

## INCLUSION OF A PLANT-BASED PRODUCT IN THE DIET OF KNOWLEDGE WORKERS TO ENHANCE THEIR VITAMIN AND MINERAL STATUS

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Environmental conditions and strenuous cognitive workload necessitate optimization of nutrition. This study aimed to evaluate the effectiveness of a predominantly plant-based product in improvement of the vitamin and mineral status of people engaged in intellectual labor. The formula for the product was developed after assessment of the said status and working conditions of the participants. The treatment group ( $n = 30$ ) has been supplementing its diet with the product for 21 days, while the control group ( $n = 30$ ) has not. The blood plasma levels of vitamins (B9 and B12, and 25(OH)D) and minerals (K, Na, ionized and total Ca, Fe, Mg, and P) were determined. By degree of strain, the considered occupations were classified as harmful strenuous work (class 3.2). Initially, the level of vitamin B9 in each group was in the "low-normal" zone. Through the experiment, in the treatment group it increased by 3.2–3.8%, while in the control group the said level dropped by 3.7–3.9%; the level of vitamin B12 increased by 36.7–46.7% and decreased in 23.3–36.7%, respectively, and that of 25(OH)D increased by 3.0% ( $p = 0.02$ ) and decreased by 3.3% ( $p = 0.03$ ). The level of ionized calcium in the treatment group increased by 7.0% ( $p = 0.001$ ) and decreased by 50.0–53.3% in the control group. Iron levels increased by 3.1% in 80% of the treatment group participants ( $p = 0.04$ ), and sodium levels increased by 0.9% ( $p = 0.04$ ), which was 46.7–60.0% higher than the baseline values; in the control group, sodium levels dropped by 23.3–26.7%. No significant changes were recorded for the levels of K, total Ca, P, Mg, but at the level of individual indicators we observed multidirectional changes. Thus, the use of the multicomponent plant-based product demonstrates the promise of this approach for preventing vitamin and mineral deficiencies.

**Keywords:** Subarctic, harmful strenuous work, vitamins, minerals, multicomponent plant-based product, efficiency

**Author contribution:** Rakhmanov RS — study concept and design, article authoring; Bogomolov ES — article editing, approval of its final version; Razgulin SA — literature data collection, participation in the interpretation of the results; Narutdinov DA — collection, systematization of primary data; Shurkin DA — analysis and statistical processing of data.

**Compliance with ethical standards:** the study was conducted in accordance with the World Medical Association Declaration of Helsinki and approved by the Ethics Committee of Privolzhsky Research Medical University (Minutes No. 4 of March 14, 2022). All participants have voluntarily signed informed consent forms.

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## КОРРЕКЦИЯ ВИТАМИННО-МИНЕРАЛЬНОЙ НАСЫЩЕННОСТИ ОРГАНИЗМА ЛИЦ, ЗАНЯТЫХ УМСТВЕННЫМ ТРУДОМ, РАСТИТЕЛЬНОМ ПРОДУКТОМ

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Условия экологического неблагополучия и напряженный умственный труд обуславливают необходимость оптимизации питания. Целью работы было оценить эффективность коррекции витаминно-минерального статуса лиц, занятых умственным трудом, растительным продуктом. После оценки витаминно-минерального статуса организма, условий труда разработали рецептуру продукта для повышения стрессоустойчивости. Лица из основной группы ( $n = 30$ ) 21 день в дополнение к рациону принимали продукт, группа сравнения ( $n = 30$ ) рацион не меняла. В плазме крови определяли уровень витаминов (B9 и B12, 25-ОН витамина D), минералов (K, Na, Ca ионизированный и общий, Fe, Mg, P). Условия напряженности трудового процесса оценивали как вредный напряженный труд (класс 3.2). Исходно уровень витамина B9 в каждой группе находился в зоне «пониженный уровень-норма». При приеме продукта он повышался на 3,2–3,8%, а в группе сравнения снижался на 3,7–3,9%. Уровень витамина B12, соответственно, вырос у 36,7–46,7% и снизился у 23,3–36,7%. Уровень 25-ОН витамина D вырос на 3,0% ( $p = 0,02$ ) и снизился на 3,3% ( $p = 0,03$ ). Уровень ионизированного кальция у лиц основной группы повысился на 7,0% ( $p = 0,001$ ), а в группе сравнения снизился у 50,0–53,3%. В основной группе повышение уровня железа имело место у 80,0%; в группе сравнения зафиксирован рост на 3,1% ( $p = 0,04$ ). На 0,9% ( $p = 0,04$ ) повысился уровень натрия (по этапам наблюдения был выше исходных значений у 46,7–60,0%), в группе сравнения отмечено снижение у 23,3–26,7%. По K, Ca общему, P, Mg значимых изменений не отмечено, но по индивидуальным показателям определены разнонаправленные изменения. Использование многокомпонентного растительного продукта подтверждает перспективность данного направления профилактики витаминно-минеральной недостаточности организма.

**Ключевые слова:** Субарктика, вредный напряженный труд, витамины, минералы, многокомпонентный растительный продукт, эффективность

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As a stress factor, strenuous cognitive workload causes fatigue, malaise, anxiety, worsens the quality of work, productivity of the individual, and handicaps the cognitive functions of the brain. Depending on the severity and time of exposure to this factor, the consequences may include depletion of the adaptive reserves of the body [1, 2]. In addition, strenuous cognitive workload increases the individual's need for nutrients, including vitamins and minerals [3, 4]. For example, vitamin C deficiency impairs cognitive function; replenishing it boosts motivation, improves concentration, and enhances productivity on attention-demanding tasks [5]. An association was established between affective disorders and vitamins B6 and B12 deficiency [6]. As for vitamins E, B9, and magnesium, their levels affect mental health [7, 8].

One strategy for maintaining normal brain function and the body's stress resistance is eliminating nutrient deficiencies caused by internal or external factors [9–11].

This study aimed to evaluate the effectiveness of a predominantly plant-based product in improvement of the vitamin and mineral status of knowledge workers employed in the Subarctic zone.

## METHODS

The study was conducted in the Subarctic zone. We observed two groups of men (healthy and practically healthy), 30 in each, over the summer. All the participants held similar jobs and performed their duties in an anthropogenically polluted urban area (Norilsk). They were  $34.2 \pm 0.92$  years of age, and their work experience in the North was  $6.4 \pm 0.6$  years. We assessed their working conditions [12].

Relying on data available from the scientific literature, we designed a multicomponent food product (MCFP) from predominantly plant-based raw materials to enhance the body's stress resistance. Ingredients of the MCFP: beetroot, oats, red grapes, eggshells, celery, parsley, kelp. The production employed cryogenic technology [13], yielding a final product rich in vitamins and minerals, the content of which was calculated taking into account the fraction of water remaining after cryogenic processing [14].

The treatment group supplemented their usual home-cooked diet with 10 g (2 teaspoons) of MCFP, added to the second course of dinner, for 21 days. The control group maintained their usual home-cooked diet and refrained from taking vitamin or mineral supplements before and throughout the study, including the observation period. The range of food consumed by individuals in both groups was the same.

We measured plasma levels of the considered vitamins and minerals three times: before the MCFP course, at its completion (on day 22), and on the 32<sup>nd</sup> day of observation (to confirm the effect).

**Table 1.** Vitamin content per 100 g of product

Product	A*, mg	E, mg	C, mg	B1, mg	B2, mg	B5, mg	B6, mg	B9, µg	B12, mg	PP, mg	Biotin, µg	D, µg	K, µg
Beet	0.18	0.025	20.13	0.04	0.04	0.32	0.14	22.05	0	0.805	0.339	–	0.339
Oats	0.55	12.55	0	0.23	0.018	0.38	0.04	7.413	0	0.326	4.118	–	–
Red grapes	0.07	0.195	11.1	0.07	0.072	0.05	0.088	1.487	0	0.193	–	–	14.226
Eggshell	0.02	0.31	–	–	0.015	–	–	–	–	–	–	–	–
Celery	0.084	9.422	6.78	0.066	0.032	0.538	–	33.25	–	0.7	1.029	–	46.391
Parsley	0.064	0.144	164.38	0.055	0.048	0.164	0.109	9.835	0	0.603	2.45	–	830.93
Dried kelp	0.113	0.035	0.707	0.014	0.006	–	–	0.169	0.109	0.109	0.475	0.261	10.23
Total	1.081	22.68	203.1	0.475	0.231	1.452	0.377	74.204	0.109	2.736	8.411	0.261	902.116

**Note:** \* — combined in terms of carotenoids.

The plasma content of electrolytes (total calcium, magnesium, inorganic phosphorus, iron) was determined using an AU5800 analyzer (Beckman Coulter; USA), the content of ionized calcium, potassium, and sodium was established with a Roche AVL9180 analyzer (Roche Diagnostics GmbH; Germany). The results were evaluated in accordance with accepted standards [15].

The level of 25(OH)D, an intermediate in vitamin D metabolism, enabled assessment of the saturation of the body's vitamin D status. The tests were performed on an AB SCIEX QTRAP 5500 mass spectrometer (SCIEX; Germany). The results were categorized as follows: severe deficiency (5–10 ng/ml); deficiency (10–20 ng/ml); insufficiency (20–30 ng/ml); optimal level (30–100 ng/ml) [16].

The level of cyanocobalamin (vitamin B12) was determined using the ARCHITECT® i2000 automated system (Abbott; USA). The normal range was taken as 25–165 pmol/L. Level < 32 pmol/L was considered vitamin B12 deficiency [17].

The level of folic acid (vitamin B9) was determined on an AB SCIEX QTRAP 5500 liquid chromatography-mass spectrometer (SCIEX; Germany). The range of normal values was taken as 5–9 ng/ml [18].

When statistically processing aggregate indicators in tables generated in MS Office Excel (Microsoft; USA) using the Statistica 6.1 (StatSoft; USA), after determining the type of distribution using the Kolmogorov-Smirnov test, we calculated the following: for normal distribution — means (M) and their standard deviations ( $\sigma$ ), for non-normal distribution — median values (Me) and interquartile range ( $Q_1$ – $Q_3$ ). The significance of the differences for paired samples was determined in the first case with the Student's *t*-test, in the second — with the Wilcoxon test, at  $p < 0.05$ . In addition, we assessed the dynamics of deviations of individual indicators from the reference boundaries.

## RESULTS

By the intensity of labor, the working conditions of the participants were classified as harmful and strenuous (class 3, degree 2). The emotional stress associated with the responsibility for decisions made, the likely risk to one's own safety and the safety of others supported the conclusion. Cognitive workloads and working hours yielded similar classification: heuristic type of work, comprehensive assessment of information, control and assignment of tasks, irregular work hours, non-compliance with regulated breaks. Sensory loads were also harmful (class 3, grade 1) and stemmed from prolonged use of a computer.

The calculated content of vitamins and minerals in the MCFP is given in Tables 1 and 2. In addition, 100.0 g of MCFP contained 17.62 g of dietary fiber.

**Table 2.** Mineral content per 100 g of product

Product	F, µg	J, µg	Cu, mg	Zn, mg	Fe, mg	Mn, mg	Cr, µg	Se, µg	Mg, mg	P, mg	Na, mg	Ca, mg	K, mg
Beet	40.25	24.15	0.125	0.425	2.45	1.12	0.01	1.409	4.63	80.52	157	32.21	579.78
Oats	31.86	2.04	0.31	3.3	7.7	1.44	0.03	–	28.87	119.83	5.45	12.25	116.83
Red grapes	12.33	11.31	0.06	0.072	0.37	0	3.08	0.1	7.194	20.55	2.055	10.277	196.3
Eggshell	13.26	4.08	0.11	0.92	3.06	0	0.024	0.015	56.1	13.27	9.184	340	178.56
Celery	8.75	3.28	0.91	3.63	2.2	0.163	0.15	0.438	24.07	52.516	175.05	87.527	260
Parsley	126.03	13.7	0.82	3.2	3.94	0.08	0.23	0.082	35.07	41.644	60.274	119.45	279.45
Kelp	36.96	326.09	0.56	1.14	3.36	0.03	2.69	0.076	13.37	4.565	29.35	20.65	14.13
Total	269.44	384.65	2.895	12.687	23.08	2.833	6.214	2.12	169.3	332.9	438.36	622.364	1625.05

Initially, the Q1 values for vitamin B9 in each group were in the "low level" zone. In the treatment group, it increased by 3.2–3.8% during the follow-up period and reached the reference range, while in the control group, on the contrary, it dropped by 3.7–3.9%. On the level of individual indicators, the folic acid level in the treatment group was initially lower than normal in 30.0% of the participants; consumption of the MCFP decreased this value to 13.3% during the course and further to 10.0% during the follow-up period. In the control group, before the start of follow-up, the vitamin B9 level was below the reference limit in 25.0% of the participants. On the 22<sup>nd</sup> day, 35.7% exhibited a decrease thereof within the normal limits. On day 32, a decreased B9 level was registered in 28.6% of the participants, and another 28.6% had the value dropping but not beyond the normal range.

There was no significant dynamics of vitamin B12 content in the groups; it was normal. However, in the treatment group, on days 22 and 32 of the follow-up period, 36.7% and 46.7% of the examined individuals showed an increase in the blood plasma level of this vitamin. In the control group, on the contrary, the said level decreased in 23.3% and 36.7%.

As for the 25(OH)D balance, the changes were multidirectional. There were no significant changes in the treatment group by the end of the MCFP course. However, on the 32<sup>nd</sup> day of follow-up, the level of 25(OH)D was 3.0% than the baseline. The positive trend was created by the participants who initially showed a deficit of the micronutrient: their share decreased from 60.0% to 40.0%. At the same time, the share of those verging on having a deficit thereof increased by 10.0%. In the control group, on the contrary, the proportion of people with a deficit increased and the proportion of people with insufficiency decreased; on the 22<sup>nd</sup> and 32<sup>nd</sup> days, the drop reached 3.3% (Table 3).

The blood levels of ionized calcium in both groups were between the lower limit of the normal range and the range

of insufficiency. In the treatment group, after the MCFP course, it increased by 7.0%, and by the end of the follow-up it was 6.5% higher than the baseline value, that is, within the reference range. At the level of individual participants, 73.3% of them exhibited growing levels of ionized calcium, and 70% retained the achieved results until the end of the follow-up period. In the control group, the level of this micronutrient decreased in 50.0–53.3% of the participants; at all stages of the follow-up period, it was below the norm in 40.0% of individuals.

By the end of the MCFP course, blood iron levels in the treatment group increased by 3.1%, which is significant. This result was observed in 80.0% of the participants. On the 32<sup>nd</sup> day of follow-up, it remained the same in 66.7% of individuals. In the control group, blood iron dropped in 30.0–10.0% of the participants.

Sodium levels grew slightly (by 0.9%), but significantly: on the 22<sup>nd</sup> and 32<sup>nd</sup> days of follow-up, the increase was registered in 46.7–60.0% of the treatment group participants. In the control group, sodium levels decreased in 23.3 and 26.7%.

As for other substances, their mean values remained largely unchanged (no significant fluctuations) and within the reference limits, but considered individually, they exhibited multidirectional changes: in the treatment group, 46.7% of the participants had the levels of potassium growing, and in the control group they dropped in 23.3%; total calcium was higher than the baseline in 36.7–40.0% of the treatment group individuals, while in the control group the respective value decreased below the initial figures on 20.0–30.0% of the participants; the level of inorganic phosphorus grew in the treatment group (33.3–40.0% of the participants), and in the comparison group it dropped in 16.7–23.9%; magnesium was higher than the baseline in 56.7–60.0% of treatment group subjects, while in the control group, the drop in its levels was observed in 23.3–13.3% of the examined participants (Table 4).

**Table 3.** Comparative characteristics of blood plasma vitamin content in knowledge workers, Me (Q<sub>25</sub>–Q<sub>75</sub>)

Group	Follow-up period, M ± σ		
	Baseline	Day 22	Day 32
Vitamin B9, 5.0–9.0 ng/ml			
Treatment	4.65 (4.11–6.24)	4.96 (4.89–6.6)/0.04*	5.15 (4.94–6.65)/0.03* *0.018***
Control	4.35 (4.45–8.0)	4.32 (4.33–7.8)/0.001	4.19 (4.2–7.66)/0.001/0.317
Vitamin B12, 25.0–165.0 pmol/L			
Treatment	109.95 (64.0–128.0)	105.0 (73.0–124.0)/0.25	111.0 (71.0–123.0)/0.2/0.28
Control	97.0 (78.5–164.0)	94.0 (78.0–169.50)/0.08	94.0 (77.5–169.5)/0.07/0.3
25(OH)D, 30–100 ng/ml:			
Treatment	18.65 (13.2–21.0)	18.9 (15.0–21.2)/0.85	18.95 (15.25–21.85)/0.02/0.12
Control	24.6 (19.25–35.55)	21.9 (18.25–34.85)/0.03	22.05 (18.25–34.85)/0.02/0.54

**Note:** \* — significance of differences (p) relative to the baseline; \*\* — significance of differences (p) relative to the baseline; \*\*\* — significance of differences (p) relative to the data recorded after the MCFP course.

Table 4. Absolute mineral content in blood

Group	Follow-up period, M ± σ		
	Baseline	Day 22	Day 32
Potassium, 3.5–5.1 mmol/L			
Treatment	4.82 ± 0.5	4.83 ± 0.46/0.93*	4.81 ± 0.46/0.85**/0.056***
Control	5.0 ± 0.46	4.99 ± 0.47/0.45	4.99 ± 0.43/0.63/0.33
Sodium, 136–145 mmol/L			
Treatment	144.1 (142.0–146.0)	145.0 (144.0–147.0)/0.04	145.1 (144.0–147.0)/0.04/0.423
Control	144.0 (142.0–144.0)	143.0 (141.0–144.0)/0.41	143.0 (141.0–144.0)/0.41/0.919
Ionized calcium, 1.15–1.35 mmol/L			
Treatment	1.16 (1.11–1.2)	1.19 (1.1–1.33)/0.001	1.2 (1.1–1.32)/0.002/0.035
Control	1.14 (1.11–1.17)	1.13 (1.11–1.117)/0.054	1.13 (1.1–1.18)/0.07/0.929
Calcium, 2.02–2.60 mmol/L			
Treatment	2.59 (2.32–2.74)	2.5 (2.31–2.57)/0.09	2.5 (2.31–2.56)/0.3/0.49
Control	2.54 (2.44–2.62)	2.53 (2.43–2.61)/0.63	2.5 (2.4–2.59)/0.63/0.91
Inorganic phosphorus, 0.7–1.8 mmol/L			
Treatment	1.19 ± 0.19	1.21 ± 0.17/0.21	1.21 ± 0.18/0.162/0.16
Control	1.09 ± 0.12	1.1 ± 0.12/0.31	1.1 ± 0.12/0.48/0.67
Magnesium, 0.66–1.03 mmol/L			
Treatment	0.91 ± 0.07	0.9 ± 0.08/0.987	0.9 ± 0.08/0.172/0.17
Control	0.92 ± 0.13	0.92 ± 0.13/0.731	0.92 ± 0.13/0.869/0.574
Iron, 9.5–30 mmol/L:			
Treatment	20.74 ± 4.5	21.16 ± 5.21/0.049	21.38 ± 5.07/0.04/0.68
Control	19.98 ± 5.52	21.8 ± 4.94/0.711	21.8 ± 4.94/0.5/0.081

Note: \* — significance of differences (*p*) relative to the baseline; \*\* — significance of differences (*p*) relative to the baseline; \*\*\* — significance of differences (*p*) relative to the data recorded after the MCFP course; for nonparametric data — Me (Q<sub>25</sub>–Q<sub>75</sub>).

## DISCUSSION

Norilsk is the most problematic city in the Arctic macroregion; here, the population's health is affected by a combination of natural and environmental factors [19]. Amid anthropogenic pollution and strenuous intellectual workloads, the vitamin and mineral status of the examined individuals deviated from normal levels, potentially impairing their cognitive functions. In particular, the baseline levels of vitamin B9, 25(OH)D, and ionized calcium were reduced; overall, the levels of the considered vitamins and minerals were decreasing in the control group.

Previously, it has been established that nutrients consumed with food can alleviate neuropsychiatric stress associated with intense mental work [20, 21]. Accordingly, there was formulated a multicomponent product that promotes detoxification (via beetroot and oats), boosts antioxidant protection (from red grapes), enhances overall resilience by supplying essential vitamins and minerals (from all herbal components), and eliminates heavy metals (using eggshell [22]). Since the considered group had a high incidence of diseases of the genitourinary system, the formula was complemented with parsley and celery [23].

Kelp was used to address the pronounced iodine deficiency common in northern regions. The said deficiency hampers cognitive functions and promotes development of a secondary immunodeficiency [24].

The MCFP contained both minor and biologically active substances:

- beetroot: betaine, organic acids, organic antioxidants;
- oats: beta-carotene, betaine, lutein, zeaxanthin, gum, beta-cryptoscanthin, methylmethionine sulfonium, phytosterols;
- red grapes: carotenoids, lutein, zeaxanthin, betaine, phytosterols, antioxidants, essential oils, phenolic compounds;

– celery: beta-carotene, lutein, zeaxanthin, methylmethionine sulfonium, phytosterols;

– parsley: gamma-tocopherol, beta-carotene, betaine, methylmethionine sulfonium, phytosterols, flavonoids, antioxidants, lycopene;

– kelp: beta-carotene, fucoxanthin.

These substances perform "the functions of exogenous regulators of metabolism and play an important role in the adaptive reactions of the body, maintaining health" [25]. They have a positive effect on mental endurance and stimulate the activity of the nervous system [26–32].

Analysis of micronutrient intake showed that the treatment group received the following additional amounts daily (percentage of the recommended daily amount): up to 20.3% for vitamin C, 12.0% for vitamin A, 25.7% for iodine, 29.0% for copper, 23.1% for iron, 14.2% for manganese, and 10.6% for zinc. The proportion of dietary fiber reached 8.8% of the daily requirement [25].

In our study, adding the MCFP to the participants' diets increased cyanobalamin saturation in almost half of them. The deficiency of vitamin B12 can negatively affect hematopoiesis, the body's energy metabolism, and the state of the nervous and antioxidant systems under extreme conditions. It can be assumed that the negative effects worsened in the control group: levels of vitamins (B9, B12, 25(OH)D) dropped, and those of minerals (ionized Ca, Fe, Na) decreased significantly.

In 20.0% of the treatment group, folic acid levels were within the reference limits by the end of the follow-up; initially, they were below these limits in 30.0% of the participants from this group. In the control group, deviations from the norm only increased. Vitamin B9 is involved in hematopoiesis and regeneration, it boosts the anabolic and adaptive processes

in the body. Being involved in the synthesis of nucleic acids, vitamin B9 affects the normal development and function of the brain not only during pregnancy and after birth, but also later in life.

Despite the fact that the study was conducted in the summer, a significant proportion of the subjects showed vitamin D deficiency (established by measuring its major metabolite). Vitamin D is associated with regulating neurohormonal effects in the brain and maintaining cognitive function, memory, and behavior. It plays an important role in the mechanism of oxidative stress and regulation of phosphorus-calcium metabolism [33]. In our study, participants' vitamin D levels increased despite its low content in the MCFP. This may relate to elevated minerals (calcium, phosphorus, magnesium) that facilitate vitamin D metabolism.

In addition to micronutrients, minor and biologically active substances, the product contained dietary fiber, which is important for the intestinal microbiota.

## CONCLUSIONS

In this study, we have shown that environmental problems and strenuous mental work increase the body's need for micronutrients, which necessitates optimization of the diet in such conditions. Given the work conditions and the habitat factors, the use of the multicomponent plant-based product demonstrates the promise of this approach for preventing vitamin and mineral deficiencies.

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