ZOOTECHNICIZING THE INTEGRATED FOOD SYSTEM, BASED ON THE PRINCIPLES OF BIOHARMONISM

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Abstract. *This paper examines the transformation of cereals into meat, milk, eggs, and other animal products, alongside optimizing the Farm-to-Fork flow as a core objective of the integrated food system in the modern world. The study focuses on optimizing agro-zootechnical anthroposystems by introducing systemic-level conceptual contributions. With the goal of developing highly efficient solutions, the primary objective is to explore future pathways for animal husbandry, driven by multi-layered integration aimed at maximizing added value through the process of bioharmonization. The paper discusses aspects of the dynamic biological-technological equilibrium tied to the homeoresis process, a feature of the "Living Planet" model. The concept of new zootechnicization promotes the implementation of the bioharmony model within the integrated food system, guiding animal production anthroposystems toward scientific and technological harmony with the environment and its resources, while responding to the needs of a rapidly evolving society*.

Keywords: bioharmonism, food system, integration, zootechnicization

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1. Introduction

"Studies by the UN through FAO show that it is becoming urgent to address how we use natural resources across the entire 'farm-to-table' axis, focusing on sustainability and resilience. This means optimizing and maximizing the yield and efficiency of the food supply chain in the face of climate, social, and geopolitical changes. In this regard, FAO offers a comprehensive guide explaining strategies for integrating livestock farming with other agricultural sectors to achieve more efficient and sustainable food systems [3].

Of interest along this axis is the approach based on the integrated food system, within which the role and importance of animal-based foods are clarified. The integration of livestock farming into global circular agriculture is addressed,

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discussing ways in which by-products and resources are efficiently reused within food systems [1]."

An integrated food system refers to a holistic approach to food production, in which various components of the agricultural and livestock system are interconnected to maximize efficiency, sustainability, and the quality of food products. In short, an integrated food system offers a comprehensive approach to food production that leverages synergies between different elements of agriculture, with a focus on livestock farming, aiming to promote sustainability, efficiency, quality, and food safety. This effectively leads to the concept of sustainable agricultural intensification, including integrated livestock production as part of the solutions for ensuring food security. The interactions between livestock systems, the environment, and human well-being are explored, with a particular emphasis on economic and ecological impact [6, 9, 12, 21, 28].

Here are some key aspects of this integration concept: sustainability, food safety, interconnectivity, diversification, innovation and technology, economic and social aspects, educating and involving farmers, all accompanied by brief comments to help understand the integrated food system approach [8,15,24,26], as summarized in Table 1.

Tabel 1. Essential Elements in Supporting the Integrated Food System

No.	*Key Aspects*	*Summary Specification*
1	**Sustenability**	Integrated agri-food systems are designed to reduce environmental impact through the efficient use of natural resources, minimizing waste, and promoting sustainable agricultural practices. # *For example, this includes soil conservation, water management, and reducing greenhouse gas emissions.*
2	**Food Security**	By maximizing resource efficiency and reducing losses, integrated food systems contribute to increasing food production, thereby improving food security for communities. # *For example: quantitatively, for large urban agglomerations, and qualitatively, for the market segment with special requirements.*
3	**Interconnectivity**	Integrated food systems combine plant and animal production, ensuring an efficient flow of resources such as nutrients, water, and energy. # *For example, waste from livestock can be used as fertilizer for crops, while plant residues can be used as feed for animals.*
4	**Production Diversification**	These systems promote the diversification of plant crops and animal husbandry, which not only enhances and values biodiversity but also helps reduce economic and ecological risks. # *For example, cultivating multiple types of plants and raising*

		different breeds of animals that utilize genetic resources with economic potential can create a more resilient food system
5	**Innovation and Technology**	The integration of modern technologies, such as precision agriculture, biotechnology, and data management, can support integrated food systems by helping to optimize production and monitor the health of plants and animals.
6	**Economic and Social Aspects**	Integrated food systems can support rural development and create jobs by improving the economic efficiency of farms. Additionally, involving local communities in the management of integrated systems can strengthen social ties and collaboration.
7	**Farmer Education and Involvement**	Implementing integrated food systems requires education and training for farmers to help them understand the benefits of this approach and adopt new techniques and practices.

As we know, a pressing issue in the food system is "protein hunger," particularly for high-quality proteins of animal origin. From this perspective, we address the importance and role of animal-derived foods, especially for the proper development of children and young people. Diversifying the menu or a special nutritional regimen (diet) is recommended by integrating various food sources, including animal products, as part of sustainable and biodiverse food systems [4,13,14, 29].

Therefore, the importance of the idea and process of animal husbandry itself is directly related to the production of animal protein, with the following fundamental scientific arguments:

- The human body can produce non-essential amino acids, while essential amino acids can only be obtained from food, with animal proteins being the best sources of essential amino acids.
- Generally, animal-derived foods tend to be sources of complete proteins (containing over 20 types of amino acids that can form proteins in the body), while proteins from plant sources are generally incomplete.
- Animal proteins are extremely important for the healthy growth and development of children, adolescents, and pregnant young mothers.
- High-quality animal protein produced through livestock production has the ability to enhance its added value through processing in the food industry and the production of products in the gastro-industry, resulting implicitly in the animal husbandry of integrated food act.

In this context, the current state of knowledge in the field of integrated animal production within food systems reflects significant progress in integrating animal husbandry into sustainable and efficient agriculture. This trend genuinely

represents a new paradigm, which we refer to as the *"NEW ZOOTECHNICIZATION"* specific to the 21st century.

Within this trend, research over the last few decades [2, 5, 7, 18, 19, 25] focuses on three main directions, which briefly refer to: - **Resource Management**, i.e., the integration of animal husbandry with the efficient use of land and water, promoting circular agriculture. / - **Environmental Impact**, specifically the reduction of the ecological footprint through nutrient cycles and the use of livestock waste for fertilization. / - **Advanced Technologies**, such as biotechnology and cyber systems that optimize productivity and reduce greenhouse gas emissions. These are indeed specific directions found in the modular agriculture approach and also in productive animal ecosystems, which highlight their sustainable application adapted to climate change.

One aspect of animal husbandry that deserves consideration as inspiration in animal husbandry models is the focus on small farmers in tropical or African regions and how integrated systems can contribute to increasing efficiency and reducing negative environmental impacts under extreme temperatures and drought conditions, where mixed crop and livestock systems adapted to these conditions play an essential role in increasing productivity and reducing poverty [17, 20, 22, 27].

The purpose and utility of the study on "new zootechnicization" refer to the integration of principles and practices of animal husbandry in managing genetic animal resources and related technologies to improve production yield and economic efficiency, animal health, and the sustainability of production systems. **The new zootechnicization** represents a complex and multidimensional process aimed at optimizing animal production through the use of scientific knowledge and modern management techniques. Within the structure of the concept, we can specifically mention in Table 2 some essential elements that converge with agriculture, the food industry, and the food system as a whole.

Tabel 2. Elements of the Anticipated Animal Husbandry Process for the Coming Decades

No.	*Pillars of Process*	*Brief Description*
1	**Genetic Improvement**	Animal husbandry involves the selection and breeding of animals with desired traits, such as disease resistance, productivity in animal production (especially in milk or meat), and adaptability to different environmental conditions.
2	**Animal Nutrition**	An essential component of animal husbandry is ensuring a large-scale, balanced, and appropriate diet for animals, which involves the use of scientifically formulated rations to maximize the growth and health of animals and, consequently, the health of consumers of animal-derived foods.

3	**Health Management**	The new animal husbandry includes animal health practices such as vaccination, deworming, and health monitoring to prevent diseases and improve animal welfare, in accordance with regulations that enable participation in the international market.
4	**Integration with Agriculture**	The new animal husbandry must be an integral part of the agro-food systems circuit, where animals contribute to soil fertilization, vegetation management, and food production for humans.
5	**Economic Aspects**	The implementation of new animal husbandry practices can lead to increased productivity and, consequently, improved incomes for farmers and communities, based on supportive legislation.
6	**Sustenability Process**	By applying modern management concepts and techniques, the new animal husbandry promotes the efficient use of natural resources and reduces environmental impact, contributing to the production of sustainable food under changing climate conditions.

Objectives: The work aims to achieve a better understanding of the systemic aspects related to the dynamic balance of animal production anthroposystems, in accordance with an Integrated Food Policy on the agro-rural-urban axis. Therefore, through a systemic approach based on the principles of bioharmonism, along scientific and managerial interdisciplinary lines, the study seeks to highlight the solutions for sustaining animal-based nutrition that enable the realization of an integrated, high-quality food system.

More specifically, it refers to a series of methodologies for modern animal husbandry („new zootechnicization") in the biological and technical direction, aligned with the largely undecoded process of *systemic homeorhesis specific to the "Living Planet" model*. This model is seen as necessary for maintaining the **dynamic balance and bioharmony** of the integrated food system, in relation to the environment, its resources, and the needs of a society undergoing profound change

2. Materials and Methods

The present study utilizes a documentary analysis conducted by consulting reviews from the specialized literature, which refer to the analysis of documents containing information about the studied phenomenon, namely the production of animal-based products in relation to the integrated food system. The basic methodological approach is linked to the strategic synthesis of the food process, with concrete elements concerning the analysis of trends in the development and integration of animal husbandry, using principles of multicriteria analysis, comparisons, and statistical processing [9,12]. A managerial diagnosis is employed, with a focus on the socio-economic aspects of the components of the integrated food system. Consideration is given to the principles, techniques, and

specific directions of sustainable development regarding the provision of animal-based food. Schematic structural and functional expressions are made as a guide for action, with applications in policies and strategies for the quantitative and qualitative development of animal husbandry and related food production in the early decades of the 21st century.

3. Results and Discussions

To better understand the topic addressed, it is necessary to examine the terminology from a semantic point of view, through the complementary elements of the new paradigm, as shown in the box below:

TECHNICIZE (verb): to give an (exclusively) technical character.
TECHNOCRATISM (noun, neuter): a sociological orientation according to which, in contemporary society, leadership roles should be exclusively held by specialists from various fields of science, technology, etc.
BIOHARMONISM: a concept referring to the systemic harmonization of balanced diversity and holistic organization in relation to the complex model of Nature and the existential triad (I, E, S), using the "living" information ("bio-") and the non-linear reality of life in all its complexity, in convergence with the techno-economic and socio-cultural models of today's society.
HOMEORHESIS: a concept referring to the property or state of a system (including planetary systems, but here we focus on the livestock and food systems) to maintain a ***dynamic balance***, to achieve and return to a specific trajectory of its dynamic state, in contrast to systems that tend towards a *static equilibrium* in their constants (homeostasis).

Starting from the meaning of the mentioned terms, it becomes appropriate to define the process under discussion, while also taking into account the different stages of its evolution:

- **STANDARD ZOOTECHNIZATION** (Fr. zootechnisation or élevage; Eng. zootechnicization or animal husbandry) – the process by which the field of animal husbandry is given an exclusively technical character, based on the sociological orientation according to which, in contemporary society, leadership roles should be held exclusively by specialists from various fields of science, technology, etc., including agroecosystems and animal production anthroposystems (farms, livestock complexes, supply chains, etc.).
- **THE NEW ZOOTECHNIZATION** or **modern zootechnization** represents the process that supports the approach of "zootechnicizing agriculture" in a new paradigm based on the concept of bioharmonism and dynamic balance. This includes, through multiple

integrations, the new directions of action in the field for the challenges of the coming decades: animal biotechnologies, modular and cellular agro-livestock farming, information technology and artificial intelligence, bioeconomy, the environment and ecosanogenesis, nutrigenomics and the psycho-sociology of nutrition, as well as the overall policy of the integrated food system.

From the above, it can be observed that the "new zootechnicization" is, in fact, an element of integration within the integrated food system, specifically based on principles of nutritional bioharmonization between plant-based and animal-based food resources, in terms of quantity versus quality.

3.1. Animal Husbandry in Relation to the Integrated Food System

The integrated food system refers to a holistic and sustainable approach to food production and consumption, which integrates all stages of the supply chain, from agricultural production to final consumption [11,13,14]. This may include interactions between different sectors, such as agriculture, animal husbandry, the food industry, and commerce (Fig. 1).

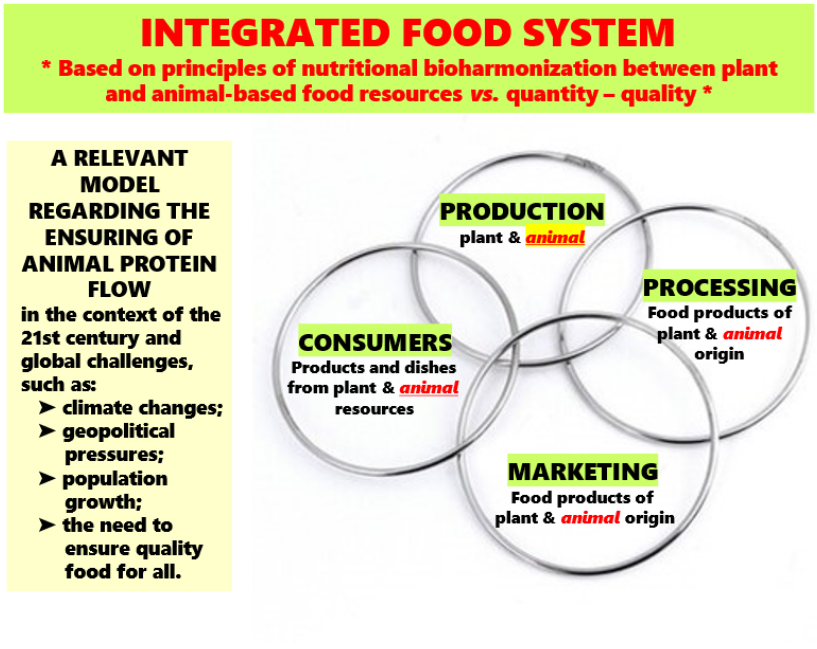

Fig. 1. Block diagram of the food system highlighting multiple integrations and the omnipresence of animal-based food.

To understand the complexity of the FOOD SYSTEM, highlighting the importance of animal-based foods, the functionality of the system is based on the mechanism of multiple integrations (integronic dynamics) that target specific factors and processes such as sustainability, food safety, innovation, collaboration between sectors, economic efficiency, and social responsibility.

Within the integrated food system, it can be observed that the evolution of animal production today is heavily integrated into the feeding process, being influenced by a range of global, technological, economic, and environmental factors [3,5,7,30]. Some of the main evolution scenarios are mentioned in Table 3.

Table 3. Global Factors Influencing the Evolution of Animal Production in the 21st Century

No.	*Evolution Scenarios*	*Directions of Action and Research Theme*	*Specification*
1	**Technologization and Digitalization of Agro-Livestock Farming**	Precision Agriculture and Digitalization of the Agro-Food Sector	The use of sensors, drones, and artificial intelligence to monitor animal health and efficiently manage resources.
		Farm Automation	Robotic systems for feeding, milking, and caring for animals, reducing labor costs and increasing operational efficiency.
		Advanced Genetics	Genetic manipulation to produce more productive animal breeds that are resistant to diseases and adapted to climate change.
2	**Sustainability and Environmental Impact**	Reduction of Carbon Footprint	Development of more environmentally friendly production systems, such as the use of renewable energy sources, reduction of methane emissions, and development of technologies for converting animal waste into biofuels
		Circular Economy	Integration of animal production into circular agro-food systems, where waste from one process becomes a resource for another (e.g., using waste for fertilization or bioenergy).
3	**Climate Change and Adaptation**	Climate Stress Resistance	Development of animal breeds that are more resilient to extreme conditions (heat, drought), as well as adaptation of production technologies to cope with changing climatic conditions.
		Water Resource Management	Animal production will need to become more efficient in terms of water use, considering droughts and the scarcity of freshwater resources.
4	**Increasing Demands for Animal Welfare**	Welfare Standards	Increased demand for animal products from farms that adhere to higher animal welfare standards.

		Free-Range and Organic Farms	Growing popularity of farms that offer free-range animals, reflecting consumer preferences for more natural and ethical meat and animal products
5	**Alternatives to Traditional Animal Production**	Lab-Grown Meat	Binary foods (natural & artificial) are an emerging alternative to conventional animal production, with the potential to reduce environmental and ethical pressures associated with animal husbandry.
		Proteins from Alternative Sources	Development of proteins obtained from insects or plants to partially replace animal-based products.
6	**Globalization and Supply Chains**	Changes in Global Demand	In developing countries, the demand for meat and dairy products continues to grow, while in developed countries, there are trends towards reducing meat consumption in favor of plant-based foods.
		Strengthening Supply Chains	Emergence of global production and distribution networks, focusing on efficiency and reduction of food waste (e.g., short supply chains between producers and consumers).

3.2. The Transition towards *New Zootechnicization*

These trends indicate a transition of animal production towards a more sustainable, efficient, and technologized model that seeks to address future challenges without compromising the basic needs of consumers or the environment.

Animal-based foods produced on the principle of QUANTITY aim to ensure food supply for large urban populations, which is why agro-livestock farming has developed in an intensive-industrial system over the past few decades. Foods produced on the principle of QUALITY focus on providing high-quality food (ecological, organic, traditional, mountain, etc.) obtained through natural and/or semi-intensive production systems ensured by farmers and various local producers. In this case, we refer to the production of meat through traditional animal husbandry that values the pastures and lands of local communities [2,10,16,23]. The bioharmonization of these two principles makes the approach related to the new zootechnicization of the 21st century relevant, a model that is certainly useful for Romania as well.

The new zootechnicization is present at all stages of the food process, as a well-defined conceptual and methodological paradigm (Fig. 2).

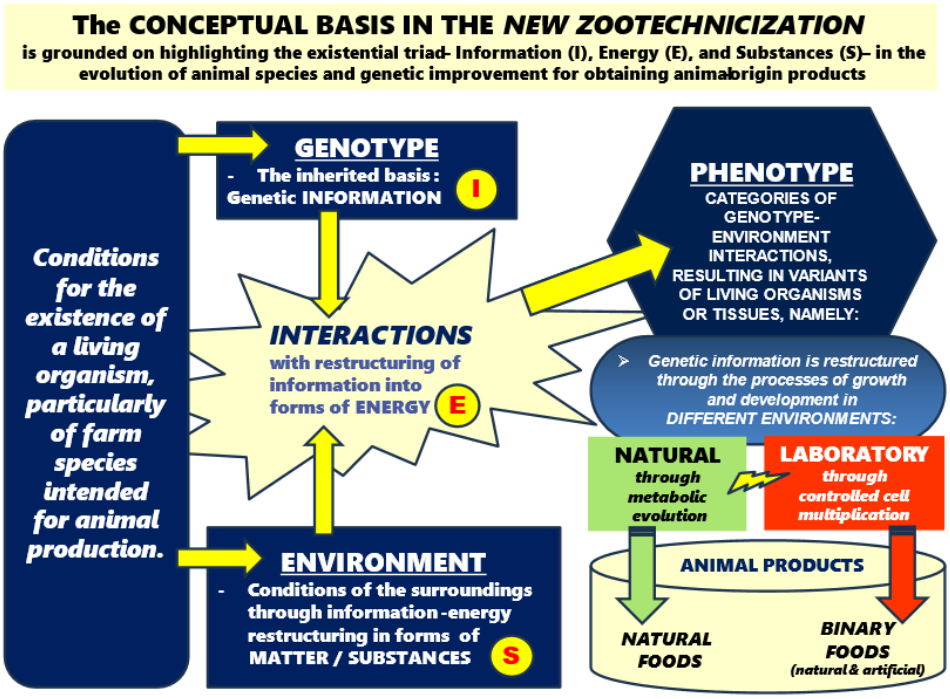

Fig. 2 – Zootechnical flow in the metabolic circuit of farm animal organisms, with the disjunction of production through: **STANDARD TECHNOLOGIES** (breeding – weaning – slaughter or direct marketing, depending on the type of animal product) or **ALTERNATIVE TECHNOLOGIES** (e.g., precision animal husbandry / binary animal products: stem cell harvesting – multiplication – production of animal tissues – marketing).

Precision livestock farming, as an element of the new zootechnicization, aims to improve the efficiency and quality of the sector and animal-based food products. It provides solutions that will be rapidly implemented in the coming decades, through various types of sensors that measure numerous effects occurring within and outside the animals' bodies, integrated algorithms, and robots that almost completely replace a wide range of human activities on farms. In fact, the time has come for us to be ready to transition from traditional, probabilistic animal husbandry to precision livestock farming, which offers very high economic efficiency and greater control over the quality of production and animal-based foods.

In the new paradigm, a balanced and unbiased approach is essential when addressing society's need for all types of food. This involves fostering a constructive mentality of complementarity, rather than a destructive (mercantile

interest-driven) mentality of exclusion. The argument is that the unknown challenges of the future necessitate humanity's ability to face all challenges, and for that, all categories of food are needed, adapted to the situation. It is important to build a balanced strategy that considers all the factors of the complex world we live in today (Fig. 3).

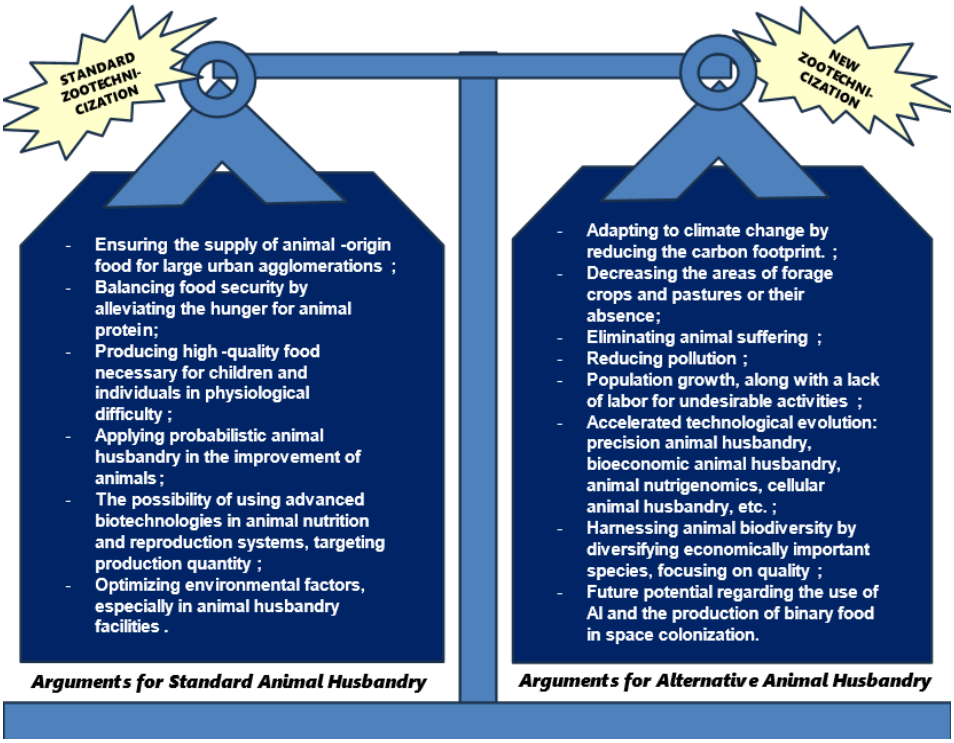

Fig. 3. The balance of a transition in equilibrium through bioharmonization of production methodologies, comparing the old and new zootechnicization of the 21st century.

Within **modern zootechnicization**, expressed through the polyvalent aspects of **alternative livestock farming**, a promising future lies in the production of binary foods that "combine" natural and/or semi-intensive systems applied in the deep Romanian regions and mountainous areas with large-scale laboratory-produced livestock systems (via cellular multiplication) necessary for supplying large urban agglomerations. This refers to **binary processing** (natural & artificial), meaning the harvesting of "natural" unspecialized cells (stem cells that have the ability to differentiate into various cell types and self-replicate) from live animals in eco-farms in mountainous or remote, unpolluted areas (the in vivo phase), followed by their multiplication in the laboratory (the in vitro phase) to form tissues (e.g., muscle tissue). The most relevant example is the so-called **"cultivated meat"**, which can be obtained through an innovative technology that allows meat to be

produced in the laboratory without the need to intensively raise and slaughter animals in the production process. Through the multiplication of undifferentiated cells using laboratory methods, the food supply for billions of consumers can be secured.

Therefore, in the new paradigm, animal-based foods are produced either traditionally on unpolluted pastures, focusing on high-quality zooproducts, or through binary processing—combining natural and artificial elements in two phases. We can essentially talk about both **"natural foods"** (traditional) and **"binary foods"**, as presented in Table 4.

Table 4. Typology of foods based on the contribution of the environment or human intervention in production processes

Phase	***NATURAL FOODS*** *(with minimal human intervention, the predominant role being the contribution of the environment, thus obtained through natural and metabolic processes)*	***BINARY FOODS*** *(obtained through a combination of natural and artificial processes, involving both environmental inputs and significant human intervention in production, such as laboratory-based cellular multiplication)*
In natural phases:	- **Primary products**: These are products obtained directly from nature, without significant human intervention, or with minimal intervention. For example, agricultural harvests (grains, fruits, vegetables), milk, honey, forest resources, or fishing. - **Organic/bio products**: These are products resulting from methods of plant cultivation and animal farming that aim to minimize chemical or technological interventions, in order to preserve the natural characteristics as much as possible.	➢ **Harvesting embryonic stem cells** – these have a very high capacity to transform into any type of cell. ➢ **Harvesting adult stem cells** – extracted from muscles, with the ability to transform only into certain types of cells (such as muscle or fat cells).
In artificial phases:	- **Primary processed products:** Example: products obtained by transforming natural products through various technological processes of the food industry, such as flour, oil, sugar, etc. - **Obtaining composite foods:** Example: foods produced by the food industry based on technological recipes. - **Obtaining complex foods:** Example: culinary preparations and manus from the gastro industry made based on culinary recipes.	➢ Obtaining Animal Tissues Example of muscle tissue created through a process that, by utilizing existing genetic information, mimics the natural development of muscles in a living animal / such as steak-type muscle, etc.

All of these are variations in which various livestock products are also found, in different forms, contributing gradually to the bio-harmony of the complex "constellation" of the integrated food system.

Conclusions

(1). Animal biotechnologies are a feature of the present, that is, of *Industry 4.0*, with the potential for their implementation in agriculture through livestock production ("new zootechnicization"), aimed at conceptual and methodological adaptation to contemporary requirements, through a gradual and bioharmonized transition based on complementarity between classical (probabilistic) zootechnics and alternative (precision) zootechnics. This should be carried out with transparency and honest communication, supported by appropriate education to avoid manipulations stemming from conspiracy theories or new obscurantism.

(2). The new zootechnicization represents a complex and multidimensional concept and process aimed at optimizing animal production through the use of scientific knowledge and modern techniques for balanced and unbiased management of feed. This is essential because the unknown prospects of the future require humanity to confront all challenges, necessitating all categories of food that can adapt to the current situation.

(3). The new zootechnicization or modern zootechnicization represents the approach of "zootechnicizing agriculture" within a new paradigm based on the concept of bioharmony and dynamic balance. This includes, through multiple integrations, the new directions of action in the field during the challenges of the coming decades: animal biotechnologies, modular and cellular agro-livestock farming, information technology and artificial intelligence, bioeconomy, the environment and ecosanogenesis, nutrigenomics and the psycho-sociology of nutrition, as well as the overall policy of the integrated food system.

(4). In the new paradigm, animal-derived foods are produced either traditionally on the unpolluted pastures of mountainous regions and deep areas of the country, focusing on the biodiversity of reproductive animals (producers of SDTEM cells) and high-quality zooproducts, or through binary processing, which involves two phases combining natural and artificial elements. This results in both **"natural foods"** (classical) and **"binary foods"** that blend natural phases (harvesting undifferentiated cells from living animals) with artificial processing phases in laboratories (through controlled cellular multiplication), yielding large quantities of animal products necessary for supplying future large urban agglomerations amid climate and demographic changes.

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