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Innovative Technologies for Deep Milk Processing

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"Green economy" — modern concept of human development (global trend)

Scientists believe that the future of humanity is possible only under the conditions of transitioning to the principles of the "green economy," which necessitates searching for and implementing innovative approaches to increase production efficiency while minimizing the risks of negative environmental impact, including resource consumption.

Main elements of "green economy" implementation in the food industry

The main elements of the implementation of the "green economy" in the domestic food industry include the following:

- **control and supervision by the state**
- **formation of the policy of state regulation of production**
- implementation of lean production principles
- development and implementation of deep processing of raw materials
- processing of secondary agricultural raw materials
- increasing the production efficiency
- support for domestic producers of raw materials
- production of organic food
- reduction of supply chains
- development and implementation of resource-saving technologies
- other.

Key directions of development of innovative technologies for processing agricultural raw materials:

1. innovative concept of food production — product "disassembly/assembly"
2. reduction of losses of raw material components during processing
3. development of enriched (functional) products
4. innovative approaches to forming dairy product quality (design of specified characteristics)
5. recycling of secondary raw materials
6. production of organic food
7. support for domestic producers of food ingredients
8. development and implementation of resource-saving technologies
9. development of technologies to reduce losses of nutritional value of raw materials

The need to develop innovative lean milk processing technologies

The development and implementation of innovative lean technologies is, in a sense, a prerequisite for the development of the dairy industry because:

- government regulation will encourage/enforce
- high competition will encourage/enforce
- these areas are economically feasible in the medium and long term.

Key areas of development of innovative technologies for milk processing




1. Innovative concept of food production — product "disassembly/assembly"

So many different products made from one type of raw material — milk!

This is because different products have concentrations of different native milk components:

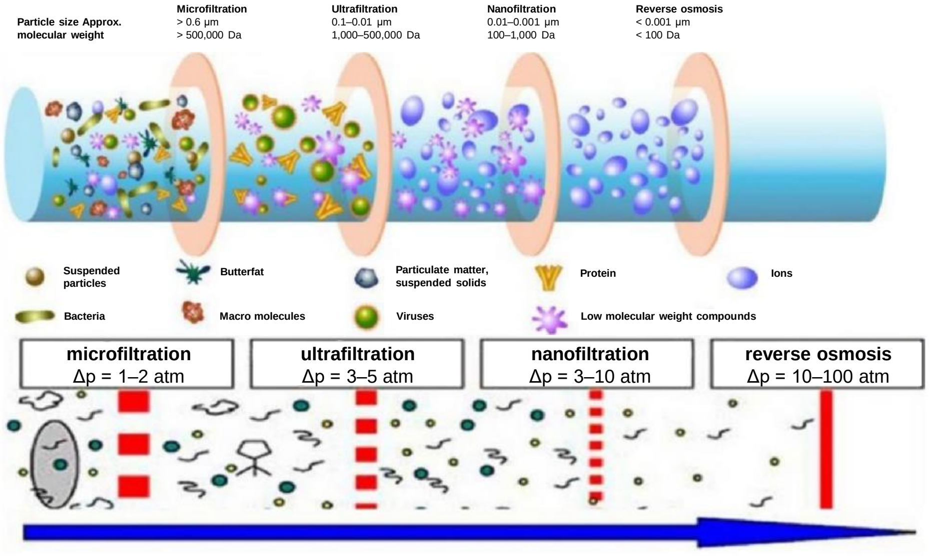
The basic idea of product "disassembly/assembly" is to decompose raw materials into constituent food components and then construct products from the various constituent components.

This enables to:

- create natural products with a given increased nutritional and biological value (children's, therapeutic, preventive, gerodietic nutrition, etc.)
- give products the required consumer properties
- provide standardized values of quality indicators

The main methods of "disassembly" of dairy raw materials are:

- **separation** (of the fat fraction of milk)
- **filtration** (separation of various milk components using specialized filters with various pore diameters)



This type of production (product disassembly and assembly) **is the future**, as it is the only way to design specific product properties, including to ensure high concentrations of **natural beneficial food components**:

- immunoglobulins
- whey proteins
- vitamins
- mineral substances
- enzymes
- many other components

2. Reducing milk component losses during milk processing

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Milk is a unique food product "designed" by nature precisely as a food product.

Milk contains **all necessary** food components for the life and development of a living organism (mammal) in an **easily digestible** form.

Even the **minor** components of milk are of **great** value.

The nutritional and biological value of milk is unique

Mineral substances
(in mg/liter)

Ca	P	K	Mg
Up to 1200	950	1200	110

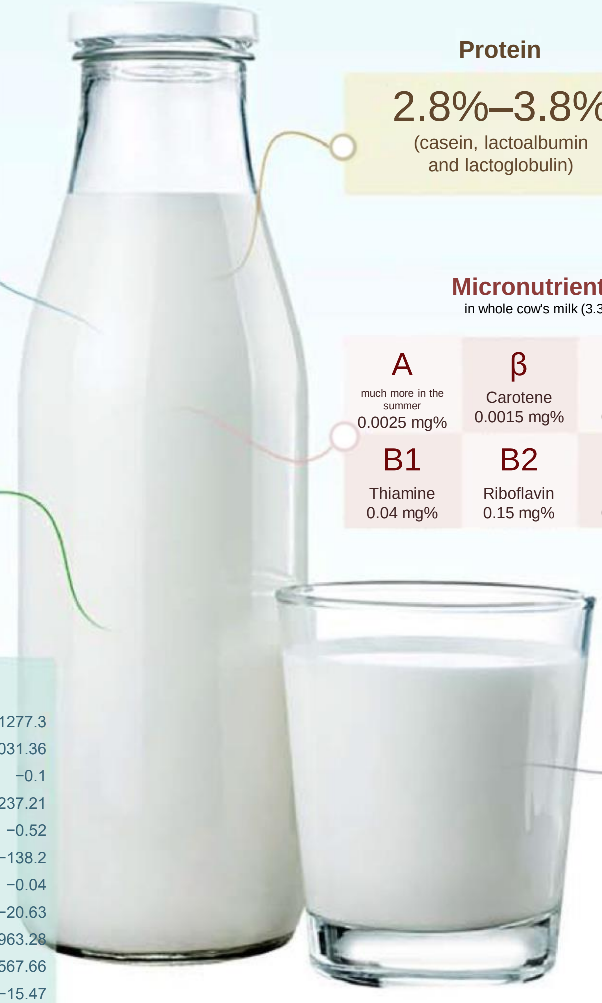
Fe, Co, Cu, Zn, Pb, Cr, Mn, J, Ag, Sn

Amino acids
(in g/100 g)

Tryptophan	−0.049	Tryptophan	−0.061
Isoleucine	−0.223	Leucine	−0.344
Lysine	−0.272	Phenylalanine	−0.170
Valine	−0.240	Arginine	−0.128
Histidine	−0.032	Methionine	−0.086
Cystine	−0.031		

Micronutrient content
in whole cow's milk (3.3% fat content)

Vitamins		Minerals	
A (IU)	−1299.5	Calcium (mg)	−1277.3
B1 (mg)	−0.39	Chlorine (mg)	−1031.36
B2 (mg)	−1.76	Copper (mg)	−0.1
B3 (mg)	−0.87	Iodine (μg)	−237.21
B5 (mg)	−0.43	Iron (mg)	−0.52
B12 (mg)	−3.68	Magnesium (mg)	−138.2
Biotin (mg)	−19.6	Manganese (mg)	−0.04
C (mg)	−9.69	Molybdenum (μg)	−20.63
B (mg)	−41.25	Phosphorus (mg)	−963.28
E (mg)	−1.54	Potassium (mg)	−1567.66
Folate (mg)	−61.57	Selenium (mgg)	−15.47
K (mg)	−41.25	Sodium (mg)	−505.36
Pantothenate (mg)	−3.24	Zinc (mg)	−3.92



Protein

2.8%–3.8%
(casein, lactoalbumin and lactoglobulin)

Micronutrient content
in whole cow's milk (3.3% fat content)

A	β	D	E
much more in the summer 0.0025 mg%	Carotene 0.0015 mg%	Vitamin D 0.05 mg%	Vitamin E 1.5 mg%
B1	**B2**	**D**	**E**
Thiamine 0.04 mg%	Riboflavin 0.15 mg%	Niacin 0.10 mg%	Vitamin E 3.68 μg%

Carbohydrates

Lactose **4.9** mg%

Unfortunately, there are high losses of milk constituents during processing:

- not recycling secondary raw materials
- destruction and reduction of digestibility of milk components during production process operations
- equipment design imperfections contributing to high losses (milk components remain on the equipment)
- production of substandard or unsafe products

3. Development of enriched (functional) dairy products

According to the WHO FAO, about **50%** of non-contagious diseases are related to nutritional disorders: obesity, diabetes, hypovitaminosis, cardiovascular and cancer pathologies, etc.

The Federal State-Funded Educational Institution of higher education, the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy, by Order No. 616 of 11.11.2020, approved the establishment of a Scientific School "Ensuring the Quality and Safety of Agricultural Raw Materials and Food Products."

The key direction of the Scientific School is the development of functional foods.

The Head of the Scientific School is the Head of the Department of Quality Management and Commodity Science of Products of the Technological Institute, Doctor of Technical Sciences, Professor Nina Dunchenko.

What are healthy food products?

According to GOST R 52349-2005, "*an enriched food product is a functional food product produced by adding one or several physiologically functional food ingredients to traditional food products to prevent or correct a nutrient deficiency existing in the human body.*"

Functional food ingredients include:

- vitamins
- macronutrients and micronutrients
- live probiotic microorganisms
- ω-3 and ω-6 fatty acids
- antioxidants, etc.

The content of functional food ingredients should be no less than 15% of the daily norm of physiological needs of the organism.

Under the guidance of Professor N. Dunchenko, scientific research is carried out at the Department of Quality Management and Commodity Science of Products of the Russian State Agrarian University — Moscow Timiryazev Agricultural Academy

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within the framework of the implementation of the program for the creation and development of the World-class Scientific Center "Agrotechnologies of the Future" (Agreement on providing a grant in the form of subsidies from the federal budget for state support for the creation and development of world-class scientific centers performing research and development on priorities of scientific and technological development (internal number 00600/2020/80682) No. 075-15-2022-317 dated November 16, 2020) with the financial support of the Ministry of Science and Higher Education of the Russian Federation and with the support of educational institutions of higher education to form a group of leaders as part of the implementation of the strategic academic leadership program "Priority-2030" of the national priority "Science and Universities."

We hypothesized that cryopowders of vegetables, berries, and algae can be an innovative ingredient in the production of dairy products, providing the necessary high content of functional food ingredients.

Cryopowders can be made from virtually any agricultural raw material. Drying and cryogrinding at temperatures as low as negative 120–190 °C ensures the preservation of original organoleptic characteristics, high microbiological purity, fine dispersibility, and high content of native vitamins, micro- and macro-elements, and other beneficial substances.

Study of the composition of cryopowders

Content of vitamins and trace elements in cryopowders of berries as a source of enrichment of functional food products

FFI means Functional Food Ingredient

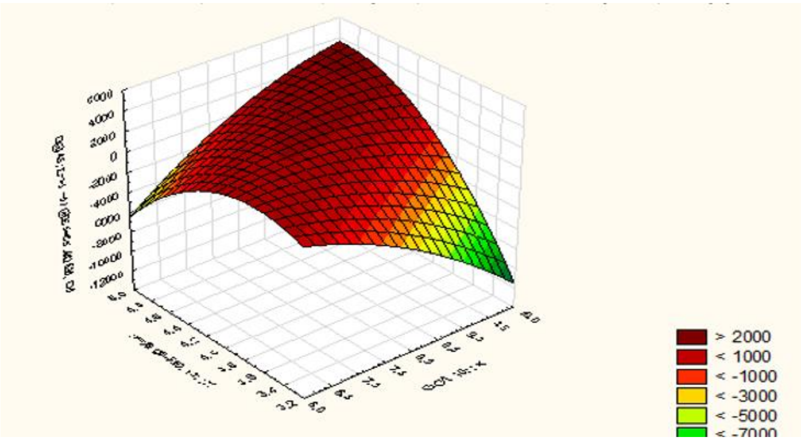
RDI means Reference Daily Intake

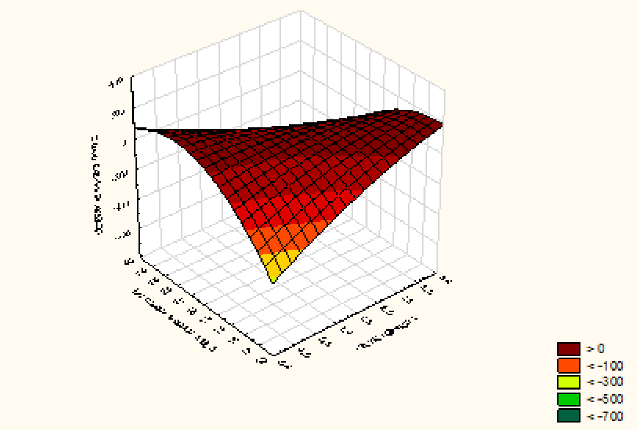
m means mass of FFI contained in 100 g of cryopowder, g
$m_{15\%\ RDI}$ means mass of cryopowder, which contains 15% of RDI, g

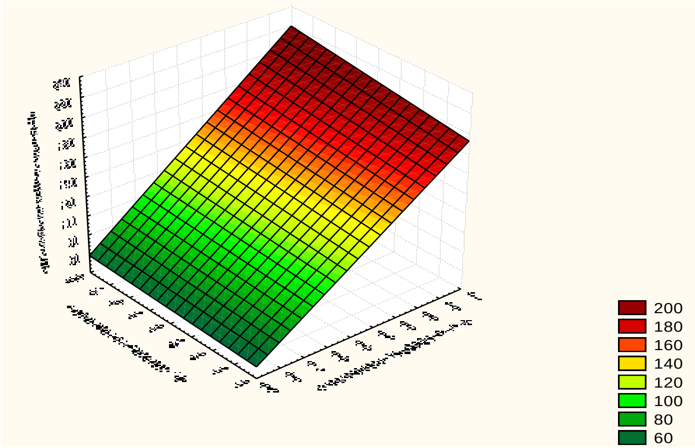
Name of cryopowder	Measured value	vit C, mg	carotenes, mcg	Si, mg	V, µg	Co, µg	Mn, mg	Mo, µg	Other FFIs (based on literature data)
	RDI	60	5000	30	15	10	2	70	
apricot	$m_{100\,g}$	71.81 ±0.39	10716.96 ±54.55	35.29 ±0.22	76.45 ±0.82	14.33 ±0.16	1.71 ±0.02	52.22 ±0.38	pectins
	$m_{15\%\ of\ RDI}$	12.53	**7.00**	12.75	**2.94**	10.46	17.58	20.11	
grapes	$m_{100\,g}$	30.21 ±0.23	128.13 ±0.63	163.20 ±1.21	15.65 ±0.08	8.55 ±0.69	9.16 ±0.07	6.54 ±0.07	antioxidants
	$m_{15\%\ of\ RDI}$	29.79	585.33	**2.76**	14.38	17.54	**3.28**	160.55	
strawberries	$m_{100\,g}$	462.28 ±9.23	196.65 ±1.01	783.10 ±5.42	0.16 ±0.01	30.2 ±0.25	1.63 ±0.03	76.3 ±0.81	ω-3, phiosterols, antioxidants
	$m_{15\%\ of\ RDI}$	**1.95**	381.39	**0.57**	1449.39	**4.96**	18.40	13.75	
sea buckthorn	$m_{100\,g}$	1195.10 ±21.08	10784.12 ±32.65	18.39 ±0.25	148.15 ±1.05	2.90 ±0.07	5.42 ±0.05	64.51 ±0.46	antioxidants, vit E, lycopene, ω-3, vit B12, Cr, phytosterols, pectin
	$m_{15\%\ of\ RDI}$	**0.75**	**6.95**	24.47	**1.52**	51.02	**5.54**	16.28	
red currants	$m_{100\,g}$	165.19 ±3.72	1365.97 ±6.83	418.56 ±3.63	0.13 ±0.01	26.68 ±0.18	1.14 ±0.02	150.96 ±1.08	antioxidants
	$m_{15\%\ of\ RDI}$	**5.45**	54.91	**1.08**	1770.72	**5.62**	26.23	**6.96**	
black currants	$m_{100\,g}$	1209.68 ±15.54	593.53 ±2.65	325.60 ±2.98	0.50 ±0.01	22.6 ±0.30	1.07 ±0.02	13.51 ±0.11	antioxidants, ω-3, phytosterols.
	$m_{15\%\ of\ RDI}$	**0.74**	126.36	**1.38**	442.27	**6.63**	27.93	77.72	
blueberries	$m_{100\,g}$	121.11 ±2.23	243.00 ±1.21	152.77 ±1.17	119.10 ±0.82	5.61 ±0.09	2.88 ±0.04	15.50 ±0.09	antioxidants
	$m_{15\%\ of\ RDI}$	7.43	308.64	**2.95**	**1.89**	26.73	10.43	67.74	
black rowan	$m_{100\,g}$	83.11 ±0.32	6491.69 ±3.24	48.59 ±0.35	46.28 ±0.22	66.39 ±0.84	2.46 ±0.03	41.90 ±0.36	antioxidants, Se, vit K
	$m_{15\%\ of\ RDI}$	10.83	11.55	9.26	**4.86**	**2.26**	12.20	25.06	

A range of functional structured dairy products with cryopowders has been developed based on mathematical modeling and experimental studies:

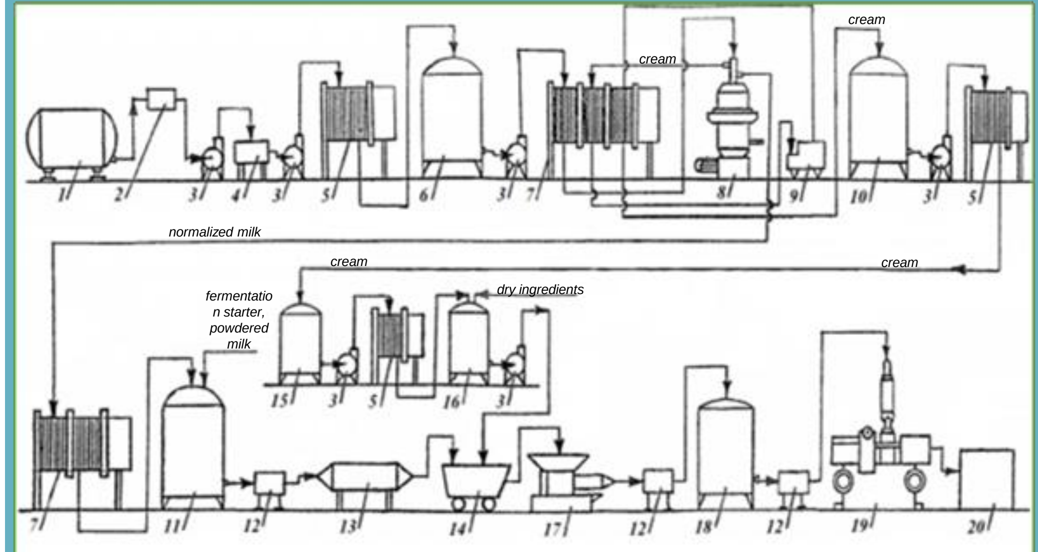
- yogurt
- yogurt product
- cottage cheese
- cottage cheese product
- cottage cheese
- sour cream product







Innovative production technology and technical documentation to provide high quality and safety of new products



1 — raw milk tank; 2 — flow filter; 3 — pump; 4 — balancing tank; 5 — plate pasteurization/cooling unit; 6 — raw milk intermediate storage tank; 7 — plate pasteurization/cooling unit; 8 — cream separator with normalizing device; 9 — homogenerator; 10 — cream intermediate storage tank; 11 — milk fermentation tank; 12 — pump for viscous products; 13 — tubular cooler; 14 — tank for compositions according to the recipe; 15 — skim milk intermediate storage tank; 16 — tank for mixing cream and dry components; 17 — mixer; 18 — product storage tank; 19 — automatic packing machine; 20 — finished product storage chamber

Production technology (example)

Patents for formulations and technologies of innovative functional products

Participation in competitions and exhibitions

4. Innovative approaches to the formation of dairy product quality (design of specified properties)

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The existing practice of food product quality formation implies:

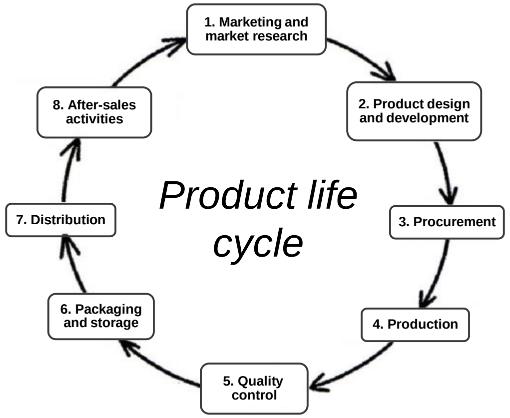
- either giving it certain functional properties
- or solving specific technical problems (e.g., achieving the viscosity required for more efficient operation of equipment, or enabling the use of variable raw materials)
- or realizing consumer or customer requirements in the product
- or something else

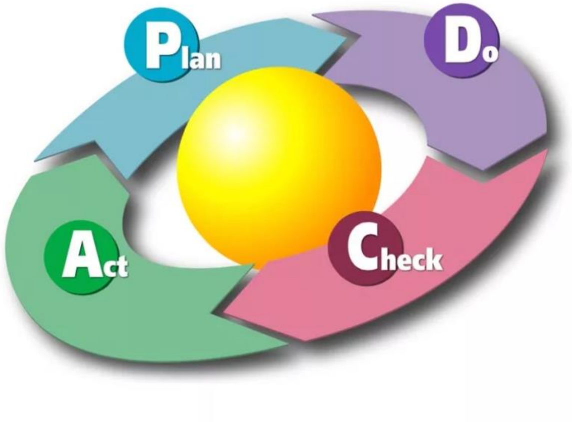
This approach does not consider that production faces a complex set of tasks and their solution should be systemic and comprehensive.

The development of competitive products with specified characteristics requires the creation of a scientific and methodological basis for predicting and ensuring the required product properties, including:

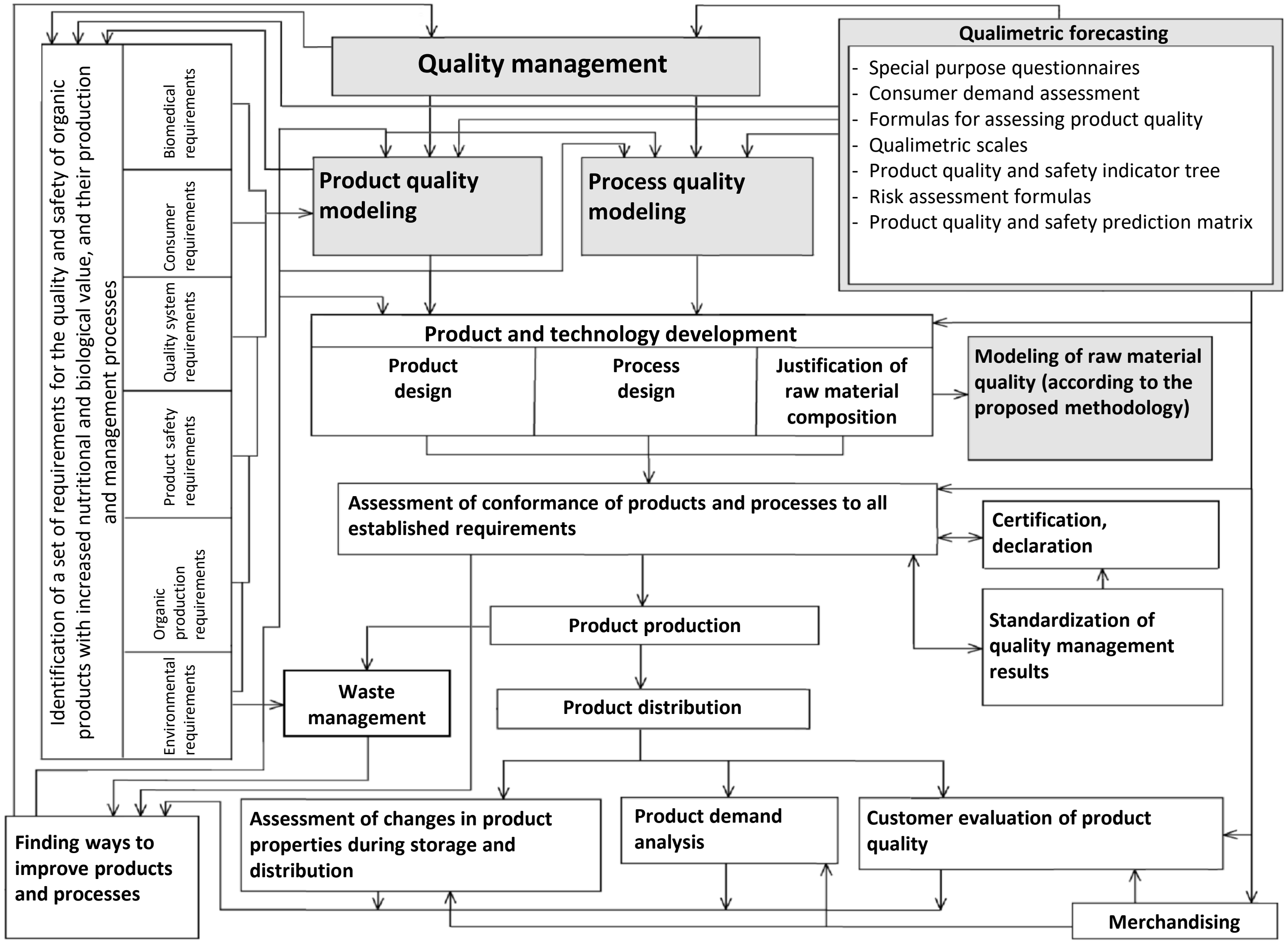
- established and anticipated requirements for products and production processes
- ensuring high consumer properties of products
- studying the regularities of transformation of raw material properties into quality indicators of finished products
- using state-of-the-art methodological approaches to form the quality and safety of products
- reducing the risks of producing low-quality and unsafe products

As part of the work of the world-class scientific center "Agrotechnologies of the Future," we at the Department of Quality Management and Commodity Science of Products developed a new scientific concept of forming product quality indicators based on the synergy of qualimetric forecasting and the PDCA cycle (implemented in the development of functional foods, particularly structured dairy products).





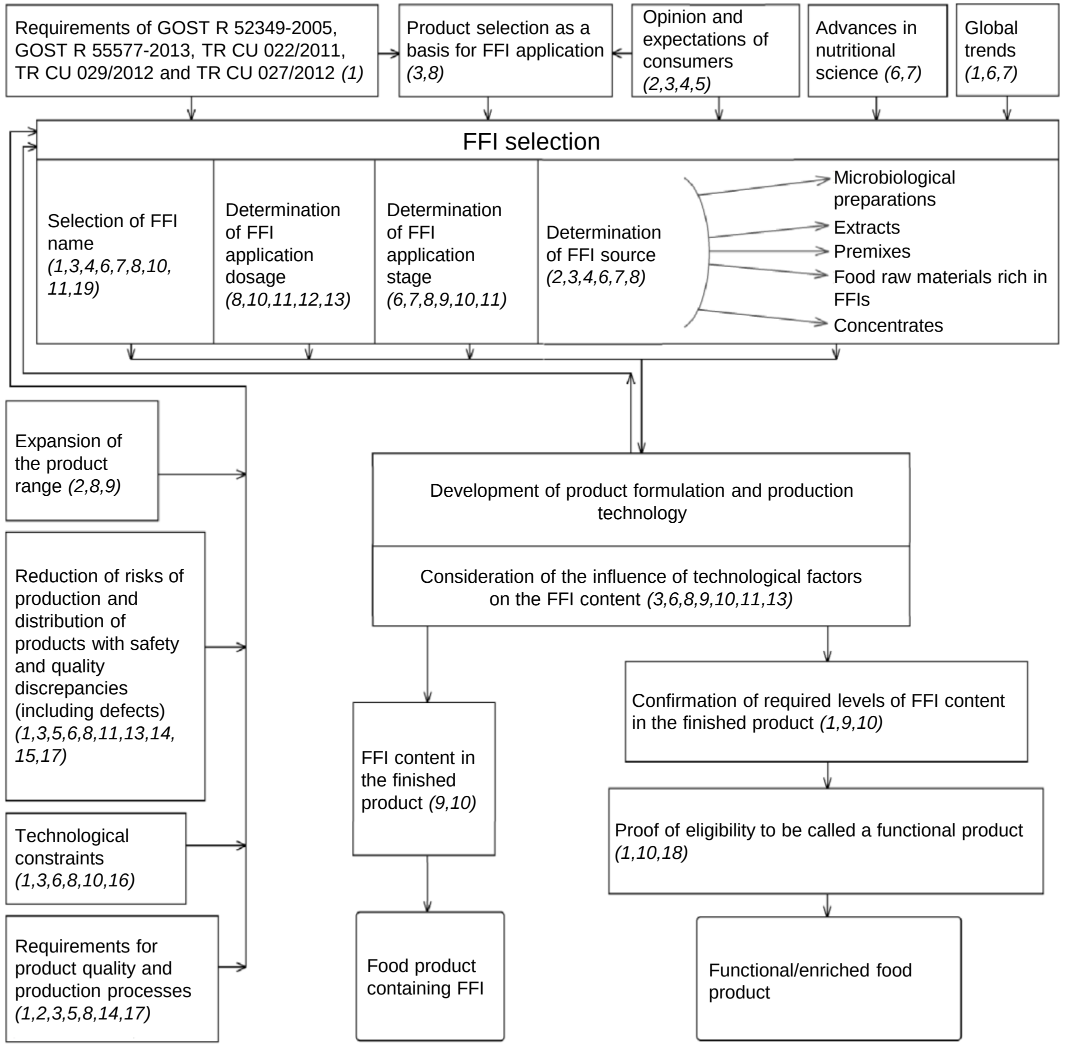
Innovative approach to forming the quality of functional food products



Algorithm of selection of functional food ingredients in food production

Legend:

1 — Analyzing regulatory documentation
2 — Sociological research
3 — Qualimetric forecasting
4 — QFD methodology
5 — ISO 9000 requirements
6 — Analyzing scientific and technical literature
7 — Analyzing patent literature
8 — Expert qualimetry (intellectual and sensory methods, formation of expert groups, data processing)
9 — Computational methods
10 — Experimental studies
11 — Information matrix model
12 — Recipe modeling
13 — Risk qualimetry
14 — HACCP principles
15 — Traceability
16 — Process modeling
17 — Collecting and analyzing data on discrepancies (Pareto diagrams, Ishikawa diagrams, checklists)
18 — Data validation by accredited organizations



The proposed innovative approaches were used to develop technologies of functional dairy products and showed their efficiency. Implementation of such approaches of product quality formation can be considered as a competitive advantage in the production of products.

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Thank you!