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PRODUCTION OF TEST PRODUCTS FROM THE BIOPROCESSED CERAMIC MASSES UNDER PRODUCTION CONDITIONS OF JSC “BELKHUDOZHKERAMIKA”

The production expediency of bacteria *Bacillus amyloliquefaciens* G, isolated from clay from Belarusian deposit Gaidukovka for improvement of properties of raw materials was shown under production conditions of JSC “Belkhudozhkeramika”. Preparations for processing of raw clay materials were obtained by cultivation of bacteria *B. amyloliquefaciens* G in different nutrient media. Processing of a forming slurry was carried out during 72 h at a temperature 28–30°C, pottery mass was kept for 5 days at a temperature 23–25°C. Further, the technological process of production of pottery corresponded to production regulations.

The viscosity and coefficient of solidification of a ceramic slurry decreased as a result of bacterial processing, crock set duration significantly reduced. Air linear shrinkage of samples after burning did not exceed 5%. The processing conditions leading to the most essential decrease of water absorption of samples are established, that is the evidence of increase of their mechanical strength, are established. Electron microscopic images of chipped surfaces of test samples are characterized by higher firmness and uniformity in comparison with an industrial sample. The maximum dense surface is formed and porosity of products decreases at the repeated molding.

Positive impact on maturing of clays, processed by cultural liquid of bacteria *B. amyloliguefaciens* G, on plastic properties of pottery masses was first shown.

Key words: ceramic industry, clay, *Bacillus amyloliquefaciens*, bacterial preparation, ceramic slurry, water absorption, plasticity number.

Introduction. JSC “Belkhudozhkeramika” is the largest manufacturer of ceramic household products and artistic articles in the Republic of Belarus. The main raw material for production at the enterprise is dispersed; soft, mid-sensitive to drying clay from Belarusian deposit “Gaidukovka”. High mechanical strength of finished ceramic products can only be achieved by using finely divided, highly ductile materials.

There are a number of traditional (reagent) methods of processing raw clay, which lead to particle dispersion and increase in the plasticity number that inevitably leads to increased sensitivity of clay to drying. An alternative method to increase the plasticity number and thus reduce the sensitivity to drying clay is microbiological treatment. Changing the properties of clay raw materials in the long-term deposits is due to the microbial products. When some bacterial- based compounds are introduced the technological characteristics of clay are improved for considerably shorter period [1].

The purpose of the work was to determine the possibility of improving the quality and increasing the mechanical strength of finished ceramic products made from biologically treated clay from Belarusian deposit “Gaidukovka”.

Main part. The most common target for investigating the influence of microbial treatment on the properties of the clay materials are bacteria of the genus *Bacillus*. Efficiency of the bacteria *B. amyloliguefaciens* G isolated from the clay of the Belarusian deposit “Gaydukovka” and *B. mucilaginosus* 4 is shown; it improves the quality of the clay Belarusian deposit “Gaidukovka” [2].

Compounds for the clay treatment of the were prepared by growing bacteria *B. amyloliquefaciens* F in a shaker-incubator ES-20 (200 rev/min) at 30°C for 48 hours. For obtaining the cultural liquids of bacteria with different composition, it was used different nutrient medium (g/l): medium No. 1: sucrose – 5; $(NH_4)_2SO_4$ – 0,5; $K_2HPO_4 \cdot 3H_2O$ – 0,26; $MgSO_4 \cdot 7H_2O$ – 0,2; NaCl – 0,1; K_2SO_4 – 0,1; medium No. 2: sucrose – 20; $NaNO_3$ – 0,5; $K_2HPO_4 \cdot 3H_2O$ – 0,26; $MgSO_4 \cdot 7H_2O$ – 0,2; NaCl – 0,2; K_2SO_4 – 0,1.

Production tests include two series of experiments. In the first series the ceramic products were manufactured by injection molding of biologically treated slip, the second series of experiments was to obtain finished products on a throwing wheel after souring biologically treated clay. Furthermore, in order to compare effects on the properties of clays and finished articles bacteria *B. amyloliguefaciens* G and *B. mucilaginosus* 4 clay was treated with cultural liquid of the bacteria.

In a series of experiments on processing the molding slip preliminary studies were conducted to select the processing cultural bacterial liquid and the duration of set crock filling. Each of the cultural liquids of bacteria *B. amyloliguefaciens* F obtained in different nutrient media was added in the amount of 2 ml per 100 g dry weight of the clay material. Treatment of the ceramic slip with 58–

59% humidity without addition of the electrolyte was carried out for 72 hours at temperature of 28–30°C. It was established that bacterial treatment resulted in a viscosity decrease and slip densification.

After exposure time the slip was manually poured into plaster molds of containers to extinguish “Pumpkin” (first molding). To select the required length of time, the crock set was changed in the range of 30–80 minutes in the intervals of 10 minutes. The optimum thickness of the walls of the products was obtained at the duration of the crock set for 40 minutes. Drain off the residual slurry was used to mould mugs (second molding), the crock set duration was also 40 minutes.

Further process of manufacturing ceramic products met the company production regulations: after airing, cooling and drying to 3% moisture content of the product was fired in a box furnace at temperature of 860–880°C. Then the products were glazed with addition of pigments. Glazed products were fired in a tunnel kiln at temperature 980°C. The appearance of the glazed goods corresponded to the required standards (STB 841-2003 “Ceramic products of folk art”), defects in the glaze coating were not found. Aerial linear shrinkage after firing samples did not exceed 5%.

The mechanical strength of the products depends on their density and porosity, as in a production media it is judged by the water absorption index (GOST 2409–95) (Table 1). The results showed that to treat microbiologically the molded slip, it is appropriate to use the bacteria cultural liquid *B. amyloliguefaciens* G, prepared in a nutrient medium number one.

In order to study the possibility of reducing the cost of production of bacterial drug, an experiment was carried out to make products with the addition of a smaller amount of bacteria cultural liquid *B. amyloliguefaciens* G (1 ml per 100 g of dry clay). The technological cycle of production did not differ from that described above; it produced casting products in different sizes and shapes: beer mugs and children cups, coffee cups, plaques.

It is found that, as in the previous case, the bacterial treatment helped to change the technological properties of the slip (densification index) after calcination in the experimental sample compared to the production, decreased aerial linear shrinkage. There is a substantial reduction in the number of pinholes (especially clearly it is displayed on the small-sized products), which significantly reduces the defect rate.

As it can be seen from Table 2, the change in the amount of introduced bacterial drug led to a decrease in water absorption of the ready-made articles: to 14.3% in the case of the first molding and to 13.8% in a second one. Duration of the crock set is 30 minutes.

Below there are the electron-microscopic image (Fig. 1) chips surfaces of experimental and advanced industrial products manufactured by slip casting. These images were obtained with a scanning electron microscope JSM-5610 LV.

From these photos you can see that the samples are characterized by greater density and uniformity of the surface compared with the production sample. It is also apparent that the second molding can produce maximally dense surface and reduce the porosity of the products.

As a result of the bacterial processing of ceramic raw materials, it is due to changes in the microstructure, the water absorption capacity decreased by 15–18%, which positively affected their mechanical strength.

Table 1

Characterization of the samples when introduced into a molding slip 2 ml drug per 100 g of dry clay

Sample types	Water absorption capacity, %	Duration of the crock set, min
Production	16.8–17.0	110–120
Experimental sample with cultural liquid CL *B.a.*-1 (first molding)	15.9	40
Experimental sample with cultural liquid CL *B.a.*-1 (second molding)	15.6	40
Experimental sample with cultural liquid CL *B.a.*-2 (first molding)	16.2	40
Experimental sample with cultural liquid CL *B.a.*-2 (second molding)	16.4	40

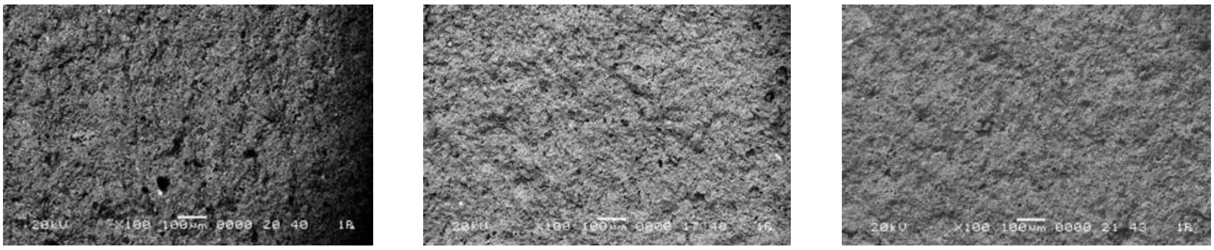
Note: CL *B.a.*-1 – a cultural liquid of bacteria *B. amyloliquefaciens* G obtained in the medium No. 1; CL *B.a.*-2 – a cultural liquid of bacteria *B. amyloliguefaciens* G obtained in the medium No. 2.

Table 2

Characterization of the samples when introduced into a molding slip 1 ml drug per 100 g of dry clay

Sample types	Water absorption capacity, %	Duration of the crock set, min
Production	16.8–17.0	110–120
Experimental sample with cultural liquid CL *B.a.*-1 (first molding)	14.3	40
Experimental sample with cultural liquid CL *B.a.*-1 (second molding)	13.8	30

Note: CL *B.a.*-1 – a cultural liquid of bacteria *B. amyloliquefaciens* G obtained in the medium No. 1.



a *b* *c*

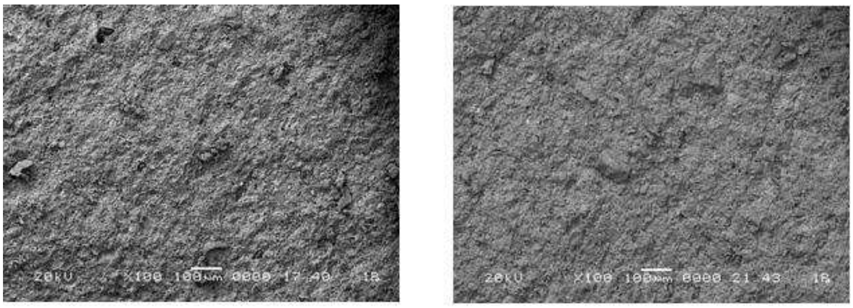
Fig. 1. Electron microscopic images of surfaces chips (×100):
a – the production sample; *b* – experimental sample of the first molding; *c* – experimental sample of the second

The second series of the production tests on the production of "Belkhudozhkeramika" was to mature the pottery mass with the addition of a bacterial drug and subsequent obtaining of the finished products on potter's wheel. Plasticity of the raw material influences greatly the process and the result of the work. In turn, the increase of the clay plasticity leads to the formation of a dense structure, which has a positive impact on the mechanical strength of the products.

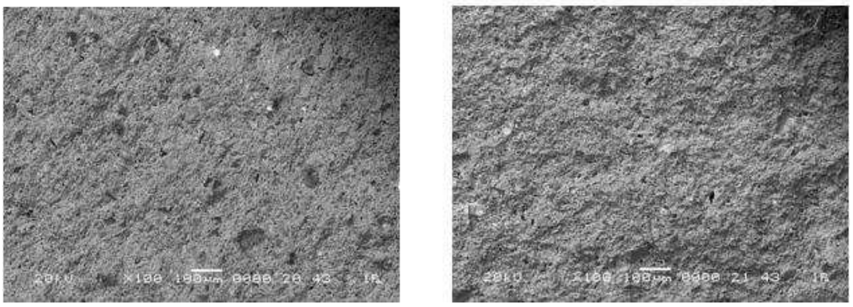
In to the pottery mass of 18% humidity it was introduced bacterial cultural liquid *B. amyloliguefaciens* G of different composition in concentrations of 1 and 2 ml per 100 g of clay (dry basis). Biologically processed pottery material was stored for 5 days at temperature 23–25°C (the temperature in the workshop), and then it was used to make products on a potter's wheel. After drying and mandrelling baking was carried at temperature 920°C, and then poured calcining was carried at 950°C.

Appearance of the products meets the requirements of the standard (STB 841-2003). In the process of manufacturing products on the wheel it was observed more comfortable working conditions by increasing plasticity of clay which was treated with cultural liquid of bacteria *B. amyloliguefaciens* G prepared in a nutrient medium No. 1 added in the amount of 1 ml per 100 g of dry clay.

As shown in Table 3, the plasticity index of clay (GOST 21216.1–93) after maturing with the addition of bacterial culture liquids *B. amyloliguefaciens* G and *B. mucilaginosus* 4 increased by 36 and 29%, respectively. Water absorption of the products obtained at the potter's wheel from biologically treated masses, is presented in Table 3, and electron-microscopic images of the surfaces of chips of these products are shown in Fig. 2.



a *c*



b *d*

Fig. 2. Electron microscopic images of surfaces chips (×100):
a – the production sample; *b* – reference sample; *c* – a sample of the pottery mass treated with cultural liquid *B. amyloliquefaciens* G; *d* – a sample of the pottery mass treated with cultural liquid *B. mucilaginosus* 4

Table 3

Characterization of the samples when pottery mass is maturing

Sample types	Water absorption capacity, %	Plasticity index, %
Production	13.8–14.0	12.2
Reference	13.6	12.5
Experimental sample with cultural liquid CL *B.a.*-1	12.1	16.6
Experimental sample with cultural liquid CL *B.a.*-1	12.6	15.7

Note: CL *B.a.*-1 – a cultural liquid of bacteria *B. amyloliquefaciens* G obtained in the medium No. 1; CL *B.a.*-2 – a cultural liquid of bacteria *B. amyloligue-faciens* G obtained in the medium No. 2

Maturing clay with the addition of a cultural liquid of bacteria *B. amyloliquefaciens* G leads to reduced water absorption of the sample prepared from this clay by 13%. This model is characterized by the lowest porosity and the highest density and homogeneity.

Conclusion. The experiments which were carried out at production proved the ability to improve the quality and increase the mechanical strength of the finished products made from ceramic materials biologically treated with Belarusian clay deposit "Gaydukovka". When using bacteria *B. amyloliguefaciens* G it was shown the possibility of reducing twice the amount of drug of these bacteria when compared with the previously used drug of bacteria *B. mucilaginosus* 4 [2]. The fact of reducing water absorption and increase of density and homogeneity of products in the second molding was shown. For the first time it was demonstrated a positive effect of maturing clay which were treated with cultural liquid of bacteria *B. amyloliguefaciens* G on plastic properties of the pottery mass.

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