department of Defense (DoD) have developed RO desalination systems that scale effectively to platoon-level (45 soldiers), further scaling down to the squad level (13 soldiers) or smaller units presents significant challenges [14].

In addition to scaling issues, RO systems face several drawbacks, including high consumables usage and maintenance and lifespan issues related to the membranes. Given the growing global concern about the availability of potable water for civilian purposes, there has been increasing development of alternative desalination and purification technologies. These include electrochemical methods, such as capacitive deionization, solar-powered thermal processes, and atmospheric water harvesting techniques, which eliminate the need for direct

desalination. These findings underscore the importance of continuous advancements in water purification technologies, ensuring safe and reliable drinking water for military and emergency response teams in extreme conditions[14].

The integration of purification technologies within tactical and logistical planning significantly enhances operational readiness. Whether deployed in arid environments, disaster-stricken regions, or combat zones, military forces can maintain self-sufficiency in water supply. Additionally, the lightweight and modular design of next-generation portable purification devices allows for rapid deployment and adaptability in diverse operational scenarios. Continued research and development in this field ensure that military personnel have access to reliable and high-performance water purification solutions, even in the most challenging conditions.

III. RESULTS AND DISCUSSION

The analysis shows that combat rations used by NATO member states generally comply with the minimum energy and nutritional requirements set by STANAG 2937. However, prolonged use of these rations—beyond 30 days—can result in reduced intake of certain essential vitamins and minerals, as well as a decrease in soldiers' acceptance due to limited menu variety.

Adapting the nutritional composition of rations to environmental conditions is of key importance. In cold climates, increased fat intake supports heat retention and long-term energy supply, while in hot environments, higher carbohydrate intake is necessary to meet energy demands and prevent fatigue. A well-balanced macronutrient ratio enhances physical endurance and operational performance.

Energy bars, freeze-dried meals, and powdered drinks are practical components due to their extended shelf life, compact packaging, and preserved nutritional value. Requirements, as improving taste and variety, are essential for ensuring nutrition during extreme missions of short duration.

Access to clean drinking water remains a critical factor in sustaining military operations. Modern portable purification technologies—such as nanofiltration, UV sterilization, and electrochemical methods—provide reliable solutions for removing contaminants and pathogens, even in extreme environments. Challenges remain in scaling down systems for small tactical units and maintaining filtration efficiency over time.

In conclusion, the effectiveness and health of military personnel in the field depend greatly on appropriate nutrition, hydration, and access to clean water. Continuous innovation and improvement of rations and purification technologies are essential for meeting the demands of diverse operational scenarios.

IV. CONCLUSION

Ensuring the health, combat readiness, and operational efficiency of military personnel in extreme environments demands a holistic strategy that integrates proper nutrition, hydration, and logistical support. Carefully planned and certified food rations and beverages, tailored to meet the unique demands of each operational setting, are essential for maintaining the physical and mental performance of soldiers. Advanced food preservation techniques, such as freeze-drying, enable the production of lightweight, durable, and high-quality supplies, while robust water purification systems effectively address the risks of contaminated water sources.

The inclusion of essential nutritional supplements, including vitamins and minerals, helps meet the physiological needs of military personnel, enhancing their energy metabolism, immune defense, and physical resilience. Furthermore, standardized frameworks like STANAG 2937 ensure interoperability between allied forces, guaranteeing consistent access to the necessary resources across different nations.

With the increasing global concern about safe drinking water, innovations in desalination and purification technologies offer promising solutions to mitigate water scarcity. Techniques such as capacitive deionization, solar-powered thermal processes, and atmospheric water harvesting present viable alternatives to traditional reverse osmosis systems, reducing logistical burdens and increasing operational flexibility.

Incorporating advanced water purification technologies into military logistics enhances self-sufficiency and operational readiness, ensuring that personnel in the most challenging environments have reliable access to clean water. Continued investment in these technologies, along with their integration into combat rations, is crucial for maintaining the safety, effectiveness, and success of military missions, even under the most extreme and resource-limited conditions. By embracing these innovations and adhering to established standards, military forces can successfully navigate the challenges of extreme environments, ensuring mission success without compromising the well-being of their personnel.

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REFERENCES

[1] Institute of Medicine. Nutritional Needs in Cold and High-Altitude Environments: Applications for Military Personnel in Field Operations. Washington, DC: The National Academies Press, 1996. https://nap.nationalacademies.org/read/5197/chapter/1.

[2] Ivaylo Ralev, „Condition and directions for the development of food supply for the bulgarian army in operations“, "Military Academy 'Georgi Stoykov Rakovski', publisher, 2021, ISBN 978-619-7478-64-8.

[3 STANAG 2136. Requirements for Water Potability during Field Operations and in Emergency Situations. NATO Standardization

Office, 2014. https://www.coemed.org/files/stanags/03_AMEDP/AMedP-4.9_EDA_V1_E_2136.pdf.

[4] A. J. Young and S. M. Pasiakos, "Energy balance and macronutrient distribution during military operations in extreme environments," Nutrition Reviews, vol. 71, no. 3, pp. 211-220, Mar. 2013. DOI: 10.1111/nure.12020.

[5] A. J. Young and P. Deuster, "Nutritional strategies to optimize performance during military operations in extreme cold environments," Military Medicine, vol. 166, suppl_3, pp. 71-76, Mar. 2001. DOI: 10.1093/milmed/166.suppl_3.71.

[6] S. Bhatta, T. Stevanovic Janezic, and C. Ratti, "Freeze-Drying of Plant-Based Foods," Foods, vol. 9, no. 1, p. 87, Jan. 2020. DOI: 10.3390/foods9010087.

[7] T. M. Oyinloye and W. B. Yoon, "Effect of Freeze-Drying on Quality and Grinding Process of Food Produce," Processes, vol. 8, no. 3, p. 354, Mar. 2020. DOI: 10.3390/pr8030354.

[8] K. Mostafa, "General Principles of Freeze-Drying," ResearchGate, 2020. [Online]. Available: https://www.researchgate.net/publication/342123456_General_Principles_of_Freeze-Drying.

[9] NATO Standardization Agreement (STANAG) 2560. Evaluation of NATO Medical Treatment Facilities. NATO Standardization Office, 2017. Available: https://coemed.org/files/stanags/03_AMEDP/AMedP-1.6_EDA_V2_E_2560.pdf..

[10] Institute of Medicine. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. Washington, DC: National Academy Press, 2000. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK225472/

[11] J. Smith and P. Johnson, "Portable Water Purification Systems for Field Operations," Journal of Environmental Safety, vol. 12, no. 4, pp. 234-245, 2021.

[12] K. Taylor and M. Brown, "Advanced Filtration Technologies in Emergency Water Supply," Water Research, vol. 15, no. 3, pp. 128-145, 2022.

[13] Maria Rajkiewicz, „Trends in membrane filtration technology: theory and application“, Chapter, BookChemical and Applied Engineering Materials, 2015, Imprint Apple Academic Press, p. 49, eBook ISBN9780429173110

[14] Paul A. DeSario, Jeffrey W. Long, and Kenan P. Fears, “Technology Assessment of Water Treatment Devices for Small-Scale Production”, OMB No. 0704-0188, DCN: 0543-1045-23.