Hybrid expert system to model the ice cream recipes

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Abstract

Introduction. The method of ice cream recipe modeling is developed, which, unlike traditional ones, is based on the application of processing expert data and optimization methods. It allows to significantly expand the range of tasks. These tasks solutions can bring significant economic effect.

Materials and methods. To create a database and knowledge base, a relational database under the control of Firebird DBMS was used. IBExpert software tool was used to ease the database structure development. While creating a user interface, the integrated Microsoft Visual Studio software development environment is used.

Results and discussion. The hybrid expert system for modeling ice cream recipes is intended to improve the existing ones or develop new types of ice cream in a wide range of changes in the chemical composition by applying fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the chemical composition of the ice cream recipes of guaranteed quality taking into account the available raw materials. The knowledge base formed in the expert system will improve the nutritional structure of the population due to the exclusion of chemically modified and synthesized food additives from the recipe ice cream composition and their replacement on natural, biologically complete ingredients of domestic production.

Conclusions. Using an expert system in the production environment will allow you to constantly update and accumulate knowledge of expert technicians who work in this field. The constant accumulation of new knowledge about the ice cream recipe will enable the creation and expansion of partnership programs with domestic and foreign enterprises. Using this expert system will reduce the cost of modeling new ice cream recipes.

Introduction

Providing the rhythmic production and sales of the final products, maximizing profits from their activities are the main priorities of any manufacturing.

There are some problems with the formation of complex disperse ice cream systems and frozen desserts in the low-temperature technologies of the food industry. Such food systems, in terms of colloidal chemistry, are at the same time foams, emulsions and suspensions. The continuous dispersion medium is not frozen water, which contains numerous dispersed particles of different nature – fat balls, air bubbles, ice crystals and lactose. Consistency defects are most often caused by large ice crystals that are capable of growing and forming a solid ice frame. A similar consistency defect is the reason of the formation of a too rigid product structure with tangible ice crystals during its consumption. Therefore, the first priority for the technologists is the practical solution to the mentioned problem by optimizing the recipe composition.

The product demand depends on both the price and quality, which are laid at the stage of its production. Therefore, the product profitability largely depends on its composition, namely, the cost, quantity and quality index of the individual recipe components. In today's market conditions, food industry companies in order to reduce the price try to use alternative, cheaper components instead of those that are listed in the classic recipe. The reason is that some components have a high price because they are imported from other countries or their manufacturing or cultivation require certain expenses. However, new ingredients in food systems can show unpredictable antagonistic effects and give the effect opposite to the anticipated one. Though, the synergistic manifestation of component interaction, which gives a high technological effect on the economic feasibility of such innovation, is possible [1–3].

It's easy to make a recipe if you have the whole range of high quality raw materials and relatively low cost. But this is an exception rather than a rule. If the raw material is limited in quantity and not all of it is high-quality, then there is a need to replace one raw material to another. Sometimes it is very difficult for a technologist to ensure a stable quality of products, especially if there is little time to find the recipes for the selected product. In fact, the technologist's task is to create the recipe in such a way that the final product must have a minimum cost, but at the same time, meet all the requirements of consumer quality. Such tasks require, on the one hand, a great experience, but, on the other hand, a whole range of practical skills and information about the component behavior. The only way out of this situation is to use the modern information technology to improve the efficiency of the technological process management in the conditions of actually operating enterprises[4].

Related works

In the modern world literature, many domestic and foreign scientists are concerned with the use of information technologies and system analysis methods by controlling the technological processes of the food industry. The problem of supporting technological processes through the use of information technology is very widely investigated, but taking into account the complexity of the problem, most contemporary authors tend to use expert systems.

The literature provides a separate niche of expert systems, but based on the analysis, authors can argue that there are no expert systems in the world to support the modeling of ice cream recipes under the conditions of actually operating enterprises. For example, there is an expert system for the meat industry "FORECASTER", designed to predict new food

technologies and includes a set of functionally-oriented tasks, combined into the following structural elements: a database management group and knowledge base; information analysis group; logical and statistical flow processing group. The study of literary sources led to the construction of a hybrid expert system to support the design of ice cream recipes [5].

Materials and methods

The object of study is information technology for supporting the process of modeling food products recipe.

The subject of study is the expert system for supporting the process of modeling ice cream recipe.

To achieve the aim, Methods of system analysis, studying and modeling complex control system, operation analysis, mathematical programming, information modeling of systems, building expert systems and knowledge bases were used in the paper.

Firebird fully supports SQL-92 Entry Level 1 and implements most of the SQL-99 standard with some very useful additions. It includes the DML / DDL expression, the syntax of FULL / LEFT / RIGHT [OUTER] JOIN, UNION expression, DISTINCT, subqueries (IN, EXISTS), built-in functions (AVG, SUM, MIN, MAX, COALESCE, CASE), integrity constraints (PRIMARY KEY, UNIQUE, FOREIGN KEY), and all common types of SQL data.

Firebird also implements check constraints at the level of domains and fields, views, exceptions, roles and right of access management.

Firebird supports many ways to the server access, namely own component kits for C / C ++, Delphi, classes for ADO, ODBC, JDBC (Jaybird), drivers for Python, PHP, OLE DB driver, dbExpress, .NET data provider and direct access to use the client server library (fbclient.dll or GDS32.dll)

IBExpert software version 2017.11.5.1 was used to ease the development of the database structure[6]. IBExpert is a GUI shell intended for the development and administration of InterBase and Firebird databases, as well as for the selection and modification of data stored in databases. IBExpert supports versions Firebird 1.x, 2.x, 3.x, runs simultaneously with multiple databases and has:

- separate editors for all database objects with syntax highlighting;
- powerful SQL editor with the request history and the possibility of their background execution;
- automatic completion of the SQL code (table names, fields, etc.);
- debugger of stored procedures and triggers;
- metadata search;
- complete and partial extraction of data and metadata;
- analyzer of database object dependencies;
- metadata reports;
- user managers and user privileges;
- export data to various formats.

IBExpert has many easy-to-use components: a visual editor for all database objects, a SQL editor and script executor, a debugger for stored procedures and triggers, an area builder, a tool for importing data from a variety of sources, your own scripting language, database designer etc. IBExpert is free for Windows users with WIN1251 code page setup.

To create the user interface, the free integrated software development environment for the Microsoft Visual Studio 2015 Community using the Windows Forms technology

[5,7,10,11,20] is used. The work of Windows Forms applications for the Firebird DBMS is provided by the NuGet package manager. It implements the package connection: FirebirdSql.Data.FirebirdClient, Entity Framework, Entity Framework. Firebird.

Results and discussions

The hybrid expert system to model the ice cream recipes is designed to improve or develop new types of ice cream in a wide range of changes in the chemical composition and the application of fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the optimal chemical composition of the ice cream recipes of assured quality by taking into account the available raw materials. The knowledge base formed in the expert system will allow to improve the nutritional structure of the population due to the exclusion of chemically modified and synthesized food additives from the recipe composition of ice cream and their replacement on natural, biologically-complete ingredients of domestic production [4, 5].

While modeling the ice-cream composition, one should take into account the fact that for this product the concept of "quality" means a complex of special requirements for sensory and physical and chemical indexes. It is understandable that the sensory and physical and chemical quality indexes are interrelated. For example overrun, the degree of air phase dispersion and resistance to thawing, in the first place, form the sensory perception of the finished product consistency.

Among the abovementioned indicators, whipping is the most important quality indicator to ensure a creamy structure of the overrun and frozen product. The recommended level of ice cream overrun is between 60 and 160%. The ice cream overrun depends on the recipe content and equipment type. If the whipping is too high (above 160%), the ice cream structure is unstable, and the taste and smell become "null". When the overrun is less than 60%, the ice cream structure becomes rough, too dense, with a very strong taste and smell. If the overrun index is in the recommended range, the ice cream will have a creamy, stable structure with a taste and smell.

First of all, the ice-cream whipping is affected by proteins, structure stabilizers (hydrocolloids), emulsifiers that strengthen free water, reduce the surface tension, and stabilize the formed foam structure. That's why the presence of the above mentioned compounds in the ice-cream recipe composition is mandatory. Except the mentioned ingredients, the technological functions of the foam formers and structure stabilizers can be performed by the raw materials of plant and animal origin – grain products, pectin containing purees from fruits, berries and vegetables, etc. But for competent correction of ice cream recipes in the conditions of industrial production, it is necessary to develop a universal and user-friendly expert system that takes into account all production experience and recommendations of scientists concerning the composition of ice cream of various kinds [2, 3].

The hybrid expert system for modeling ice cream recipes is intended to improve the existing ones or develop new types of ice cream in a wide range of changes in the chemical composition by applying fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the chemical composition of the ice cream recipes of guaranteed quality taking into account the available raw materials. The knowledge base formed in the expert system will improve the nutritional structure of the population of Ukraine due to the exclusion of

chemically modified and synthesized food additives from the recipe ice cream composition and their replacement on natural, biologically complete ingredients of domestic production.

A hybrid expert system for modeling ice cream recipes should address the following main tasks:

- to develop recipes of new ice cream types with the given consumer characteristics and low cost;
- to substantiate the recommendations of the industry concerning the recipe ice cream composition and the possible replacement of certain ingredients without reducing the regulatory quality indicators of the finished product, in accordance with the current standards (SSU, TC, etc.) provided by the target functional and technological properties of certain components;
- to analyze a set of finished product quality indexes, to identify the technological problems and to suggest the ways to solve them [5,7].

The structure of the expert system for modeling the optimal ice cream recipes is presented in Figure 2.

To implement these tasks, application packages and knowledge manipulation tools were used. Therefore, the expert system of modeling ice cream recipes is hybrid.

The main function of the expert system is to support the implementation of the algorithm for designing the optimal ice cream recipes presented in Figure 1 [3–5].

The architecture of the hybrid expert system for the modeling of ice cream recipes consists of separate four structural blocks [5,7,8,9,13], which are designed and created separately, and then bundled into one whole interacting system through the interface: database, knowledge base, mathematical apparatus and expert system implementation of the functions of the recipe composition quality control and its technological suitability.

The database is required to provide the primary information about the recipe ingredients and their physical and chemical as well as functional and technological properties, auxiliary materials, quality indexes. It stores the recipe composition data meant for users, physical and chemical characteristics of the ingredients, the recipe status [6,16].

The knowledge base is sets of knowledge in the form of rules on the technological features of making ice cream [12, 17].

The mathematical apparatus modules are a set of applied mathematical packages to solve the optimization tasks. They are aimed at obtaining a certain universal recipe due to the possible interchangeability of certain technologically active components. It has a great practical significance in the production conditions [5, 7, 17].

The expert system provides the recipe correction by taking into account all the technological properties of multicomponent food systems. It uses the knowledge base. If to model the optimal recipe only with the help of one mathematical device, without the use of the expert system, then the received recipe is unlikely to be suitable because numerous technological properties will not be taken into account.

The EU Knowledge Base is created directly in the database in the form of individual entities. A set of these entities allows you to create research objects, rules which they meet and recommendations if the rules are met. Except the rules and facts that form the declarative part of the knowledge base, it also includes a procedural part with functions and procedures that implement optimization and calculation algorithms. The knowledge of the expert system is represented in a symbolic form (simple components of knowledge representation are texts, lists, and other symbolic structures). Thus, in the EU, the principle of the symbolic nature of estimation is realized which means that the estimation process is represented as a sequence of symbolic transformations.

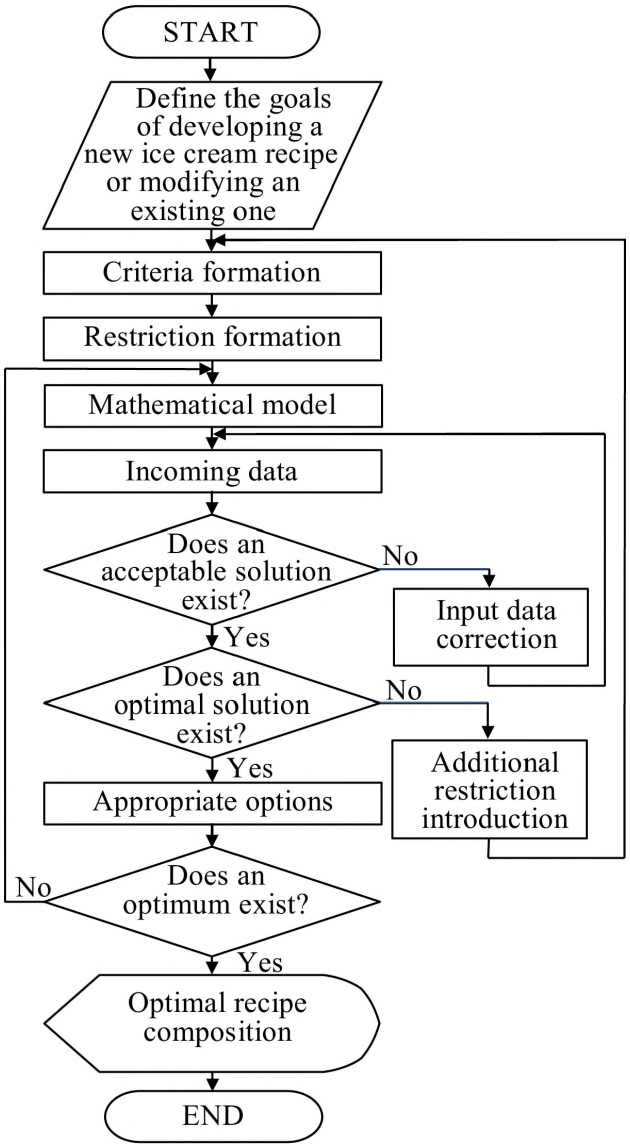

Figure 1. Algorithm for designing optimal ice cream recipes

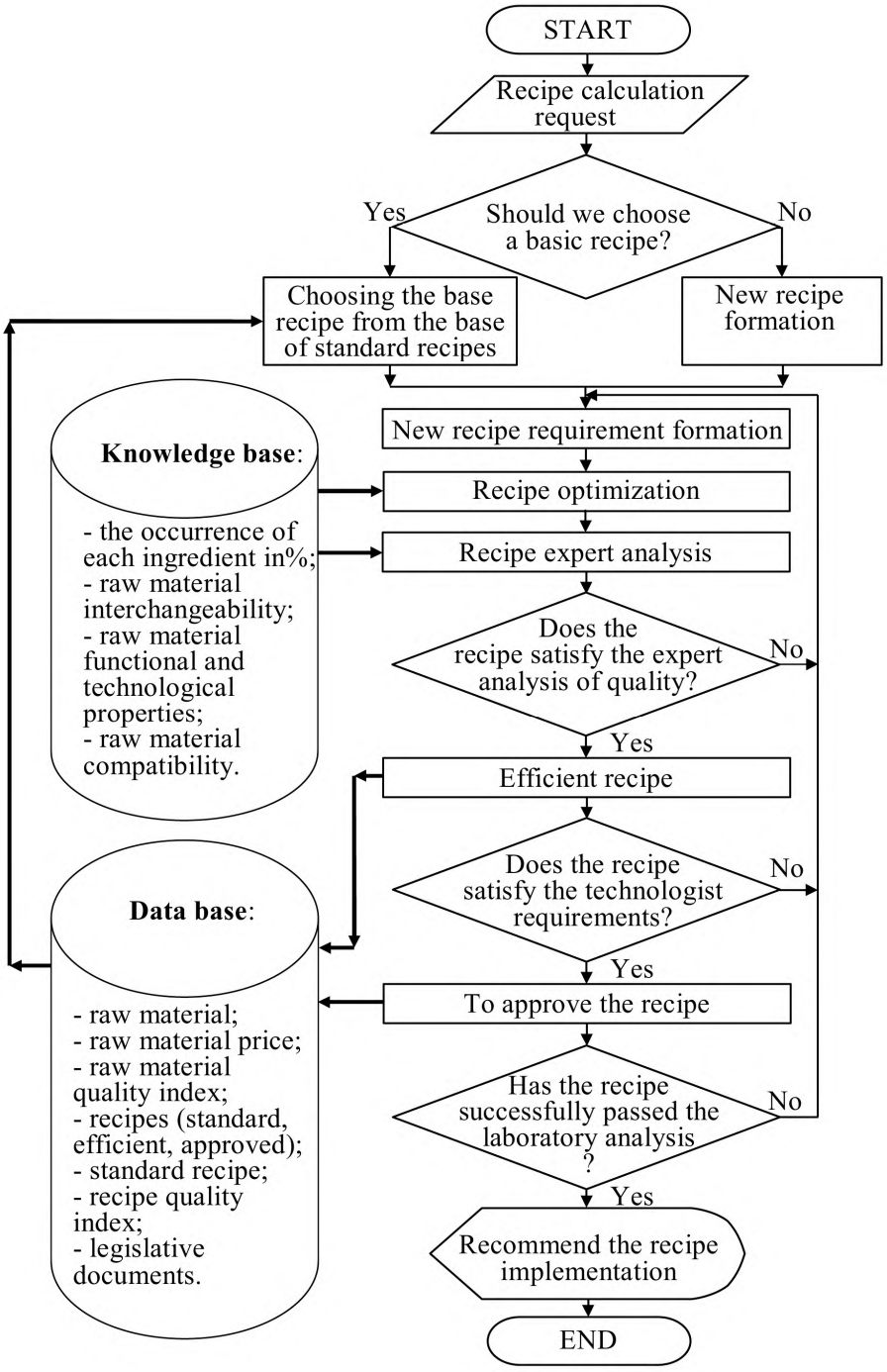

Figure 2. Structure of the expert system for optimal recipe modeling

The purpose of every essence of the knowledge base:

1. "Research objects" covers a list of objects to be analyzed in order to detect the technological deviations in the recipe.
2. "Rules" means a list of all rules which the research object can meet under those or other events. Actions included in the rules may contain new facts. When applying such rules, these facts become known to the system which means that they are included in the set of facts called the working set.
3. "Rules of the research object" are the rules relevant to the specific research object.
4. "Recommendations" is a problem description and recommendations for its solution.
5. "Recommendations of the research object" is a list of recommendations of the research object.

The knowledge base of the hybrid expert system is static. In other words, it does not change with time and the facts stored in the knowledge base are static which means that they do not change in the process of solving the problem [5, 7, 12–19].

To create a databank, a relational database under the control of Firebird 2.5 was used. [6, 18]

The benefits of Firebird are that it has a multiversion architecture. It provides parallel processing of operational and analytical queries, compactness (5Mb distribution), high efficiency and powerful language support to store procedures and triggers. Firebird is completely free; it does not require any registration or payment for support. The source code of this system is open, which allows you to develop your own nonprofit projects using its base if you follow the IDPL license requirements covered by Firebird.

Also, Firebird is a database server. One Firebird server can process several hundred independent databases with a plurality of user connections. It is completely free of license deductions even for commercial use.

Table 1 presents an experimental confirmation of the efficiency of the expert system usage taking into account the calculation of a new ice cream recipe named "Milk Ice Cream with Wheat Germs". It was based on the standard milk ice cream recipe in accordance with the standard technological instruction for the ice-cream. The expert system calculated a new optimal recipe, taking into account the partial replacement of the stabilizer Cremodan SE 406 (the manufacturer is the company "Danisco", Denmark) by the natural structuring complex named wheat germ. As a result, this new recipe satisfies the quality requirements of the finished product. The cost of 1000 kg milk ice cream with wheat germs according to a new recipe made up 642,82 USD, which is 8.64% cheaper than the base one.

Table 1

The calculation of a new ice cream recipe with a partial replacement of the stabilizer

Recipe composition	Quantity 1000 kg		At 100, %		Min,%substitutes	Max,% substitutes	Price, 1 kg/$USD	Cost 1000 kg/USD
	Base	New	Base	New				
Drinking water	650,00	650,00	65,00	65,00			0,04	26,00
Milk solids non fat (MSNF)	101,00	101,00	10,10	10,10	10,10	12,00	2,39	241,39
Cream from the whole cow milk	88,00	88,00	8,80	8,80	8,80	9,00	3,11	273,86
White crystalline sugar	155,00	155,00	15,50	15,50			0,50	77,50
Cremodan SE 406	6,00	substituted	0,60	Substituted	20,00	100,00	14,16	84,87
Total (5 ingredients):	1000,00	1000,00	100,00	100,00				703,62
Recipe name	Cost 1000 kg/USD							
Base	642,82							
New	703,62							
Difference	-60,80							
At 100 %	8,64							

Calculated quality index			
Quality index	Measurement unit	Value	Description
Disperse phase content	%	76,5	The structure is moderately dense. Creamy. Durable.
Structural element dimensions of disperse systems	mkm	37,9	The air bubble size is sufficient
Structural element stability of disperse systems	second, sec	2,82	Pretty high resistance to thawing
Cryoscopic temperature	degree, C°	-2,35	Within limits
Sensory evaluation	score	9	Rather marked smell and taste

Conclusions

Expert systems are the most effective tool for calculating ice cream recipes of different groups, as well as for selecting the optimal technological regimes for its production.

An expert system developed by the authors allows purposeful management of the quality of the finished product during the technological process of its production. The greatest significance of the development lies in the possibility of replacing traditional recipe components with fundamentally new natural raw materials. The feasibility of introducing the elaborated expert system is confirmed by the possibility to prevent the most widespread ice-cream consistency and taste problems.

The use of an expert system in production conditions enables the integration of knowledge of expert technicians working in this field and the creation of appropriate partner systems.

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