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HYDRODYNAMIC MIXING AND HOMOGENIZATION TECHNOLOGY. (New hydrodynamic technology for mixing liquid food components with simultaneous whipping in a dynamic, periodically repeating kinetic mode)

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Abstract

The article discusses a new hydrodynamic technology for mixing and homogenizing liquid food components with simultaneous whipping in a dynamic, periodically repeating kinetic mode. Particular attention is given to the development of innovative food technologies intended for smart production environments and modern food processing systems.

Special emphasis is placed on equipment operating on the principle of hydrodynamic kinetic pulsations within a closed system. The proposed technology enables the formation of stable and homogeneous mixtures from components that are difficult to combine under conventional conditions without thermal treatment or additional processing methods.

The article describes the technological features of the proposed apparatus and its application in processing milk and milk-based matrices combined with plant and animal additives. It is concluded that the proposed technology can improve product quality, stability, and production efficiency while expanding possibilities for the development of innovative food products.

Keywords: *Mixing; Homogenization; Smart Food Technologies; Dynamic Mode; Direct Milk Processing; Wide Performance Range Independent of Energy Consumption; Hydrodynamic Pulsations*

Introduction

Food products, as well as pharmaceutical products and, to some extent, cosmetic products, represent a highly quality-controlled sector within the innovative activities of inventors.

First of all, this field is characterized by the necessity for new innovative products and technologies to fully comply with health-care standards and existing environmental regulations.

It should be acknowledged that this technological field is strongly influenced by traditions, as well as climatic and cultural characteristics specific to the region in which an innovative product is introduced to consumers.

However, it is also important to recognize that the most successful local innovative

solutions and inventions, which have applications not only in the food industry but also in broader technological fields, can serve as effective driving forces in the progressive development of integrated innovative technologies.

One such technology is proposed for the readers' consideration below.

New technology for hydrodynamic mixing of various liquid components with simultaneous whipping in a dynamic, periodically repeating, advanced kinetic mode with regeneration of accumulated kinetic energy and its sequential transfer into the process.

The proposed innovative technology represents a process of dynamic influence on liquid or partially consistent components that are subjected to mixing and whipping.

The most extensively studied components, frequently applied in different variations of this process, are components derived from various dairy products. Researchers, considering current technological trends and focusing on the development of smart food technologies for application in startup environments and intelligent production facilities, are conducting studies and developing specialized technological equipment. The purpose of these studies, experimental design activities, engineering developments, and the creation of dietary algorithms and programs is to identify new approaches for producing composite, compounded, or uniformly combined food products with reduced or minimal fat content and increased concentrations of vitamins and biologically active elements.

An additional objective of the proposed process is to obtain mixtures or whipped mixtures of components, mainly dairy or fermented dairy products, without thermal treatment or other forms of product processing. Such mixtures may involve components that under conventional conditions either do not mix, mix poorly, or do not remain stable.

To enable the practical application of the proposed technology under modern production conditions and according to contemporary consumption standards and regulations, another objective of the developers is to obtain stable and homogeneous mixtures using only basic food ingredients that maintain their properties and uniformity over extended periods of time.

The final products of the proposed technology include:

- butter whipped from sour cream with an unusually low fat content of no more than 13%;
- butter whipped from sour cream with multivitamin additives, including a mixture of sour cream and carrot juice;
- butter whipped from sour cream with tomato juice;
- butter whipped from sour cream with various fruit syrups;
- butter whipped from sour cream with honey;
- butter whipped from sour cream with garlic and dill;
- butter whipped from sour cream modified with egg oil;
- butter whipped from sour cream modified with alpha-lecithin;
- butter whipped from sour cream modified with albumin;
- butter whipped from sour cream modified with lysozyme;
- butter whipped from sour cream modified with cocoa butter;
- butter whipped from sour cream modified with avocado paste;
- butter whipped from sour cream modified with vegetable pastes;
- butter whipped from sour cream modified with fruit pastes.

Direct milk processing and its modification through mixing with other components make it possible to create new modified combined dairy composites with novel and unusual properties and exceptionally high consumer quality.

One of the primary examples is a whipped mixture of milk and honey. For this mixture, low-fat milk containing 1% fat and cooled to a temperature of 2–3 °C is used together with natural bee honey in a proportion of 75% milk and 25% honey. The resulting mixture is stable, homogeneous, possesses a delicate and pleasant taste, and has beneficial nutritional properties.

Due to the broad capabilities of the hydrodynamic mixing and whipping apparatus, mixtures can be prepared using numerous variations and combinations of materials, liquids, consistent pastes, and syrups.

The device implementing the proposed technology may be designed for a wide range of production capacities. One version, with a productivity of approximately 1 liter or 850 grams of butter per whipping cycle, may serve as equipment for farmers and can be used for processing excess milk.

The apparatus is based on an invention utilizing the principle of generating hydrodynamic kinetic linear reciprocating pulsations within a closed volume containing mixed and whipped components. The generated movements are sufficiently effective to achieve mixing and whipping within a relatively short period of time while producing an exceptionally homogeneous structure of the resulting mixture or butter.

The device may be designed as a mass-market product with a relatively small capacity for mixed and whipped components of approximately 1 liter. It may be equipped with an electric drive or may also be manually operated, which can significantly reduce production costs and increase sales potential.

The device may also be designed as supplementary equipment for cafés and restaurants. In such cases, its capacity may reach 2 liters and the equipment package may include several interchangeable containers to improve operational efficiency and versatility.

The device may additionally be designed as specialized technological equipment for industrial enterprises involved in dairy processing and used for producing small-scale batches of dairy food composites.

The device may also be implemented as automated technological equipment for large-scale and mass production of modified dairy products.

The principal differences between the proposed butter-whipping process and existing processes of the same purpose are as follows:

- whipping is performed in a flask with a cylindrical shape, closed at both ends by hemispherical covers containing axial conical openings;
- the whipping process with a similar efficiency level may also be performed in vessels equivalent to the described flask design;
- the entire structure, consisting of a cylindrical shell with conical recesses at its ends and two hemispherical covers with conical chamfers at their bases and corresponding axial conical openings, is assembled and sealed through fixing, orienting, sealing, and clamping devices mounted in threaded openings of the mixer frame. These devices include axial openings with closure mechanisms and conical tips aligned with the same axis and inserted into the conical openings of the covers during assembly;
- due to these structural features, the whipping process provides not only significant design distinctions but also substantial advantages in product quality and in the technological capabilities of the butter-whipping process.

Additional capabilities of the proposed process include:

- the volume in which the whipping process occurs is detachable and reconfigurable;
- during the whipping process, controlled access to the internal volume is possible for introducing components into the mixture, removing waste materials, or extracting specific components from the working volume;
- the conical openings of the hemispherical covers contribute to more effective fragmentation of the mixture during impact with the inner hemispherical surfaces. They simultaneously perform activating, orienting, sealing, fixing, and technological gateway functions for both input and output operations depending on the flask position;
- the design allows multiple flask sets to be used with a single device, enabling changes in whipping component composition, dairy matrix characteristics, fat content, and other parameters during relatively short processing cycles;
- the hydrodynamic parameters of the whipping process, combined with the geometry of the flask elements and the presence of a spherical recess with an activating cone at the end of each linear movement, significantly improve process efficiency. This occurs because the moving mass transforms from

a cylindrical to a spherical shape within a very short time during each impact event;
- the described method of impact on the processed mass, resulting from the kinetic diversity of forced volume and shape changes under the influence of multiple forces generated by vessel geometry and apparatus kinematics, enables the production of a homogeneous composite product that differs substantially from products obtained using conventional methods.

From the presented models of the hemispherical covers, it can be observed that:
- their design is technologically efficient;
- they possess high mechanical strength;
- they are convenient for maintenance;
- they satisfy hygienic requirements;
- they can be manufactured from a wide range of materials;
- different variants of covers, differing in sphere curvature and axial conical opening depth, can be used with the same cylindrical shell design while maintaining identical connecting elements.

The distinctive design features of the apparatus also indicate that the frame may be produced in various configurations. In one possible implementation, the frame may take the form of a flat ring with threaded openings arranged along one geometric coordinate extending from the periphery toward the center. When at least two fixing openings are provided on the disk surface for attachment within the spindle support units, and when more than two openings are available, the flask may be positioned at different angles relative to the frame rotation axis by selecting different fixing points within the spindle supports.

The method further specifies that loading raw materials into the internal volume of the flask and removing liquid waste products are performed while the flask remains assembled through axial openings within the fixing devices equipped with threaded plugs for sealing these openings. During material introduction, aerodynamic or other activating and stimulating devices may be inserted if necessary and later removed after completing their functions. The openings are then sealed and frame rotation begins.

The method also specifies that additional raw materials may be introduced during the butter-whipping process by temporarily stopping frame rotation.

Furthermore, if required, waste materials and components that have completed their function may be removed from the internal flask volume by interrupting the rotation process and temporarily stopping the frame with the flask.

Thus, in addition to the explicitly stated characteristics, the general distinguishing features of the process also include the following additional capabilities:
- the possibility of positioning the flask at any angle relative to the spindle axis, with the angle being adjustable depending on viscosity, consistency, composition, temperature, density, acidity level, quantity, volatility, specific weight, and mass proportions of the raw material components;
- the possibility of introducing and removing components during the whipping process;
- the possibility of accessing the internal volume during the whipping process;
- the possibility of modifying or supplementing ingredient composition during the whipping process, including the introduction of flavor additives, stimulants, emulsifiers, and similar substances at any stage of processing;
- the possibility of introducing substances responsible for forming the aromatic profile of the finished product at any stage of the whipping process, including pheromones or other aroma- and fragrance-forming ingredients and compounds;
- the possibility of introducing various flavor-forming ingredients, including synthetic additives, capable of creating taste sensations that differ from those naturally associated with the original materials introduced into the process.

As a result of the expansion of structural and technological relationships between the principal characteristics of the proposed invention process, additional features for the apparatus are also derived.

The device may be designed as a mass-market product with a relatively

small capacity for mixed and whipped components of approximately 1 liter. It may be equipped with an electric drive or may also be manually operated, which can significantly reduce its cost and increase sales potential.

The device may also be designed as supplementary equipment for cafés and restaurants. In this case, its capacity may reach 2 liters, and the equipment package may include several interchangeable containers to improve operational efficiency and versatility.

The device may also be designed as specialized technological equipment for industrial enterprises involved in dairy processing and used for producing small-scale batches of dairy food composites in production environments corresponding to the category of smart manufacturing facilities.

The device may additionally be implemented as automated technological equipment for large-scale and mass production of modified dairy products.

The specified equipment may be used to produce a food composite based on a naturally fermented dairy-fat matrix obtained by adding a fermenting agent, such as kefir, to cream derived from whole milk.

Various additives may be introduced into the matrix, including nut paste, garlic sauce, and similar ingredients that do not alter the color of the resulting composite product.

Of particular importance is the capability of homogenizing the composite simultaneously with the mechanical-hydraulic whipping process. This makes it possible to incorporate components obtained from deep waste-free processing of chicken eggs.

These components may include highly purified fine-dispersed albumin powder, liquid highly purified alpha-lecithin, gel-like multivitamin carotenoid mixtures, or liquid highly purified lysozyme, a natural preservative capable of providing unique long-term storage properties to the product.

Product tasting demonstrated exceptionally high sensory and taste characteristics across different combinations of ingredients.

Process and apparatus for whipping composite animal butter from multicomponent raw materials containing plant- and animal-derived components incorporated into a fermented dairy matrix in various proportions.

What has been invented:

1. Process of whipping animal butter primarily from multicomponent raw materials based on a fermented dairy matrix with any fat content, including reduced fat content.

Including:

- formation of the initial material within the internal volume of the mixer flask through the sequential introduction of a fermented dairy matrix and additives of plant and animal origin;
- installation of the mixer flask into the mixer carrier frame and sealing of its internal volume by axial fixation of hemispherical covers;
- mounting of the mixer carrier frame within the drive bracket of the mixer while maintaining a defined angle between the axis of the mixer flask and the axis of rotation of the drive bracket spindles, with this angle remaining constant throughout the entire whipping process;
- reciprocating movement of the initial material along the axis of the mixer flask, bringing the material mass into impact contact with the inner surface of the hemispherical covers at every half rotation of the drive bracket spindles;
- initiation of changes in the movement direction of the initial material at every half rotation of the drive bracket spindles;
- accumulation of kinetic energy of the moving mass of the initial material during each change in movement direction;
- discharge of technological waste generated during the whipping process;
- depressurization of the mixer flask and its removal from the mixer carrier frame;
- separation of the cylindrical shell of the mixer flask from the hemispherical covers and removal of the whipped product from the cylindrical shell of the mixer flask.

2. Apparatus for whipping animal butter from multicomponent raw materials based

on a fermented dairy matrix and additives of plant and animal origin.

Consisting of permanent and interchangeable elements, wherein the permanent elements include spindles positioned within a drive bracket for rotating the interchangeable elements, sharing a common axis of rotation and carrying a mixer carrier frame, predominantly square in shape, with fixation and sealing units for the mixer flask shell and hemispherical covers arranged along its diagonals. The ends of the mixer flask shell include conical recesses into which conical projections of the hemispherical covers are inserted. The hemispherical covers contain conical openings at the top of the hemisphere into which fixing and sealing elements are inserted, at least one of which includes a ball valve connected, in the fixed position of the element, to the internal volume of the mixer flask.

3. Apparatus for whipping animal butter from multicomponent raw materials based on a low-fat fermented dairy matrix and modifying additives of plant and animal origin.

Including permanent and interchangeable elements kinetically connected through rotation mechanisms and mechanisms for generating reciprocating movement of the whipped masses of the specified multicomponent raw materials, wherein the installation axes of the permanent and interchangeable elements are positioned at an angle relative to each other, and the axis of rotation of the spindles included in the kinematic chain of the permanent elements is arranged horizontally.

4. Apparatus for whipping animal butter containing modifying additives of plant and animal origin from multicomponent raw materials based on a fermented dairy matrix with various fat-content parameters.

Consisting of an assembled and disassembled mixer flask having at least two fixation, sealing, and orientation centers relative to the mixer carrier frame, wherein one of these centers includes a device for the discharge of whipping waste products, and their axes are aligned with the axis of the specified flask. The flask is incorporated into an autonomous kinematic chain that generates reciprocating movement of the initial material inside the mixer flask along its axis, positioned at an angle relative to the rotation axis of a second autonomous kinematic chain connecting the drive bracket with at least two spindles, one of which is the driving spindle and the second is the driven support spindle. In addition, the rotation axes of both spindles coincide and are arranged horizontally.

5. Process of whipping animal butter containing various additives of plant and animal origin introduced into the initial product prior to the whipping process.

The process generally involves additives of plant and animal origin introduced into the initial product, in most cases in liquid form, before the butter-whipping process begins. The initial product consists of a liquid fermented dairy matrix which, after the introduction of additives, forms a multicomponent mixture in which the additives are incorporated into the base fermented dairy matrix.

The process includes sequential impact contact of the specified mixture with hemispherical surfaces that define the internal cylindrical volume of the assembled and disassembled flask. The impact interaction is performed in direct kinematic dependence on the rotational speed of the spindles included in the kinematic chain of the permanent elements of the apparatus implementing the process. The direction of reciprocating movement and kinetic acceleration continuously tends to change the direction of the movement vector and kinetic acceleration to the opposite direction relative to the instantaneous rotational phase of the assembled and disassembled flask.

List of references, patent documentation, and licensing information

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