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Complex Assessment of Dairy Products using Color Images and Spectral Analyses

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Abstract. The paper provides an overview and analysis of known methods and solutions for quality assessment of dairy products based on color images and NIR spectral analysis. The main features of quality, safety, and healthiness of Bulgarian white brine cheese and Bulgarian kashkaval are specified. An overview of the possibilities for express and non-destructive assessment of basic dairy products quality features by color images and spectral analysis is done. It is made a proposal of a complex assessment of dairy products by fusing the results of both analyzes.

Keywords: dairy products, computer vision, color images, spectral analysis, quality and safety assessment

1. Introduction

Dairy products are basic food products. [1] They are widespread on the market and sometimes, they are improperly stored. That is the reason why it is necessary to control their quality and safety on spot. According to the Bulgarian food control law, an official control must be done in the different stages of the chain manufacturer-retailer-consumer, and this control is based on the risk management with appropriate time intervals. [2] The official controls are carried out by the Bulgarian Agency for Food Safety. [3] While at the production stage there is some control by the company, the retailers usually do not have the necessary resources to do the control. Sometimes, even in high-quality production and compliance with all the necessary measures for safe production and transportation, improper storage may cause drastic variations in the quality and safety of food. For effective quality control is necessary to take into account the risks associated with food production and food trade, the use of foods or processes, materials, substances, activities or actions that may affect the safety of food.

In traditional (including regulatory) quality assessments of dairy products two basic approaches are applied: physicochemical and organoleptic. These are laboratory methods related to time-consuming experiments, specific equipment and supplies, highly qualified specialists. A significant part of the assessment results are based on the subjective assessment of the experts, which makes the results dependent on the knowledge and experience of experts, as well as their ability to interpret the results. Due to the subjective nature of the assessment, it is possible for the results to be manipulated. Therefore, it is necessary to look for new methods of express, non-destructive analysis and quality assessment of dairy products, which are based on advanced technological solutions that significantly reduce the subjectivity of the assessment.

In summary, the results from the reviewed papers show that recent studies concerning the assessment of the quality of dairy products are mainly related to the application of computer vision systems and spectral analysis.

The main goal of this paper is to give an overview of known methods and solutions for quality assessment of dairy products based on color images and spectral analysis, and to propose a new approach for integrated assessment of basic quality and safety features by fusing the results of both analyzes.

2. Basic quality features

The main features used in dairy product assessment are described in the normative documents and standards. The features for assessment of Bulgarian white brine cheese are shown in the tables below (Table I, Table II and Table III). They are grouped into three tables – organoleptic features, physicochemical features and microbiological features. The specifications and requirements are described in front of every feature. Similar features are used for the Bulgarian kashkaval [4]

TABLE I
ORGANOLEPTIC FEATURES

Features	Specifications and requirements
	Bulgarian white brine cheese
Shape	Pieces with parallelepiped shape, square base and rectangular sides.
Size -base, square with side -thickness	10+/-2 8 +/-2
Mass, kg -for metal and plastic packages -for custom packages	0,900+/-100 Up to 2,0
Brine	With light green color, without bad aroma, with moderate sour and salty taste, without pollution and viscosity
Appearance of the pieces	Well shaped, can be separated easily, no crumble, without any surface pollution
Consistency at 18 C-20 C	Moderately hard, elastic
Surface, structure and color	Smooth porcelain surface , without or with single bacterial pores, without visible layers, with specific for the kind of milk color
Taste and aroma	Specific for matured cheese and for the type of milk. Moderately salty and pleasant lactic acid taste.
*NOTICE: The features are available for cheese in metal or plastic packages	

TABLE II
PHYSICOCHEMICAL FEATURES

Features	Requirements				
	Bulgarian white brine cheese				
	Cow's	**Sheep's**	**Buffalo's**	**Goat's**	**mixed**
Dry matter, % at least	46,0	48,0	48,0	46,0	46,0
Butter content in the dry matter, % at least	44,0	48,0	48,0	44,0	45,0
Acidity, in Törner degrees - of the cheese - of the brine	 from 200 to 270 from 160 to 180				
Preservatives	absence				
Stabilizers and emulsifiers	absence				
Salt, % - in the cheese - in the brine	 3,5+/- 0,5 from 6 to 10				
Degree of maturity(ratio of soluble to total protein)	14,0	16,0	14,0	14,0	14,0
Energy value, in kcal/100g, at least :	264	287	287	264	269

TABLE III
MICROBIOLOGICAL FEATURES

Features	Requirements
	Bulgarian white brine cheese
Staphylococcal enterotoxins	n=5,c=0,m(M)- absence in 25 g
Listeria monocytogenes	n=5, c=0, m (M) -absence 25 g, before release in the market n=5, c=0, m<100 cfu/g until expiration date
NOTICE: n- required number of samples to be tested c- number of samples with allowed deviations of the norm; m-norm.	

The tables show that the main quality and safety features of cheese are related to appearance (brine, surface texture, and color) and the composition of the products (dry matter content, butter content, salt content, and acidity).

3. Basic approaches and methods for analysis and assessment of dairy products

3.1. Traditional methods

In the quality assessment of dairy products, two basic approaches are applied: physicochemical and organoleptic. Various methods based on these two approaches are recognized as standards and are described in the regulations.

Organoleptic methods usually precede the physicochemical testing of the samples. They determine the shape, size, weight, appearance, texture, cut surface, texture and color, flavor and as a rule, experts do this. However, experts' assessment is not accurate because of the imperfections of human sensory organs. Such an assessment is sometimes too subjective, often depends on qualification, experience and the current health state of the expert. [5]

Physicochemical methods give more accurate and reliable results. In general, both approaches are expensive, labor intensive, require a long time to obtain the results, and are associated with the destruction of the samples.

It can be suggested that physicochemical and organoleptic methods are not suitable for nondestructive and rapid assessment, which is preferred for inspection at retail stores and food warehouses.

3.2. Modern methods based on color images and spectral analysis

As it was previously discussed in Section II, the main quality and safety features of cheese are associated with the appearance and the composition of the product.

Experts evaluate features from the first group by visual assessment. It can be suggested that the measurement of such features can effectively be done by using computer vision systems (CVS) [5, 6, 11, 13, and 14]. Sundaram Gunasekaran and Kexiang Ding [7] made a comparative analysis of human and computer vision. Many researchers believe that computer vision has more and significant advantages such as objectivity and greater run-time, but the authors take into account that some disadvantages as hardware limitations and problems with insufficient or inadequate lighting should not be underestimated. This important aspect of the application of computer vision in the food quality estimation is discussed in [8].

Modern methods of analysis and assessment of quality and safety of various food products are related to the composition of the products and are based mainly on the use of spectrophotometric systems and methods for spectral analysis (SFMS)[5, 9, 10, 11].

3.2.1 Computer vision systems application

Sundaram Gunasekaran [12] provides an overview of the applications of computer vision for quality assessment mainly for cheese. The author pays attention to the fact that the concept of quality is conditional especially for dairy products and draws attention to the fact that the test methods are too biased. A review has been made on the possibilities for assessment of some general properties of cheese by computer vision. To assess the melting properties of cheese they have used an interesting approach in which the sample is placed on a pre-marked surface coordinate system. Then, the sample is heated and with the help of video cameras, the degree of deformation is measured. The degree shred forming and browning when baking cheese is also considered a possible application of computer vision. Several examples of the oiling off property of cheese are discussed. The proposed method is similar to the previous method. The sample is placed on a piece of filter paper. When heated the oil soaks into the paper and forms a ring around the sample. Computer vision is used to extract the characteristics of the ring and this gives information about the amount of oil released. Those applications of computer vision analysis of cheese have been identified as key in this area [13]. Analyzing chips also provides valuable information on the properties of the cheese. [12] The characteristics of sawdust are extracted by analyzing the images. Proposed are different algorithms and procedures for determining the quality of grated cheese. Some common defects such as the formation of crystals of calcium lactate are discussed. This defect is not dangerous to health, but gives a bad appearance of the product and it is recommended being avoided. More interesting are defects as pores or holes. Sometimes they can be formed from bacteria in cheese (most often Clostridium tyrobutyricum). The presence of pores can be an indication of improper storage. Sometimes they occur with abrupt cooling of cheese.

The author discusses the possibilities of computer vision to analyze the microstructure of cheese including three-dimensional images. The opinion in general is that overall computer vision has not found wide application especially in the dairy industry.

Hai-Hong Wang and Da-Wen Sun [14] also investigated some functional properties like melting and browning of cheese. Using computer vision system, they conducted some experiments and a comparison of results obtained at different temperatures.

The same authors [15] studied oiling off property of cheese with computer vision and implementation of the traditional method with the formation of a ring of oil released onto filter paper. They use computer vision for other features such as histograms and some general parameters such as the number of image pixels, minimum, maximum, etc. The results are compared with the other results obtained from the traditional methods. The percentage of released fat determined by computer vision is referred to the R-value obtained by the traditional method and it appears to be a reliable parameter. It turns out that the general parameters of the images do not provide valuable information since their values change with different temperatures.

In [16] the authors pay more attention to these parameters and monitor the changes in different experimental conditions and different sizes of test samples for two types of cheese. The results show that these parameters are not suitable for determining the oiling-off properties of the cheese.

Tomas Jelinski, Cheng-Jin Du, Da-Wen Sun, Jozef Fornal [17] used computer vision to determine the distribution and quantity of spices in pasteurized cheese. For localization of the spices they used threshold that is appropriate in this case since the color of spices differs from the cheese color (paprika, pepper, etc.) The results show that computer vision can be successfully applied to monitor the production of cheese with spices included.

3.2.2 Spectral analysis of dairy products

Spectral analysis has found wider application in assessing the quality of dairy products. Moreover, the possibilities for the application of spectral analysis in the near-infrared and mid-infrared region are well studied in the assessment of dairy products. This includes monitoring the production process, identifying the geographical origin, quality, monitoring the ripening process of some dairy products and more.

The majority of publications on these topics are related to studies conducted in laboratory conditions [18]

Spectral analysis is safe, does not destroy the test samples and it does not use any additional chemicals and reagents. It works on the electromagnetic spectrum with wavelengths from 700nm to 2500nm for the near infrared. Can be used in liquid, solid, gas, and semi-solids. In fact, a great advantage is that it can be applied to many samples without any significant impact on the cost and timing of the study. [19]

In [18] are discussed some applications of spectral analysis. Specifically, it is used to determine the composition of milk. It successfully predicts the main ingredients as the amount of fat, lactose, protein and more. The possibilities of infrared spectral analysis to characterize callable milk and finished dairy products are discussed. The authors notice that his type of analysis can be used in processes for the production of dairy products in three ways: off-line, outside the production line when the sample is sent to a laboratory; at-line testing, directly next to the production lines and in-line when the spectrometer is integrated within the production line and analyze the parameters in real-time.

For effective analysis, it is often necessary to use different wavelengths for different types of test models. On the other hand, it is necessary to take into account the conditions under which the analysis is done, such as dust and vibration. Spectral analysis in the near infrared region is not enough - it must be applied in the right way. [19] For example, in [18] is stated that spectral analysis by near-infrared absorption gives more accurate results that

the analysis with the reflection of light when predicting the water content. However, many authors agree that the spectral analysis by reflection of light is better suited for predicting the milk components.

A very interesting feature of spectral analysis is the geographical origin determination of the cheese and the possibility for determining whether is produced in summer or winter. One of the most important tests for dairy products - microbiological applied to the spectral analysis also give accurate results.

M.Drackova, L.Hadra, B.Janstova [20] analyzed goat milk by spectral analysis in the near infrared. They predict fat, lactose, freezing point, protein, etc. by applying FT-NIR method. The results show that the proposed method has been successfully applied to determine the composition of goat milk.

Douglas McQueen, Reginald Wilson [21] made a comparative analysis of two methods-OT-NIR and FTIR-ATR. These methods were applied to 24 samples of cheese for predicting fat, protein, and water. Along with this study, the same parameters are obtained through chemical reference methods. Using the first method, correlation coefficients among 0.93 and 0.96 and error among 2% and 5% are achieved. The second method gives poor results and its correlation coefficients are among 0.81 and 0.92, and errors increased from 4% to 9%.

Ruzickova J., Sustova K. [22] applied spectral analysis of dairy products by near-infrared FT-NIR method. The results were compared with results of the reference methods. Reached is best correlated in the study of yogurt - 0989 Fat, 0875 for pH, 0.989 dry non-fat solids.

Yongni Shao, Yong He and Shuijuan Feng [23] determine the sugar content and acidity in yogurt. They explore three methods (S. Golay with smoothing, S. Golay 1st Der and WPT) for preparation of data before being analyzed by PLS method. They find out that the best results are reached when data is processed with WPT method. In this case, correlation coefficients reach 0.91 and 0.90 respectively, and the RMS error 0.36 and 0.04.

Roman Balabin and Sergei Smirnov [24] examined the use of spectral analysis for the presence of melamine in dairy products. They apply analysis in the near infrared, as well as middle infrared region and find out a non-linear attitude between mid spectra and the presence of melamine.

R. Tsenkova, S. Atanasova [9], [21] explore the possibilities of spectral analysis in the near-infrared range of 1100 to 2400 nanometers to measure fat, protein and lactose in non homogenized milk during milking. In the experiment, 260 samples were collected. To compare the results of spectral analysis with those of the reference methods used SECV method (standard error of cross validation). The errors range from approximately 0.107% to 0.138% of the fat content, 0.092% to 0.125% for proteins, and 0.066% to 0.096% of the lactose content.

Based on the review of the application of computer vision and spectrophotometric analysis for quality assessment of dairy products, the following statements can be suggested:

1) The computer vision can assess only particular, specific quality features (such as color, surface texture, etc.), which are usually based on different types of features, mainly morphological, color or color-texture features. It can be expected that with such insufficient information it is not possible a complex assessment to be done.

2) The spectral analysis is one of the most effective approaches for non-destructive determination of qualitative and quantitative features related to the internal structure and composition of the products (dry matter, butter content, salt, and acidity).

3) The assessment of the basic quality features of dairy products requires an integrated approach for the analysis, which allows to be analyzed and evaluated both organoleptic quality features and features related to the composition of the products. An assessment based only on color images or spectral analysis is insufficient. In order to obtain complex and accurate assessment based on the key quality features it is necessary to be developed methods, approaches and tools for combining the results of both the analyses. In the reviewed papers, such an approach is not proposed.

4. Complex assessment-unification of the two approaches for analysis

Since dairy products assessment is related to the determination of both the visible features and the composition of the products, the complex assessment must be based on combining the results obtained from the analysis of color images and spectral data.

This approach was successfully applied in assessment of grain samples [5, 25, and 26]. The author makes a complex research of the possibilities for the determination of basic quality features of grain samples by using a computer vision system and spectrophotometric system.

It is shown that errors in the classification of grain samples in accordance with the regulatory requirements, obtained by analysis of color images, and spectral analysis in separate can be significantly reduced by combining the results of both analyzes (Table IV).

TABLE IV
ERRORS IN CLASSIFICATION OF GRAIN SAMPLES

TESTING ERRORS		
Image analysis	**Spectral analysis**	**Fusion the results from image and spectra**
8,6	7,3	5,3

5. Conclusion

Certainly, physicochemical and organoleptic methods are not satisfactory for rapid, nondestructive assessment of dairy products, which is necessary for inspection at retail stores and food warehouses. Furthermore, for routine commercial site inspections, it is more efficient to use methods that provide fast and accurate results in real-

time without destroying the samples. The review of the computer vision application and spectrophotometric analysis for dairy products quality assessment showed that these two approaches allow evaluating of certain specific quality and safety features.

Assessment of basic quality features of dairy products requires an integrated approach for the analysis, which makes possible to be estimated both the physicochemical and organoleptic features. As a result, such an assessment cannot be obtained by analysis of color images and spectral data in separate. In conclusion, it is necessary to be developed approaches, methods, and tools for combining the results from both analyzes, in order to obtain an accurate complex assessment.

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