

INSTRUMENTAL TEXTURE MEASUREMENT OF MEAT IN A LABORATORY RESEARCH AND ON A PRODUCTION LINE

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Received: 2013.06.05
Accepted: 2013.08.07
Published: 2013.09.06

ABSTRACT

Components of meat texture are especially important features for consumers. The systems with guaranteed repeatable quality must be associated with online, reliable and quick measurements of chosen, critical for consumers, quality features. In case of the texture features, the most important is tenderness. In laboratory conditions it is measured using shear test. However, it is a time-consuming and destructive method without possibility of measurement automation. Hence, in case of online measurements, there is a necessity to use other methods. The most promising methods are near-infrared spectroscopy and computer image analysis, enabling measurement of a lot of features, *inter alia* texture features.

Keywords: meat, texture, industrial measurements, online measurements.

INTRODUCTION

Components of the meat texture are from the consumer's point of view the features of particular importance. Tenderness, chewability and a small muscle fibres are those textural features that are most important differentiators that determine consumer acceptance of meat. From consumer's point of view, the most desirable meat is tender, juicy, low-fibrous [3]. And for such meat, consumer is willing to pay a higher price than for other, if they are characterized by other properties at comparable levels [16].

The quality of the meat in consumer evaluation of sensory attributes, is associated primarily with four main features – tenderness, juiciness, colour and flavour, with tenderness being particularly important, not only among the textural characteristics, but also in general – among the general qualities. Studies indicate that low score for each

of the mentioned characteristics of the product, may contribute to low overall score of meat sample. Moreover, the tenderness was identified as the most important attribute for the meat [12].

In meat production, guarantee of the textural characteristics desired by consumers – tender meat characterized by low fibrousness, are of a great value. The producer is sure that customers will find such meat attractive and, what is more, it will be possible to obtain a higher price for it than for meat which is not characterized by guaranteed features desired by the consumer.

However, the need for traceability of meat production should be emphasized. It is necessary to indicate the suitable information on the package to inform the consumer and provide a real guarantee of desired traits. Only meat product of reproducible quality can convince consumers of their high quality and that it is worth paying a higher price for it. Quality systems created to

ensure repeatability must be based on real, honest and fast measurement of selected quality features, critical from consumer's point of view. Meanwhile, the problem of meat production sector is usually associated with the lack of the communication between participants of meat production chain, as well as lack of the consumer-oriented policy [10].

Producers should contribute to building and maintaining consumer confidence, what is possible by using a number of tools to automate the measurements on the production line to introduce necessary changes to correct the current defect as well as to archive the results for further analysis resulting in the continuous improvement of the process.

SHAPING THE TEXTURAL FEATURES OF MEAT

The above-mentioned quality features may be ensured by production systems which are designed to guarantee a consumer a constant and reproducible quality of meat products. It is possible not only by building the mechanisms for implementing the system of feedback from consumers, but primarily through the use of precision control devices. This is due to the fact that guaranteed food quality systems are forcing producers to maintain stable quality of the produced food, hence, it must be controlled during the process of production and distribution.

Meat production strategies, selected by the producers, should be aimed at obtaining tender meat, as such meat is of highest value for the consumers. Growers and producers should take into account the ante-mortem and post-mortem factors that could significantly affect the tenderness. However, it should be emphasized, that such factors may affect other textural characteristics of meat, both in a positive and negative way, so at the same time, producers should focus on the introduction the factors which have a positive effect on the texture and avoiding factors that may have a negative impact [7].

Tenderness is referred to as the resultant of the length of sarcomeres, the postmortem proteolysis, the amount of connective tissue and its structure (integrity). Formation of this feature is complex, as it requires taking into account a number of factors and must be individualized depending on breed, conditions, including *inter alia*

method of feeding, planned slaughter age of the animal, as well as maturation process, packaging and heat treatment. It should be also emphasized that the creation of meat tenderness depends on muscle – it is concluded that depending on the element of the carcass, higher or lower tenderness is observed [7].

INSTRUMENTAL MEASUREMENT OF MEAT TEXTURE IN THE LABORATORY – SHEAR TEST

The most commonly used test to determine the texture in laboratories around the world are the methods which use testing or strength testing machines with appropriate instrumentation. The most frequently used measurement sensors are Warner-Bratzler blade (WB) and the Kramer cell. The principle of the methods is based on the simulation of chewing food products. The first idea of cutting test, conducted using samples of cooked meat, was developed in 1920 by Kenneth F. Warner and colleagues to measure the fragility [22]. The method using a Warner-Bratzler's blade was developed in 1932 by Lyman J. Bratzler and since the 1950's it is widely used to determine the tenderness of meat products, fish and cakes. U.S. scientists, through multicenter studies, created a definite procedure to deal with samples and pointed the test conditions, so that the WB test conducted in accordance with the protocol allows for direct comparison. This method applied in case of meat samples, require flat, V-shaped blade (thickness of 0.04 inches, the angle of the blade 60°, the speed of the working element 200–500 mm/min) (Fig. 1). In addition, the sample should be characterized by diameter of half an inch and be conducted with the cutting blade configured perpendicularly to the direction of muscle fibres [21].

The second previously mentioned method – a method using Kramer cell was developed in 1959 by Amihuda Kramer and Bernard A. Twigg and is used to assess the texture of fine products such as cereals, vegetables and small pieces of fruit or chopped products, and in the case of meat products – minced meat and products such as pates. This method uses a chamber with a set of 5 or 10 parallel blades. It is assumed that the number of blades is eliminating local deviations of the measured values that are becoming irrelevant. Moreover, a better simula-



Fig. 1. Texture analysis equipment with the V-blade

tion of biting and chewing during the consumption of such food products is achieved. These methods used in a laboratory have a high suitability for detailed analysis, for example to focus on the dependencies associated with used breeding techniques and their impact on the final quality of meat (Fig. 2.)

The mentioned methods necessitate special equipment, as well as training and qualifications of the research team, which are needed not only to conduct test but also to interpret the results. However, the most important problem associated with using on an industrial scale methods commonly used in laboratory tests, is the destructive character of these methods. The analysed meat cannot be subjected to market procedures or consumption [15]. Consequently, in the case of analyzes carried out on an industrial scale, which requires many samples' examination in a short period of time and obtaining the results quickly, these methods are not optimal [5].

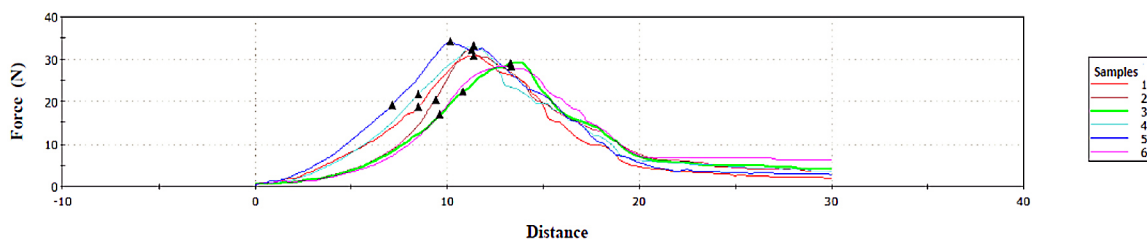


Fig. 2. Example of graph of instrumental texture measurement

INSTRUMENTAL TEXTURE MEASUREMENT OF MEAT IN THE PRODUCTION LINE

Accordingly, research carried out “online” – on a production line are a different group of methods. This group includes methods of visible and near-infrared reflectance or computer tomography (including methods based on X-ray). The most widely used method is near-infrared spectroscopy. Another option which allows the assessment of the texture of meat is the use of vision systems – image analysis, which allows for a broad assessment of the analyzed meat products: their colour, shape, fat cover, loss during thermal treatment and textural characteristics indirectly.

INSTRUMENTAL TEXTURE MEASUREMENT OF MEAT USING THE METHOD OF INFRARED (IR) SPECTROSCOPY

The IR spectroscopy, as concluded by experts may be in the future a very important tool in the food industry. It can be used for quality control of production and product on the production line and thus – is an essential element for maintaining a high standard of production. However, the importance of rapid control of the selected quality parameters not only in the production line, but also at the stage of raw material quality control should be also emphasized [19].

Method of infrared spectroscopy is characterized by high utility and a broad spectrum of applications. However, it should be noted that this does not allow direct texture measurement of meat, but only a prediction and approximate determination, while the accurate calibrations have been established for a particular tested materials based on reference chemical methods [15]. It is also used for other than meat groups of food products and for the measurement of specific components, such as cholesterol.

Knowledge on the chemical composition of the material allows proper conduction of the production process, including its adaptation to the required final quality. However, the quality of the final product is affected not only by basic composition, but also other product attributes, such as added salt, spices or texture [17, 18].

In addition to the previously indicated characteristics of the tested material (such as composition), using this method it is also possible to try to identify other features, including the textural features. Correlation of instrumental measurement of textural properties of meat conducted using instrumental tests (mainly a shear test using a Warner-Bratzler blade) with those estimated using reflectance spectroscopy in the near infrared, is statistically significant, however, some authors indicate that it could be higher. There were also studies comparing the results obtained using this method with the results obtained from expert sensory evaluations, however the achieved results were not satisfactory. The opportunity to improve the accuracy of texture parameters, especially beef tenderness, prediction is indicated. It could be done after obtaining more accurate reference data that is necessary to conduct analysis using this method on a large scale.

Additionally, this method, among those which can be used to assess the meat textural parameters on the production line, is characterized by a relatively high degree of correlation of results with the results of sensory evaluation performed by consumers. The disadvantage of this method is a labour-intensive preparation of calibration, which must be made using reference methods.

Of these methods the ones primarily used are near-infrared spectroscopy – NIR (the range from 700 to 2500 nm) and mid-infrared spectroscopy – MIR (the range from 2500 to 50 000 nm). Near-infrared spectroscopy allows conducting the analysis lasting only several minutes, during which it is possible to obtain the results of the various quality characteristics of meat.

The most important advantage of near-infrared spectroscopy is high repeatability of the results, although it may be characterized by relatively high values of errors, particularly in the case of the incorrect sample preparation or lack of appropriate standards. High measurement accuracy is critical in the assessment of methods used to analyze the qualitative characteristics on the production line – these methods must primarily meet the required level of measurement accuracy

[19]. This method, in contrast to the mentioned computer image analysis, is a destructive method in its traditional form (Fig. 3), therefore, it is not possible to analyze samples which are planned to be placed on the market afterwards. However, it requires a relatively small sample of the tested material, which may be comparable with the size of the sample used in the a share test.

The advantage of this method is the fact that sample preparation is very simple and a measurement, as well as the interpretation of results does not require special preparation, training and substantive knowledge. Moreover, it is a method that does not require the use of chemicals. Therefore, it could be possible to automate the production line during conducting research using the near-infrared spectroscopy for the analysis of various types of products, *inter alia*, to evaluate the fat content in beef [1].

Near-infrared spectroscopy may be used “online” at different stages of meat production – to assess the carcasses before cutting or maturation process, to assess the maturation processes, and to evaluate the final product. Using special sensor also non-destructive analysis may be made using optical techniques (fiber-optic contact probe) [19].

This method not only allows controlling the quality of raw materials, the final product and the accuracy of the process, but also gives additional benefit of enabling the production process changes. In the production, dynamic process changes for example; changes in the stage of maturation or other stages, conducted taking into account the detailed composition of the product observed on the production line, would be of a great value [15]. As a result, the producer can be flexible in the production process, that is associated with a high quality final product.

Studies conducted using near-infrared spectroscopy to evaluate the textural meat properties may be carried on with samples of raw meat, as well as meat after thermal treatment. Analyses using meat after thermal treatment, according to research, are characterized by a higher correlation with the results of sensory analysis, however, it should be noted that such analyzes are more labour-intensive and time-consuming, so for this reason cannot be used on the production line.

It is also necessary to indicate certain disadvantages of near infrared spectroscopy method, which may affect its utility in application on large-scale in the industrial conditions. It requires



Fig. 3. Near-infrared spectroscopy analysis equipment

a high homogeneity of the analyzed sample, so the authors of the studies indicate that the meat, including pork, as a heterogeneous product is not the optimum product during the analysis conducted using the near-infrared spectroscopy, as the results are just approximate and this method cannot replace the reference methods, but on the other hand, allow obtaining a rapid, reproducible results.

INSTRUMENTAL MEASUREMENT OF MEAT TEXTURE USING METHODS OF COMPUTER IMAGE ANALYSIS

Computer image analysis is a method that allows conducting the assessment of all the visual characteristics of meat and, what is more – also to predict the texture, which may be evaluated on the basis of surface image of the culinary element (Fig. 4).

The principal factors that may be assessed using this method are all features of the image - the colour of muscle tissue, fat and connective tissue [8, 9], size of the element, shape, the share of intramuscular fat (called marbling), the fat cover and a connective tissue, the surface appearance, including the thickness and composition of visible fibres [20].

The computer image analysis method is used both in the laboratory and industrial scale. Moreover, it is possible to carry out analyzes of the carcasses (eg. classification performed on the automatic measurement lines using meat image analysis to assess the degree of fatness and conformation by EUROP classification), the culinary elements and individual steaks (slices of meat). It



Fig. 4. Computer image analysis equipment

allows to analyze the relationships of the applied breeding techniques or methods of slaughter and processing to visual quality of meat. At the same time, there is a huge potential of using this method in the industry, for analysis and quality testing carried out on industrial scale [6].

Computer image analysis may be used in the research conducted “online” because it is a repetitive, non-destructive method and allows getting the results correlated with the chemical and sensory evaluation. Particularly important advantage of this type of analysis is that one picture (image of the area) of meat enables the simultaneous analysis of many factors. Therefore, the object of the study is the obtained image of meat slice surface that is associated with the possibility of further complex analysis of the image using specific algorithms conducted without stopping the production. This method also provides quick results, allows changing and flexibly adapting production process depending on the quality of the raw meat. Consequently, it is very favourable, in the conditions of the production line, to assess not only the visual characteristics, but also, to estimate and predict other features, including the textural features if possible [4].

It may be stated that, in case of the prediction of texture, using computer image analysis, there are high expectations, and the method itself is de-

scribed as very promising. Research indicate that there is a possibility of estimation of structural features, including tenderness, which can be carried out 2–3 days after slaughter. The researchers conclude that the widespread use of computer image analysis is possible, as it enables the analysis of the visual and textural features, what is important in the measurement and control of raw material and product to ensure the quality of the final product.

The evaluation of these traits of meat using computer image analysis is based on the surface planimetry analysis. The material can be subjected to the analysis of images obtained under constant conditions using a camera, photo camera, ultrasound or computer tomography scan. The use of appropriate computer software allows accurate and precise analysis that would be impossible to carry out using the simple visual assessment of the elements or carcass conducted during traditional assessment based on a comparison of patterns and classification in the appropriate quality classes [2].

Forecasting meat texture using computer image analysis is carried out by analyzing the characteristics of colour images of surface of the culinary element with appropriate algorithms and based on correlations with instrumental texture measurements obtained using a universal texture testing machine [14]. Observing the surface of meat a consumer is able to specify, with some approximation, its texture; the computer image analysis allows also such a prediction. Consumer's perception of texture features by observing the visual features is based on the primary characteristics, such as size, orientation, and contrast, perceived with respect to the observed components. Therefore, while evaluating textural features of meat, using computer image analysis, it is appropriate to use colour images instead of gray scale images. Research indicate that computer image analysis method, based on the surface images of cooked beef, pork and lamb elements, allows defining the characteristics of texture and, more importantly, also to do the classification of meat images. It can be concluded that properly taken images of meat surface allow classifying meat in terms of texture – characterized by higher tenderness and lower fibrousness, as well as lower tenderness and higher fibrousness [2, 13]. Elaboration of such an algorithm that allows quick and simple classification of elements or carcasses taking into account a number of meat qualitative characteristics would

have a highly significant impact, not only on meat production industry, but also on processing and the whole meat market. Introduction to the widespread use of qualitative methods of meat quality assessment would be a quick way to improve the quality of meat available on the market. It would give an opportunity to improve the perception of meat by consumers.

CONCLUSIONS

For consumers, the tenderness is a critical attribute of sensory palatability of meat. It is an element of meat texture, which includes also the fibrousness, juiciness and other features. The differences in the texture of meat are a result of differences in the structure of raw meat (muscle tissue) and relate to changes in protein, fat and carbohydrate components. Therefore, through the indirect measurement of these features using a non-destructive method, texture, including meat tenderness, measured instrumentally or sensory, may be predicted with high probability. It may be also predicted on the basis of the visual analysis of the structure, as the texture results from specified structure of muscle fibres. Progress in methods of meat texture analysis is done by using the modern non-destructive and non-invasive technologies, including methods of near-infrared spectroscopy and computer image analysis.

Acknowledgements

Research was realized within the Project "BIOFOOD – innovative, functional products of animal origin" no. POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007–2013.

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