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Freeze-Dried Food in the Diet of Temporary Residents of the Far North

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Abstract.
Introduction. The Russian Arctic, also called the Far North, attracts a lot of people who work on a fly-in fly-out basis. These temporary residents experience the negative impact of the harsh climate and suffer from unvaried diets and poor ration. Freeze-dried products might be the optimal solution to this problem. The research objective was to find a rationale for the use of freeze-dried long-storage products in the diets of temporary residents in regions with harsh climatic conditions.
Study objects and methods. The research featured scientific publications on two topics: 1) nutrition and diet of shift workers in the Far North, 2) development of freeze-dried products for long-term storage in extreme conditions.
Results and discussion. Shift workers consume a lot of fats and carbohydrates, while their diet lacks complete proteins, vitamins, minerals, dairy products, and fresh fruits and vegetables. Taking into consideration the high content of sugar and confectionery, the diet ruins the health of the temporary residents and causes alimentary chronic non-infectious diseases. A healthy diet for the Russian Arctic should correspond to the metabolic profile typical of people in chronic environment stress and be complete both quantitatively and qualitatively. Important food products are difficult to deliver to the Far North. As a result, they are microbiologically and chemically contaminated. Therefore, the region needs high-quality functional products with prolonged shelf life.
Conclusion. Freeze-dried fermented milk products, fruits, and vegetables can help temporary residents of the Far North to maintain their usual food patterns. Freeze-dried foods have a long shelf life in unregulated temperature conditions, which can solve the issue of food supply even to the most remote settlements.

Keywords. Diet, ration, freeze drying, freeze-dried food, functional food, stress, adaptation, Far North, Russian Arctic

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Особенности питания населения, временно пребывающего в условиях Крайнего Севера, и перспективы применения сублимированных продуктов

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Аннотация.
Введение. В статье собраны сведения об особенностях питания населения, работающего вахтовым методом в условиях Крайнего Севера. Цель работы – сбор и анализ научно-технической информации о структуре питания временно работающего приезжего населения в российских регионах с трудными климатическими условиями, а также перспективах использования сухих сублимированных продуктов с функциональными свойствами в условиях повышенных физических нагрузок.
Объекты и методы исследования. Научные публикации, посвященные вопросам питания и рациона населения, проживающего в условиях Крайнего Севера, а также разработки сублимированных продуктов длительного хранения в экстремальных условиях.
Результаты и их обсуждение. Выявлено, что рацион вахтовиков характеризуется повышенным содержанием жировых и углеводных продуктов, при недостатке полноценного белка, витаминов и минеральных веществ. В рационах отмечено недостаточное количество молока и молочных продуктов, свежих фруктов и овощей, и повышенное содержание сахара и кондитерских изделий, что отрицательно влияет на здоровье населения и приводит к развитию наиболее распространенных алиментарно-зависимых хронических неинфекционных заболеваний. Показано, что рацион должен соответствовать особенностям обмена веществ при хроническом стрессе и быть полноценным не только по количественному содержанию компонентов, но и по качественному. Определено, что отсутствие необходимых продуктов связано со сложностями их доставки в регион, что приводит к микробиологической и химической контаминации пищевых продуктов во всех административных территориях Арктической зоны. В связи с чем, возникает необходимость в специализированных продуктах высокого качества с длительными сроками хранения.
Выводы. Предложено расширение ассортимента и улучшение структуры питания путём использования в рационах сублимированных функциональных продуктов. Дана информация по примерам использования сублимированных продуктов в нашей стране и за рубежом в условиях повышенных нагрузок в питании космонавтов, военнослужащих, спортсменов и др. Показана экономическая эффективность применения сублимированных продуктов питания в зависимости от продолжительности хранения и дальности перевозки, по сравнению с холодильным хранением. Обобщены данные о перспективах метода вакуумной сублимационной сушки для создания специализированных сублимированных продуктов.

Ключевые слова. Питание, рацион, сублимированные продукты питания, функциональные продукты, стресс, адаптация, макронутриенты, микронутриенты, Крайний Север

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Introduction

The Russian Arctic occupies about 70% of the Russian Federation. It is an important and developing source of natural resources. It accounts for 90% of coal reserves, 80% of hydropower resources, large strategic reserves of oil and gas, almost the entire volume of explored rare metals and diamonds, 50% of iron ore deposits, 80% of forest resources, and more than 60% of fresh water reserves [1, 2]. Intensive development of natural resources attracts a lot of shift workers. However, the harsh climatic conditions make it difficult for the temporary residents to live and work in the Russian Arctic: rapid temperature changes, extreme light regime, and various geomagnetic, gravitational, and radiation anomalies [3–7]. Moreover, such conditions are quite often accompanied by unfavorable social and industrial environment. Together with information overloads, it causes additional mental fatigue and emotional stress in the migrant workers, which can become chronic [3, 8–12].

In October 2020, Russian President Vladimir Putin signed the Strategy for the Development of the Russian Arctic and Ensuring National Security for the period until 2035. The pressing issue makes it extremely relevant to improve the adaptation of shift workers and strengthen their health. First of all, shift workers need access to adequate nutrition [6, 8, 9, 13–15]. Second, they should be provided with functional and preventive foods to maintain health, restore energy costs, reduce the loss of working time, and increase performance [16–18].

The research objective was to collect and process scientific and technical data on the food patterns of communities that experience constant physical exertion under harsh climatic conditions and to prove the prospects for introducing freeze-dried long-storage products into local diets.

Study objects and methods

The paper introduces a review of domestic and foreign scientific publications in two major fields: nutrition and diet of the residents of the Far North and the development of freeze-dried products for long-term storage in extreme conditions.

Results and discussion

Diets and food patterns of Arctic communities often become focus of scientific attention. As a rule, research objective is to calculate deviations from the recommended nutrient intake [19, 20].

Ionova studied the diet of the shift workers in the Yamal-Nenets Autonomous Region and revealed a highly atherogenic character of their diet: more than

25% of the temporary residents demonstrated excess fat consumption [20]. Epidemiological studies on the territory of the Yamalo-Nenets Autonomous Region showed that local shift workers aged 20–59 were prone to metabolic syndrome. Their actual diet was imbalanced in many aspects as it contained too much common fats, cholesterol, and sodium, while lacking ω-3 polyunsaturated fatty acids, carbohydrates dietary fiber, vitamins, and minerals, e.g. B-group vitamins, potassium, calcium, magnesium, phosphorus, etc. [19, 21, 22].

At a mine in the North-Yenisei region of the Krasnoyarsk Territory, the food in the stationary canteen fully met the requirements for proteins. In fact, the local shift workers received more protein than recommended for the daily intake, because they habitually chose meat or fish for lunch and dinner, while their breakfast consisted mostly of boiled eggs, cheese, sausages, and cottage cheese with sour cream. However, the Federal Research Center for Nutrition and Biotechnology warns that protein assimilation can fall down to 80%, which justifies the increased protein intake. The diet satisfied the physiological need for fats by 100% and for digestible carbohydrates – by 85.3%. The content of dietary fiber in the daily ration exceeded the norm by two times because vegetable salads, bean puree, cereals, bread, etc. were the most popular and affordable dishes for breakfast or as a side dish. The miners' diet proved to be quite complete, varied, and balanced. However, the distribution of calories by meals was imbalanced, and the diet was poor in vitamin C, calcium, and magnesium [8].

In the Norilsk industrial region, miners' diet appeared lacking in calories and essential micronutrients. The diet revealed a significant shortage of dairy products, fresh vegetables, and fruits. The share of fish, seafood, eggs, and vegetable oil was below the recommended level, while that of sugar and confectionery products exceeded the norm [23].

A research on the food patterns and nutritional status of industrial workers in the Sverdlovsk region showed an excessive intake of fats, saturated fatty acids, and mono- and disaccharides, as well as a lack of polyunsaturated fatty acids and dietary fiber [24].

Since the 1990s, the Federal Service of State Statistics for the Republic of Sakha (Yakutia) has registered a downward trend in the annual production and consumption of many foods per household member. For dairy products, this amount has fallen from 437 to 279 kg; vegetables and melons – from 82 to 62 kg; eggs – from 269 to 176 pcs. By 2012, the share of agricultural products produced in Yakutia was 28% of the norm for meat products, 73% – for dairy products, 66% – for eggs, and 46% – for vegetables and melons. These data indicate that the local food pattern is undergoing a transformation as the share of carbohydrates and fats increases due to the decreasing protein intake [25].

The Federal Research Center for Nutrition and Biotechnology studied the food patterns of the indigenous and migrant communities of the Russian Arctic. Compared to the indigenous people, the newcomers appeared to consume less bakery products, fatty products, and fish while eating more vegetables, dairy products (kefir, fermented baked milk, yogurt, sour clotted milk, cheese, cottage cheese, sour cream, etc.), and – less often – such canned dairy products as sweet condensed milk [26]. In general, the local level of consumption of dairy products is not high enough. For instance, in the Tyumen region, only 45.5% of surveyed residents consume dairy products every day. The insufficient calcium intake is typical of all age groups [27].

In 2014, the level of self-sufficiency for milk in accordance with the recommended rational consumption rates was 9.3% in the Murmansk Region and 0.5% in the Chukotka Autonomous Region [13]. A similar study for 2013 also confirmed that the level of self-sufficiency for certain foods was lower than the recommended nutritional standards. For milk, it ranged from 0.6 in the Chukotka Autonomous Region to 59% in the Republic of Sakha (Yakutia); for meat – from 4 in the Magadan Region to 34.3% in Chukotka and Yakutia; for eggs – from 21.7 in Chukotka to 69.5% in the Murmansk Region [28].

Scientists believe that introducing functional and locally produced foods into the local diet can increase people's resistance to unfavorable environmental and labor conditions [8, 13, 29–31]. However, there is evidence that European settlers who adjusted to the local products and food patterns of the indigenous population developed negative changes in lipid metabolism later in life. Their metabolism shifted from the carbohydrate type to the fatty type, and it is fats that compensate for increased energy consumption, which increases serum cholesterol and atherogenic lipids in peripheral blood, thus triggering atherosclerosis [32].

Panin *et al*. performed a longitudinal study, which resulted in *the principle of adequacy of nutrition to the state of energy metabolism*. The obtained results made it possible to reconsider the nutritional standards for shift workers in order to adjust them to the adaptive changes in their metabolism. The research team developed carbohydrate, basic, and protein-lipid diets for young male shift workers and tested them under real-life conditions in the Far North. Both the carbohydrate diet and the diet of the indigenous population proved inadequate for the migrant working population. The ideal of proteins:fats:carbohydrates ratio was 16:40:44. However, energy value can vary depending on the severity of labor [33].

Available publications demonstrate that the diet of temporary residents of the Far North should correspond to the metabolic profile typical of people in chronic environment stress and be complete both quantitatively and qualitatively [8, 19, 29, 31, 34]. Most studies on the diet of non-indigenous communities register excessive consumption of carbohydrates, refined sugars, and

saturated fatty acids against the deficiency of vitamins, some minerals, essential proteins, and amino acids.

If combined with low ambient temperatures and insufficient calorie intake, even a short-term physical activity can lead to vitamin C deficiency. Low temperatures are known to affect the metabolism of vitamin C and B-group vitamins [6, 35, 36]. Moreover, vitamin D deficiency is quite common in high latitudes [37, 38]. These factors trigger the development of such alimentary chronic non-infectious conditions as obesity, atherosclerosis, cardio-vascular problems, arterial hypertension, diabetes, vitamin deficiency, etc. [20, 22, 26, 34, 39, 40].

Fresh vegetables, fruits, berries, as well as eggs and dairy products, are hard to find in the Russian Arctic. It is connected with the existing microbiological and chemical contamination of food products in all administrative territories of the Arctic zone [13, 14]. Nowadays, the microbiological indicators of milk, fermented dairy products, meat, poultry, fish, and seafood seldom meet sanitary and epidemiological standards [14].

This situation results from the economic difficulties associated with the food supply to these remote territories [8, 14, 40, 41, 42]. The most cost-effective and popular way of food delivery is first by railroad and then by river transport. Other options are the Northern Sea Route and air transport.

The food delivery scheme to the Republic of Sakha (Yakutia) shows that the shipping cost for perishable food by rail and river transport is 82 rubles (30 days), by the Northern Sea Route – 118 rubles (13–20 days), by air – 283 rubles (7 h). All these deadlines are hard to meet in the harsh climate, and delivery period often exceeds shelf life of such perishable goods as dairy products, fresh fruits and vegetables, etc. [2].

Such conditions require new long-storage food products with a low weight and volume, which can be achieved by lowering the final moisture content and using vacuum packaging. For instance, Filippova *et al*. developed a technology for natural cryogenic products to be used in extreme living conditions. The team ground raw materials at cryogenic temperatures and then dried them at moderate temperatures. The experiment involved contract servicemen (n = 30 in each observation) that performed extreme physical activities. Introducing 30 g of the experimental product per day for 15 days had a positive effect on their morphological and functional condition. The scientists reported reliable data on the positive changes in the respiratory, cardiovascular, and central nervous systems [43].

The modified diet had a beneficial effect on lipid and protein metabolism as well as liver function. 46.7% of the test subjects improved the muscle strength of the dominant hand. The share of soldiers with excellent physique increased by 1.6 times, the number of those with good physical adaptation – by 1.4 times. The number of test subjects whose defense mechanisms improved their adaptive potential increased by 1.5 times. The new product was also tested on a group of conscript servicemen with weight deficit (n = 650), who consumed up to 35 g per day for 15 days. The new diet helped them to restore standard body weight in 75% of cases. After the experiment was repeated, 99% of the test subjects reached standard body weight [43].

Freeze-dried food products are another promising direction in improving the diets of temporarily residents of the Arctic regions. Such products are obtained by vacuum freeze drying, which increases shelf life while preserving the nutritional value. The method can be applied to a wide range of food products, especially vegetables and fruits, but also dairy and meat products. Domestic freeze-dried products often proved invaluable in harsh conditions. For instance, freeze-dried meat and cottage cheese were in the diet of the famous Arctic expeditions organized by *The Komsomolskaya Pravda* in the summer of 1973–1974 in order to find traces of Russian pioneers. The expeditions received wide media coverage. The freeze-dried products were developed by the All-Russian Research Institute of Canning and Vegetable Drying. During the ascent to Everest in 1984, Russian climbers gave full marks to the freeze-dried products developed by Vladimir Voskoboinikov [44].

In the early 1960s, the Moldavian Research Institute of Food Industry developed and tested a wide range of vegetable-based freeze-dried products, which were regularly used in space flights. In the mid-1970s, the Research Institute of Food Concentrate Industry and Special Food Technology became the leading organization for the development of rations and foods for cosmonauts, borscht with meat being their first successful freeze-dried project.

The contemporary list of space foods includes 300 types of high-quality, reliable, long-storage products designed for specific conditions of transportation and operation [45, 46]. Another list of 100 commercial foods ensures the diversity of space diet. These products passed cold-and-hot control tests and were divided into two groups: those with limited shelf life (60 days) and those with prolonged shelf life (12–15 months). The first group includes pressed beluga caviar, adjika, horseradish, ketchup, and salami mini sausages, while the second consists of liver pate, canned fish, meat, vegetable and fruit, freeze-dried yoghurts, dry instant drinks, and chocolate.

The ration of ISS crews includes the following freeze-dried products:

– beef-based soups, e.g. borscht, green cabbage soup, sauerkraut cabbage soup, pickle soup, potato soup, and smoked borscht;

– main courses, e.g. goulash, pork tenderloin, roast beef with side dishes (cabbage, peas in milk sauce, mashed potatoes, buckwheat porridge), pork with lecso, vegetable stew with meat, home-style beef, and pasta with meat;

– canned meat, e.g. chopped pork with eggs, veal with vegetables, chicken with eggs, chicken with prunes, chicken omelet, etc., and commercial canned food, e.g. liver pate with dill or bacon; and
– canned fish, e.g. five kinds of pike perch, five kinds of salmon, beluga, sturgeon, aspic sturgeon, bream in spicy tomato-mustard sauce, etc.

The diet also includes such complete protein products as freeze-dried milk, cottage cheese with blackcurrant puree, sea buckthorn puree, and freeze-dried nuts, as well as canned processed cheeses. Freeze-dried products include pea puree soup, Bulgarian beans, and canned beans in tomato sauce.

Freeze-dried foods are also known to be part of NASA rations [47]. In the early days of the US space program, space flights lasted from a few minutes to 24 h and required no substantial meals. However, astronauts involved in project Mercury contributed to the development of space food. They tested the physiology of chewing, drinking, and swallowing solid and liquid food in microgravity. The first astronauts ate freeze-dried foods from aluminum tubes. Those tubes caused many problems: it was like sucking in a beverage through a straw, except that the food was much thicker. Special materials coated the inner surface of aluminum tubes because the metal could interact with acids found in such products as applesauce and produce hydrogen gas. Aluminum tubes often weighed more than the food they contained.

Eventually, tubes gave way to lighter plastic containers. Scientists developed small-size solid freeze-dried foods compressed into dehydrated pieces or cubes. The cubes were rehydrated with saliva when chewing. Food crumbles floating in microgravity could damage equipment, or the astronaut could inhale them. That is why the cubes were coated in gelatin to reduce crumbling. Those products were vacuum-packed in separate portioned containers made of transparent three-layer plastic foil, which prevented moisture ingress, preserved taste, and helped to avoid spoilage.

More recent diets included freeze-dried grape and orange drinks, fruit cocktails, turkey chunks, applesauce, cream chicken soup, shrimp cocktail, beef stew, chicken with rice, and turkey with gravy. The menu was repeated every four days. Each astronaut received 0.58 kg of freeze-dried food per day.

Freeze-dried products are an important part of NATO army rations, which proves its rationale. For example, individual LRP rations are used in to feed small, well-armed reconnaissance teams that patrol deep in enemy-held territory. Each package contains 40 bags, each of which provides one soldier with three meals. The food packet weighs 300 g, and its calorie content is 1540 kcal [48–50].

In addition, freeze-dried foods are used by professional athletes during outdoor competitions and are part of emergency food reserves [51–53].

Vacuum freeze drying includes freezing the product and removing moisture by sublimating ice crystals in vacuum. The process requires low temperatures, which preserves all important characteristics and quality indicators of the product [54]. High-quality freeze-dried products – vegetables, fruits, fermented milk products, minced meat and fish – are important both as independent food products and as part of existing rations and formulations. This principle can improve the diet of temporary residents of Arctic Russia, both shift workers and their families.

At the production stage, freeze drying is more expensive than simple freezing. However, storage, transportation, and cooking of frozen products require more energy costs, which is confirmed by foreign and domestic studies [55, 56].

Russia has good prerequisites for increasing the share of freeze-dried foods in the food patterns of Arctic communities. The city of Borovsk, Kaluga Region, boasts a freeze drying plant with 20 domestic freeze-drying units that produce 340 kg of raw materials per drying cycle each. The plant delivers one hundred different food products of plant origin. The technologies meet the best international standards. Freeze-dried products from Borovsk are highly appreciated by Russian consumers and receive prizes at domestic and foreign exhibitions.

Freeze drying is a prospective technology to be used in the diet of shift workers in the Russian Arctic [54]. Freeze-dried products have numerous advantages:
– they preserve nutritional value, including biologically active thermolabile components, i.e. vitamins, enzymes, amino acids, probiotic microorganisms, etc. [56, 57];
– maintain excellent sensory properties, e.g. size, taste, color, smell, etc. [58–62];
– are resistant to radiation;
– have low moisture content, which makes it possible to store them for up to two years in sealed packaging in unregulated temperature conditions, and they maintain high sanitary and hygienic parameters [63];
– possess good porosity and high hygroscopicity; as a result, they regain their initial state quite easily, and the powders get totally dispersed during rehydration [64];
– can acquire new consumer properties and increase their nutritional value if rehydrated with various biological fluids, e.g. minced meat reconstituted with milk;
– contribute to new technologies due to traditional and non-traditional raw materials [65];
– have low weight, which reduces transport costs [66]. For example, the mass of vegetable-based freeze-dried products is ten times lower than that of corresponding fresh fruits and vegetables.

The review shows that the contemporary diets of shift workers in the Far North have a lot of flaws. They contain a lot of fats, fast-digesting carbohydrates, and sodium, but lack fermented dairy products, fruits, and vegetables. Functional foods with prolonged shelf life can improve the situation.

Conclusion

Theoretical and practical research in new technologies of freeze-dried products for preventive dietary nutrition is especially important as it contributes to the extensive development of natural resources in the Russian Arctic, which is fueled by the migration of able-bodied population from the central regions. Shift workers have their own food patterns which local food cannot satisfy. As a result, their diet is imbalanced and poor in various macro- and micronutrients. Industrial production of freeze-dried products could improve the diet of shift workers in the Far North and people in emergency situations, e.g. they can be added to autonomous survival kits. Freeze-dried products can increase the adaptive potential and improve the health of shift workers in hard-to-reach regions.

Contribution

E.I. Titov supervised the research. V.I. Ganina reviewed the available scientific publications on nutrition and diets of shift workers in various regions of the Far North. I.S. Krasnova reviewed articles on the experience of using freeze-dried products for long-term storage in extreme conditions. E.G. Semenova was responsible for the section about alimentary non-infectious chronic diseases and the deficiency of various macro- and microelements in the diet of temporary residents of the Far North.

Conflict of interest

The authors declare that there is no conflict of interests related to the publication of this article.

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