BIOLOGICAL AND NUTRIENT BASIS OF HUMAN ALIMENTARY ADAPTATION UNDER ENVIRONMENTALLY DETERMINED XENOBIOTIC LOAD

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Abstract.*The article addresses the problem of alimentary adaptation of the human body under conditions of increasing xenobiotic exposure caused by environmental degradation and pollution. Particular attention is paid to the metabolic activation of xenobiotics, lipid peroxidation, and the importance of enzymatic and non-enzymatic antioxidant systems. The principles of organizing population nutrition under environmental load conditions, as well as practical measures to reduce the intake of radionuclides and other contaminants with food, are considered. The preventive potential of rational nutrition is emphasized as a crucial means of increasing the adaptive resistance of the body and reducing the risk of pathological conditions.*

Keywords: *alimentary adaptation, xenobiotics, environmental load, nutrition, dietary fiber, vitamins, minerals, radionuclides, homeostasis.*

Within the framework of this problem, nutrition is considered one of the most important factors determining the adaptation of the human body to changing environmental conditions. On the one hand, up to 90–95% of xenobiotics enter the human body via the alimentary route, namely through food products and drinking water. This circumstance emphasizes the critical importance of ensuring food safety and quality control at all stages of production, processing, storage, and distribution, carried out by manufacturers and regulatory authorities. Food products must comply with established safety standards in order to minimize chemical exposure risks.

On the other hand, nutrients play a decisive role in the realization of adaptive and protective mechanisms. At all stages of metabolism, nutrients may interact directly with xenobiotics, entering into competitive, synergistic, or neutral interactions, and serve as essential substrates for maintaining the stability of homeostatic systems. Increased alimentary xenobiotic load caused by environmental pollution exerts a pronounced negative influence on the internal environment of the body, leading to the development of a stress-related metabolic state characterized by altered energy and substrate utilization.

According to the World Health Organization, adaptation is defined as a genuine adjustment of the organism to changing environmental conditions that occurs without disruption of biological integrity or exceeding the limits of homeostatic capacity. Under conditions of chronic chemical exposure, adaptive responses may result either in dynamic adaptation (adaptive resistance) or in maladaptation followed by pathological states.

Dynamic adaptation is characterized by increased resistance to stressors and an expansion of the organism's protective and compensatory capacity, leading to a relative balance between living systems and their environment. The development of adaptive resistance is possible only under conditions of adequate intake of essential nutrients. Thus, alimentary adaptation may be defined as the process of increasing organismal resistance to adverse environmental factors through optimization of nutrition, ensuring sufficient intake of essential nutrients and biologically active compounds that support metabolic stability.

As an open self-regulating biological system, the human body relies on a set of universal protective mechanisms to maintain the integrity of its internal environment. Nutrition provides both the energy and substrate basis for these mechanisms. Under conditions of xenobiotic load, nutrition must fulfill additional protective functions, including:

- reduction of xenobiotic absorption in the gastrointestinal tract;
- attenuation of adverse cellular and organ-level effects;
- limitation of xenobiotic accumulation in target tissues and acceleration of their elimination.

The absorption of xenobiotics in the gastrointestinal tract depends on several factors, such as intestinal transit time, integrity of enterocyte membranes, digestive enzyme activity, gut microbiota composition, and the chemical structure of the diet. Nutrient–xenobiotic interactions may occur both in the intestinal lumen and at the cellular level, influencing transmembrane transport and systemic bioavailability.

A substantial body of evidence indicates that certain dietary components can effectively reduce xenobiotic absorption. These include natural nonspecific sorbents such as dietary fiber, alginates, collagen, mucilaginous substances, zeolites, and chitin. These compounds bind xenobiotics and enhance intestinal motility, thereby shortening the effective absorption period. Dietary fiber intake may reduce xenobiotic bioavailability by up to 50% or more, although excessive intake may impair mineral and vitamin absorption and disturb gastrointestinal function.

Certain minerals, including calcium, iron, magnesium, potassium, and iodine, can form poorly absorbable complexes with xenobiotics or competitively inhibit their transport across enterocyte membranes. Adequate intake of these minerals reduces

membrane permeability to xenobiotics, and under conditions of increased chemical exposure, their requirements may rise by 50–60% above physiological norms.

Despite effective intestinal barriers, a portion of xenobiotics inevitably enters systemic circulation. Once incorporated, xenobiotics may initiate pathological biochemical processes, undergo detoxification to harmless end products (CO_2 and H_2O), or accumulate in tissues. The ultimate fate of these compounds depends on intracellular adaptive defense systems, which operate under stress conditions during chronic environmental exposure.

Three major cellular defense mechanisms have been identified:

1. the lysosomal enzyme system;
2. the xenobiotic biotransformation system;
3. the antioxidant defense system.

Xenobiotic biotransformation is a universal two-phase process. Phase I reactions involve functionalization mediated primarily by the NADPH-dependent cytochrome P450 monooxygenase system. Phase II reactions involve conjugation with endogenous substrates such as glucuronic acid or glutathione, facilitating excretion.

However, many synthetic xenobiotics (e.g., pesticides, polychlorinated biphenyls, plastic degradation products, certain pharmaceuticals) and some natural toxins (e.g., aflatoxin B_1) undergo metabolic activation, producing more toxic intermediates than the parent compounds. These electrophilic metabolites can damage cellular macromolecules, leading to membrane dysfunction, genetic instability, immune sensitization, and carcinogenesis.

Protection against electrophilic metabolites involves both prevention of covalent binding to macromolecules (ascorbic acid, retinol) and active conjugation with reduced glutathione via glutathione-S-transferase. Adequate glutathione synthesis depends on sufficient intake of sulfur-containing amino acids, particularly cysteine.

Metabolic activation of xenobiotics often results in excessive production of reactive oxygen species, leading to oxidative stress and lipid peroxidation. The antioxidant defense system counteracts these processes and includes enzymatic and non-enzymatic components.

The enzymatic system comprises superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase, all of which require specific micronutrients (Zn, Cu, Mn, Fe, Se, riboflavin) as cofactors. Non-enzymatic antioxidants include vitamins E, A, C, β-carotene, bioflavonoids, ubiquinone, and uric acid.

Adequate intake of these nutrients is essential for maintaining antioxidant capacity, particularly under conditions of environmental stress. Calcium also plays a critical regulatory role in intracellular signaling and stabilization of adaptive responses.

In environmentally unfavorable conditions, irrational nutrition should be regarded not only as a risk factor for diet-related diseases but also as a determinant of reduced adaptive capacity. Nutritional strategies under xenobiotic exposure involve two primary objectives: minimizing dietary intake of contaminants and ensuring adequate intake of protective nutrients.

This includes strict food safety control, elimination diets that enhance xenobiotic excretion, normalization of gut microbiota, and development of functional foods enriched with dietary fiber, antioxidants, minerals, and high-quality protein. Proper culinary processing—washing, peeling, soaking, boiling, and discarding broths—significantly reduces contamination by radionuclides, heavy metals, and nitrates.

Alimentary adaptation thus represents a scientifically grounded and practically applicable approach to reducing the adverse health effects of environmental xenobiotics and remains one of the most effective preventive strategies available.

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