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CONCEPT OF MICROBIOLOGICAL GRAPH OF FEED AND FOOD PRODUCTION

‘***Abstract***

Compound feeds are favorable environments for microorganisms, namely bacteria and fungi. Both groups contain non-pathogenic, opportunistic and pathogenic members. Bacteria can cause infections, and fungi can cause mycotoxicoses, so controlling microbial contamination of feed is of great importance. Sources of microbial contamination of compound feed include both raw materials and the production environment: air, surfaces, equipment, and the hands and clothing of employees. As raw materials and pre-products move through production lines, they undergo certain processes that can either reduce or increase microbial contamination. The reducing processes include grain dehulling and high-temperature processing (moisture and heat treatment, conditioning, extrusion, expansion, drying of minerals, granulation), while the increasing processes include making preliminary mixtures, grinding, dosing and mixing, and the production of grits. In dosing and mixing, the contribution of each component is determined by its dose and has a two-way effect: the component contributes its microbiota, but its mass dilutes the mixture. The sequence of these processes represents a certain dynamics of microbial burden, which will result in the contamination level of the finished product lower or higher than in the initial raw material. This sequence can be represented as a microbiological graph, the vertices of which are the positive or negative contributions of the processes to the microbiological burden of the material. And the system of such vertices can be represented as a simple mathematical equation. Creating microbiological graphs for individual production lines or for the manufacture as a whole can help to understand the microbiological dynamics in a material or product and apply appropriate corrective measures to prevent microbiological hazards in the final product. This paper proposes a method of making a microbiological graph with two types of vertex designations for the IV generation compound feed production, as well as a mathematical apparatus for calculating the vertices of the graph.

Keywords: microbiological contamination, microbiological graph, microbiota dynamics, mathematical calculation, equation.

Introduction. Formulation of the problem

Animal feeds are well known to be a favorable medium for the development of various microorganisms, both bacteria and fungi, which include spoilage microbiota, opportunistic and pathogenic microbiota [1, 2]. Pathogenic and opportunistically pathogenic bacteria can cause infectious diseases, and fungi can cause mycotoxicoses. Feed microbiota can affect egg contamination in birds and is of great importance for aquaculture [3, 4]. Therefore, controlling the level of microbiological contamination (sanitary condition) of feed raw materials, intermediate products and finished feed is an important factor in the production of safe and high-quality feed.

To understand the changes in microbiological contamination of material as it moves through production lines, it is necessary to have an idea of the levels of contamination at different points or sections of the lines before and after certain technological processes.

The ***objective*** of this work was to develop a theoretical basis for modeling the microbiological "profiles" of modern feed production.

Purpose and tasks of the work

The ***aim*** of the study was to propose a mathematical framework for modeling the dynamics of microbiological contamination of raw materials and products at feed mills.

To achieve this goal, the following ***tasks*** were set:

1) to highlight possible points (sites) of positive or negative changes in the levels of contamination of feed raw materials and products on production lines;

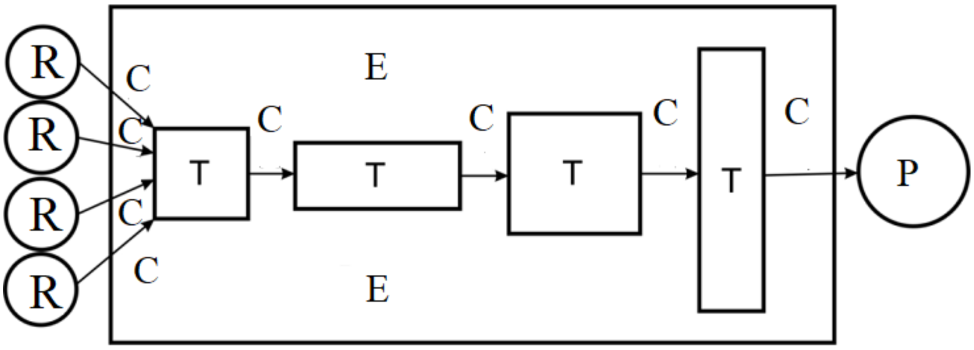
2) to develop a mathematical apparatus for calculating microbial contamination that would allow predicting such contamination and preventing its excess.

Literature review

1. Ways of feed contamination. Changes in the microbiota during production

Feed raw materials have their own initial microbiota, which consists of various microorganisms and depends on the material's composition [5, 6]. Once in production, raw materials and intermediate products undergo various technological processes that can either increase or decrease the microbiological contamination of the material. Decreasing processes include all types of high-temperature treatments (moisture-heat treatment, conditioning, extrusion, expansion, granulation, drying, etc.) and grain dehulling. Increasing processes include dosing and mixing, grinding, and making grits. Recontamination can also come from the surfaces of equipment and the air of production facilities, the clothes and hands of workers, and containers when finished products are packaged.

These fluctuations in the microbial "load" will be similar for different feeds within the same production



R – raw material, C – communications (gravity flows, feeders), T – technological process and its equipment, E – production environment, P – finished product

Fig. 1. Sources of recontamination in feed production based on the diagram from [7]

technology. Their general course can be described according to the scheme proposed for food products by the authors [7]. A modified version for compound feeds is shown in Fig. 1.

The diagram shows that the sources of recontamination can be both equipment (machines and transportation lines, such as gravity pipes) and the air in the workshop. At certain stages, the clothing and hands of workers may be added to this diagram. However, the greatest impact is exerted by shop equipment and the processes that take place in it.

Materials and methods

To achieve the stated goals, analytical methods of data processing, mathematical and statistical methods of data processing were used in the work: construction of equations and graph theory [8].

Results and discussion

1. Mathematical apparatus for the dynamics of microbiological contamination

The same work [7] proposes a general formula for estimating the number of microorganisms of a certain pathogenic species in food. This formula can be modified to reflect the level of total bacterial contamination:

$$N_F = N_0 - N_T + N_R, \quad (1)$$

where N_F is the level of microbial contamination of the final finished product or compound feed, CFU per unit weight or volume,

N_0 is the initial level of contamination before processing, CFU per unit weight or volume,

N_T is the number of microorganisms killed by a treatment or process (heat, chemical etc.), CFU per unit weight or volume,

N_R is the number of microorganisms introduced during recontamination or produced by multiplication in favorable conditions, CFU per unit weight or volume.

The N_F indicator must not exceed a certain level established as a criterion for the safety or quality of the product or feed (N_C):

$$N_F \leq N_C \quad (2)$$

Since there are usually many treatments and recontaminations on a production line, the N_T and N_R indicators can be expanded as a sequence of components, and the formula will take the following form:

$$N_F = N_0 - N_{T1} - N_{T2} - \ldots - N_{Ti} + N_{R1} + N_{R2} + \ldots + N_{Ri} \quad (3)$$

The dosing and mixing process differs from others in that it combines different components in different quantities, which determines the microbiological contamination of the mixture. Using either the weight or volume dosing, the formula for the microbiological load of the mixture will be as follows:

$$N_{mix} = \frac{D_a N_a + D_b N_b + D_c N_c + \cdots + D_i N_i}{D_a + D_b + D_c + \cdots + D_i}, \quad (4)$$

$$N_{mix} = \frac{\sum D_i N_i}{\sum D_i}, \quad (5)$$

where N_{mix} is the microbiological burden of the mixture,

D_i is the dose of each component measured by the doser,

N_i is the level of contamination of the prepared component of the mixture.

The units of measurement of the level of microbiological burden should always correspond to the measurement of doses, for example, if doses are measured in kilograms, then the number of microorganisms is taken per 1 kg (CFU/kg).

When liquid components are added by microspraying or microencapsulation, the microbiota that comes with the liquid component will be located on the surface, although it can later pass into the feed particles. In the case of vacuum application, this microbiota will immediately enter the particles. In both cases, the final contamination of the pellets will correspond to formulas (4) and (5), which take into account the ratio of the quantities of feed and the added liquid component or mixture of such components.

2. Microbiological graph

Each treatment ($-N_{Ti}$) and each recontamination ($+N_{Ri}$) contributes at certain stages corresponding to certain technological processes that raw materials and intermediate and final products undergo. Accordingly, using the mathematical theory of graphs and the concept of material flow graphs, it is possible to build a microbiological graph of a particular manufacture (Fig. 2). In the

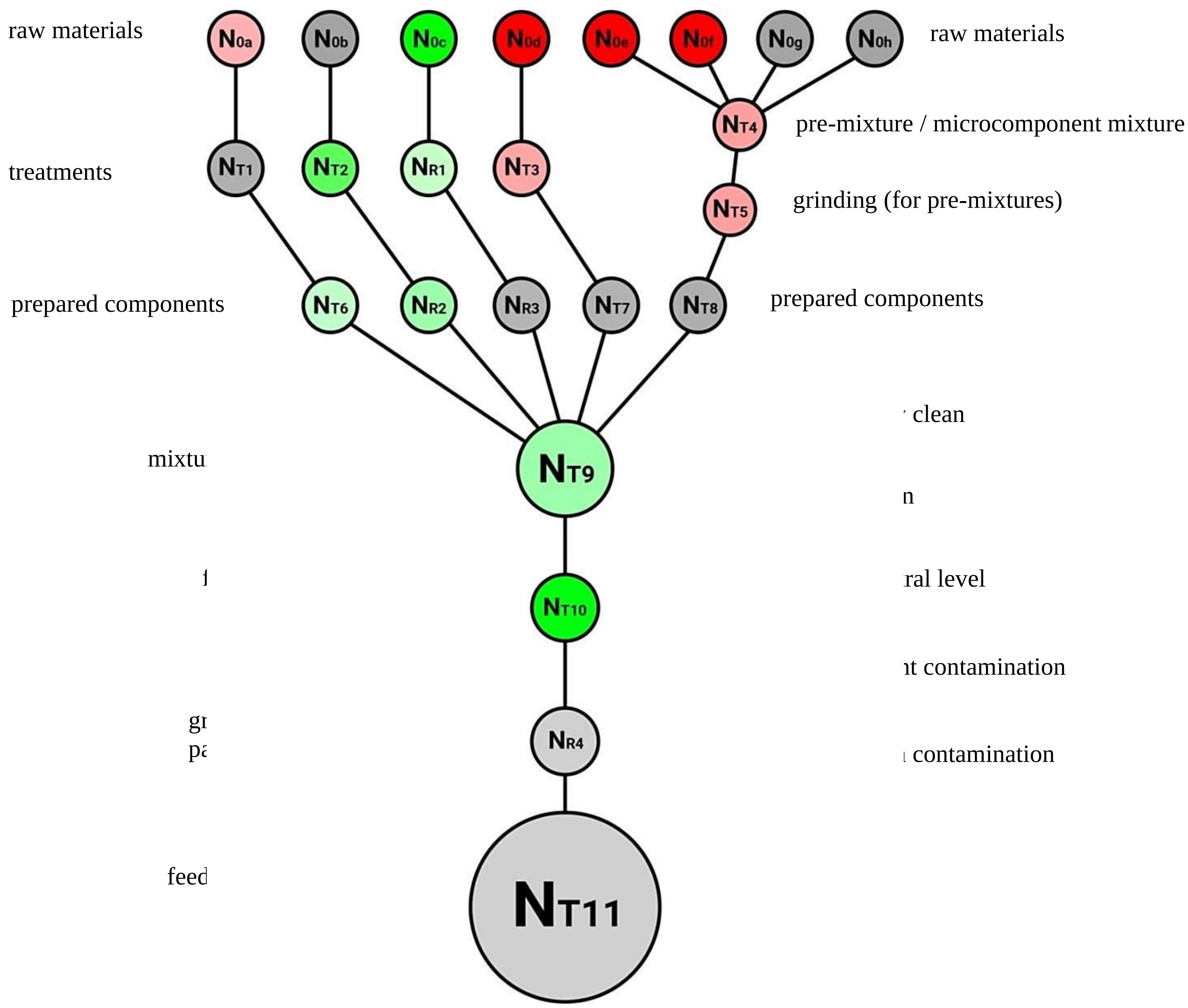


Fig. 2. General diagram of the microbiological graph of feed production

figure, the N_0 labels with indices *a...h* correspond to the initial microbiota of different types of raw materials, and the N_T (treatments) and N_R (recontaminations) are numbered sequentially.

The N_{T4} designation corresponds to a pre-mixture of components for joint grinding and/or a mixture of microcomponents after microdosing. It is assumed that during mixing, more contaminated components will be diluted with less contaminated ones, which will reduce the overall contamination of the mixture. Colors indicate the level of contamination relative to N_C:

- if $N_i > N_C$ - the color is red,
- if $N_i < N_C$ - the color is green,
- if $N_i = N_C$ - the color is gray,
- small deviations are pale green and pink, respectively.

The creation of microbiological graphs is assumed to be useful for:

– determination of the nature of changes in microbiological contamination of the material from raw materials to the final product;

– detection of the points of most likely or most severe contamination on production lines and their control or elimination;

– implementation of the HACCP system based on the identified critical control points;

– development of a systematic integrated control of production and product quality.

A potential disadvantage of the proposed method is the labor intensity and corresponding time consumption for microbiological examination of a sufficiently large number of samples. However, it is sufficient to conduct such a comprehensive study once, and then examine only critical points as needed.

Conclusions

A system of mathematical modeling of changes in microbiological contamination of materials on a production line as they move and are processed is proposed. The system consists of mathematical calculations of the dynamics of contamination and the development of a microbiological graph of the manufacture. The approach consisting of mathematical calculations and the construction of a microbiological graph is useful for improving the state of production and the quality and safety of the final product.

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КОНЦЕПЦІЯ МІКРОБІОЛОГІЧНОГО ГРАФА КОМБІКОРМОВИХ ТА ХАРЧОВИХ ВИРОБНИЦТВ

Анотація

Комбікорми є сприятливим середовищем для мікроорганізмів, до яких входять бактерії та гриби. Обидві групи містять непатогенних, умовно патогенних та патогенних представників. Бактерії здатні викликати інфекційні захворювання, а гриби – мікотоксикози, тому контроль мікробної забрудненості комбікормів має велике значення. Джерелами забруднення комбікормів мікроорганізмами є як сировина, так і виробниче оточення: повітря, поверхні, обладнання та руки й одяг працівників. Під час руху виробничими лініями сировина та попередні продукти проходять певні процеси, які можуть як знизити, так і підвисити мікробіологічне забруднення. До обробок, що знижують забруднення, належать очищення зерна та високотемпературні обробки сировини (вологотеплова обробка, кондиціонування, екструдування, експадування, сушіння мінеральної сировини, гранулювання), до підвищуючих забруднення – виготовлення попередніх сумішей, подрібнення, дозування-змішування, виготовлення крупки. У процесі дозування-змішування внесок кожного компонента відповідає його дозі та має подвійну дію: компонент вносить свою мікробіоту, але його маса розбавляє масу суміші. Послідовність цих процесів відповідає певній динаміці мікробного забруднення, яка закінчиться рівнем забруднення готового продукту нижче або вище від початкового рівня у сировині. Цю послідовність можна відобразити у вигляді мікробіологічного графа, вершинами якого є додатні або від'ємні внески процесів у мікробіологічне забруднення матеріалу. Відповідно, систему таких вершин можна представити у вигляді простого математичного рівняння. Складання мікробіологічних графів для окремих виробничих ліній або для виробництва в цілому може допомогти зрозуміти мікробологічну динаміку в матеріалі або продукті та застосувати належні заходи щодо її коригування, аби не допускати мікробіологічної небезпеки кінцевого продукту. В даній роботі пропонується спосіб будування мікробіологічного графу з двома видами позначень вершин для комбікормового виробництва IV покоління та математичний апарат розрахунків вершин графа.

Ключові слова: мікробіологічне забруднення, мікробіологічний граф, динаміка мікробіоти, математичний розрахунок, рівняння.

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