Study of the hydrodynamic structures of opposite flows of phases during the final distillation of miscella of vegetable oil

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Abstract. Oil production technology includes a large number of processes in its cycle, such as extraction, pressing, extraction, evaporation of miscella is one of the most complex and energy-intensive processes. Intensification and optimization of these processes, increasing the efficiency of distillation units is a very urgent task. The study of heat and mass transfer in gas-liquid streams, taking into account the hydrodynamic situation in distillation units, makes it possible to objectively assess the advantages and disadvantages of devices, contributes to more targeted developments in the field of rational design of technological units. An increase in the productivity and optimization of the distillation processes of oil miscalls can be achieved by organizing a rational structure of phase flows, which ensures the maximum gradients of temperatures, concentrations and intensification of heat and mass transfer.

1. Introduction

Today in the world there is a high growth in the production of vegetable oil, which is one of the leading in the food production industry. Final distillation in an extraction system in vegetable oil plants is one of the most complex and energy intensive processes. Therefore, the introduction of intensive methods necessary for the production of vegetable oils, the creation of modern equipment and technology is of scientific and practical importance [1].

The world pays great attention to research on the preparation of raw materials, processing processes and intensive industrial development of vegetable oil production, the creation of equipment and technologies that meet modern requirements. In particular, large-scale scientific research is being carried out to study the hydrodynamic structures of flows and to create a modern, highly efficient method and installations for the final distillation of vegetable oils.

The production of vegetable oil from oil-containing crops at the factories of the republic is carried out in two ways: pressing and extraction, which are accompanied by various technologies, using a complex of mechanical, hydraulic, heat exchange, mass transfer processes.

Most of the vegetable oils in the standards include the following characteristics: mass fraction of moisture and volatile substances, acid number, color number, iodine number, mass fraction of non-fatty impurities, fluorine-containing and unsaponifiable substances [2].

The distillation process of oily miscella is one of the main processes in the extraction technology for the production of vegetable oils [3].

The quality of the obtained vegetable oil during the distillation of miscella depends both on the technological parameters of the process - the final temperature of the oil and the duration of the
processing of the miscella, and on the content and composition of lipids extracted during extraction from the extracted material - phospholipids, carotenoids and other fat-soluble pigments, as well as on the content of vitamins and provitamins, as well as lipid oxidation products, etc. The thermal effect on these lipid groups leads to their change and not only reduces the quality of the oil, but also significantly complicates the distillation of miscella.

Although there is a lot of research work on vegetable oils that oxidize when exposed to moderate temperatures, there is not a lot of research work on the effects of high temperatures. Therefore, these unresolved issues should still be investigated.

Methods Distillation is the process of heat treatment of a solution of oil in a solvent. It consists in transferring the solvent into a gaseous state, removing vapors and their condensation. The solvent should be removed from the oil as completely as possible at the lowest temperatures in the shortest possible time. Distillation is carried out in two periods: preliminary and final distillation.

In the first period, evaporation is carried out, which obeys all the known laws of this process and can be carried out both at atmospheric pressure and under vacuum. During this period, miscella should reach such a concentration that the boiling point does not exceed 100°C [4].

In the second period, hot water vapor is additionally applied, therefore, the laws of the process are different. The system will consist of three components: solvent, oil, water, which represent three phases: two liquid (miscella, water) and one vapor - solvent. According to the phase rule, such a system has two degrees of freedom. This means that without disturbing the equilibrium, you can change two parameters, in this case - the total pressure and the concentration of miscella.

Usually the process of distillation of vegetable oils is carried out in the modes of spraying, flowing and lifting in a film and distillation in a layer.

During spray distillation, the miscella exits the nozzle in the form of a jet, which is crushed into droplets. The interface between the liquid and gaseous phases significantly increases, which increases the productivity of the process and reduces its duration. According to hydrodynamic changes in the liquid phase, three periods are conventionally distinguished: the formation of individual drops, the development of turbulence within individual drops and the attenuation of this process. In the gas phase, the state and properties of vapors are the same at any point due to mixing.

For preliminary distillation by spraying, only one period is characteristic — boiling; in final distillation by spraying, as a rule, both boiling and evaporation.

There are some difficulties in the process of distillation of a solution of vegetable oil in a solvent, for example, the gas solvent is removed from the oil in the shortest possible period of time at minimum temperatures.

Distillation is the separation of a mixture of mutually soluble components due to the evaporation and condensation of vapors enriched in a highly volatile component. During distillation or simple distillation, molecules leaving the evaporation surface move in the same direction until they reach the condensation surface. The separation of components depends on many factors and, first of all, on the physicochemical properties of the mixture, the hydrodynamics of the phases, the geometric characteristics of the apparatus and the conditions of their operation.

The final distillation process is carried out in different designs of apparatuses. The hydrodynamic structure in the apparatus is created by its configuration as, the presence of partitions and their arrangement, the diameter of the apparatus, the number of pipes and the number of strokes, the flow rate of the flows. The study of the hydrodynamics of flows of counter phases in heat and mass transfer apparatus was carried out by the authors in the works [5].

2. Methods
"Study of the hydrodynamic structures of countercurrent flows of phases during the final distillation of miscella of vegetable oil" shows the studies carried out to determine the residence time of the product in the apparatus. For this, a technique for conducting experiments has been developed and an experimental installation has been created for studying the hydrodynamic structures of phase flows in the process of final distillation [6-8].
In the experimental setup to increase the kinetic energy of air in the spray nozzle 1, a nozzle with a diameter $D = 2 \ldots 4$ mm is installed. The length of the confuser is 181 mm, the diameter of the inlet area is 218 mm, and the diameter of the outlet area is 40 mm. The length of the diffuser is 396 mm, the diameter of the inlet area is 40 mm, and the diameter of the outlet area is 72 mm.

The experimental setup consists of a tank 2 for containing water used as a liquid phase; compressor 3 for creating parameters of live steam; rotameter 4, designed to measure the flow rate of air supplied from the compressor; reservoir 5 for containing the indicator solution; separator 7 for separating the liquid and gas phases; containers 8 and 9 ariometer for measuring the density of the solution.

The fourth chapter of the dissertation "Technological part" describes the device and the principle of operation of the proposed apparatus for the final distillation of vegetable oil miscella based on multi-stage spraying.

Before the start of the experiments, a 20% sodium chloride solution is prepared in advance, which is then poured into a container 5 for the indicator, while the valve 11 is in the closed position (figure 1).

The principle of operation of the experimental setup boils down to the following: at the input of the setup operating in a steady-state mode, a pulsed disturbance of the concentration of the indicator and, at the same time, air is fed to the nozzle 1, while the tank 2 provides a uniform supply of the tracer. Air is supplied by compressor 3 through flow meter 4 to the middle part of the nozzle. The response curves at the inlet of the spray nozzle are obtained by sampling at equidistant intervals and measuring the concentration of the tracer in the liquid phase.

In the spray nozzle with the help of the compressor 3 through the flow meter 4 hot water vapor is supplied, which is used as air. Next, observe the figure of the flow meter; using the valve 12 of the compressor 3, the required air flow is set. Using a water supply line, container 2 is filled with water until a predetermined level is reached. Opening the valve 10, set the required water flow. Then measure the flow of water with a measuring glass and a stopwatch. When the valve is closed, the required liquid level in the dispenser is collected. By regulating the compressor valve 12, the air flow rate set at the beginning of the experiments is set. Slowly opening the valves, the installed separator achieves such a flow rate at which the previously set level would not change. Having measured the flow rate of water through the valves with the help of a measuring cup and a stopwatch, they check the constancy of the inflow and outflow of liquids.

![Figure 1. Experimental setup for studying the hydrodynamic structures of opposite phases.](image-url)
3. Results and discussion
Below are the values of the change in the concentration of the solution over time. The experiments were carried out at different values of the air flow rate (table 1).

**Table 1.** Change in the concentration of the solution when leaving the apparatus.

| Output concentration at different values of air flow rate, $G_{air}$, m$^3$/s | Time, s |
|---|---|---|---|---|---|---|---|---|---|
| 0.002 | 0 | 1 | 1 | 1 | 1.01 | 1.11 | 1.14 | 1.1 | 1.05 | 1.01 | 1 |
| 0.0025 | 0 | 1 | 1 | 1 | 1.02 | 1.12 | 1.08 | 1.05 | 1.03 | 1.01 | 1 |
| 0.004 | 0 | 1 | 1 | 1 | 1.05 | 1.1 | 1.17 | 1.08 | 1.06 | 1.02 | 1 |
| 0.0045 | 0 | 1 | 1 | 1 | 1.07 | 1.14 | 1.1 | 1.04 | 1.03 | 1.02 | 1 |
| 0.008 | 0 | 1 | 1 | 1 | 1.1 | 1.15 | 1.12 | 1.1 | 1.05 | 1.01 | 1 |
| 0.0085 | 0 | 1 | 1 | 1 | 1.12 | 1.14 | 1.08 | 1.03 | 1.03 | 1.02 | 1 |
| 0.009 | 0 | 1 | 1 | 1 | 1.13 | 1.11 | 1.1 | 1.06 | 1.04 | 1.03 | 1 |
| 0.0095 | 0 | 1 | 1 | 1 | 1.13 | 1.14 | 1.1 | 1.04 | 1.03 | 1.02 | 1 |

Below are graphs of curves of changes in concentration over time on the basis of table 2.

**Figure 2.** Graph of changes in the concentration of the solution by the time of arrival in the apparatus.

Based on the results of the obtained experiments, curves were given to determine the time of presence of raw materials in the apparatus. Here, the time of stay of the raw material in the apparatus is determined by the curve of change of concentration (density) of the indicator at the output of the apparatus. For different values of technological parameters, the average stay time of the raw material in the apparatus was 30-40 seconds.

4. Conclusion
An experimental setup and a technique for conducting experiments in them for studying the hydrodynamic structures of phase flows on the proposed setup were recommended, and the average residence time of the product in one stage of the proposed apparatus was determined ($\tau = 30 \div 40$ s).
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