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Applying QFD to Quality Management of Biologically Active Additives

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Abstract – **QFD is a system to convert customer expectations to fit the relevant requirements of an industry at each stage of the product development from the research stage through design and production to sales. This study uses QFD approach to determine the requirements for biologically active additives, popular with international customers. The seven principal categories of customer requirements assessment regarding biologically active additives have been identified: functional orientation, consistency, odor, shape, price, manufacturer, safety and efficacy. The research of design and engineering showed that the "type of packaging" has a weak association with the "mass of soluble solids" and a strong association with "shelf life". The corresponding importance of technical specifications and their correlation are evaluated to develop the most effective business strategy. The findings are discussed in terms of the production value.**

Keywords – quality function deployment, QFD, biologically active additives, dietary supplements, product development, competitive recovery

I. Introduction

The conducted studies of present-day human nutrition patterns indicate the lessening of essential food components. According to official statistics 64.1% of the population do not comply with a proper diet [1]. This happens due to objective reasons that exert a decisive influence on the building of the food ration in all economically developed countries. Due to various climatic, national and social factors there is a certain deviation of actual nutrition programmes from the recommended norms of consumption.

Adjustment of a diet alteration or improvement cannot be achieved simply by an increase in the norms of natural food consumption. One of the most effective ways to do that is to enrich the food with specific natural regulators which will improve different functions of organs and systems of the human body, these natural regulators are currently represented by a wide range of biologically active food supplements [2].

Biologically active additives are a good alternative to vitamin-mineral premixes as a means of adjusting inadequate and unbalanced diets.

The market of dietary supplements in Russia began to form at the end of the XX century. The medical and consumer interest to dietary supplements was caused by the results of scientific research on rational nutrition aimed at strengthening of immunity system. In contrast to drugs, dietary supplements help the body to self-adjust and eliminate disorders that lead to the development of a disease without damaging the body, or any kind of side effects inherent in many medications [2, 3].

According to the research of the monthly retail audit of the pharmaceutical market in Russia, conducted by the DSM Group, in 2017, 340.7 million items of dietary supplements were sold through the pharmacy network at the cost of 51.2 billion roubles (in retail prices). For the recent 12 months of 2017 the market of dietary supplements has increased by 4.6% in roubles and by 1.7% in product items in comparison to 2016.

But in January 2018, the capacity of the Russian market of BAA decreased by 0.7% in value terms in comparison with December 2017 and cost - to 4.3 billion roubles. In natural units, the market fell by 4.5% to 27.9 million items. The growth rate of the pharmacy segment of dietary supplements in early 2018 declined, continuing the negative dynamics of Q4 2017.

Given there is negative dynamics, manufacturers are trying to attract consumers, focusing on their preferences. So, for example, in recent years, biologically active additives made

from plant raw materials have successfully competed with synthetic drugs.

Accordingly, a manufacturer must take care to ensure the competitiveness of his product. The advance of new products is a strategic step for the successful setup and development of manufacturing enterprises. However, to achieve and maintain the advantage in a competitive and dynamic market, it is not enough to produce a product that meets only the requirements of technical regulations or standards. Any disregard for the real needs of future customers in the course of production, deployment and circulation of innovative products can lead to unpredictable consequences for the manufacturer. In this regard, when designing new and improving existing products, more and more attention is paid to the use of modern scientific methods. Carefully examined consumer behaviour, efficient ways of expertise reviews, improved methods of quality management might definitely help.

Today there are many low-cost, but effective methods to identify consumers' expectations of new products and the key to success is to become informed about them faster than competitors. For example, a couple years ago manufacturers used to produce a pilot sample release with a limited quantity of new goods to the market to conduct the required research, losing valuable time and bearing significant costs, today a virtual model of the product is enough to investigate the consumer's reaction.

Many researchers [1, 4-7] agree that the most effective model for transforming customer requirements into high-quality features of a new product is the method of shaping the product quality, usually applied in combination with sociological (marketing) methods, benchmarking and other technologies.

The quality function structuring (synonyms - the deployment management, Quality Function Deployment, QFD-analysis, the House of Quality) is the original Japanese methodology for the systematic and structured transformation of the consumers demands into quality requirements of a product [8, 9].

Additionally, with the view to enhance the research on QFD, we provide the results with product properties. The BAA description is structured in the form of tables and graphs based on the suggestions of the researchers. At the final stage, a conclusion was made about the feasibility and prospects of some developing technologies and equipment for the production of a new generation BAA.

Regardless the fact of the availability of publications on the application of this method in various fields, the studies concerning the use of QFD in the development of biologically active additives, which this article is devoted to, can be seen as insufficient. Thus, this work demonstrates the application of the House of Quality tool in the production of dietary supplements with antacid effect. The following sections present the concept of QFD and its use in the development of food products.

The methods and stages of the research used to carry out this work, as well as proposals for the application of the House of Quality in the development of dietary supplements, will be discussed further.

II. Analysis of recent research and publications

The purpose of the QFD application [8] is to translate quality requirements from customers into product quality indicators; it can also be used to develop services [10]. The use of QFD improves product reliability, reduces the time of product development, and increases customer satisfaction.

The QFD method of structuring the quality function or focusing on the consumer voice is one of the most effective approaches to organize the planning process. It arose in Japan in 1972. However, nothing was known about this technique until in 1983 the first notes appeared in the US press [11]. The most vivid example of the application and further development of QFD methodology is Toyota Automobile Corporation [12].

The success led to a wider use of the QFD methodology, which was adopted in other countries, in particular in the US and Europe in the 1980s. Since 1987, there have been the first publications on the QFD method in the food industry [13, 14]. After the 1990s, the method was introduced in Brazil and other countries [15]. At that time many researches referred to this method in the discussions of food products design and packaging materials [16-18].

Customer-centred food products design, based on QFD method, allows the creation of new BAA products, in which the requirements of consumers are taken into account in the technical requirements of a product, while significantly reducing heavy expenses for the design development as well as labour costs [19]. This makes it possible to place on the market high-quality products with reasonable and competitive price.

QFD has long been considered the most comprehensive and consistent method, which helps to integrate the goals and processes aligning them with customer requirements. Thus, QFD has become subsequently adopted as a tool for product development and quality improvement in many countries including Russia.

To transform customers' requirements into the technological parameters and quality parameters of the expected products, the House of Quality method *or structuring of quality functions* (SFC) is used. The method of structuring consumers' needs and wishes. The key principle of the SFC is a graphic tool in the form of a table, called the House of Quality. It reflects the relationship between actual quality indicators (consumer properties) and auxiliary indicators (technical requirements). This method allows making well-founded decisions on the quality management of the manufacturing processes. At the same time, it is possible to avoid changes of parameters of a product after its production, and, consequently, provide a relatively low cost by minimizing non-production costs and high product value [9].

The QFD is a method in which wishes (established and perceived needs) of consumers via matrices are translated into detailed product specifications and design goals [8]. The structure consisting of several matrix-like tables is called a quality house.

First, the important needs of consumers are transformed into detailed technical characteristics of the product, then the three subsequent stages are given: the specific characteristics of

different components of the product, the characteristics of the processes and system of production control, management and the equipment for the implementation of this production – from the first House through the fourth House accordingly. These technical requirements for production must ensure the achievement of high quality products. As a result, a high level of customer satisfaction is ensured by the production of high-quality products at an affordable price.

QFD has its advantages and disadvantages. There are tangible benefits, such as improved reliability, decrease of volatility, effective time use and costs reduction [10]. And less obvious benefits such as flexibility of the method, improved communication, assistance in decision-making and priority-setting, as well as improved proficiency knowledge and increased customer satisfaction [10].

The difficulties stem from the lack of knowledge on how to use the method and the necessity to use all four stages of the quality function deployment for the proper translation of customer requirements into technical specifications.

Given the advantages and difficulties presented by Benner, Linnemann, et al., 2003, this method was successfully applied in the development of food products such as chocolate [20], chocolate sweets [21], cakes [22], wheat flour [23], fruits [24], meat [25], mineral water [26], olive oil [5], as well as a number of functional products [22].

The study of literature on the topic shows that there were no publications on the adaptation of the House of Quality technique with respect to production of biologically active additives. Besides, the study was conducted within the analysis of the framework of the House of Quality application on the Russian market.

III. Research Materials and Methods

To apply the QFD methodology, a study scheme consisting of a number of stages was used. At the first stage, a survey was conducted to identify consumer preferences and satisfaction with dietary biological additives marketed in Kemerovo with the aim of the following segmentation of the consumers according to: demographic, socio-economic and behavioural features. The consumer properties of dietary supplements affecting purchase of dietary goods have been studied. To carry out sociological research 3 types of questionnaires were developed. Questionnaire No. 1 is designed to conduct sociological research identifying the target consumer and their motivation when purchasing products, this helped to establish a range of consumer indicators for the quality of dietary supplements.

At the second stage, with the pairwise comparison method, Questionnaire No. 2 was developed to determine the effective weighing factor and the levels of consumer quality indicators of biologically active additives. The expert evaluation questionnaire was developed with the involvement of the enterprise specialists to study the consumer evaluation of the quality of such competitive supplements on the market. The results of designing in the development and commodity evaluation of gel forms of dietary supplements are presented. Sociological research of consumer preferences in relation to dietary supplements as a specialized food product was conducted using the method of questionnaire survey among residents of Kemerovo.

At the third stage, we developed the Questionnaire No. 3 to evaluate the quality of competing products and the degree of customer satisfaction with these products.

A. Choosing the Poll Technique

Sociological research was conducted using the questionnaire method. At the stage of studying consumer preferences, one of the non-random (nonprobability) samplings was used – the quota selection (the parameters of sex and age were quoted), which makes it possible to spread the data obtained from the total number of respondents to the preferences of the whole population of Kemerovo.

There are several reasons for using the sampling method:

- Improved data accuracy. The reduction in the number of units of the sample observation reduces registration errors. Due to incomplete coverage of the units, there may be an error in the representation of the sample data. But even taken together, the sample observation error and the error in the representation still guarantee more valid statistics as compared to the complete coverage method results.
- Sampling significantly saves the material, labour and time expenses.
- Ethical problem – objects cannot be forced to respond if they refuse.

The core principle of the method lies in the fact that the research will use only one or two features that are important to control the sample. The number of units in a sample that has certain characteristics should be proportional to the number of such units in the general totality.

B. Development and preparation of the questionnaire

To study consumer preferences, the survey was conducted with the help of standardized instrument – an inquiry plan (questionnaire).

This is the most common method of quantitative marketing research. With the help of consumer survey, it is possible to spot the shifts in consumer demand timely, and therefore to make the right decision at the forecasting and production stage.

The research relies on the results of the personal and phone interviews held in accordance with the content of pre-designed questionnaires.

Questionnaire No. 1 is designed to conduct interviews with a group of 530 people to determine the target group of BAA consumers, the purpose scheme and the motivation stimuli, as well as the listing of product properties specified by the consumers of BAA and to range the properties in accordance with their importance rate.

Several options are suggested as possible answers for questions No. 2, 4, in Questionnaire No. 1. Giving their answer to question 4 of Questionnaire No. 1, respondents list the desired properties of BAA.

As a result, after the processing of the answers in Questionnaire No. 1 with Statistica 6.0 software, a list of all the stated indicators of consumer requirements for the quality of dietary supplements was formed. This list is studied for the possibility of duplication and mutual exclusion of indicators. The nomenclature of the most frequently used indicators of consumer requirements for the quality of dietary additives was formed. On the basis of this nomenclature, Questionnaire No. 2 was formed.

Questionnaire No. 2 is designed to rank the indicators of consumer requirements for dietary supplements. Questionnaire No. 2 is based on the quantitative consumer testing approach, which involves a survey of a large number of respondents, that is, from 50 to several hundred people. Conducting this survey involves the use of the pairwise comparison method, which requires the respondent to be attentive and make extra effort while giving their response. It is recommended, therefore, that the respondent should be provided with a short explanation on the procedure of filling the corresponding table and that questionnaire should be completed in a written form.

As a result of a sociological survey, 100 respondents answered the questionnaire about their experience of the BAA use. A nomenclature of consumer quality indicators has been worked out and the consumer requirements weighting factors were specified with absolute and relative importance weights.

C. Survey

From November 2017 through December 2017, the “Study of Kemerovo consumers’ attitude to dietary supplements” was carried out. The field research phase was held from November 10 to November 17, 2017. The information was gathered in the form of an interview taken from people on the streets of the city.

Filling out the Questionnaire No2. To determine the weight coefficient, *the pairwise matching method was* used. Each customer had to fill-in an incomplete matrix with x and y axes which help to locate the estimated indicators.

Each cell of the matrix should be filled with the numerical indicator, which, from the point of view of the consumer marks the most important parameter. Later, the matrix is processed for the further analysis.

At the next step the subjects filled-in the Questionnaire No. 3. Fifty people took part in the process of evaluation. Based on the results, the right part of the consumer preferences matrix has been completed, the consumer quality indicators allowed of creating the guidelines for the required improvements in the property of BAA product.

D. Processing of profiles

The data were processed using mathematical statistics on a PC with Microsoft Excel and Statistica 6.0 software.

IV. Results of the Research and Their Discussion

The purpose of the study was to conduct the analysis of consumer behaviour and their preferences regarding the biological dietary additives. The first stage of sociological research was aimed at the collection of statistical data. The interview of 530 people who met the requirements of the representative sample was held in compliance with the content of the Questionnaire No. 1.

The consumer profile is built on the following behaviour analysis of data-blocks: the reasons they refuse to buy BAA; the places they purchase BAA; the factors affecting the purchase of BAA; the most significant consumer properties of BAA; the preferences of BAA by functional orientation; the type of BAA used.

Answers to Questionnaire No. 1 show that the target group of BAA consumers have different reasons for rejecting dietary supplements.

For the customer voice to be heard the researchers analysed the information about the most significant attributes of the purchased BAA products, which allowed to establish a nomenclature of consumer indicators of the quality of dietary supplements, expressed in the "language of consumers." The outcome then was processed using the affinity chart by examining the inconsistency of consumers' demands, duplication of indicators in the identified list of quality indicators, their complementarity and mutual exclusion. Based on this, the final formation of the list of consumer quality indicators of dietary supplements has been carried out.

The quality and safety indicators for specialized nutrition (food items) is the main (or necessary) product property, which according to the model of Noriaki Kano is "obvious and ordinary" food attribute for a consumer. However, the results of the conducted studies demonstrate the consumer's uncertainty about the quality and safety of the products on the Russian market, which challenges the manufacturer to minimize the risks and guarantee the sustained product quality to avoid any negative health consequences.

The identified consumer quality indicators of dietary supplements are systematized and processed with the help of the affinity diagram, as a result, the nomenclature of wishes of dietary supplements consumers was formed.

Safety indicators detailed by consumers are necessary and mandatory. The task of manufacturers and sellers is to minimize the risks of any possible harm. Ensuring the safety of food. Products that do not meet safety requirements cannot be distributed.

A broad scope of assortment will satisfy all possible taste preferences of the consumer, who buys the products of a particular brand from the manufacturer he trusts. Widening the range and the palette of products is a safe and sure way to attract a constant consumer. The development of the assortment of BAA has a well-established and tested procedure, which consists of the ingredients composition arrangement, adjustments of the technology of production and the choice of new package design.

Pack is the first thing that the buyer sees and evaluates. It is necessary to pay special attention to the selection of packaging materials, when developing the design, shape, colour, and content of a product package, as well as the content of the label and properties of the noticeable product visualisation. Based on the conducted sociological research, it is possible to formulate recommendations for packaging design of the BAA products:

- when choosing the packaging materials, it is necessary to strive for greater ecological compatibility and solidity;
- when working on the design and packaging, it is important to take into account the consumer expectations: a spoon for dense products; a practical cap that can be closed and opened several times, convenient for opening the product, stable and a streamline, ergonomic and user-friendly design of the container;
- when elaborating the label, one should seek for an informative, beautiful and bright example.

The control of these indicators might be irrational and is driven, for the most part, by aesthetic, psychological or ethical considerations and shaping factors.

Also, the results of the analysis show that the consumer focuses on quality, which testifies the consumer's uncertainty in the quality and safety of BAA products. This is especially important for the production of gel-based additives, since this substance can become a favourable environment for the growth of detrimental microorganisms, which makes such products easily perishable and dangerous, especially due to the fact that, for example, functional nutritional additives (the group of specialized food items) are used by people whose health is already weakened. Finally, according to the survey results among the consumers of BAA there are many women, who exhaust their body by the weight reduction diets and children whose immune system is not strong enough to cope with possible complications.

To classify the data obtained, we apply the following principles. Consumers have different demands, sometimes very contradictory. When designing and developing dietary additives, it is necessary to take into account the following requirements, giving preference to the needs and desires of the respondents.

Based on the results of the studies, we can conclude that the majority of the population uses dietary supplements; the main consumer category is the women who care about their health. The main goal of acquiring biologically active additives is to correct nutrition and preservation health. The prevalent places of BAA distribution are pharmacies, the Internet stores and specialised medical institutions.

A. Questionnaire No. 2

The second stage of sociological research (Questionnaire No. 2) shows that the most important factors that shape the requirements and product quality expectations, expressed in the language of consumers, are: the functional orientation and safety, as well as the price. The presence of dyes, flavours and preservatives or consistency, are the features of the least interest, which indicates a certain confidence in product quality and trust to the manufacturer. The main condition that guarantees the production and maximized turnover of a competitive product is the respect for clients requests and proper customization of the product.

The data gathered from the participants of the conducted surveys was used to formulate the consumer decision tree – a scheme that shows the parameters of customer preferences. Also, the marketing research materials were structured and grouped to build the tree diagram of the BAA preferences.

The modal weighting factors of consumer demands were specified using a pair-wise comparison method.

A sociological survey of 100 respondents (focus group) was carried out using the developed questionnaire to establish the weight indicators of the identified BAA consumer quality demands. Thus, by operating the consumer demands with high-rate indicators, it is possible to improve consumer quality standards for dietary supplements with low labour and financial costs.

The evidence obtained by means of the sociological studies was classified and structured. It became the basis for the nomenclature of consumer preferences that form one of the branches of the tree diagram with indicators of the BAA quality and safety requirements. The use of the proposed nomenclature of indicators allows the BAA manufacturer to place the proper focus on the product quality control and identify the ways to purposefully rise specific quality indicators.

B. The House Quality

The collected data were used to complete the subsection “Customer Expectations” (sub-table 1) of the “House Quality” matrix, these are: functional orientation, consistency, smell, form, price, producer, safe, efficient. The weight factors consumer indices of the importance are specified by a five-point scale, where 5 is "very valuable", 4 is "valuable", 3 is "less valuable", 2 - "not very valuable", 1 -" not valuable".

The results are presented in the section named “The Importance of Expectations” of the House of Quality matrix (see Fig. 1).

Next, the sample was compared with the best type of competing products (model). The result has contributed towards improved awareness and understanding of the objective quality and the perfection factor of evaluated product as compared with the best analogue of a competing enterprise. In this case a 5-point scale is also used. The comparison results are presented in the sub-table 2 (Fig. 1).

The survey involved 50 respondents who independently filled the Questionnaire No. 3.

The experts’ assessment of the comparison of competing products added to the results collected on the previous stages of the research allowed one to build the projective matrix to predict and plan a required BAA quality and determine the degree of the correlation between organoleptic indicators of consumer preferences and quantitatively measured indicators of the finished product.

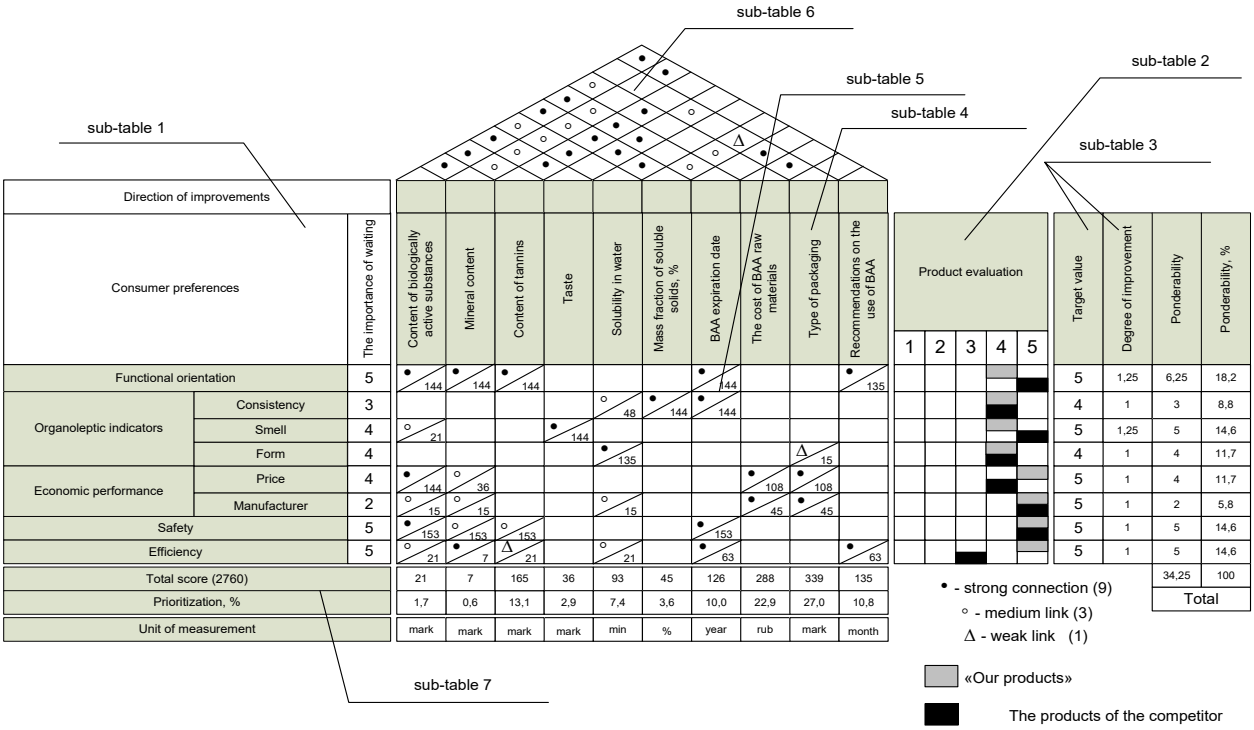

Fig. 1. The House of Quality (diagram, matrix) for the designed products

In the scheme, it becomes obvious that in order to improve the competitiveness of the test sample, it is necessary to improve such indicators as “functional orientation”, "consistency", "smell". On the other hand, the benchmark was evaluated as inferior in terms of "price" and "efficiency." The obtained data indicate the potential capacity for BAA product improvement.

Subsequently, the objective for the quality improvement project was set. In the sub-table 3 (section "Target value"), the target values (in numeric data) were determined for each bit of consumer product expectations (see Fig. 1). The working group constructing the House of Quality decided that consumer expectations like "price" and "efficiency" do not require any improvement. On the basis of certain target values, the relative values of the "degree of quality improvement" are calculated using the formula: *Degree of improvement = Target value / Rate*. The results are listed in the section "Degree of improvement" (Fig 1).

Then the weight of each bit of consumer expectations is established, the values are listed in column 3 of the sub-table 3. Then the weight in percentage was calculated all the values are listed in the House of Quality matrix. The greatest index weight is attributed to the "functional focus".

At the fourth stage, we have to choose technical requirements of the analyzed product, adjusting them will help to achieve the best product quality and satisfy the consumers. At this stage, we have assembled the data in a catalogue of the product technical requirements. The results are listed in the sub-table 4 of the House of Quality.

Next, it is necessary to determine the relationship between the technical requirements and expectations of consumers, while filling the matrix of associations, which is the central part of the quality matrix of the House of Quality (Fig 1). The relationship matrix shows the correlation between customer expectations and technical requirements. To determine the strength of the rapport, a scale of values was used, where “9” is strong, “3” is medium, “1” is weak. An empty cell in the matrix indicates that there is no connection between the technical requirement of the product and the corresponding expectations of the consumer.

In the House of Quality scheme, it can be seen that the consumer’s demand of "efficiency" is strongly related to such technical requirements as "the chemical analysis of the product mineral content" and "the duration of BAA use". At the same time, there is also a loose relation between the efficiency demand and the attributes like "the content of biologically active additives", "the water solubility", and slightly related to "the content of tannins".

Numerical data representing the relevance of the relationship between the product technical requirements and the customer quality expectations are presented in the corresponding cells of the relationship matrix, identifying their correlation. The numbers are calculated according to the formula: *Relevance of the relationship = Strength of the relationship* ^{x} *Weight,%.*

Thus, in Fig. 1 it is clear that the technical requirements of "the content of biologically active additives" receive the highest overall quality score of 498, “the shelf life of dietary supplements” scores 495 points and “mineral content” totals 381 points. So at this stage of the BAA product development

process, the quality special attention was paid to the above mentioned technical requirements.

The stage six established the relations between the technical requirements of the product. The strength of the correlations between technical requirements is presented in the "roof" part of the House of Quality. For example, it can be seen that “the type of packaging” has a weak relationship with "the shelf life".

The next step labels the units of measurement for particular product requirements in the top graph of the sub-table 8.

With these units of measurement, the corresponding values of the technical requirements of the examined and competing products are given in the second and third lines of the sub-table.

At the final stage, the target values of the product technical requirements are determined taking into account their priority rates and are directly associated on the account of the impending product quality development. As can be seen from Fig. 1, the illustrating sample shows that the manufacturer is to put a special emphasis on the increasing the quality indices of "the content of biologically active additives" (18%) and "the shelf life of dietary additives" (17.9%).

V. Conclusion

With the help of the House of Quality, the following ways of BAA product development have been identified:

1) to increase the BAA shelf life, an innovative, environmentally friendly and reasonably priced packaging should be chosen, with the best possible capacity to maintain the product properties and safety indicators for a significantly longer period;

2) to achieve the efficiency criteria of the BAA concept, it is important to ensure the quality and quantity of raw materials. This is achieved by monitoring and evaluating the wanted suppliers and commodities;

3) to improve the functional orientation indicator it is necessary to conduct clinical beta testing procedures with various groups of patients with varied disease aetiology.

The data received were taken into consideration when designing, elaborating, and manufacturing new forms of dietary supplements and brought to the attention of prospective BAA producers.

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