MÉTODO PARA OBTENÇÃO DE UM CONCENTRADO DE PROTEÍNA-VITAMINA PARA PREVENÇÃO DE DOENÇAS EM ANIMAIS DE FAZENDA**METHOD FOR OBTAINING A PROTEIN-VITAMIN CONCENTRATE FOR DISEASE PREVENTION IN FARM ANIMALS****СПОСОБ ПОЛУЧЕНИЯ БЕЛКОВО-ВИТАМИННОГО КОНЦЕНТРАТА ДЛЯ ПРОФИЛАКТИКИ ЗАБОЛЕВАНИЙ У СЕЛЬСКОХОЗЯЙСТВЕННЫХ ЖИВОТНЫХ**

SAVVINOVA, Margarita S.^{1*}; PROTODYAKONOVA, Galina P.²; POPOVA, Nadezhda V.³; TATARINOVA, Zinaida G.⁴; PAVLOVA, Aleksandra I.⁵

^{1,3,4} Yakut State Agricultural Academy, Department of Veterinary and Sanitary Expertise and Hygiology, 3 Sergelyakhskoye highway, 3rd km, zip code 677007, Yakutsk – Russian Federation

^{2,5} Yakut State Agricultural Academy, Department of Parasitology and Epizootiology, 3 Sergelyakhskoye highway, 3rd km, zip code 677007, Yakutsk – Russian Federation

* Correspondence author
e-mail: MSavvinova@mail.ru

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RESUMO

Suprimentos de ração regionais em Yakutia incluem estoques de feno, alimentos suculentos, bem como produção própria e importação de alimentos concentrados para a república. As principais alimentações de inverno incluem feno, ensilagem e silagem; no verão a grama de pastos naturais está disponível. A provisão anual de gado com nutrientes chega a 60-65% do normal, o que é um fator limitante para o desenvolvimento do potencial genético de raças de gado de Yakutia. A compreensão dos padrões gerais nos processos digestivos e mecanismos fisiológicos e bioquímicos de assimilação de nutrientes foi baseada nos resultados dos estudos de animais domésticos ruminantes (bovinos, ovinos). Questões de aumento da segurança alimentar continuam sendo urgentes para a produção agroindustrial. Os autores descrevem em detalhe um método de obtenção de um concentrado vitamínico-proteico com propriedades farmacológicas. A maioria desses processos envolve componentes gasosos, substâncias líquidas ou sólidas. Processos hidrodinâmicos complexos, térmicos e de troca de massa ocorrem simultaneamente em fermentadores. É proposto um método para expandir a produção de proteína alimentar utilizando uma combinação de características e parâmetros de transferência hidrodinâmicos e de massa com otimização simultânea do projeto do fermentador e seus modos de operação, levando em consideração o consumo mínimo de energia para dissolução de oxigênio e capacidade de produção de biomassa. Vários tipos de dispositivos estão atualmente disponíveis; basicamente, eles fornecem suprimento de oxigênio, pois é parte integrante do projeto de dispositivos, para o cultivo de microrganismos baseados na síntese microbiana. Deve-se enfatizar que um fermentador é o principal dispositivo de qualquer produção microbiológica e determina em grande parte sua eficácia econômica. Os resultados obtidos permitirão considerável aceleração dos trabalhos de finalização para o desenvolvimento e aprimoramento de projetos de fermentadores em perspectiva.

Palavras-chave: troca de massa, biorreator, transferência de massa, teor de gás, produtividade.

ABSTRACT

Regional feed supplies in Yakutia include hay stocks, succulent feeds, as well as own production and import of concentrated feeds to the republic. Main winter feeds include hay, silage, and haylage; in summer grass of natural pastures is available. Annual provision of livestock with nutrients reaches 60-65% of normal, which is a limiting factor for the development of the genetic potential of local cattle breeds in Yakutia. Understanding of general patterns in digestive processes and physiological and biochemical mechanisms of assimilation of nutrients was based on the results of the studies of domestic ruminant animals (cattle, sheep). Issues of increasing feed security remain urgent for agro-industrial production. The authors describe in detail a method of obtaining a protein-vitamin concentrate having pharmacological properties. Most of these processes involve gas components, liquid or solid substances. Complex hydrodynamic, thermal, and mass exchange processes occur simultaneously in fermenters. A method for expanding the production of feed protein using a combination of hydrodynamic and

mass transfer characteristics and parameters with simultaneous optimization of the fermenter design and its operation modes is proposed, taking into account minimum energy consumption for oxygen dissolution and biomass production, based on technical capacity. Various types of devices are currently available; basically, they provide oxygen supply, as it is an integral part of device design, for the cultivation of microorganisms based on microbial synthesis. It should be emphasized that a fermenter is the main device of any microbiological production and largely determines its economic effectiveness. The obtained results will allow considerable acceleration of finalizing works for the development and improvement of perspective fermenter designs.

Keywords: *mass exchange, bioreactor, mass transfer, gas content, productivity.*

ABSTRACT

Региональные поставки кормов в Якутию включают запасы сена, сочные корма, а также собственное производство и импорт концентрированных кормов в республику. Основные зимние корма включают сено, силос и сенаж; летом доступна трава естественных пастбищ. Ежегодное обеспечение скота питательными веществами достигает 60-65% от нормы, что является сдерживающим фактором для развития генетического потенциала местных пород скота в Якутии. Понимание общих закономерностей процессов пищеварения и физиолого-биохимических механизмов усвоения питательных веществ было основано на результатах исследований над домашними жвачными животными (крупный рогатый скот, овцы). Вопросы повышения кормовой безопасности остаются актуальными для агропромышленного производства. Авторы подробно описывают способ получения белково-витаминного концентрата, обладающего фармакологическими свойствами. Большинство из этих процессов включают газовые компоненты, жидкие или твердые вещества. Сложные гидродинамические, термические и массообменные процессы происходят одновременно в ферментерах. Предложен способ расширения производства кормового белка с использованием сочетания гидродинамических и массообменных характеристик и параметров с одновременной оптимизацией конструкции ферментера и режимов его работы с учетом минимальных затрат энергии на растворение кислорода и производство биомассы, основанный на технической вместимости. В настоящее время доступны различные типы устройств; в основном они обеспечивают снабжение кислородом, поскольку оно является неотъемлемой частью конструкции устройства, для культивирования микроорганизмов на основе микробного синтеза. Следует подчеркнуть, что ферментер является основным устройством любого микробиологического производства и во многом определяет его экономическую эффективность. Полученные результаты позволят значительно ускорить завершающие работы по разработке и совершенствованию перспективных конструкций ферментеров.

Keywords: *массообмен, биореактор, массообмен, газосодержание, производительность.*

1. INTRODUCTION

Agriculture of Yakutia is a unique, extremely complex industrial, socio-economic and ecological system in which agricultural businesses, such as cattle breeding and farming, develop in extremely harsh natural and climatic conditions.

Regional feed supplies in Yakutia include hay stocks, succulent feeds, as well as own production and import of concentrated feeds to the republic. Main winter feeds include hay, silage, and haylage; in summer grass of natural pastures is available. At the same time, the annual provision of livestock with nutrients reaches 60-65% of scientifically proven feeding norms. Such a constant lack of feeds is a limiting factor for the development of the genetic potential of local cattle breeds in Yakutia. Understanding of general patterns in digestive processes and physiological

and biochemical mechanisms of assimilation of nutrients was based on the results of the studies of domestic ruminant animals (cattle, sheep). Animals require big amounts of feeds. Protein deficiency is a current priority in domestic and world practice of feeding farm animals. Currently, the Republic of Sakha (Yakutia) has accumulated a unique experience in feeding farm animals in the extreme climatic conditions of the North. Various methods were adapted, developed, and used in conditions of permafrost. Issues of increasing feed security remain urgent for agro-industrial production. Leading producers pay special attention both to improved technologies and methods of feed supplements production and measures to intensify them and eliminate their harmful effects on the environment and humans. Methods for production of a protein-vitamin concentrate (PVC) having pharmacological properties (Gendler et al., 2015).

It should be noted that a fermenter is the

main device of any microbiological production and largely determines its economic effectiveness. Various types of devices are currently available; basically, they provide oxygen supply, as it is an integral part of device design, for the cultivation of microorganisms based on microbial synthesis. Most of these processes involve gas components, liquid or solid substances. Complex hydrodynamic, thermal, and mass exchange processes occur simultaneously in fermenters.

2. MATERIALS AND METHODS

In the production of PVC, feed protein producers are aerobic microorganisms. Their growth in industrial fermenters is usually carried out in a continuous manner. The mass exchange plays a crucial role in the achievement of desired device performance if technological and microbiological conditions are met. It is believed that microorganisms consume dissolved oxygen only. Oxygen is a poorly soluble gas. Oxygen consumption occurs at a rate that does not depend on the concentration of dissolved oxygen as long as it remains above the critical one. The effect of oxygen dissolution rate on the growth of microorganisms is not required. Single units are mainly devices for intensive mass transfer.

Advantages of the processes occurring with oxygen supply:

- devices equipped with aerators of various designs providing oxygen supply to the culture fluid with almost any given parameters;
- availability and simplicity of technological equipment design.

Figure 1 shows a schematic structure of a device for the cultivation of microorganisms consisting of three zones (Vasilyeva and Gerasimova, 2018; Gogoleva *et al.*, 2018; Darbasova and Vasilyeva, 2018; Dondokov and Dranayeva, 2018) (Figure 1).

- zone 1 – zone of intense mass transfer;
- zone 2 – cooling zone, which includes bioreactor with a heat exchanger; in this zone, together with mass transfer and biosynthesis, the medium is cooled;
- zone 3 – circulation zone; in this zone, the gas content of the medium and the intensity of mass transfer decrease.

3. RESULTS AND DISCUSSION:

The process of microbial cultivation

includes various steps, most of which take place when oxygen is supplied. Oxygen plays a significant role in the production of feed protein since microbial protein grows and intensifies with oxygen. At the moment, it is impossible to determine the concentration of dissolved oxygen without experimental determination of oxygen concentration and mass transfer coefficient (Kokieva, 2013; Kokieva, 2014).

The process of microbial cultivation in the food, chemical, and pharmacological industry takes place in fermenters (Kokieva, 2016; Nikonova, 2018; Pavlova, 2018). Cultivation in equipment (Table 1).

Figure 2 shows the study results of the dependence of biomass growth on cultivation duration using the experimental substrate. The biomass stops growing after 9-10 hours of cultivation at 50 mg/l biomass substrate production. With further increase in cultivation time, biomass growth was not observed. We can assume that the experiment reached the performance when the experimental substrate 0.05 g/l/day or 0.0035 kg/day was used (taking into account 70-L volume of the experimental reactor) (Figure 2).

Based on the experimental results, it was found:

- The optimum diameter of the stirrer with the maximum performance is 100-120 mm.
- The greater the density of the culture medium, the greater the performance of the device, the density of the culture medium depends on the concentration of macroelements and the oxygen saturation of the substrate under production conditions.

Foam is produced on the culture medium surface in the process of microbial cultivation. The diameter of the foam bubble d_{π} is determined by the hole size in the bubbler and the physicochemical properties of the culture fluid. (Vasilyeva and Gerasimova, 2018; Gogoleva *et al.*, 2018; Fedorova and Parnikova, 2018) (Equitation 1), where: d – hole diameter; σ – surface tension; q – acceleration of gravity; ρ_f – fluid density; ρ_g – gas density. Hence the number of bubbles (Equitation 2), where V_r – total air volume flow under normal conditions.

Use the following equation to study the process of oxygen absorption in the culture medium of different viscosity to calculate the gas content (Equitation 3), where D – diameter of the device.

At this time, a number of scientists carried

out systematic studies (Darbasova and Vasilyeva, 2018; Kokieva, 2013; Pavlova, 2018; Fedorova and Parnikova, 2018) and made recommendations for determining φ of the following dependence (Equitation 4).

In the study of gas content in the recirculation column with diameter ≈ 0.15 m and height $H = 10.5$, the authors (Darbasova and Vasilyeva, 2018; Nikonova, 2018) obtained the following equation (Equitation 5).

According to (Dondokov and Dranayeva, 2018; Fedorova and Parnikova, 2018), when a device model made of glass pipes with a height of 3 meters and diameters of 0.055; 0.08 and 0.11 m was used, the dependence, which allows determination of the fluid velocity in the transport AirLift (gas lift) was obtained (Equitation 6).

Here ξ – total hydraulic resistance of AirLift equal to (Equitation 7), where: λ – coefficient of hydraulic friction when fluid moves in a pipe with the same superficial velocity; φ_0 – gas content at the point where the stream leaves the airlift.

According to (Kokieva, 2014; Kokieva, 2016; Sharifullin *et al.*, 1980; Shebatin *et al.*, 1977; Yuding, 2001) for calculation of W_f , it is recommended to use the Bernoulli's equation, converted to the circulation loop, as follows (Equitation 8).

At the moment, a series of reactions occur in the fermentation liquid with oxygen in the process of production of feed protein during the microbial cultivation in the culture fluid. A number of authors (Darbasova and Vasilyeva, 2018; Kokieva, 2014; Chernouvanov, 1989; Kipke, 1978) recommend the dependence for reactions of liquids with oxygen widely used in industry to calculate W_f as follows (Equitation 9).

This calculation is performed by the method of approximations in one of the selected equations suitable for the determination of the gas content in the culture medium. With a pressure of up to 4 MPa on the culture medium with properties close to the properties of the water-air system, and the ratio of bubbling and circulation zones $f_b \cdot f_c^{-1} = 1$, approximate to the value of the reduced fluid velocity, the same authors propose to calculate W_f by simplified equation (Equitation 10), where $\xi_k = 5.1 + 0.03(\frac{H}{d_b} + \frac{H}{d_c})$ – resistance coefficient of the circulation circuit.

Air films develop at the gas and liquid interface of the air bubble. They pass through the culture, impede the diffusion of oxygen throughout the volume of the fermenter and reduce the

resulting resistance. A number of studies (Leamy, 1973; Mercer, 1981; Moreasi, 1981; Chapman, 1983) investigated the processes of oxygen absorption in fermenters.

While considering this case with a poorly soluble gas (oxygen), the values of m_{pc} and K_r are large, and the diffusion resistance in the gas phase can be neglected, and the inequation is observed (Equitation 11). Hence it follows (Equitation 11). Based on inequation $k \approx k_{la}$ mass transfer equation: $\frac{dc}{dy} = \kappa_i * a (c_p - c) - \kappa_b * x$,

Left term of the equation: $\frac{d^2M}{dv_p dt} = \kappa(C_p - C)$, which is called the velocity of the bulk oxygen mass transfer or the rate of oxygen dissolution, can be written in the following way for the absorption of atmospheric oxygen by the culture fluid (Equitation 13).

The stability and efficiency of the applied numerical methods allow further modification of the calculation, including the selection of turbulence models to improve the accuracy of calculations (Talismanov *et al.*, 2018; Talismanov, 2018).

4. CONCLUSIONS:

It should be emphasized that a fermenter is the main device of any microbiological production and largely determines its economic effectiveness. Various types of devices are currently available; basically they provide oxygen supply, as it is an integral part of a device design, for the cultivation of microorganisms based on microbial synthesis. Most of these processes involve gas components, liquid or solid substances. Complex hydrodynamic, thermal and mass exchange processes occur simultaneously in fermenters.

Based on the conducted studies, it can be concluded that an optimal combination of calculations and experiments allows the expansion of the scope of the studies, reduction of the number of experiments and significant acceleration of finalizing works for the development and improvement of promising designs of fermenters for PVC production of improved pharmacological properties. A method for feed protein production scaling with a combination of hydrodynamic and mass transfer characteristics and parameters, including simultaneous optimization of the fermenter design and its operation modes, has been proposed, taking into account minimum energy consumption for oxygen dissolution and biomass production,

based on technical capacity.

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$$d_{\Pi} = \sqrt[3]{\frac{6d_0\epsilon}{q(p_f - p_g)}}, \quad (\text{Eq. 1})$$

$$n = \frac{6v_r}{\Pi d_{\Pi}^3}, \quad (\text{Eq. 2})$$

$$\frac{\varphi}{(1-\varphi)^4} = 0.2 \left(\frac{D^2 * \rho_f * g}{\sigma} \right)^{0.62} * \left(\frac{D^3 * \rho_f^2 * g}{\mu_f} \right)^{\frac{1}{12}} * \frac{W_r}{(D * g)^{0.5}} \quad (\text{Eq. 3})$$

$$\varphi = \frac{1}{2 + \left(\frac{0.35}{W_g} \right) \left[\left(\frac{P_f}{l} \right) \left(\frac{\sigma}{782} \right) \right]^{1/3}} \quad (\text{Eq. 4})$$

$$\varphi = W_g (0.24 + 1.35 W_g m^{0.93})^{-1} \quad (\text{Eq. 5})$$

$$Wf = \sqrt{\frac{2gH}{\xi} \left(\frac{h}{H} - 1 + \varphi_{cp} \right) (1 - \varphi_{cp})^2} \quad (\text{Eq. 6})$$

$$\xi = 0.5 + \lambda \frac{H}{d} \left(\frac{1 - \varphi_0}{1 - \varphi_{cp}} \right)^{0.5} + \left(\frac{1 - \varphi_{cp}}{1 - \varphi_0} \right)^{0.2}, \quad (\text{Eq. 7})$$

$$H(p_f - p_r) \varphi^* g = \Delta P_b + \Delta P_c \quad (\text{Eq. 8})$$

$$H(\rho_f - \rho_r)^* g = \left[\left(1.5 + \lambda_c \frac{H}{d_c} \right) \left(\frac{f_b}{f_c} \right)^2 + 2 + \frac{1}{(1-\varphi)^2} + \frac{\lambda_6 * H}{(1-\varphi)^{1.75} * d_6} \right] * \frac{\rho_f W_f^2}{2}. \quad (\text{Eq. 9})$$

$$W_f = 3.5 \left[\frac{H * \beta}{\xi k} * \left(\frac{\Delta \rho}{\rho_r} \right)^{0.125} \right]^{0.5} \quad (\text{Eq. 10})$$

$$\frac{1}{K_L a} \gg \frac{1}{K_r m_{pc}}, \quad (\text{Eq. 11})$$

$$k \approx k_{la} \quad (\text{Eq. 12})$$

$$\frac{d^2 M}{dV_p dt} = K_L a (C_p - C) \quad (\text{Eq. 13})$$

Table 1. Cultivation data in equipment

No.	Cultivation time	Parameters				Minimal generation time, g _{min} , hr	Amount of glucose during cultivation, ml
		$\mu_{\max}$		Biomass accumulation, billion/ml			
		Optical density	Number of viable cells	Optical density	Number of viable cells		
Instructional mode							
1		1.1±0.06	0.9±0.004	5.4±0.15	4.8±0.01	0.6±0.1	35.4
2	12	1.1±0.07	0.98±0.05	6.7±0.2	5.9±0.21	0.71±0.01	36.2
Experimental mode							
3	14	1.14±0.03	0.77±0.33	15.4±0.4	14.2±0.35	1.0±0.01	330.20
4	12	0.1±0.02	0.92±0.02	20.4±0.45	15.4±0.4	0.82±0.01	280.14
5	9	0.47±0.02	0.01±0.001	8.4±0.3	4.0±0.02	0.9±0.01	129.18
6	10	0.711±0.03	0.62±0.02	12.9±0.04	5.0±0.1	1.62±0.02	150.00

Figure 1. Schematic structure of a device for the cultivation of microorganisms consisting of three zones: 1 – zone of intense mass transfer; 2 – cooling zone; 3 – circulation zone

Figure 2. Dependence of biomass growth on cultivation duration