Review and analysis of extrusion technology in the production of feed additives based on probiotic microorganisms

Dmitry Rudoy 1,2*, Victor Pakhomov 1,2, Arkady Babajanyan 1, Tatiana Maltseva 1, Evgenia Rumyantseva 1, and Anastasia Tatarova 1

1 Don State Technical University, Gagarin Sq., 1, 344003 Rostov-on-Don, Russian
2 FSBSI Agricultural Research Center “Donskoy”, Nauchny Gorodok Str.3, 347740 Zernograd, Russian

Abstract. Ensuring a well-organized and sustainable feed base is the main condition for the development of animal husbandry, increasing its productivity and product quality. To ensure active growth and high productivity, probiotic feed additives are added to the feed, which increase the immune response of the host organism to pathogenic microorganisms, increases the conversion of feed and live weight gain. One of the main processes of feed production is extrusion, which can be cold, warm and hot. The hot extrusion process takes place at a temperature above 130°C and cannot be used in the production of compound feeds with probiotics that withstand temperatures up to 85°C. During cold extrusion, the temperature reaches no higher than 70°C, which allows the extrusion of mixed feed mass, which contains probiotic feed additives.

1 Introduction

A decisive role in the development of animal husbandry, poultry farming and aquaculture belongs to a balanced feed base, the organization of full-fledged feeding of animals, providing them with high-quality feed. Ensuring a well-organized and sustainable feed base is the main condition for the development of animal husbandry, increasing its productivity and product quality. The prospects of modernization and intensification of all branches of animal husbandry depend on the rational organization, volume and quality of feed production.

To ensure active growth and high productivity, the manufactured compound feeds must meet the needs of animals, birds and fish in proteins, carbohydrates, fibre, minerals, vitamins and other substances. Probiotic feed additives are increasingly used in compound feeds, which have a positive effect on the animal's body: increased immunity, normalization of the microflora of the gastrointestinal tract, increased survival, reduced feed conversion and weight gain [1-4].

In the technology of compound feed production, the extrusion process is often used, which allows to increase the digestibility of compound feed, improve its organoleptic
But high temperatures are harmful not only for pathogenic microorganisms, but also for beneficial probiotic strains. Therefore, the extrusion process in the production technology of compound feeds with probiotic activity is carried out separately only for vegetable raw materials. Then the extrudate is crushed, mixed with other components (including probiotic feed additive) and granulated in a gentle mode, where the temperature does not exceed 60 °C. This technology allows you to get a high-quality product with a high content of beneficial bacteria and a high cost due to a large amount of equipment. The purpose of this article is to consider in detail the extrusion process, its modes, to make a literary review of the thermal stability of various probiotic strains and to conclude that it is possible to reduce the cost of compound feed by carrying out the extrusion process for all components of compound feeds with the selected optimal temperature range.

2 Application of extrusion

The most effective way to prepare feed is extrusion is wet pressing with an explosion. The technological process of the extrusion process consists in hydrobarothermal processing of raw materials, when the feed mass is pressed and pushed through the dies under high pressure into the atmospheric pressure area, after which it explodes, increasing in volume. The advantages of extrusion include the ability to process any raw material individually or in various compositions. In comparison with other methods of moisture-heat treatment, extrusion gives a more noticeable increase in the nutritional value of the feedstock. One of its main effects is a sharp increase in the digestibility of carbohydrates, which is the least accessible part of feed raw materials for animals. It is achieved mainly due to deep gelatinization (gelatinisation) of starch, destruction and modification of the ligno-cellulose complex.

<table>
<thead>
<tr>
<th>No.</th>
<th>Advantages</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High digestibility</td>
<td>About 95% of the feed is easily digested. After extrusion, the digestibility of legumes (soybeans, peas, vetch, etc.) increases up to 10 times. This will allow the body to get the maximum amount of proteins, amino acids and vitamins, which are so rich in legumes.</td>
</tr>
<tr>
<td>2</td>
<td>Economy</td>
<td>The extruded product is consumed two times less, compared to conventional whole raw materials.</td>
</tr>
<tr>
<td>3</td>
<td>Minimum resource costs</td>
<td>Raw materials can be processed without pre-sorting and drying.</td>
</tr>
<tr>
<td>4</td>
<td>Effectiveness</td>
<td>Even damp grain that has been lying in the granary for several years can be extruded; good eating due to a pleasant bread taste and aroma; stimulation of growth and strengthening of immunity; providing the body with the necessary sugar without the use of food additives; storage duration due to low moisture content; reduction of gastrointestinal diseases due to the sterility of the feed.</td>
</tr>
</tbody>
</table>

Extrusion can be cold (20-70 °C), warm (70-130 °C) and hot (130-200 °C). The process of hot extrusion of compound feed is accompanied by gelatinisation of starch, denaturation and destruction of protein occurs, resulting in increased digestibility and organoleptic properties. Cold extrusion is used in the technology of production of loose feed to give...
3 The use of probiotic supplements

The use of probiotic supplements is one of the ways to improve the quality of feed products. Probiotics are defined by the World Health Organization as "living microorganisms that, when eaten in certain quantities, have health benefits that go beyond the usual general diet.

In the article by K. Hill, F. Garner et al. [16] write that probiotics are described as "living beneficial microorganisms that, when ingested in sufficient quantities, increase the host's immunity against intestinal pathogens and prevent many gastrointestinal disorders.

Probiotic bacteria are components that mainly ferment food, increasing its digestibility and therapeutic potential [17]. Some probiotic bacteria, such as Lactobacillus johnsonii, L. rhamnosus and Saccharomyces boulardii provide healthy intestinal flora and promote host health [18]. Since the probiotic is a living organism, adding its feedstock for extrusion at high temperatures and pressure is impractical, but instead applied as a coating on the outer surface of the granules. Such coating on pellets after extrusion not only reduces the cost of feed production, but also allows better preservation of the nutritional value of the ingredients, since these ingredients do not pass through the extruder and therefore are not exposed to pressure and temperature [19-20].

In order to create a wider range of compound feed and the ability to work in a continuous mode, non-replicating probiotic microorganisms (postbiotics, metabolites) [21] and spore bacillary probiotics [22-25] capable of surviving at high temperatures (up to 85°C) due to their physical properties began to be used.

Postbiotics and paraprobiotics indicate that non-viable microorganisms or bacterial-free extracts can benefit the host by offering additional bioactivity to probiotics, including, but not limited to, anti-inflammatory, immunomodulatory.

Despite in vitro and in vivo studies that support the promising use of postbiotics and paraprobiotics as health stimulants, the mechanism of action and signaling pathway is not yet fully clarified.

Probiotics can exhibit anti-inflammatory, immunomodulatory, antiproliferative and antioxidant activity, which can positively affect several metabolic and signaling pathways of the host [26]. Given this premise, postbiotics and paraprobiotics have potential applications in several fields, mainly in food and nutrition (e.g. food additives, feed additives, etc.) [27]. However, despite these suggestions, evidence of the exact mechanisms of action by which postbiotics and paraprobiotics exert their specific effects in certain systems or diseases has not been fully elucidated [28, 29].

In addition, the results of a recent literature survey by Piquet and his colleagues [30] emphasize that postbiotics have several pharmacodynamic features compared to live bacteria, as indicated below:

1. There is no risk of bacterial translocation from the intestinal lumen into the blood among vulnerable and immunodeficient subjects.
2. There is no chance of acquiring and transferring antibiotic resistance genes.
3. It is more natural to extract, standardize, transport and store.
4. Loss of viability during cell lysis may have further beneficial effects.

Enhanced interaction of each released molecule from disturbed cells with epithelial cells...
4 Conclusion

Extrusion is the most effective method in the technology of compound feed production, which helps to increase the nutritional properties of the feedstock, as well as its digestibility. Probiotics can withstand temperatures up to 85 °C and can be subjected to the cold extrusion process, which occurs at a temperature of 20–70 °C. When the temperature rises above 110 °C, probiotic microorganisms die. “Paraprobiotics” (dead/inactive probiotic cells) and “postbiotics” (healthy probiotic metabolites) are emerging concepts in the field of functional biotics. They have several advantages over traditional probiotics, such as known molecular structure, use in purified forms, specific mechanism of action, better availability of MAMP-PRR interaction when starting a specific downstream path, better availability of the production process for industrial scaling, ease of production and storage, etc. Various beneficial properties of paraprobiotics and postbiotics include anti-inflammatory, intestinal barrier properties, anti-adhesion, antibiotic films, antiviral, immunomodulatory, antihypertensive, hypocholesterolemic, antiproliferative, antioxidant, etc. attributes. These attributes indicate the possibility of paraprobiotic and postbiotic molecules to improve host health by modulating host physiology (amelioration of the disease state or prevention of disease occurrence).

Acknowledgements

The study was supported by a grant within the framework of the “Nauka 2030”.

References


29. C. N. De Almada, C. N. Almada, R. C. R. Martínez, A. de Souza Sant’Ana, Paraprobiotics: Evidences on their ability to modify biological responses, inactivation methods and perspectives on their application in foods, Trends in Food Science & Technology, 58, 96-114 (2016)