The graphical dependence of the washing capacity of ethanol-containing soapstock on the concentration in an aqueous solution and the temperature of interaction with the polluted material has been determined. It is proposed to use a 40 % aqueous solution of ethanol-containing soapstock in the hand cleaning paste technology. This soapstock solution has a washing capacity of 92–98 % at the temperature of interaction with the polluted material of 25–40 °C.

The regularity of the effect of the structurant content on the consistency of hand cleaning paste was investigated using an approximating polynomial. This made it possible to substantiate the effective concentration of carboxymethyl cellulose (0.4…0.6 %) and cetylstearyl alcohol (1.8…2.0 %) in the formulation. The obtained regression equation is useful for adjusting the content of structurants in the formulation, depending on the consumer's requirements for the viscosity of the developed detergent.

A comparison of the quality indicators of the developed hand cleaning paste based on ethanol-containing soapstock with a sample of similar "Primaterra Automotive" commercial hand cleaning paste was carried out. The quality indicators of the developed paste are as follows: effective viscosity at 20…22 °C – 32.0 Pa·s; foaming capacity – 23 mm, foam stability – 62.0 %; washing ability – 92.0 %. It was determined that these quality indicators do not differ significantly in the developed detergent and commercial analogue. The data obtained indicate the prospects of processing ethanol-containing soapstock into the hand cleaning paste based on natural surfactants. The developed detergent due to the content of ethanol, glycerin and hydrogen peroxide has antiseptic properties, which is a competitive advantage among analogues. Such utilization of ethanol-containing soapstock makes the process of oil neutralization environmentally safe and economically viable

Keywords: waste of oil and fat industry, alkaline neutralization of oils, water – glycerin – ethanol system, soapstock, hand cleaning paste, washing ability

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PROCESSING OF ETHANOL-CONTAINING WASTE OF OIL NEUTRALIZATION IN THE TECHNOLOGY OF HAND CLEANING PASTE

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1. Introduction

Oil refining is a complex multistage process based on chemical and physicochemical methods of processing oils in order to improve their quality and technological properties. The refining process is characterized by the openness of the resource cycle, which leads to the formation and accumulation of waste, in particular, hydro-processed oil sludge, soapstock, waste bleaching clay and filter powders, deodorization distillates that require further processing or disposal. It should be noted that the waste contains a significant amount of valuable triacylglycerols and their derivatives, but their processing requires additional equipment, reagents and energy [1]. Therefore, in the oil processing industry around the world, a promising and priority research area is to reduce the harmful impact of waste on the environment, as well as to improve the methods of their processing for the production of valuable raw materials [2, 3]. This increases the compliance of production facilities with environmental requirements and the economic efficiency of the technology.

Alkaline neutralization of oils is a special technological treatment in order to reduce the content of free fatty acids in them. The neutralization of oils and fats is based on the selective ability of free fatty acids to interact with alkalis and form fatty acid salts – soap. The bulk of the liquid waste of oil refining is formed at the stage of neutralization in the form of an aqueous solution of neutralized fatty acids (soaps) and an unreacted alkali. This liquid waste is called soapstock. It should be noted that soapstock contains a significant amount of valuable triacylglycerols (total fat content ranges from 8 to 45 %, depending on the refining method) [1].

Soapstock has a complex and unstable composition and is a direct-type emulsion system. Soapstock contains water, soap formed as a result of saponification of free fatty acids and neutral fat, trapped neutral fat, phospholipids, waxy substances, natural dyes, and an unreacted alkaline agent. In addition, during the pretreatment of the oil with phosphoric acid, its sodium salts pass into the soapstock. The composition and technological properties of soapstock depend on the nature of the oil being refined, its impurities, the method of neutralizing free fatty acids, and the composition of the alkaline agent. Also, the structure and viscosity of soapstock vary depending on the concentration of the alkali solution: the higher the content of neutralized fatty acids and neutral triglycerols in the soapstock, the higher the viscosity of the waste [1].

The use of soapstock as a raw material for new products entails a reduction in the cost of refined oils and at the same time solves a number of environmental problems. There are a number of ways to process soapstock into valuable raw materials [1]. Each of the existing methods has its own advantages, but they have the same disadvantage – low environmental performance indicators due to the use of aggressive media, including concentrated acids, and a low yield of fatty products. As a result, a significant amount of polluted wastewater is formed, which contains useful components of soapstock.

An urgent task is to develop environmentally friendly and cost-effective methods for obtaining competitive raw materials from soapstock without the use of aggressive reagents and a large amount of polluted wastewater. This is possible due to the production of concentrated soapstock with a high content of neutralized fatty acids and at the same time a low content of neutral triacylglycerols. Recycling of this kind of oil neutralization waste will improve the environmental safety of the process and reduce the cost of the products obtained.

2. Literature review and problem statement

In [4], the composition of soapstock obtained by a continuous method with the distribution of phases on separators when oil is neutralized with concentrated alkali solutions (130–200 g/l) has been analyzed. It has been shown that such soapstock contains up to 40 % of total fat, therefore, has a high viscosity and is inactive. In addition, there remains an unresolved issue related to the high content of neutral triacylglycerols in soapstock, that is, significant oil losses during refining. An option to overcome these disadvantages can be using a continuous method of neutralizing oils in a soap-alkaline medium with weak alkali solutions (30–60 g/l), used in [5]. It is described that soapstock obtained by this technology contains up to 15 % saponified fatty acids and neutral triglycerols, is easily mobile and therefore transportable. A separate disadvantage of this neutralization method is the formation of diluted soapstock (mass fraction of neutralized fatty acids not exceeding 10 %), which requires further concentration by salting out the soap with sodium chloride or evaporation under vacuum, which is economically inexpedient. In order to obtain concentrated soapstock by neutralizing oils in a soap-alkaline medium, it is necessary to create conditions for the most effective phase separation between neutral fat and an aqueous solution of neutralized fatty acids. The authors of [6] solved this problem and proposed a scientifically substantiated method for alkaline neutralization of oils in a soap-alkaline medium in the water – glycerin – ethanol solvent system. This method ensures that there is no loss of neutral fat during neutralization, as well as the production of concentrated soapstock (mass fraction of fatty acids 28–34 %), which are transportable due to their mobility. Further research of ethanol-containing soapstocks obtained by the described technology and the search for ways to process them are of interest.

The work [7] describes the traditional methods of soapstock processing. This is the demulsification of soapstock components followed by phase distribution into fat-containing and soap-containing phases or decomposition of soapstock triacylglycerols into fatty acids, followed by processing of the mass without separation. It should be noted that these methods of soapstock processing do not meet modern technological, environmental and economic requirements for waste processing. The reason for this is the use of aggressive chemicals, in particular, concentrated inorganic acids, which require special equipment to carry out the processing.

Fatty acids are a particularly valuable component of soapstock, which are used in many industries. The work [8] describes the use of fatty acids in the synthesis of food additives, in particular, foam stabilizers, components for glazing, defoamers. The works [9, 10] describe the use of fatty acids, respectively, as components of cosmetics, in particular, surfactants, and in soap making. But the raw materials for such industries must be of a high degree of purification, which is extremely difficult to implement using soapstocks with a constantly changing composition.

As shown in [11, 12], fatty acids from soapstock are widely used in the production of biodiesel fuel. The work [13] describes a method for improving the production of biodiesel from soapstock using enzymatic catalysis. The authors of [14] have shown the possibility of using soapstock in the production of aromatic additives to gasoline by catalytic pyrolysis of acidified soapstock. It must be said that the aforementioned technologies have a number of disadvantages, because they consist of many stages and require special equipment, which increases the cost of the products obtained.

The authors of [15] propose to use the wastes of alkaline neutralization of oils as a carbon source in a nutrient medium for the production of exopolysaccharides by Acinetobacter strains. This direction is justified, but such microbiological facilities are not able to process large volumes of soapstock.

An innovative method of soapstock processing, described in [16], is the removal of biologically active substances specific to certain oils, in particular, γ-oryzanol from rice bran oil soapstock. The disadvantage of this method is the significant loss of fatty acids and neutral triglycerols during the process, which increases the cost of the target product.

It should be noted that the authors of [17], as part of the continuation of the studies described in [6], proposed an environmentally sound technological solution for the processing of soapstock in the system of selective solvents water – glycerin – ethanol into liquid soap. The work investigated the quality indicators of soapstock (dynamic viscosity, foaming ability, foam stability and detergent ability) in comparison with samples of commercial detergents. It has been proven that the developed product is not inferior to commercial analogues in terms of these indicators. The paper also substantiates rational conditions for discoloration of the resulting oil neutralization waste with hydrogen peroxide in order to improve the color characteristics.

Based on the above, it is of interest to continue research [17] in the direction of expanding the range of competitively attractive detergents based on ethanol-containing soapstock for economic compensation of costs for the process of neutralizing oils in the system of selective solvents. In particular, in recent years, special hand cleaning pastes have become especially popular among car service workers, turners, millers, etc. It should be noted that these detergents have conflicting data on the cleaning effectiveness and safety of exposure to the skin, as well as a fairly high cost [18]. The above gives grounds to assert that it is expedient to conduct research on the possibility of processing ethanol-containing soapstock to obtain a competitive detergent – hand cleaning paste, which should find demand among the target group of consumers.

3. The aim and objectives of the study

The aim of the work is to develop a method for processing ethanol-containing soapstock in the technology of hand cleaning paste.

The following objectives were set to achieve this aim:

– to determine the rational concentration of ethanol-containing soapstock in the formulation of hand cleaning paste as a source of surfactants;

– to experimentally investigate the effect of the content of such components as thickener and structurant on the consistency of the paste and determine their optimal concentrations;

– to compare the quality indicators of the developed ethanol soapstock-based hand cleaning paste with a commercial analogue.

4. Materials and methods for processing ethanol-containing waste of oil neutralization

4. 1. Materials and equipment used in the experiment

The following materials were used for research:

– decolorized ethanol-containing soapstock according to the results of [17];

– aerosil according to GOST 14922;

– cetylstearyl alcohol 30/70 according to normative documents;

– Akucell AF 3265 carboxymethyl cellulose according to normative documents;

– sunflower oil according to DSTU 4492;

– Café flavoring according to normative documents.

Ethanol-containing soapstock according to the results of [6, 17] is a waste of alkaline neutralization of oils in the soap-alkaline medium in the system of WGE solvents (water, glycerin, ethanol in the mass ratio of 30:30:40, respectively). Soapstock is decolorized by adding 0.8 % hydrogen peroxide. The mass fraction of fat in soapstock is 46.8 %, including the mass fraction of neutral lipids – 0.2 %, fatty acids – 46.6 %.

4. 2. Method of hand cleaning paste production

The production of hand cleaning paste involves sequential mixing of water; discolored soapstock; carboxymethyl cellulose; a premixed mixture of sunflower oil and cetylstearyl alcohol; flavoring previously dissolved in water; ground coffee and aerosil. The mixing temperature of the components is 60 °C. Mixing is carried out until a homogeneous mass is formed.

4. 3. Methods for examining samples of ethanol-containing soapstock, soapstock-based hand cleaning paste, and commercial analogue

Determination of the washing ability of solutions of ethanol-containing soapstock, samples of soapstock-based hand cleaning paste and commercial paste consisted in a comparative assessment of the washing ability of the test composition and the reference composition in a laboratory washing machine. Washing ability is determined by the ratio of the degree of pollution removal with a solution of the test detergent to the degree of pollution removal with a solution of the reference composition on the same fabrics, under the same washing conditions. The laboratory washing machine is a water thermostat containing an element consisting of a rotor with holes for installing containers with test solutions. The reference composition is a solution of sodium alkylbenzenesulfonate (0.1 %) and sodium tripolyphosphate (0.2 %) in water. The washing ability of the samples of ethanol-containing soapstock, soapstock-based hand cleaning paste, and commercial hand paste was tested on cotton cloth polluted with a pigment-oil polluting mixture. The polluting mixture consisted of soot (3.00 %), DS-10 synthanol (0.03 %), oleic acid (28.00 %), sunflower oil (35.00 %), vaseline oil (19.00 %), powdered casein (1.00 %), 25 % ammonia (14.00 %).

The effective viscosity of the samples of soapstock-based hand cleaning paste and commercial hand cleaning paste was determined on a Rheotest 2 rotational viscometer (Germany) at room temperature. This instrument measures the viscosity of non-Newtonian fluids in the coaxial cylinder system. Before the determination, the samples of detergents were kept for 2 hours at a temperature of 20...22 °C.

Determination of the foaming capacity of the samples of soapstock-based hand cleaning paste and commercial hand cleaning paste was carried out according to the Ross-Miles method. The method consists in determining the height of the column of foam formed during the free fall of 200 cm^2 of an aqueous solution of the test detergent from a height of 900 mm onto the surface of the same solution. Foam stability is defined as the ratio of the foaming capacity after 5 minutes to the original foaming capacity.

4. 4. Experimental design and statistical processing of research results

To determine the rational concentrations of the constituents of the hand cleaning paste based on ethanol-containing soapstock for the consistency of the product, the experimental design method was used. For experimental design and processing of the results, mathematical methods were applied using the Misrosoft Office Excel 2003 and Statistica software packages. The experiments were repeated three times. The relative error at the given degree of probability P=95 % did not exceed:

– 2 % in determining the washing ability of soapstock solutions, samples of soapstock-based hand cleaning paste and commercial paste;

– 3 % in determining the effective viscosity of the samples of soapstock-based hand cleaning paste and commercial paste;

– 4 % in determining the foaming ability of the samples of soapstock-based hand cleaning paste and commercial paste.

Table 1

Model formulation for hand cleaning paste

Ingredient	Content, %
Soapstock in the WGE system	40.0
Natural ground coffee	15.0
ARD-1 aerosil (E 551)	6.0
Akucell AF 3265 (E 466) carboxymethyl cellulose sodium salt	0.2–0.8
Cetylstearyl alcohol 30/70	0.7–2.8
Sunflower oil	1.0
Flavoring	0.2
Water	34.2–36.9

5. Research results on the processing of ethanol-containing waste of oil neutralization in the technology of hand cleaning paste

5. 1. Determination of the rational concentration of ethanol-containing soapstock in the formulation of hand cleaning paste

The dependence of the washing ability of decolorized ethanol-containing soapstock on its concentration in an aqueous solution (in the range of 20...50 %) and the temperature of interaction with the polluted material (in the range of 10...40 °C) was investigated. The results are shown in Fig. 1.

It has been found that the rational concentration of ethanol-containing soapstock in an aqueous solution in terms of effective washing ability of 92–100 % is 40 % at a temperature of interaction with the polluted material of 25–40 °C. The specified temperature range is the most comfortable when washing hands. A model formulation for hand cleaning paste is proposed, which is presented in Table 1.

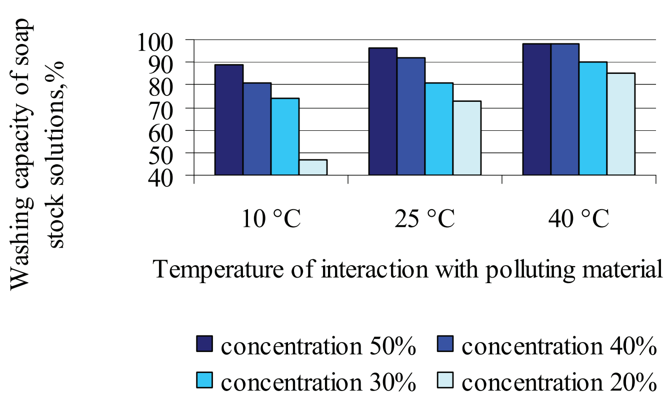

Fig. 1. Dependence of the washing ability of decolorized ethanol-containing soapstock on its concentration in an aqueous solution and the temperature of interaction with the polluted material

Hand cleaning paste based on ethanol-containing soapstock should be used for washing hands polluted with grease, oil products, soot, rust, and the like. Given this, it is necessary to ensure the plastic consistency of the paste due to the presence of mainly natural ingredients, and not only effectively cleansing the skin of the hands, but also having a protective and emollient effect. The problem was solved by using the mixture of abrasives – ground coffee and aerosil, carboxymethyl cellulose thickener, cetylstearyl alcohol structurant and emollient, sunflower oil emollient. The ingredients of the paste must provide moistening, nourishment and protection to the skin of the hands from the harmful effects of pollutants.

It is worth noting that as a component of hand cleaning paste, we propose the reuse of coffee grounds, which is a waste of instant coffee enterprises.

5. 2. Study of the effect of thickener and structurant content on paste consistency

The regularity of the effect of the content of carboxymethyl cellulose thickener and cetylstearyl alcohol structurant and emollient on the consistency of the paste was investigated. To determine the dependence of the effective viscosity of hand cleaning paste on the concentration of the above ingredients, a multifactor regression method was chosen with the construction of the corresponding response surface using the full factorial experiment method. The concentration of carboxymethyl cellulose was varied in the range of 0.2...0.8 % of the paste mass with a step of 0.2 %. The concentration of cetylstearyl alcohol was varied in the range of 0.7...2.8 % of the paste mass with a step of 0.7 %. The effective viscosity of the paste samples obtained during the experiment was in the range of 10...45 Pa·s. With the help of mathematical processing of experimental data, the equation of the above dependence was obtained, which is a model of two-factor polynomial regression of the second degree, which has the form:

$$V_e\left(c_{kmc},c_{csa}\right)=-9.375+48{,}4375\cdot c_{kmc}+13.8393\cdot c_{csa}-$$
$$-23.4375\cdot c_{kmc}^2+3.2143\cdot c_{kmc}\cdot c_{csa}-1.9133\cdot c_{csa}^2, \quad (1)$$

where $V_e(c_{kmc},c_{csa})$ – effective viscosity of the hand cleaning paste; c_{kmc} – carboxymethyl cellulose content, % (in the range of 0.2...0.8 %); c_{csa} – cetylstearyl alcohol content, % (in the range of 0.7...2.8 %).

Using the Student's test, the significance of the individual coefficients of the regression equation was checked by testing the hypothesis that the parameters of the equation were equal to zero. When evaluating individual regression coefficients, the absolute value of the Student's test was calculated and compared with the corresponding critical theoretical value at a given level of significance and the number of degrees of freedom for multiple regression (df=13). In the case when the calculated value of the Student's test was greater than the theoretical value, the hypothesis of the equality of the equation parameter to zero was rejected and, at a given probability, the value of a certain coefficient of the regression equation was recognized as significant. Otherwise, the coefficient of the regression equation was considered insignificant and excluded. The results of the analysis of the significance of the coefficients of the equation of the obtained regression are shown in Table 2.

The completeness of the effect of the content of the selected ingredients on the effective viscosity of the paste was estimated using the coefficient of determination R^2, which in this case is

0.90. This allows us to conclude that variations in the thickener and structurant content have a significant effect on variations in the effective viscosity of the model paste samples. In turn, the significance of the regression model was determined by comparing the calculated Fisher's test (F(2.13)=36.188) with its critical table value (F_{table}(2.13)=3.80) at a significance level of p=0.05 and the number of degrees of freedom df_1=2 and df_2=13. The obtained result of the analysis allowed us to recognize the value of the coefficient of determination R^2=0.90 as significant, and the model as meaningful.

Table 2

Results of the analysis of the significance of the coefficients of the equation of the model of the dependence of the effective viscosity of the paste on the thickener and structurant content (1)

Data for determining the significance of the coefficients of the equation	Equation coefficient at variable		
	Intercept	c_{kmc}	c_{csa}
Equation coefficient value	–9.375	48.4375	13.8393
Calculated absolute value of the Student's test t (13)	–4.11788	4.55188	7.18719
Critical table value of the Student's test t_{table}(13)	2.160		
Probability of the null hypothesis for the coefficient of the regression equation (*p-level*)	0.001212	0.000543	0.000007
Conclusion about coefficient significance	Meaningful	Meaningful	Meaningful

The surface of the dependence of the effective viscosity of model samples of hand cleaning paste on the content of thickener and structurant is shown in Fig. 2.

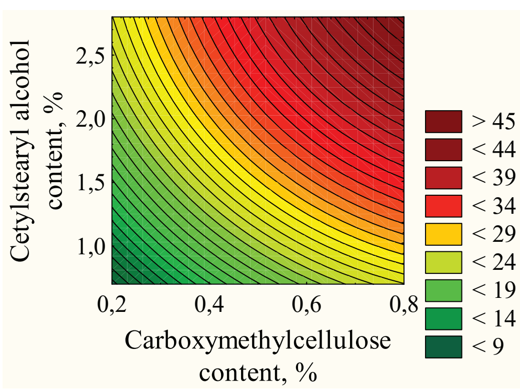

Fig. 2. Dependence of the effective viscosity of model samples of soapstock-based hand cleaning paste on the thickener and structurant content

As a result of the studies carried out, the ranges of the ratios of the selected ingredients in the formulation of the hand cleaning paste were determined, in which the effective viscosity at room temperature is in the range of 30–35 Pa·s. In addition, in the considered range of ingredients content, such a ratio of carboxymethylcellulose (0.4...0.6 %) and cetylstearyl alcohol (1.8...2.0 %) was chosen, which ensures the creation of a plastic structure of the paste with a spectacular glossy surface. The survey has shown that the consistency of detergent pastes with a reasonable content of carboxymethyl cellulose and cetylstearyl alcohol is perceived by consumers as the most pleasant, creamy, not too thick and not too liquid.

The effective viscosity of the sample of hand cleaning paste, containing 0.5 % carboxymethyl cellulose and 2.0 % cetylstearyl alcohol, of 32 Pa·s was experimentally determined.

5. 3. Comparison of quality indicators of the developed hand cleaning paste with the commercial analogue

The quality indicators of the ethanol-containing soapstock based hand cleaning paste samples were evaluated in comparison with the sample of the "Primaterra Automotive" commercial hand cleaning paste, made under the manufacturer's regulations. The data obtained are shown in Table 3.

Table 3

Quality indicators of hand cleaning paste based on ethanol-containing soapstock (1) and "Primaterra Automotive" commercial hand cleaning paste

Indicator	Paste (1)	Paste (2)
Effective viscosity at 20...22 °C, Pa·s	32.0	34.0
Foaming capacity, mm	23.0	27.0
Foam stability, %	62.0	51.0
Washing ability, %	92.0	95.5

It was found that the viscosity of the sample of soapstock-based hand cleaning paste (32 Pa·s) slightly differs from that of the sample of a similar commercial paste (34 Pa·s), which meets modern trends in consumer preferences for consistency. The foaming ability and foam stability of the developed paste sample almost coincides with the foaming ability and even exceed the foam stability of the commercial analogue paste sample. The washing ability of the sample of the developed paste is only 2.6 % lower than that of the commercial one.

It should be noted that some of the components of raw materials for the developed paste are antiseptics, namely ethanol, glycerin and hydrogen peroxide. It is likely that these components, being in a complex, enhance and stabilize the antiseptic effect of each other. Ethanol leads to the denaturation of structural and enzymatic proteins of microbial cells, fungi and viruses. But its disadvantages are the lack of a sporicidal effect, the ability to fix organic pollutants, a rapid decrease in concentration due to evaporation. Combined ethanol-based products are devoid of such disadvantages. Glycerin enhances the washing ability of sodium salts of fatty acids and is also used to soften the skin. Antiseptic and preserving properties of glycerin are associated with its hygroscopicity, which promotes dehydration of microbial cells. Hydrogen peroxide causes destruction of the bacterial cell membrane and is an effective and affordable disinfectant and antiseptic agent [19, 20]. Thus, the hand cleaning paste based on ethanol-containing soapstock, due to its components, has antiseptic properties, which is a competitive advantage among analogues.

6. Discussion of the research results on the processing of ethanol-containing waste of oil neutralization in the technology of hand cleaning paste

Analysis of the dependence of the washing ability of the decolorized ethanol-containing soapstock on its concentration in an aqueous solution and the temperature of interaction with the polluted material (Fig. 1) suggests the following:

– concentrated soapstock (50 % aqueous solution) exhibits a satisfactory washing ability even at low temperatures (10 °C);

– at higher temperatures (20–40 °C), a high washing ability is also observed in a more diluted soapstock (40 % aqueous solution), which makes it possible to recommend such a concentration in the composition of hand cleaning paste when using a detergent at a temperature of 25 °C and above.

Analysis of the effect of the thickener and structurant content on the consistency of the paste (Table 1) allows us to state the following:

– in the composition of hand cleansing paste based on ethanol-containing waste of oil neutralization, it is advisable to simultaneously use the carboxymethyl cellulose thickener (E 466) and cetylstearyl alcohol structurant, which has emollient properties. This complex of ingredients affects not only the effective viscosity of the developed product, but also the plastic properties;

– in the developed formulation of the hand cleaning paste, the effective ratio of carboxymethyl cellulose (0.4...0.6 %) and cetylstearyl alcohol (1.8...2.0 %) is determined, which provides positive characteristics of the consistency of the detergent, which is presented in Fig. 2.

The obtained mathematical dependence (1) is expedient from a practical point of view. The regression equations allow you to adjust the content of thickener and structurant in the formulation of hand cleaning paste based on ethanol-containing soapstock, depending on the consumer's viscosity requirements. However, it should be noted that the mathematical relationship (1) does not take into account the effect of the content of fatty acid salts in ethanol-containing waste on the consistency of the resulting paste. Within the framework of this study, this ambiguity has not been resolved. This is the task of further research, which, in particular, should be focused on identifying the overall effect of the complex of components on the technological characteristics of the paste.

Comparative analysis of the quality indicators of hand cleaning paste based on ethanol-containing soapstock and the commercial analogue (Table 3) suggests the following:

– hand cleaning paste containing soapstock is a detergent based on natural ingredients – sodium salts of fatty acids, which are biodegradable. While modern liquid detergents, in particular, the commercial analog of hand cleaning paste, contain sodium lauryl sulfate (or laureth sulfate) as the main surfactant, which has a negative irritating effect on the skin;

– the developed hand cleaning paste is not inferior to its commercial analogue in terms of effective viscosity, foaming ability, foam stability and washing ability.

Currently, no description of commercial analogues of this development has been found. Thus, the developed method of processing ethanol-containing waste of oil neutralization in the technology of hand cleaning paste makes it possible to obtain a competitive detergent. This should contribute to the introduction of environmentally friendly neutralization technology in the oil and fat industry, described in [17], as well as the effective use of oil and fat industry waste, improving the environment, increasing the profitability of oil refineries. The data obtained should be of interest both for oil and fat enterprises, and for the household chemicals industry in the production of detergents.

The limitations inherent in this study are worth noting:

– the high ethanol content in the waste of oil neutralization (24 %) according to [17] necessitates additional requirements for labor protection at enterprises involved in processing, in particular, in the field of fire and explosion safety of technological processes;

– the rational content of ingredients for hand cleaning paste with the use of ethanol-containing soapstock will depend on the requirements of the target groups of consumer-customers, so the formulation can be adjusted.

The weak point of this study is associated with the limitation of the volume of processing of ethanol-containing waste of oil neutralization into hand cleaning paste. This is due to the fact that the developed product is currently in demand only among limited groups of consumers, in particular, among car service workers, motorists, turners, milling operators, and the like. Therefore, to reduce this limitation, it is necessary to pay attention to marketing research to determine the range of potential consumers, as well as expand the range of loyal consumers.

As a disadvantage of the study, the economic aspect can be noted, namely the use of a high amount of cetylstearyl alcohol, an emollient that has a fairly high cost, in the technology of hand cleaning paste. It is worth noting that this ingredient is not commonly used in commercial paste counterparts. But based on the studies carried out, it was decided to use the specified ingredient in a reasonable concentration as it provides high organoleptic characteristics of the resulting product. The indicated raw material costs are reimbursed by the sale of the finished hand cleaning paste. The resulting paste, in addition to surfactant properties, has an antiseptic and moisturizing effect on the skin. This will help the developed detergent to gain a solid position in the market.

Difficulties in the implementation of the obtained research results may be associated with the negative attitude of the enterprise management to the implementation of innovative measures. Since investing additional funds in the purchase of atypical raw materials for the hand cleaning paste in the absence of an immediate tangible economic effect is perceived as a financial risk. This risk is well founded, since the developed mathematical model (1) requires a certain standardization of composition and quality indicators.

Considering the above, it is possible to identify the main directions for the successful development of processing of ethanol-containing waste of oil neutralization in the technology of hand cleaning pastes:

– development of fire and explosion safety requirements for technological processes at enterprises involved in the processing of ethanol-containing soapstock;

– conducting research aimed at identifying the overall effect of a complex of components on the technological characteristics of the paste;

– search for alternative emollient structurant instead of cetylstearyl alcohol to reduce the cost of the paste;

– marketing research to expand the range of loyal consumers of the developed product;

– continuation of research on the development of formulations for hand cleaning pastes of various consistencies to meet the requirements of various target groups of consumers;

– development of an effective business plan for an investment project for the processing of ethanol-containing waste of oil neutralization in the technology of hand cleaning pastes.

7. Conclusions

1. The dependence of the washing ability of ethanol-containing soapstock on its concentration in an aqueous solution and the temperature of interaction with the polluted material was studied. The rational concentration of ethanol-containing soapstock in the formulation of hand cleaning paste as a source of surfactants has been determined. In the paste technology, it is proposed to use a 40 % aqueous solution of ethanol-con-

taining soapstock, which has a washing capacity in the range of 92–98 % at a temperature of interaction with the polluted material of 25–40 °C.

2. The effect of the content of such components as carboxymethyl cellulose thickener and cetylstearyl alcohol structurant on the consistency of soapstock-based hand cleaning paste was experimentally studied. It has been determined that the concentration of carboxymethyl cellulose in the range of 0.4...0.6 % and cetylstearyl alcohol – 1.8...2.0 % ensures the creation of a plastic creamy paste structure with a spectacular glossy surface. The effective viscosity of the sample of hand cleaning paste, containing 0.5 % carboxymethyl cellulose and 2.0 % cetylstearyl alcohol, of 32 Pa·s was experimentally determined.

3. A comparative analysis of the quality indicators of the developed hand cleaning paste based on ethanol-containing soapstock with the sample of commercial analogue has been performed. The quality indicators of the developed hand cleaning paste are as follows: effective viscosity at 20...22 °C – 32.0 Pa·s; foaming capacity – 23 mm, foam stability – 62.0 %; washing ability – 92.0 %. The comparative analysis testifies to the correspondence of the quality indicators of the developed paste to the quality indicators of the "Primaterra Automotive" hand cleaning paste. In addition, the detergent obtained from ethanol-containing soapstock contains a complex of substances with a pronounced antiseptic effect, which increases the competitiveness of the product obtained.

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