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To cite this article: O.V. Shabunina *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **836** 012004

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Decision support system for quality management of cosmetic products

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Abstract. The paper describes the structure and the mathematical core of the decision support system developed by the authors for assessing the quality of cosmetic products based on machine learning approaches. The main goal of the study was to improve the system of quality control of cosmetic products, in particular, the quality of perfumes and cosmetics using intelligent methods of data processing, formalization of knowledge and experience of the experts, thus providing automatization of the decision-making process. The practical-oriented goal of the study was to obtain knowledge-supported decisions regarding the quality of the cosmetic products using the developed system of quality assessment based on intelligent methods of data processing, providing the possibility of unsupervised learning and adjustment of the developed system when changing final product characteristics.

1. Introduction

The fashion industry, the enormous potential of the perfumery and cosmetics industry and the ideology of modern society, requiring a young and healthy appearance from a person, encourage people to use various cosmetic products. Therefore, today the list of cosmetic products, as well as their producers, is very extensive.

Quality control of the final products is an important function in quality management of any enterprise. It can be defined as a set of properties and characteristics that determine the feasibility of products to meet specific needs in accordance with the application sphere.

Each product has certain properties that characterize the quality level. General quality assessment criteria are established in regulatory documents: technical regulations, standards, technical conditions for specific types of products. It is generally known, that quality assessment of goods is associated with the optimal choice of the range of evaluation indicators, determination of their values by means of various methods and instruments and cross-checking with the basic values of the indicators. The general methodological approach to optimal criteria set determination and cross-checking of the indicator values is also well understood. However due to the specific features of cosmetic products associated with their functional and therapeutic properties, assessing the quality of such products is of great complexity.

2. Quality of cosmetic products and organization of its control

The quality of any product is to be assured at all manufacturing stages. The quality begins to play a crucial role at the formulation development stage in the course of scientific research activities. Then it is ensured during the production process and depends greatly on the quality of the ingoing materials, production process, methods and instruments of testing, storage and transportation. But before the start of mass production, the product is exposed to compliance assessment tests, which are carried out in



accordance with the established legislative requirements. Compliance is typically confirmed by the following certificates: Declaration of Conformity, Certificate of State Registration, Certificate of Conformity (depending on legal requirements for specific products). But it should be noted here that such a document is issued for a certain period of time and during the period of its validity it cannot guarantee the stability of the quality characteristics of all the manufactured products. Any production process is prone to technological failures. And the target consumer will easily stop using the product if any defect or quality violation is found. Consumer confidence is very easy to lose, and, subsequently, very difficult to regain. Therefore, one of the main goals of the manufacturing process is not to provide faulty goods.

Thus, the relevance of quality control is assured by up-to-date economy requirements and must be constantly monitored at all stages of the product life cycle.

Typically, to ensure the effective quality control process at the enterprises, quality control department and laboratory are established independently of other production units.

The quality control department, as a rule, includes a quality engineer and supervisors who carry out quality tests at the production sites. The laboratories include specialists who directly cross-check the samples using testing and measuring equipment.

Quality control department plays a crucial role in prevention of faulty goods production and is responsible for the monitoring results, preventing the delivery of faulty goods to the consumers. But, nevertheless, it should be noted that quality control department does not bear full responsibility for the quality of final products. This function is also allocated to the production workers. Therefore, all the personnel should be involved in quality monitoring. At workplaces the production personnel is obliged to monitor the proper operation of the equipment, the parameters of the technological processes, the conformity of products with reference samples at certain production stages and discard inappropriate products.

The main function of employees involved in the quality control process is to conduct tests and compare the results with specified (established) requirements, followed by determination of their compliance.

As a rule, the quality control process includes sampling at certain stages of the product life cycle, conducting established tests, recording test results. All recorded data is analyzed in order to obtain information about the possible malfunctions that could lead to quality degradation.

3. Decision support system for quality management of cosmetic products

To solve the above mentioned problems, the authors of the paper have developed a mathematical model of the decision-support system, providing quality assessment of the cosmetic products.

The main goal of this study was to improve the quality assessment system of the cosmetic products, in particular the quality of perfumes and cosmetics using intelligent methods of data processing, experts' knowledge and experience formalization approaches, providing automatization of the decision-making process. The practical-oriented goal of the study was to obtain knowledge-supported decisions regarding the quality of the cosmetic products using the developed system of quality assessment based on intelligent methods of data processing, providing the possibility of self-learning and self-adjustment of the developed system when changing final product characteristics.

The structure of the developed decision support quality control system of cosmetic products can be represented as the interaction of five separate sub-systems (Fig. 1):

- Data acquisition;
- Data generation;
- Knowledge discovery;
- Decision support;
- User interface.

At the data acquisition stage, all possible data sources are determined. This block is required to evaluate the amount of data, determine the order of its collection and the required storage volume in order to build the informative database at the next step. Data sources are given as follows:

- passport data for each ingredient from the particular supplier;
- testing protocols of quality control department;
- testing reports of microbiological laboratory;
- testing reports of the toxicology laboratory;
- quality control department final statement;
- consumer testing reports.

The data generation subsystem consists of two successive stages - data pre-processing and database development. The preliminary stage of data processing is of critical importance due to the need to scale and normalize data, as well as to exclude data outliers from the initial sample.

Based on the processed initial information about the object under consideration, a set of data stored in a certain ordered way (database) is generated. The following types of data can be stored in the database:

- physical and chemical indicators;
- microbiological indicators;
- toxicological safety indicators;
- organoleptic indicators;
- consumer testing results.

The sub-system of knowledge discovery is represented by two blocks - “intelligent data analysis” and “knowledge base”. Intelligent data analysis is understood as a sub-system of data processing based on machine learning, which gives the obtain to obtain aggregated differentiated estimation of cosmetic products\quality by using “knowledge base”. The “knowledge base” block is used not only for data storage, providing rules of interaction of various models (i.e. quality assessment of the final cosmetic product using the estimation results provided for ingredients), verification of existing knowledge, but also for generation the new ones.

In the course of data analysis, the quality assessment is carried out according to the principle “from particular to general”:

- state assessment of each particular ingredient;
- quality assessment of the cosmetic product in general.

Based on the obtained quality assessment results, a decision analysis is performed in the decision-support sub-system. The result in the form of ranked solution alternatives through the output sub-system goes to the user interface. The final choice is carried out by the decision maker.

As a result of quality control the following actions can be implemented:

- no actions required, the products comply to established requirements;
- quality assurance actions required, faulty goods are identified;
- product re-manufacturing with subsequent quality control;
- production cycle modification.

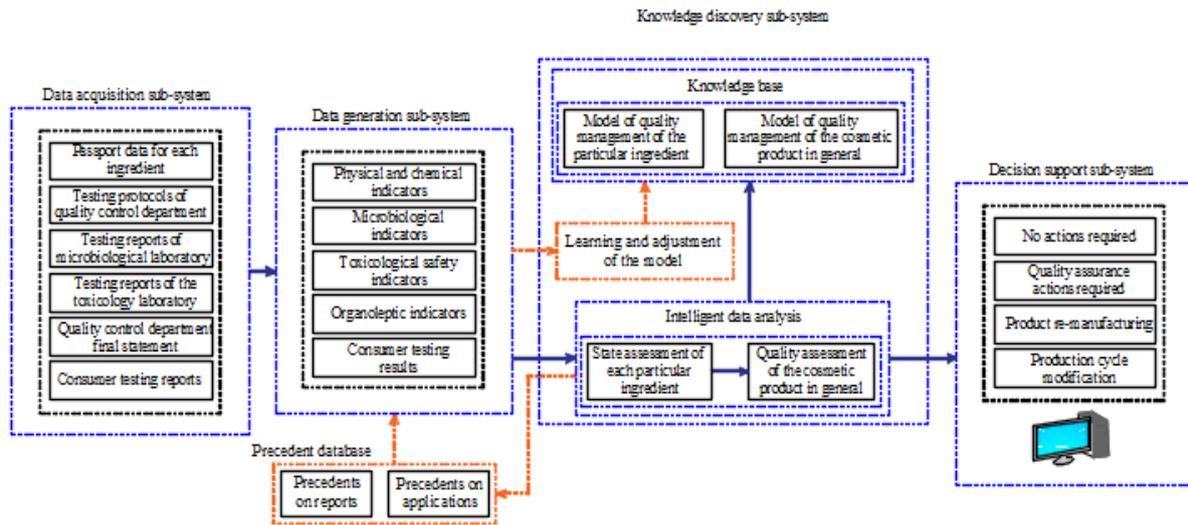


Figure 1. The structure of the developed decision support quality control system

4. Mathematical apparatus for cosmetic products quality assessment

In order to provide decision-support of quality control tasks, i.e. choosing the optimal solution based on the previous experience and rational analysis of all available data about the object under consideration, the instruments that implement human intelligence function are needed. Based on numerous author's studies, the Random Forest method was chosen as the optimal mathematical approach the introduced problem solution. In this case, Random Forest is used for the classification problem, arising from the multi-ingredient composition of the final cosmetic product, which is referred to as the supervised classification problem. The advantage of the proposed method is complete elimination of the overfitting problem even when the number of features significantly exceeds the number of observations. Moreover, the training sample required to compose a random forest may contain features measured on different scales: numerical, ordinal, and nominal, which is unacceptable for many other classifiers. A Random forest consists of a large number (ensemble) of decision trees.

The algorithm for constructing the Random Forest, consisting of N trees, is given as follows:

For each $n = 1, \dots, N$: X_n sample is generated using the bootstrap process.

The decision tree b_n is built according to the X_n sample:

- according to the specified criterion, the best attribute is selected and the tree is partitioned until the sample is completely enumerated;
- the tree is built until each leaf node has no more than n_{min} objects or until we reach a certain tree height;
- at each partition m random features are selected from n initial ones, and the optimal sample partitioning is searched only among them.

Then the final classifier given is as follows:

$$a(x) = \frac{1}{N} \sum_{i=1}^N b_i(x). \quad (1)$$

Thus, the decision is chosen by the majority vote. As a result, we get that Random Forest is bagging over decision trees, where the attributes are selected from some random subset of attributes during the training process.

In the Table below the example of cosmetic product quality control results is provided.

Table 1. Random Forest classification results.

Network data	Values
Number of features*	17
Number of training sample pairs	872
Number of test sample pairs	203
Average training error, % (Accuracy)	81,4
Average testing error, % (Accuracy)	74,6
Algorithm	Random-forest-classifier
Strategy for missing values	K-NEAREST-neighbours

In this table, the features are the ingredients such as plant extracts, essential oils, animal and / or vegetable fats, emulsifiers and co-emulsifiers, stabilizers, vitamins., The accuracy of identifying the quality of the developed system is 76% as shown in Table 2. This result confirms the effectiveness of the application of machine learning methods to solve these problems presented.

Conclusion

A brief overview of general consumer properties shows that, given the diverse purpose of cosmetic products, the range of properties varies significantly. Therefore, for a reliable quality assessment procedure of the cosmetic products it is necessary to conduct research on optimal range of quality indicators based on general methodological approaches. At present, the selection of consumer properties is often carried out without justification, choosing those indicators that are easy to evaluate. The main objective of the quality control system is to identify the stages at which problems may arise, and thus optimize the work of the personnel performing quality control: pay attention to where it is really needed and not to do unnecessary work where it is not required. The company considers the quality of its products as one of the most important indicators of its activities.

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