Analysis of the functions and connections of the mixer for the preparation of biologically active supplements

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Abstract. The technological advancement of preparation of biologically active supplements included in the diet of farm animals demands the search for new design schemes of mixers ensuring the implementation of the introduced, progressive technologies. The analysis of functions and connections is essential to determine the most rational design scheme of the mixer for the preparation of biologically active supplements. The most suitable means of achieving this goal is functional-morphological analysis. During the analysis, the mixer functions were determined and structured according to their relevance: the main and additional ones. The developed functional model of the mixer provides a visual representation of the hierarchy of functions and connections between them. The emerging need to study the elements of the mixer design and their connections are displayed in the developed morphological model of the mixer and the combined functional-morphological model. In the result, alternative structural elements of the mixer have been identified. Their combinations are presented in the morphological matrix of solutions. The technique used allowed us to determine a rational design scheme of the mixer, consisting of an electric drive with a paddle movable object, with the provision of heating of the chamber by U-shaped heating elements. This solution will enable the use of an automatic mixer control system and meet the guidelines of the technological process for the preparation of biologically active supplements.

1. Introduction

Today, biologically active supplements are an essential part of the diet of farm animals. They are indispensable for the health and productivity of all farm animals [13].

To prepare and mix biologically active supplements, various devices are used, such as grinders, granulators, mixers and extruders. In terms of application, the mixers are the most popular.

Analysis of existing devices for mixing and preparation of biologically active supplements has revealed their diversity in design features. A vibration mixer is one of these devices, which has a high uniformity of mixing. Nevertheless, it has disadvantages, such as frequent parts wear and a high noise level [3]. For many cases, existing mixers are expensive, or do not mix and prepare biologically active supplements (BAS) in a quality satisfying the consumer.

The quality improvement of mixing and preparation of BAS is feasible with the use of a mixer which simultaneously will satisfy veterinary and zootechnical requirements.
2. Materials and methods

We will use functional-morphological analysis [2,6,7,9,14] to develop such a mixer. The technique implies consideration of the mixer functions and the connection between the structural elements performing these functions. The composition of the functions is presented in the table 1.

| Model level | Index of function | Name of function                                           |
|-------------|-------------------|------------------------------------------------------------|
| I           | MF1               | Mixing ingredients                                         |
|             | MF 2              | Maintenance of the required temperature and pressure       |
|             | AF3               | Protection of the mixture ingredients from destruction     |
| II          | PF1.1             | Dosing of ingredients                                       |
|             | PF 1.2            | Load of ingredients                                         |
|             | PF 1.3            | Ensuring the velocity mode of the movable object            |
|             | PF 2.1            | Heating and maintaining the temperature of the chamber     |
|             | PF 2.2            | Creating and maintaining vacuum in the chamber              |
|             | PF 3.1            | Selection of material and settings of the chamber          |
| III         | F1.2.1            | Delivery of ingredients to the chamber                     |
|             | F1.2.2            | Adding additional ingredients of the mixture to the chamber |
|             | F1.3.1            | Adjustment and control of the rotation speed of the chamber |
|             | F1.3.2            | Adjustment and control of the inclination angle of the mixer's chamber |
|             | F2.1.1            | Preheating of the chamber                                  |
|             | F2.1.2            | Automatic temperature control                               |
|             | F2.1.3            | Maintaining the temperature mode in the technologically required range |
|             | F2.2.1            | Vacuum generation in the chamber                            |
|             | F2.2.2            | Maintaining the required vacuum value                       |

This method provides an option to identify the most significant challenges, the solution of which is aimed at improving technological performance: high homogeneity of the mixture and consistency of the granulometric composition [15].

Table 1 shows the functions divided into levels of relevance for the relation and the process of preparation of BAS.

To facilitate further research, the functions were visualized in a diagram (Figure 1).
The functions in the mixer model under study vary in levels of relevance. The first level of the model consists of two main functions for the mixer (MF) and one additional (AF): mixing ingredients to consistency and maintaining the required temperature and pressure. The additional function of protecting the mixture ingredients from destruction is not the main one. This problem occurs only when mixing ingredients that are susceptible to destruction. Their integrity is exposed to special requirements (the safety of vitamins and trace elements) [2].

The next (second) level of the functional model is the primary functions (PF), which describe a number of requirements for the operational process. At the second level of the model, we will identify the primary functions: PF1.3 - ensuring the velocity mode of the movable object; PF2.1 - heating and maintaining the temperature of the chamber; PF2.2 - creating and maintaining vacuum in the chamber. They are aimed at performing the main functions of the mixer MF1, MF2 and AF3 [1].

The third level of relevance contains the functions (F), which represent a detailed differentiation of the main ones (PF). The functional model of the mixer makes it possible to reveal the hierarchy of functions and contradictions between them. Table 1 indicates that the most relevant functions of the mixer: F1.3.1 - adjustment and control of the rotation speed of the chamber; F1.3.2 - adjustment and control of the inclination angle of the mixer's chamber. The type defines the quality of performance of the main function MF1.3, i.e. providing the velocity mode of the movable object.

Therefore, it is essential to justify the velocity parameters of the mixer to provide high-quality performance of the technological mixing operation as well as to meet veterinary and zootechnical requirements.

A morphological model of the installation has been designed to identify the connections between the mixer elements (Figure 2).
The given model allows to identify the main structural blocks of the mixer and to demonstrate their internal composition.

It is easy to perform the study of the interaction between the blocks and the mixer elements when they fulfill the required functions using a combined operational and morphological model (Figure 3). This model integrates the structural elements of the mixer and the functions they perform.

Figure 2. Diagram of the morphological mixer model.

Figure 3. Diagram of the functional and morphological model of the mixer.
The combined model provides an opportunity to identify in the installation the components which, being relevant (main), bear the performance of secondary functions. Such elements are unnecessary. They need to be removed by changing the layout and structure of the installation. No such elements were found in the constructed mixer model, which suggests the absence of unnecessary structures.

The functional and structural model indicates that the main structural elements perform all the main functions. However, some elements can fulfill several functions at the same time (drive, control system) [1].

The diagrams shown in Figures 1 and 3 identify the most relevant functions of the mixer as a working equipment [5]. The conducted analysis demonstrates the following: to improve the quality of their execution, the main attention should be paid to the mechanisms which set the movement of the movable object - the drive and the control system [4].

3. Results

We have compiled a table for further analysis 2. It introduces alternative structural elements that can be used in the layout of a new mixer design with the allocation of an appropriate symbol to each element.

| Drive      | Movable object | Method of chamber heating |
|------------|----------------|--------------------------|
| A1 - Air-powered | B1 – Vane-type | C1 - Microwave heating |
| A2 - Hydraulic   | B2 – Turbine (propeller-type) | C2 - IR heating |
| A3 - Electric    | B3 – Belt      | C3 – heating with a water jacket |
| A4 - Combined    | B4 – Screw     | C4 - U - shaped heating elements |

We have presented variants of combinations of structural elements in the morphological matrix of solutions using symbols (Table 3). The variants selected within the framework demonstrate promising design schemes. The decision matrix forms a space of alternatives. In addition, impossible solutions are marked among them (marked in gray), as well as promising areas of development (table 3).
The analysis of the decision matrix (table 3) provides the following conclusions. The drive of the movable object must be compact, reliable, have the ability to adjust the speed of rotation and simultaneously be slow-moving. The pneumatic drive, as well as the hydraulic one, will require the installation of a pneumatic or hydroelectric power station, which considerably aggravates and increases the cost of the design. Moreover, the pneumatic drive is high-speed. It means that a transfer device will be required to coordinate the rotational speed of the pneumatic motor and the movable object. A combined drive (for example, electrohydraulic) also considerably complicates and increases the cost of the design. Therefore, it is most reasonable to use an electric drive as part of an asynchronous three-phase electric motor and a transmission mechanism. This buddy has high reliability and efficiency. It is quite affordable, easy to maintain and operate. A frequency control should be used to control the speed of the motor shaft.

The movable object of the mixer being developed should be easy to manufacture and provide mixing of the ingredients throughout the entire volume of the chamber. The intensity of mixing is ensured by the interconnected complex spatial movement of the movable object and the chamber. Nevertheless, this solution will demand the use of an appropriate mechanism (for example, a Benet or a spatial spherical four-link). This situation considerably complicates the design. The analysis of literature and academic papers of researchers has demonstrated that the moveable-type movable object is convenient to manufacture and ensures a satisfactory quality of ingredients mixing with the necessary degree of homogeneity.

The heating techniques of the chamber given in Table 2 have both advantages and disadvantages. For example, microwave heating ensures a thermal effect in the volume of the material, which improves the heating uniformity [10,16]. Nevertheless, an expensive equipment for microwave heating, as well as the required protection from the microwave field of the maintenance personnel are substantial limiting factors. The main disadvantage is that vitamins and carotene are almost completely eroded in the microwave field.

In case of IR heating, it is required to use either special lamps that heat the walls of the chamber, or special IR heaters [12]. This heating technique has a good intensity. Nevertheless, due to the conductive heating of the material from the chamber walls, local heating with the destruction of vitamins and carotene is possible.

The safest way to heat and maintain the temperature is to transfer heat through a water jacket. This design will require the installation of an additional tank with a heated coolant (water) and a transit
pump, which considerably complicates and increases the cost of the design. Similarly, when using a water jacket, as a rule, plaque and scale are formed, which results in premature wear of the device.

4. Discussion
The performed analysis of the functions and connections of the mixer helped to justify a rational design scheme of the mixer. It considers the main features of the preparation of biologically active supplements. There is a necessity for further research of the characteristics and modes of functioning of the mixer for the preparation of biologically active supplements.

5. Conclusions
Therefore, from the above, it follows that the solution of the matrix of alternatives – А₃В₁С₄ (electric drive with a vane-type movable object, chamber heating by U-shaped heating elements) is a prospective variant of the mixer design scheme, distinguished by a rational technical solution. It will enable the use of an automatic mixer control system and adjust to the requirements of the technological process of preparation of BAS [8,13].

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