Technical and economic efficiency of processing acidic wastewater from the oil and fat industry into necessary agricultural products

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Abstract. In this artist the economic efficiency of organizing the production of crude fatty acids in the fat and oil industry of Uzbekistan is presented. Cotton soapstock is a difficult-to-saponifiable oily substance, which requires a long time for its saponification. Therefore, to intensify it, it is proposed to saponify the soap stock using the ultrasonic method. The resulting crude fatty acids after the new approach led to a reduction in the cost of the product. The second problem of enterprises is the formation of acidic wastewater, which, after neutralization with an expensive reagent sodium carbonate, is discharged into the city sewerage system. Therefore, it is proposed to neutralize wastewater with carbonate phosphorite of the Central Kyzylkum. As a result, after processing the wastewater, phosphorus fertilizer was obtained. Technical and economic calculations showed that the cost of phosphorus fertilizer is only 616,978 sums or 50 US dollars per ton. Thus, in oil and fat industry enterprises it is possible to organize the production of fertilizers, a product with an additional amount.

1. Introduction

The oil and fat industry play an important role in providing the population with vital products such as butter, margarine, mayonnaise, soap, glycerin, as well as raw materials for dietary supplements. Carbohydrates are part of the basic human diet, accounting for about 70%, and the rest are fats, proteins, vitamins, macro and microelements [1]. Intermediate waste during the processing of oilseeds produces cake, meal and husk, which in turn are included in the feed ration of farm animals - poultry, livestock and fish.

Therefore, in each country the production of oil extraction and/or oil and fat enterprises has been established. However, when crude oil is refined, a sticky oily emulsion substance is formed - soapstock, the amount of which is about 9-10% of the volume of crude oil.

Judging by the production of fatty acids, phospholipids, glycerol and other substances, soap stock is a secondary resource of fat and oil enterprises, in particular soap production. Unfortunately, processing soap stock involves energy-intensive and high consumption of raw materials and material resources, which ultimately causes both environmental and economic damage to enterprises and the environment.

The fact is that the extracted soap stock from the refining process is saponified with a 40% alkali solution. Next, the saponified soap stock is fed into the decomposition process with concentrated sulfuric acid.

$$nRCOOH + NaOH = nRCOONa + H_2O$$

$$2RCOOH + H_2SO_4 = 2RCOOH + Na_2SO_4$$

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The process is accompanied at a pH of 1.5-2.0. After phase separation, the fatty phase is separated from the acidic aqueous phase. After which, the fatty phase is washed several times with water to remove traces of acid and sodium sulfate [2]. Under such conditions, it is possible to obtain post-processing fatty acids with a KOH concentration of 171 mg/g and wastewater with a P_{org} concentration of 425 mg/dm^3 and COD of 7958 mg/dm^3 [3]. Sour drainage is dark red in color with a specific odor and bitter taste [4]. The issue of recycling this waste in a rational way has not yet been resolved due to the lack of consensus between researchers and engineers in this field. Usually, to avoid exceeding the maximum permissible concentration for the concentration of harmful substances, the wastewater is diluted with industrial or drinking water, and then it is discharged into the general city sewer. In almost all factories, the process for obtaining fatty acids is identical. It differs only in minor changes in hardware and technological design.Several solutions are available to intensify and optimize the saponification process and prevent runoff from crude fatty acid production [3, 5].

This situation also applies to enterprises in Uzbekistan processing cotton grain. In the Republic, as of May 30, 2022, oilseeds were sown as the main crop, including 178,270 hectares of oilseeds, the forecast was 96% fulfilled. In particular, soybeans were sown on 21 thousand 878 hectares of corn, 17 thousand hectares of cotton between rows, and the forecast indicator in this regard was fully met. In addition, 97 thousand 449 hectares of soybeans (98 percent of the forecast), 25 thousand 654 hectares of sunflower (86 percent), 30 thousand 763 hectares of sesame (97 percent), 2 thousand 426 hectares of flax (98 percent) and 100 hectares of rapeseed are sown in the field (16.7 percent).

According to statistical data from the O'zyogmoysanoat Unitary Enterprise, oil producing enterprises produced a total annual capacity of more than 4.3 million tons of oil seeds (3.3 million tons of cotton seeds and more than 1 million tons of soybean and sunflower seeds). Cotton seeds produce 220 thousand tons of crude oil, from which approximately 20-22 thousand tons of soap stock are formed. Considering the fact that the runoff has an acidic environment and a sufficient amount of organic substances in oxidized form, including humic acids [6], phosphorus fertilizers can be obtained from it.

The work showed the possibility of using carbonate phosphorites of the Central Kyzylkum to neutralize acidic runoff. As a result, a phosphorus-containing organic fertilizer of prolonged action was obtained, agrochemical studies of which showed an increase in the yield of raw cotton by 6.7% compared to the control [7]. However, the question arises to what extent the process of neutralizing acidic wastewater from the oil and fat industry is justified by recycling it with available local materials and then obtaining a product with an additional amount.

Based on this, the purpose of this study is to evaluate the technical and economic indicators of neutralizing acidic wastewater from the oil and fat industry using phosphorite instead of expensive sodium carbonate

2. Materials and Methods

Before determining the economic efficiency, saponification process of cotton soapstock samples were saponified using the conventional method, using a 42% sodium hydroxide solution at 95°C for 120 minutes without the use of any organic catalysts or technical solutions.

In the second case, soap stock samples were saponified with a 42% sodium hydroxide solution at 95°C for 120 minutes under surface-type ultrasound using a Cavitator Ultrasonic Cleaner (USC-3L, China) at Power: 220 VAC/20 Hz. Based on usage new method, it was found that saponification time is decreased 1.2 times.

As mentioned above phosphorite from Central Kyzylkum (PCK) with composition (wt.%):P_2O_5 - 17.54; CaO - 47.75; MgO - 1.79; CO_2 - 16.5; Fe_2O_3 - 0.73; Al_2O_3 - 0.95; SO_3 - 4.06; F - 1.7; SiO_2 - 1.24; insoluble residue - 4.03; CaO: P_2O_5 - 2.72 was used to neutralize acid wastewater. For that study the acid wastewater from JCK "Urgench yog"-moy" has pH 2.0 and 2% organic matter was used [7].

Early we studied the process obtaining phosphate fertilizers based on neutralization acid wastewater by PCK. The method of neutralization was carried out as described in [4]. As a result, phosphate fertilizers containing assimilated P_2O_5 with 30.28-50.43 and 25.58-39.93%, respectively according to citric acid and EDTA, as well as up to 4.5-8.0% of organic substances were synthesized. Phosphorus fertilizer agrochemical experiments revealed a 6.7% increase in raw cotton production over the control [7–10]. It was determined that a rise in the size and weight of the bolls as well as an earlier and more synchronized ripening of the crop were the causes of the improved quality of the cotton fiber (lint).

These particular fertilizers can be used as slow release phosphate fertilizers, which are identified by the SRPF-20 beginning component ratio [7].

In a case, we have solved to calculate price cost of crude fatty acids (CFA) produced conventional and ultrasonic methods, as well as the SRPF-20 technical and economical efficiency. The consumables needed are tabulated in Table 1 and 2.

3. Results and Discussion

Nearly all of the characteristics and operations of agrocenose soils are greatly influenced by the amount and makeup of organic molecules present in these soils. Special attention should be given to the content of fertilizers and their effect on the amount of carbon in the soil because it is known that mineral fertilizers accelerate the mineralization of organic matter due to a fast change in the C:N ratio. A adequate quantity of different organic components enhances the soil's structure, creates a good water-air regime, maximizes the makeup of microbial communities, and promotes plant growth and development. Applying fertilizers containing organic materials can help soils reach their full potential in terms of nutrition and environmental benefits.

It should be mentioned that only a 1.5–3.0% increase in humus content could be achieved in a single growing season with the use of the extended fertilizers under study. Frequent application can raise soil organic matter levels, even though the change is not regarded as significant (at $P<0.05$). The nitrogen content of the mineral soil makes up no more than 1% to 3% of the total. Ammonia, a byproduct of microbial fixation in the soil, is the form in which oxidized or bonded nitrogen reaches the soil through fertilizers and precipitation. Under specific circumstances, the mineralization of soil-based organic nitrogen-containing molecules occurs concurrently [7].

The entire range of ammonium forms of nitrogen in the experiment was limited to 1.46–3.61 mg N–NH3. The maximum amount of ammonium ions was only detected in the budding phase of the control variation, 5.89 mg N–NH3 in 100 g of soil. It is crucial that the amount of ammonium ions in the soil treated with SRPF-20 and SRPF-40 be lower than K1 (by 6-75%) during all stages of development.

It should be mentioned that only a 1.5–3.0% increase in humus content could be achieved in a single growing season with the use of the extended fertilizers under study.

Table 1. Cost coefficients for obtaining 1 ton of crude fatty acid during the processing of cotton soap stock and their cost

Source materials (without VAT)	Conventional production of crude fatty acids in the traditional way			Ultrasonic production of crude fatty acids		
	Amount	Price	Sum	Amount	Price	Sum
Soapstock, kg	216.64	3035.70	657654.05	216.64	3035.70	657654.05
Caustic soda, kg	18.44	11121	205071.24	18.44	11121	205071.24
Sulfuric acid, kg	54.47	422.2	22997.23	54.47	422.2	22997.23
Water, m^3	0.29	5013.1	1453.80	0.24	5013.1	1203.14
Steam gcal/kg	0.29	147701.2	42833.35	0.24	147701.2	35448.29
Electricity, kW	8.37	524.3	4388.39	6.98	524.3	3659.61
Total sum			934 398.06			926033.56
Costs for processing CFA (30%) in the conventional way			1214717.48			
Cost for processing CFA (25%) in ultrasonic way						1 157 541,95
In terms of 1 t RFA			7 180 424.69			6 842 449.32

Table 2. Cost coefficients for the utilization of 1 ton of acidic waste from the production of crude fatty acids using carbonate phosphorite during the processing of cotton soap stock and their cost

Source materials (without VAT)	When neutralized with sodium carbonate			When neutralized with carbonate phosphorite		
	Amount	Price	Sum	Amount	Price	Sum
Na_2CO_3, kg	134	1000	134 000			
Phosphorite, kg				200	600 000	120 000
Costs for SRPF-20 (35%)						162 000
Cost of 1 ton of 100% P_2O_5 in SRPF-20, sum						4 618 015
Total cost of 1 ton SRPF-20, sum						616 978

When calculating the technical and economic indicators of CFA and SRPF-20, prices for soap stock, caustic soda, sulfuric acid, phosphorites of the Central Committee, and energy were taken at the selling cost, taking into account the railway tariff, but without VAT and as of 05.05 .2023.

For that, we need to know CFA cost price from vegetable oil production. At oil and fat industry enterprises for processing soap stock, processing costs (including labor costs, indirect costs of materials, production overhead costs,

etc.) of initial raw materials amount to 30 and 25% respectively as processing by conventional and ultrasonic ways. At the same time, recycling wastewater to produce PCK costs 35% for processing.

The cost of CFA was compared with the cost of CFA obtained at Urganch yog'-moy JSC. Calculations have shown that the cost of 1 ton of CFA based on ultrasonic way is 6 842 449.32 sums (or 539 US dollars recalculated) which is 337,975 sums cheaper compared to the cost of 1 ton of CFA (7 180 424.69 sums or or 539 US dollars recalculated) produced at Urganch yog'-moy JSC.

Currently, on the Republican Exchange, the selling price of 1 ton of single superphosphate at JSC Elektrokimyozavod (14% P_2O_5 and 1.5% N) and JSC Indorama Kokand (17% P_2O_5 and N 1.5) is 1,500,000 and 2,800,000 sum, respectively (or 118110,24 and 2 20472,44 US dollars recalculated). The cost of 1 ton of 100% P_2O_5 in them is 10,714,286 and 16,470,588 sums, respectively.

After neutralization and processing of CK phosphorites at SRPF-20, the cost of 1 ton of this types of products is 616,978 sums. Whereas the cost of 1 ton of 100% P_2O_5 in SRPF-20 is 4 ,618,015 sums.

Comparative data show that the cost of 1 ton of SRPF-20 is 883,022 and 2,183, 022 sums cheaper, respectively in compared with superphospates from JSC Elektrokimyozavod (14% P_2O_5 and 1.5% N) and JSC Indorama Kokand (17% P_2O_5 and N 1.5).

4. Conclusions

Thus, the possibility of organizing the processing of difficult-to-saponifiable cotton soap stock using an ultrasonic method has been shown. As a result, two main problems are solved:

1. The time for saponification of soap stock is reduced by 1.2 times, as a result of which energy and material resources are saved
2. The use of carbonate phosphorite from the Central Kyzylkum instead of sodium carbonate solves the problem of neutralizing wastewater and at the same time obtaining activated phosphorus fertilizers

As a result of the above, the cost of CFA obtained by ultrasonic method is 6,842,449.32, which is 337,975 soums cheaper compared to the traditional method of processing soap stock at Urganch yog'-moy JSC.

As for the utilization of acidic juice with carbonate phosphorite, it is possible to improve the environmental and social situation of the enterprise, achieve an economic effect, not only from obtaining cheap fertilizer, but also from its positive effect on the productivity of agricultural crops.

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