Quality control in the production process of sunflower oil

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Abstract. The typical problem of vegetable oil processing is to ensure the consistency of the output quality. The one parameter that mostly affects quality is the presence of wax, which commands control at all stages of the process (refinement, odours removal, freezing). Statistical methods of analysis can be usefully applied to the improvement of vegetable oil processing, as demonstrated by this study. The authors in fact used statistical methods in order to: a) optimize parameters consistency, b) enhance process efficiency, c) improve economic performance and finally, d) assess process stability. The following statistical tools were used in the study: 1) Histograms, 2) Shewhart Charts, 3) Ishikawa Diagrams and, 4) Pareto Chart. A first major finding was that the occurrence of process flaws that would result in product rejection had a 5% probability of happening at all stages of the process. Moreover, the analysis of process stability with maps of average values and ranges leads to the finding that the process itself is statistically unstable. Finally, cause-and-effect relationships of influencing factors (such as the quality of feedstock) were investigated, thus determining the main causes of flaw in the production process. This leads to the definition of corrective actions, the effectiveness of which was then investigated and evaluated.

1. Introduction
Quality management of the production process of sunflower oil consists of monitoring and, when needed, modifying the values of set parameters selected as the process main indicators. Namely, at the planning stage of the process; when we check the capabilities of the technological process, monitor quality indicators at all stages of the technological process, and during transportation between operations and process steps [1]. For the production of sunflower oil, it is necessary to take into account the requirements of consumers when developing products and serving consumers after sale. It is important that the production of sunflower oil is coordinated so that the manufactured products meet the requirements of buyers, and their functional characteristics are taken into account [2].

Vegetable oils contain the following types of fatty acids necessary for a balanced diet: saturated, unsaturated and polyunsaturated. In addition, vegetable oils are rich in phosphatides, sterols and tocopherols. Among the traditional vegetable oils, the most common is sunflower, due to its high digestibility up to 97% [3]. It contains phospholipids, vitamins and tocopherols, has antioxidant properties and affordable for consumers. Control of the required level of quality of sunflower oil is carried out at all stages of the production cycle: incoming control of incoming raw materials, control at all stages of the process, output control of products.
Refined deodorized frozen sunflower oil of the highest grade was chosen as the object of the research. The regulatory requirements for this product are outlined in TR TS 024/2011, GOST 1129-2013 in terms of organoleptic, physicochemical and safety indicators. One of the main requirements is an indicator of the efficiency of removing waxes and wax-like substances in a frozen vegetable oil, called a cold test. The wax adds turbidity and spoils the appearance of sunflower oil. It contains no nutrients. The freezing process is applied to remove it [4].

Waxes belong to multicomponent plastic and solid organic substances of various origin and composition. They are characterized by a high melting point, low molten viscosity, opacity and hydrophobicity [5].

Waxes pass into vegetable oils during the processing of oilseeds. Waxes with a carbon chain from 36 to 48 atoms were found in sunflower oil (C36 - C48). Due to the high melting point of waxes (up to 90 °C), their solubility in oils at moderate temperatures is insignificant.

Waxes removal processes (and related high-melting impurities) are part of modern technological schemes refining of sunflower oil. The wax content of the oil is measured at the extraction and freezing stages in accordance with the analytical control chart [6, 7].

Evaluation of waxes and wax-like substances removing efficiency during the freezing step is carried out by the "cold test" GOST 23261-2013, which examines the resistance of the oil to cloudiness and demonstrate the waxes presence in the oil. However, it does not show the quantitative characteristics of sunflower oil for this parameter. According to [5, 7] in case of wax content up to 10 mg/kg the sample of the studied oil remains transparent. Therefore, we take this value as the limit one, corresponding to the upper limit of the permissible values for the wax content in sunflower oil.

In order to increase the quality (and therefore the competitiveness) of a given vegetable oil, a thorough analysis of consumers complaints is the prerequisite for the definition of the “standard” values of the main process indicators which corresponds to optimum product pleasantness. Deviations of the main indicators should be studied in reference to the above said standard values.

The main goal of the study is to improve the quality of vegetable oil using methods of statistical control of the production process. This will help to reduce deviations in the parameters of the finished product, increase the efficiency of the process and improve its economic characteristics. Achieving these goals commanded the following tasks:

- quality parameters being most significant for consumers’ satisfaction were identified and studied;
- statistical analysis of the accuracy and stability of the technological process of oil production was carried out;
- technological process of production was studied and a set of cause-and-effect relationships was identified that affects the result of the process;
- set of corrective measures was defined in order to improve the quality of oil and improve the efficiency of the production process.

2. Materials and methods
In this work, the studies were carried out using statistical methods (GOST R ISO / TO 10017-2005) descriptive statistics, hypothesis testing, process-behavior charts and process capabilities analysis.

The validity of the use of statistical methods is due to the variability in the behavior and results of the process. Quantitative analysis can help to understand the nature, extent and causes of process variability in order to eliminate or reduce the likelihood of problems [8].

Statistical methods allow decisions to be made to improve the quality of products and processes, and thereby contribute to the achievement of customer satisfaction [9].

3. Results
As mentioned earlier, the wax content is an important quality characteristic of sunflower oil. In the refining process waxes are removed by freezing the vegetable oil, so that the product will not become opaque (“cloudy”) during storage [10]. The article presents the procedure and the results of laboratory
studies conducted over a period of 3 months of 2020, and then analyzes the accuracy and stability of
the production process in terms of wax content [11].

An analysis of the values of the wax content showed that at a significance level of 0.05 Gauss’
normal distribution law was commanding the spread of values. The meaning of this was that in
the production process of sunflower oil a set of factors is considered (Figure 1).

![Figure 1. The histogram of the normal distribution of the content of waxes.](image)

As it can be seen from the figure above, the amount of probable waste of refined, deodorized,
frozen premium sunflower oil is 5%, i.e. obtaining a product with a wax content exceeding the
permissible value can happen with 5% probability. This is not satisfactory and therefore it is important
to find out what factors influence the value of the wax content indicator.

In fact, over time, changes in the process may occur due to general or specific reasons. In order to
study this variability an important role is played by statistical analysis, carried out using control charts.

Representing the stability of the production process with Charts of Average Value and Range
yields is in the graphic form, a comparative analysis of the results is from the study of successive
samples. Boundaries are set based on the inherent variability of the internal process.

The resulting Shewhart charts are presented in Figure 2.

![Figure 2. Control charts: X-card for control of wax content (a), R-card for control of wax content (b).](image)

The R-charts show that the ranges are in a statistically unstable state, as there is a point 8 that goes
beyond the upper control limit. Consequently, a non-random factor appears within the process, which
can lead to the growth of defective products. Thus, it is necessary to analyze the production process with the identification of complex of cause-and-effect relationships.

The cause-and-effect diagram (Ishikawa diagram) demonstrated that possible reasons for the presence of wax and non-compliance of the oil with the established requirements are: clogged filter, low filtration rate, high temperature of the filtered oil, rapid oil cooling, damage to the filter or filter cloth, powdery substances (Figure 3).

![Cause-and-effect diagram.](image)

**Figure 3.** Cause-and-effect diagram.

Continuing the analysis, a first and basic factor which influences the value of wax content in the final product was found to be the feedstock quality. For example, inappropriate properties of the raw materials due to improper storage conditions of sunflower seeds or hybrid sunflowers [12].

In addition, it was evident that features of the modus operandi of equipment and personnel could have a negative effect, e.g., non-compliance of the equipment with sanitary and hygienic rules, untimely repair of equipment and debugging of software systems, low level of professional training of personnel, lack of responsibility of personnel, etc.

Given all of the above, it was evident that a method should be adopted in order to simplify and identify the most important causes of deviations in wax content. This was achieved by conducting an analysis using a Pareto chart (Figure 4).

As it is well known, the 80/20 Pareto principle states that 80% of non-conforming products are caused by 20% of the influencing factors. The above diagram lead to the conclusion that the highest percentage of defective oil was caused by low filtration rate, use of powders and temperature of the filtered oil.

Thus, devising and implementing corrective actions commanded the identification of the main influencing factors and an evaluation of the effectiveness of such actions. Procedure should include bringing the management of information on the actions taken for analysis.
4. Conclusion
The authors studied the production process of refined-deodorized-frozen sunflower oil with methods of statistical analysis. The research leads to focusing on the wax content of the product, which appeared to be the crucial factor to manage in order to achieve acceptable quality and process stability. It was found that the probability of obtaining a flawed product was 5%.

Quality of feedstock, filtration rates, filter powders and temperature of filtered oil were found to be the main causes of production defects. The application of statistical methods to the development of corrective measures leads to the optimization of quality control criteria.

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