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**Вінницький національний  
аграрний університет****УДК 621.9.048.6 : 664.5****DOI: 10.37128/2306-8744-2023-3-11****RESEARCH OF  
TECHNOLOGICAL EQUIPMENT  
FOR THE PRODUCTION OF BULK  
FOOD MIXTURES**

*The development of technologies and modern equipment for the agricultural sector, as well as growing competition in the field of growing major agricultural products, lead agricultural producers to try to optimize their own production.*

*The process of mixing can be thought of as the volumetric movement of particles of two or more components to obtain a homogeneous medium (in terms of composition, physical, mechanical, and other properties). To mix bulk materials, external forces must be applied to allow the particles of the components to be mixed to move relative to each other.*

*The heterogeneity of the mixture depends on a number of reasons, in particular: the supply of the initial components to the vibrating mixer; insufficient mixing of the bulk mixture causes a deviation in the distribution of component particles, etc.*

*An analysis of existing mixer designs has shown that most technological processes use rotary drum mixers and mixers with rotating working bodies - paddle, screw, frame.*

*To study the process of mixing bulk food mixtures, a laboratory and experimental setup was developed, consisting of a vibration-centrifugal mixer, a loading hopper, and a control panel.*

*The developed machine (mixer) is based on the task of intensifying the process of mixing materials by reducing the adhesive forces between material particles through the use of the gravitational effect. Vibrational impact on the mixing of materials and the mixer's working bodies significantly increases the process productivity, reduce energy consumption and improves the quality of the mixture.*

*The developed design can be widely used in various industries in the production of spices, bakery mixes, feed, protein and vitamin supplements.*

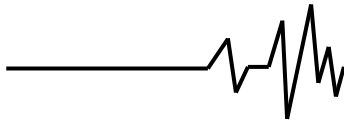
**Keywords:** vibration, mixing, bulk medium, spices, flour, vibration effect, frequency, vibrating centrifugal mixer.

**Problem formulation.** The production of bulk food mixtures directly at small enterprises using small-sized equipment is economically justified, since the cost of delivering raw materials and storing them is reduced, and in general, all resources are used more efficiently. The production of these mixtures using continuous vibration mixers has not been sufficiently studied, so this study is relevant.

**Analysis of last researches and publications.** Over the past decades, mixing technology has become more widely used in various sectors of the Ukrainian economy, in particular, in the agricultural sector. Its application has made it possible to fundamentally improve

traditional and develop new technological processes and means for their implementation. Thus, the oscillatory mode of movement of the particles of the technological load ensures both effective mixing and a decrease in the internal viscosity of the mixture and, as a result, a decrease in the friction force during mixing. Therefore, most existing technologies can use vibration technology, as these machines are much more efficient than conventional ones, both in terms of energy consumption and processing time.

The vibration effect on mixing materials and mixer working bodies significantly increases process productivity, reduce energy consumption and improves the quality of the mixture. At the



same time, vibration in some cases can only intensify the main process (e.g., screw vibration in a screw mixer), while in others it can cause specific vibration effects used for mixing (e.g., circulating vibration-transporting mixtures inside a cylindrical or torus-shaped vessel). The process of mixing with the imposition of vibrations is accompanied, in addition, by additional effects of grain destruction, destruction of coagulation structures, increased dispersion of solid particles and gas - activation of the mixture [1, 12].

**The purpose research.** The aim of this work is to improve the quality of finished products by improving the design and operating modes of a vibration centrifugal mixer of bulk food mixtures. Also, to analyze existing designs of mixers for bulk materials and identify areas for improving their designs.

**Presentation of main material.** Mixing is carried out by a large number of mixers, which

differ in both a variety of designs and different interaction of working bodies with raw materials (fig. 1).

Spice production is a complex multifactorial process in which mixing is an important operation. However, the technical means available for this purpose in small-scale production facilities do not provide high-quality homogeneous mixing at the micro-volume level. It is believed that 90...95% homogeneity is sufficient for the production of these mixtures directly at the production site.

The Ukrainian spice market is filled with both domestic and imported spices. Domestically produced spices are in demand among the population because they are much cheaper. Imported spices come from China, Georgia and India. The Ukrainian market also receives black pepper from Vietnam, bay leaf from Turkey, and cloves from Madagascar [5, 15].

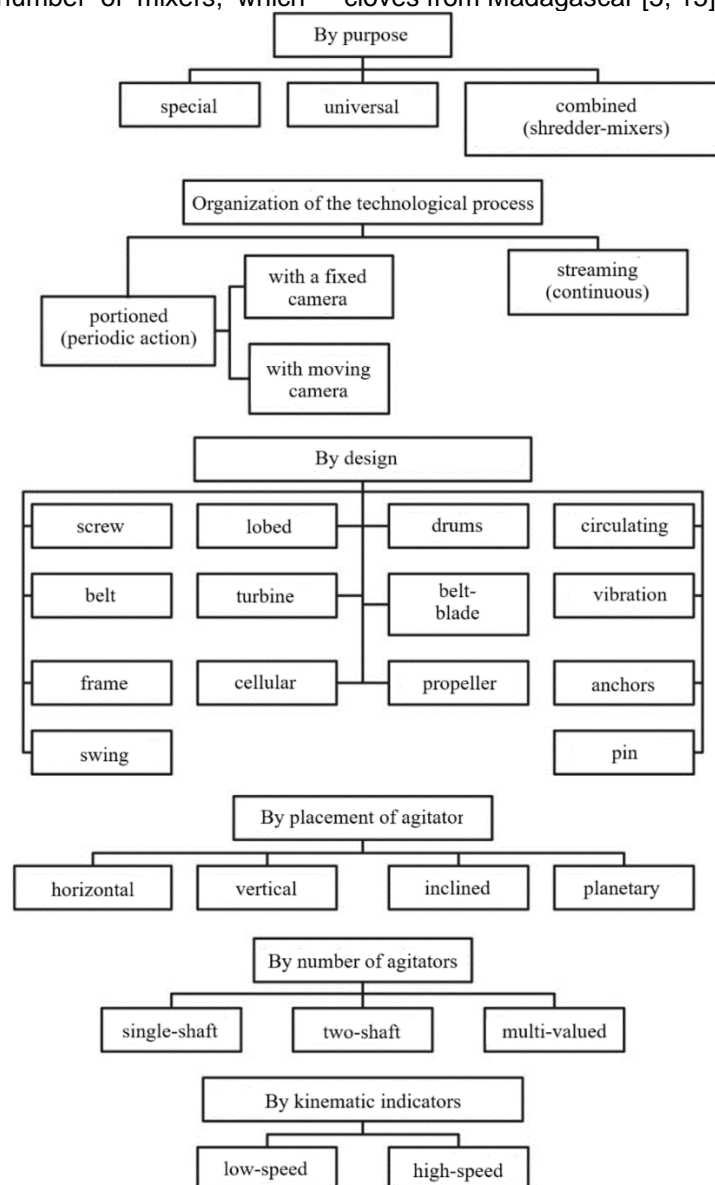
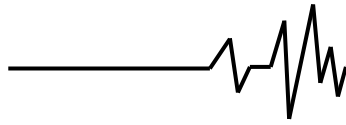
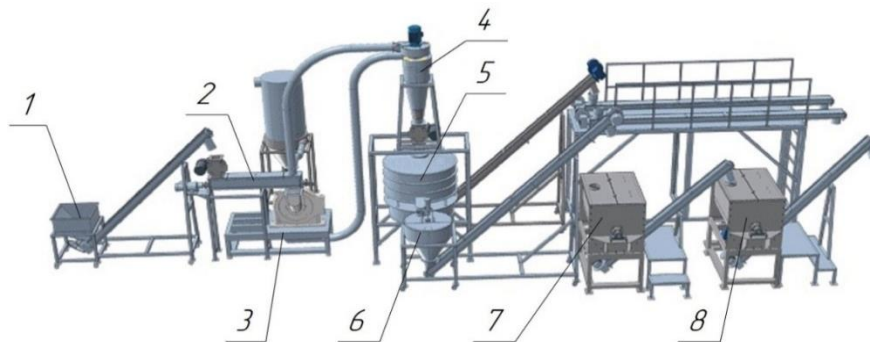


Fig. 1. Classification of food mixers



Currently, the population is interested in spices, which gives good prospects for their production [2].

The basic technological line for the production of food mixtures (spices) is shown in fig. 2 [3, 10].



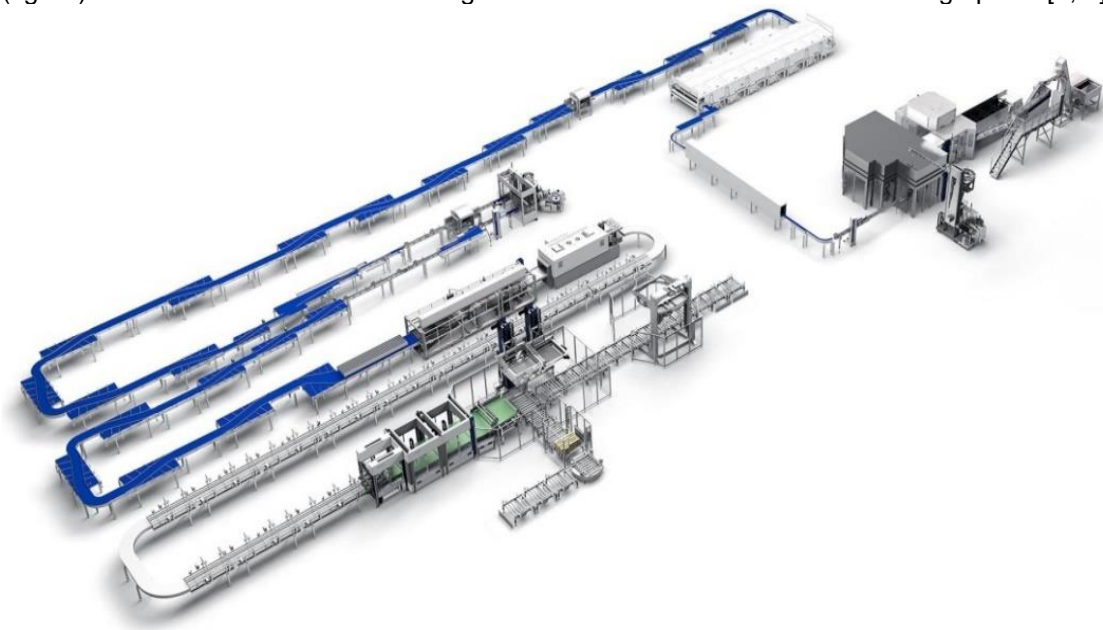
**Fig. 2. Technological line of spices production: 1 - loading hopper; 2, 6 - screw conveyor; 3 - mill; 4 - cyclone; 5 - vibrating separator with filter; 7, 8 - belt mixer**

Spices are widely used in the production of canned food and snacks.

In the canning industry, spices are used to give canned food a specific flavor and aroma. Most of the spices in the canned meat production line (fig. 3) are added at the initial stages of

cooking, and in the corn snack production line (fig. 4) before the packaging process.

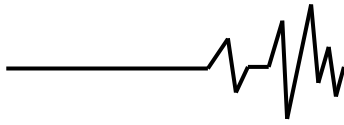
Spices are stored in paper bags at a temperature not exceeding 15°C and relative humidity not exceeding 75% in dry warehouses that are not infested with storage pests [4, 9].



**Fig. 3. Production line for canned meat**



**Fig. 4. Production line for corn snacks: 1 - mixer; 2 - screw conveyor; 3 - extruder; 4 - air conveyor; 5 - dryer; 6 - conveyor; 7 - sprayer; 8 - cooler**



In most mixing processes, rotary drum mixers and mixers with rotating working bodies - paddle, screw, frame, etc.

Rotary cone mixer (fig. 5). The mixing vessel and the inner shaft with the working bodies rotate in opposite directions, which ensures high efficiency and homogeneity (fig. 6). It is equipped with a digital timer for ease of use. This mixer is suitable for medium to small production volumes in the biotechnology, pharmaceutical and food industries.



Fig. 5. Rotary cone mixer



Fig. 6. Shaft and working bodies of cone mixer

The mixing of the mixture in such devices is caused by convective (circulation) and diffusion processes. The former arise as a result of the general movement of the entire mass of the load (macro processes), while the latter are provided as a result of the relative movement of the medium particles, which affects the change in friction and

adhesion forces between the particles (micro processes).

A horizontal belt mixer (fig. 7) is a trough-shaped vessel inside which a shaft with two "S" type belts rotates (fig. 8). The wraps of the belts are directed in opposite directions to neutralize transport phenomena. This results in intensive and uniform mixing. To improve the quality of mixing, the shaft rotation is reversed. The mixed product is unloaded with the mixer running and can be discharged from the middle or from the end of the mixer. All parts (mixer body, shaft, auger) that come into contact with food are made of AISI-304 stainless steel [5, 8, 13].



Fig. 7. Mixer with rotating working parts



Fig. 8. Shaft with two "S" type belts

The vertical belt mixer is used for mixing bulk food products. Depending on the design, they can be single-shaft (fig. 9), two-shaft (fig. 10) and multi-shaft. The mixer is a vertical hopper inside which a shaft is mounted that initiates a three-dimensional flow, creating a helical motion upward at the periphery and a downward flow in the center. It is driven from above, using only one or two bearings, respectively.

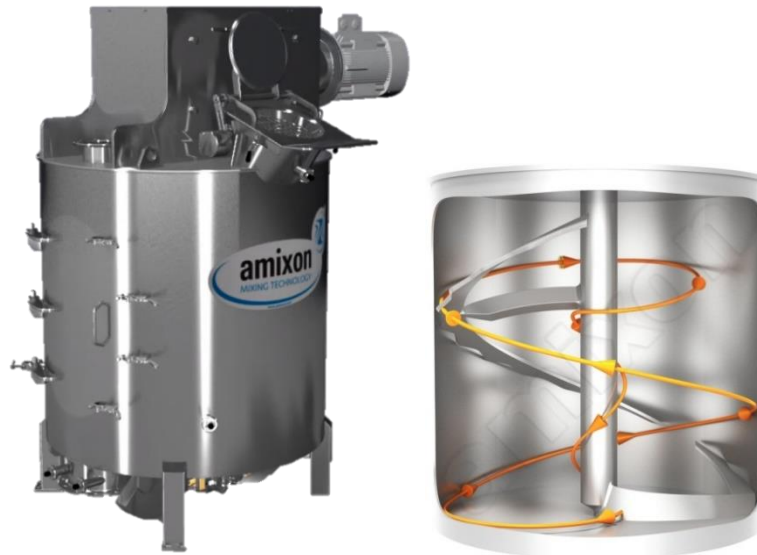
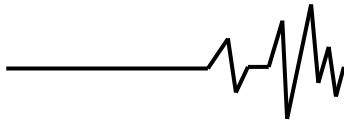


Fig. 9. Vertical single-shaft belt mixer and product circulation scheme



Fig. 10. Vertical twin-shaft belt mixer and product circulation scheme

These mixers can be used for mixing bulk, paste, liquid mixtures and dough. Ensuring perfect mixing quality at filling levels from 10 to 100% [6, 14].

The disadvantage of these mixers is (fig. 11): the high price of the mixer affects the final price of the finished product, which consequently reduces its competitiveness in the market;

insufficient intensification of the material mixing process, since the design does not provide for the possibility of 360-degree rotation of the body with the material to be mixed around the horizontal axis, which does not allow for the reduction of adhesive forces between the material particles by using the gravitational effect [7, 11].

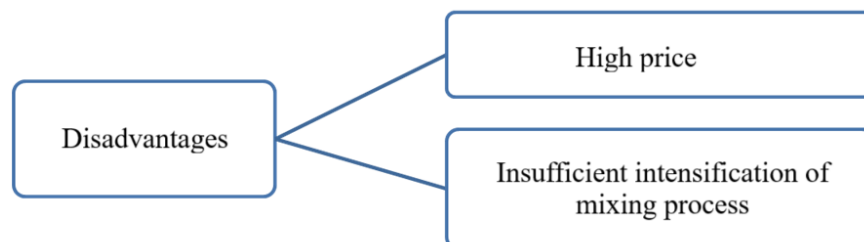
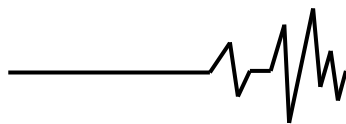


Fig. 11. Disadvantages of the reviewed mixers

The basis of the developed machine (mixer) is the task of intensifying the process of

mixing materials by reducing the adhesive forces between material particles through the use of the



gravitational effect. This is achieved by the fact that the vibrating mixer is fixed to the housing on racks with the ability to rotate 360° around the horizontal axis; the blade shaft inside the container can also rotate around its horizontal axis; the drives of the container and the blade shaft are made separately.

The vibratory mixer (fig. 12) contains a container 5, into which material is loaded through the hatch 13 to prepare one portion of the mixture. The vibration exciter 3 drives the body 1, which is

mounted on elastic elements 2, into oscillatory vibration motion. At the same time as the body 1, the container 5, along with the material loaded into it, comes into oscillatory vibration motion, since it is fixed to the body 1 on the supports 7. The electric motor 8 drives the blade shaft 6 mounted on the racks 4. The electric motor 10 drives the container 5 with the material loaded into it through the clutch 11 and the open gear 12 to rotate 360° around the horizontal axis.

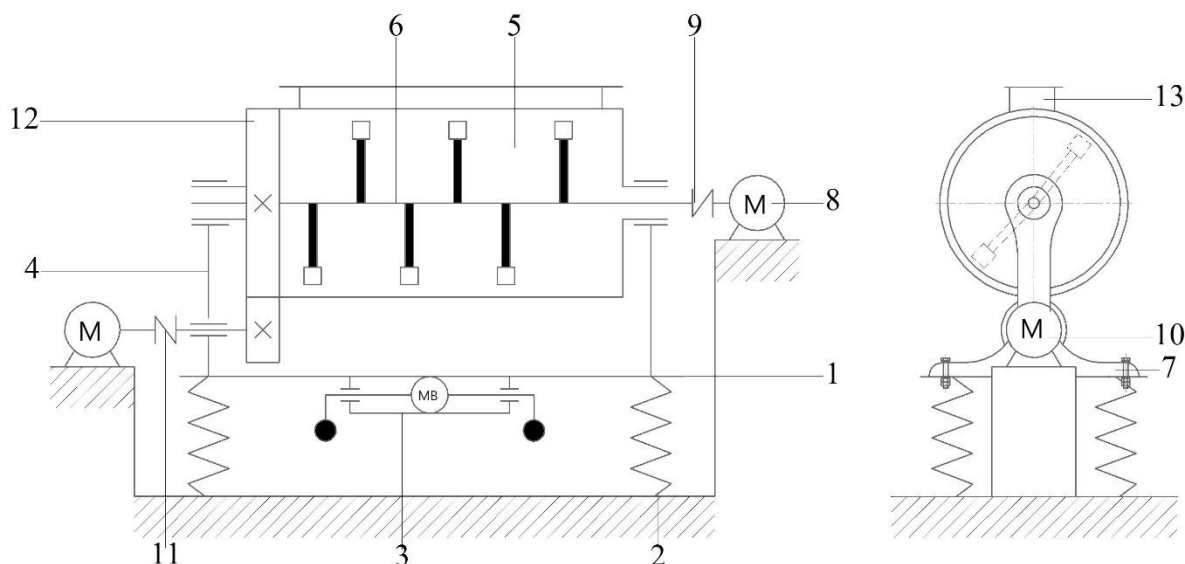


Fig. 12. Schematic diagram of a vibration centrifugal mixer: 1 - body; 2 - elastic elements; 3 - vibration exciter; 4 - rack; 5 - container; 6 - blade shaft; 7 - support; 8, 10 - electric motor; 9, 11 - coupling; 12 - gear transmission; 13 - hatch

As a result of the simultaneous, combined effect, the material particles are affected by the vibration generated by the vibration exciter 3, turbulence created by the rotation of the blade shaft 6 and the rotational movement of the container 5 around the axis by 360°, which together leads to an intensification of the material mixing process.

**Conclusions.** The combination of the movements of the working chamber (rotational, vibration) and the rotational movement of the activator, which can be realized independently of each other in one design scheme, significantly expands the technological capabilities of the mixer.

The developed design can be widely used in various industries in the production of bakery mixes, spices, mixed fodder, protein and vitamin supplements.

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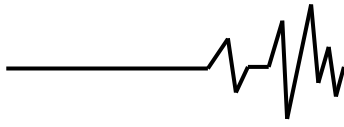
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#### ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОГО ОБЛАДНАННЯ ДЛЯ ОТРИМАННЯ СИПКИХ ХАРЧОВИХ СУМІШЕЙ

*Розвиток технологій та сучасного обладнання для агропромислового сектора, а також зростання конкуренції в сфері вирощування основних продуктів, призводять до того, що сільськогосподарські виробники намагаються оптимізувати власне виробництво.*

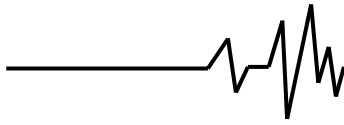
*Процес змішування можна уявити як об'ємне переміщення частинок двох і більше компонентів для отримання однорідного середовища (за складом, фізико-механічними та іншими властивостями). Для змішування сипких матеріалів потрібно докласти зовнішні зусилля, які дають змогу частинкам компонентів, що змішуються, пересуватися одна відносно одної.*

*Неоднорідність суміші залежить від низки причин, зокрема: подача вихідних компонентів у вібраційний змішувач; при недостатньому змішуванні сипкої суміші виникає відхилення розподілу частинок компонентів та ін.*

*Аналіз існуючих конструкцій змішувачів показав, що в більшості технологічних процесів має місце використання обертових барабанних змішувачів і змішувачів з обертовими робочими органами – лопатевими, шнековими, рамковими і т.д.*

*Для дослідження процесу змішування сипких харчових сумішей було розроблено лабораторно-експериментальну установку, яка складається із змішувача вібровідцентрового типу, завантажувального бункера, пульта керування.*

*В основу розробленої машини (змішувача) поставлена задача інтенсифікації*



процесу змішування матеріалів шляхом зменшення адгезійних сил між частинками матеріалу за рахунок використання гравітаційного ефекту. Вібраційний вплив на змішування матеріалів і робочі органи змішувача значно збільшує продуктивність процесу, знижує енергоємність і покращує якість суміші.

Розроблена конструкція може мати широке використання в різних галузях

промисловості при виробництві спецій, хлібопекарських сумішей, комбікормів, білково-вітамінних добавок.

**Ключові слова:** вібрація, змішування, сипке середовище, спеції, борошно, вібраційний вплив, частота, вібровідцентровий змішувач.

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