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CONCEPT OF A CONTINUOUS FERMENTATION OF A MASH IN THE PRODUCTION OF ETHANOL FROM STARCH-CONTAINING RAW MATERIALS

The concept of a continuous fermentation of a mash in the bioreactor equipped with the microfiltrational module, ensuring separation of brew with filtrate takeoff (an aqueous-alcoholic solute) and backstock of a concentrate of yeast to the barmy device is offered. Efficiency of functioning of preproduction models of the microfiltrational elements designed of pressed titan powder with the average pore size from 2 to 7 micron is introduced.

Throughput of filter cartridges on an aqueous-alcoholic solute on modelling system is experimentally defined and was 700–1.000 $dm^3/m^2 \cdot$ hour at absolute efficiency of keeping of yeast cells.

Introduction. The process of mash fermentation by alcohol-making yeast is widely used in national and international practices of ethanol production over the years.

This method has a number of formidable drawbacks: low productivity of fermenters; time and heat consuming for intermediate operations to prepare the machine to work; unstable physiological state of the yeast population which changes during the fermentation of the initial period with an excess of substrate to exhaust the time of its full exhaustion; the complexity of infection control, especially in the initial period of fermentation, when the substrate is in excess, and the yeast concentration is low; the need for biomass accumulation seed yeast to the mash inoculation of each production cycle; the complexity of the automation process.

The continuous-cyclic mash fermentation mode does not allow to get rid of these shortcomings. It is implemented in a bulky battery of eight fermenters.

To develop the technological process of continuous mash fermentation at the fermenter and ensure retention of yeast cells (ethanol producers) in the fermentation volume is relevant objective in modern conditions. The solution to this problem is possible with the use of IP-bioreactors with immobilized yeast cells or membrane bioreactors equipped with a membrane module for continuous selection of acellular alcoholic brew.

Currently the technologies of membrane separation of biosystem components (ICBM technology) are spreading in the world practice. They can be used in ethanol production of yeast biomass for holding a fermentation medium with the simultaneous selection of a hydroalcoholic solution. Membrane methods are highly efficient in the separation process of complex systems. They are distinguished by low energy consumption and flexibility of use.

Modern ICBM technologies feature various combinations of membrane and biochemical processes. More than 30 companies reducing membrane elements and modules for ICBM technology are known to exist. The largest of which are: GE WATER & PROCESS Technologies, Siemens Water Technologies, USA; Kubota, Mitsubishi-Rayon, Toray Industries Inc., Japan [1].

More than 2,200 ICBM plants of various capacities have been in operation worldwide by 2008. 75% of them is used for treating industrial and domestic wastewater. Currently about new 70 ICBM plants are put into operation in Europe every year [1].

System Configuration MDBs can be classified into two major groups:

– Circulation ICBMs that include recycling shared mixture through a membrane module located outside the bioreactor;

– Submersible ICBMs in which the membrane unit is placed inside the bio-reactor (it is widely used in the processes of biological sewage treatments).

The driving filtering force through microfiltration membranes is provided either in a sealed pressure bioreactor or by vacuum creating on the permeate side.

The high-throughout processor of mash fermentation in a continuous bioreactor equipped with a synthetic membrane for detention and return of yeast biomass in the machine, with simultaneous and continuous ethanol removal was developed in the USA [2].

The advantage of this technology is the continuous separation of yeast and its return to the bioreactor. It reduces the cost of the accumulation of biomass and reduces seed yeast fermentation cycle. Yeast return to fermenter creates a high density of cells in the fermentation environment and increases the performance of the device.

The continuous removal of ethanol from the fermentation medium gives the possibility of the fermentation process with ethanol content allowing to activate the yeast. Acellular brew contains a small amount of co- suspended substances, thereby reducing the cost of the processes of alcohol purification.

Semipermeable separating elements of various types and configurations are used in the membrane bioreactors. They are tubular, spiral, circular, plate-and, the hollow fiber membrane elements, organic (nylon, Teflon and others), metal and inorganic (ceramic) microfiltration and ultrafiltration membranes.

Tubular membrane modules are structurally similar to tubular heat exchangers. It ensures a relatively low-density of packing, but a minimal tendency to contamination, as well as the possibility of a regeneration or membranes replacement. Modules of this type are used in both pressure and submerged microfiltration.

The purpose of this work is the study of continuous mash fermentation process at the fermenter equipped with a microfiltration module.

Main part. The using of tubular microfiltration elements of pressed powders of metals, made in the Republic of Belarus, is desired in industrial processes because of the specified requirement to the membranes (selectivity, capacity, mechanical strength, resistant to environment efficiency of the shared system, availability).

Prototype microfiltration unit for separating the suspension of alcohol-making yeast was produced in SSI "Institute of metal powder industry of National Academy of Sciences of the RB". The basis of the module is a cylindrical filter element with a given pore size (4–30 mm), manufactured by compressing powdered materials - titanium or stainless steel (Fig. 1). Monolithic element is placed inside of a stainless steel cone. The element enclosed in a cylindrical housing. The cone is designed to provide high linear speed of suspension movement near the filter surface. It helps to reduce the yeast mass amount deposited on the surface of the filter element.

Operating length prototype-cylindrical filter element is 230 mm, internal diameter is 12 mm, external diameter is 18 mm, inner surface is 0.0087 m^2. Investigation of the efficiency of the microfiltration second module was con-ducted on the laboratory machine (Fig. 2). It provided a regulated flow of yeast suspension through the module. Model aqueous suspension of alcohol-making yeas and industrial mash of LtD "Bobruisk Biotechnological Plant" was used in experiments.

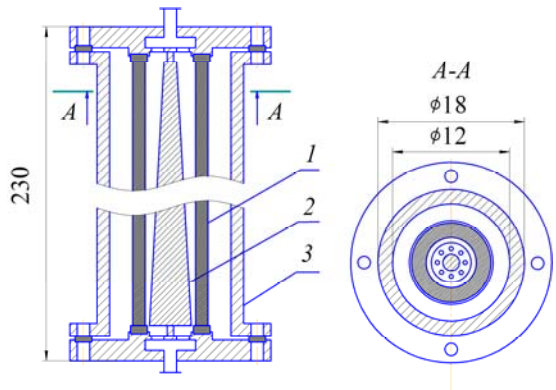

Fig. 1. Microfiltration module:
1 – filtration element;
2 – cone; *3* – cylindrical housing

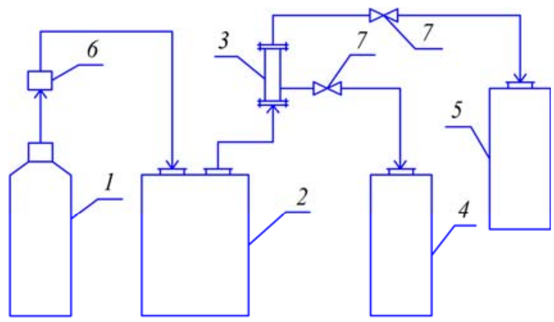

Fig. 2. Design od laboratory machine to research the operating benefit of microfiltration module:
1 – pressure nitrogen vessel; *2* – bioreactor;
3 – microfiltration module; *4* – filtrate recipient;
5 – concentrate recipient; *6* – redactor with pressure-controlled effluent gas; *7* – circulating suspension and filtrate flow control

Suspension of alcohol-making yeast Saccharomyces cerevisiae with a concentration of 20 g / dm^3 (biomass with 75% of humidity) has been used as a model for determining the medium bandwidth and performance of the microfiltration element. Model yeast suspension from the bioreactor is given on the microfiltration module by the pinch-compressed nitrogen, where it is separated into two streams (filtrate and concentrate). The concentrate is returned to the bioreactor. Separation efficiency of yeast cells in microfiltration module was controlled by microscopy samples of the filtrate in the preparation named "crushed drop".

The microfiltration module inlet pressure was adjusted by reductor at the supply line of compressed nitrogen into the bioreactor within 0.1–0.3 MPa.

At a flow rate of circulating through the module yeast suspension 2.2–3.2 dm^3/min calculated linear velocity of the suspension in the space-be- tween the inner cone and the surface of the filter element was 0.50–1.50 m/s.

Table 1

Efficiency of micro-filtering module functioning in the process of separation of model suspension of alcohol-making yeast

Filtering elements	Material and average pore size of element, μm	Specific carrying capacity, $dm^3/m^2 \cdot h$	Efficiancy of yeast suspension separation, %	Selected filtrate volume for element regeneration, m^3/m^2	Water volume for regeneration, m^3/m^2
TPP-5	Titanium, 32.8	1,000	10	–	–
TPP-8	Titanium, 5.8	900	100	0.15	0.10
PTM	Titanium, 2.2	920	100	0.20	0.08
PKh18N15	Stainless steel, 4.9	1,350	30	–	–
TPP-1	Titanium, 6.8	800	100	0.28	0.08

Table 2

Efficiency of model yeast suspension separation over a full range of circulation speed

Filtering elements	Circulation speed of yeast suspension, dm^3/m^2	Specific carrying capacity, $dm^3/m^2 \cdot h$	Efficiancy of yeast suspension separation, %	Volume of selected filtrate to element regeneration, m^3/m^2	Water volume for regeneration, m^3/m^2
TPP-8	2.5	700	100	0.17	0.08
PTM	2.2	800	100	0.21	0.08
TPP-1	3.2	820	100	0.32	0.08

From 20 to 80 dm^3 of yeast suspension was passed through microfiltration module in experiments. After each filtration cycle, the microfiltration module was subjected to regeneration by water washing at a pressure of 0.1–0.2 MPa in the reverse direction at a rate of 0.08–0.10 m^3 of wash water per 1 m^2 of filter surface. The experiments showed that such regeneration completely restores the carrying capacity of microfiltration module.

Five titanium prototypes of filtering elements made from powders of titanium and stainless steel and having a pore size of 2.2 to 30 microns were tested on the laboratory machine (Table 1). It was found that filtering elements made from powders of titanium having an average pore size of 2.2–7.0 mm (CCI-8 and TMP-1 CCI), which provide almost complete separation of the yeast cells at a rate selection filtrate 800–900 $dm^3/m^2{\cdot}h$, and the suspension circulating flow rate of 3.2 dm^3/min are very effective in yeast suspension separation. Microscopic examination of filtrate samples has shown the absence of yeast cells in the field of view of the microscope.

Reducing of the circulation rate of the yeast slurry through micro-filtering module in 1.5 times (from 3.2 to 2.2 dm^3/min) did not have a negative impact on the capacity of the filter elements (Table 2). Evidentially the titanium element TPP-1 is worth of researching because of a number of characteristics deduced from experiments. It provides the largest selection of filtrate without regeneration of the filter surface (0.32 m^3/m^2). Additional studies have shown (Table 3) that the capacity of TPP element reaches 1,050 $dm^3/m^2 \cdot h$ while maintaining the high efficiency of the separation process of yeast suspension.

Table 3

Specific output of microfiltration element TPP-1 based on the filtrate

Performance on the filtrate, dm^3/min	Carrying capacity of filtering element, $dm^3/m^2 \cdot h$
0.138	950
0.144	990
0.152	1,050

Continuous flow of yeast suspension through the module in an amount of 80 dm^3 (9.2 m^3/m^2 of surface) does not cause significant contamination of the TPP-1 filter element pores in yeast cells, and reducing the channel bandwidth (Table 4).

Table 4

Dependence of the channel bandwidth of microfiltration element TPP-1 on the flow velocity of yeast suspension

Flow capacity of yeast suspension through module, m^3/m^2	Bandwidth of the filter element, $dm^3/m^2 \cdot h$
2.3	350
4.6	405
6.9	610
9.2	550

The technological scheme of the pilot plant continuous mash fermentation in the ethanol production was developed on the bases of the research results (Fig. 3).

After deep saccharifying within 2–3 hours at a temperature of 58 °C the mash is clarified in a decanter centrifuge (pos. 1) to obtain the supernatant and cake. Cake is washed with hot water at 80°C with a multiplicity of washing on the water 2: 1, dewatered in a filter press FPAKM (pos. 5) to a moisture content of the solid residue of 60% and a screw conveyor (pos. 11) is in the hearth-rotary disc drying installation (pos. 12) for receiving food product with 10% moisture. Half of the wash water is directed to the preparation of kneading, other half is sent to a collection of supernatant (pos. 2). The mash is cooled to a temperature of 28–29 °C in the plate heat exchanger (pos. 4) and is supplied to the bioreactor (pos. 6).

The bioreactor is a fermenter equipped with an external circulation loop comprising two (working and reserve) microfiltration module (pos. 10). The fermentation process takes place in the chemostat mode, in which the substrate concentration in the mash is minimal, but the ethanol concentration is high, which limits the development of bacterial infections. Alcohol-containing vapors from the fermenters are catching in alcohol trap (pos. 7). Fermented mash enters the collection of mature brew (pos. 9) and then brew-purification department for the following processing.

The proposed technology has a number of advantages: ethanol yield is increased by the volume reducing of mash intended to produce the inoculating yeast. The process of the brew rectification no containing any suspended solids becomes easier. The steam consumption at brew column and the cost of cleaning the column from contamination are reduced. The infection control in the process of mush fermentation is easier because of the maintaining of a minimum concentration of the substrate and high concentration of alcohol-making yeast and ethanol in the bioreactor. By the way continuous mash selection takes place. The capacity of fermenter working in a constant mode is increased. Capital and operating costs of the mash fermentation because of reducing the number of fermenters and exceptions intermediate operations to prepare fermenters to work are decreased.

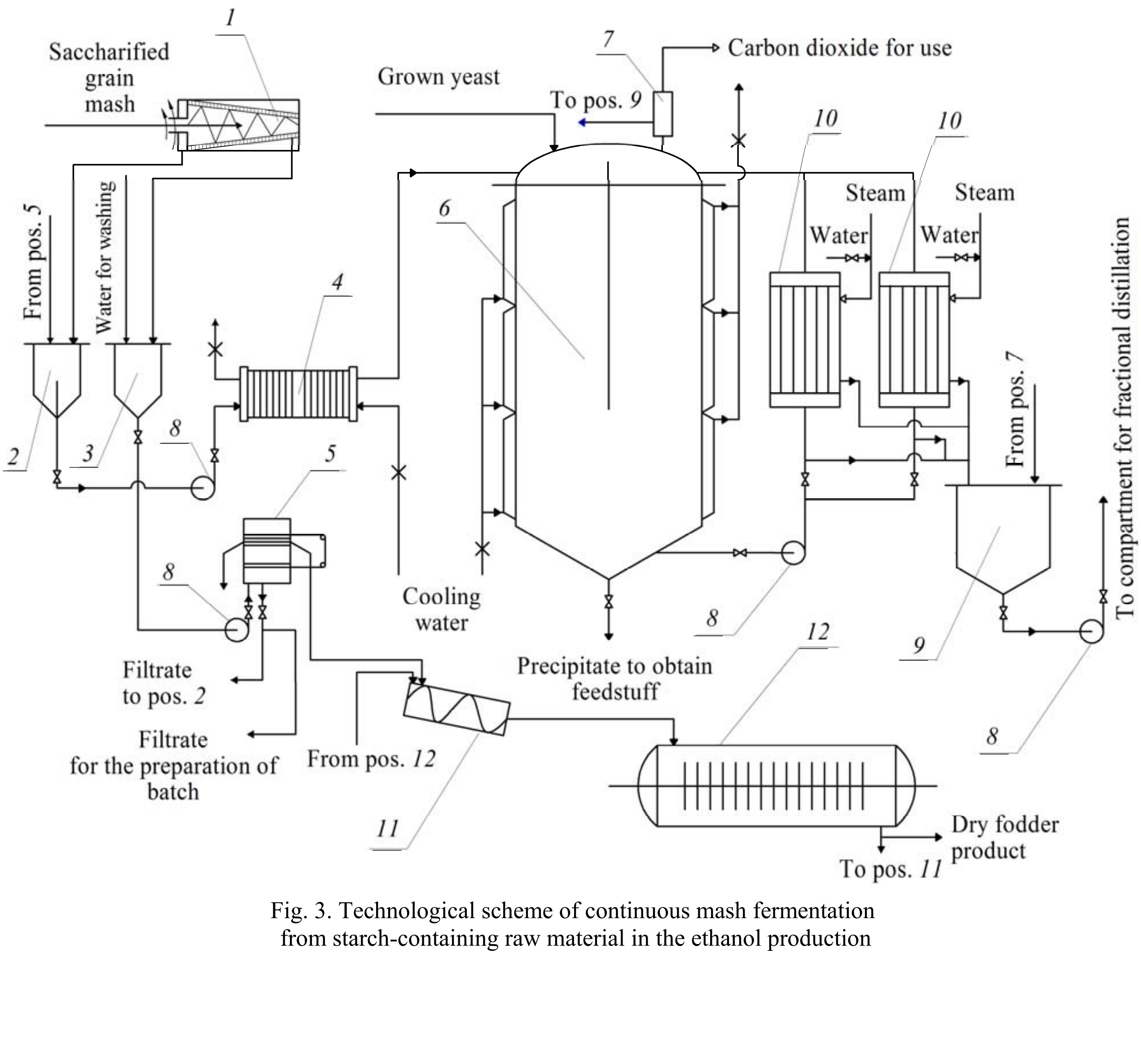

Fig. 3. Technological scheme of continuous mash fermentation from starch-containing raw material in the ethanol production

Conclusion. High efficiency of tubular microfiltration elements made by pressing the titanium powder via the separation of the aqueous suspension of alcohol-making yeast was experimentally demonstrated. The technology of continuous fermentation of grain mash in a bioreactor equipped with a microfiltration module which provides brew separation with a selection of water-alcohol solution and return of the yeast mass in the fermentor.

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