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RECENT TECHNIQUES FOR EVALUATION OF MEAT QUALITY

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ABSTRACT

Over the years, numerous and varied techniques have been used for evaluation of meat quality and carcass composition. Very few existing assessment techniques meet industrial requirements, the most promising being cited as ultrasonic measurements for assessment of potential texture on live animals and whole carcasses and image processing and NIR spectroscopy of meat joints and cuts. In this article besides these techniques, electronic nose and NMR techniques are reviewed.

Key Words : Meat, Ultrasound, Image process, NIR, Electronic nose, NMR

ET KALİTESİNİN DEĞERLENDİRİLMESİNDE YENİ TEKNİKLER

ÖZET

Karkas kompozisyonunun ve et kalitesinin değerlendirilmesinde yıllardır çok sayıda ve çeşitli teknikler kullanılmıştır. Mevcut tekniklerden endüstrinin ihtiyaçlarını karşılayanlar çok az sayıdadır. En fazla umut veren teknikler, canlı hayvanın ve tüm karkasın tekstürünün değerlendirilmesinde kullanılan ultrasonik ölçümler ve parça etler için kullanılan image proses ve NIR spektroskopisidir. Bu makalede, adı geçen tekniklerin yanısıra, elektronik burun ve NMR teknikleri de değerlendirilmiştir.

Anahtar Kelimeler : Et, Ultrason, Image proses, NIR, Elektronik burun, NMR

1. INTRODUCTION

Since the meat quality is a major problem within the meat industry, much work that is done to understand the scientific basis of sensory perceived quality attributes, their evaluation, prediction and control remain mostly elusive within the meat processing plant.

In the past three decades there had been increasing demands for:

- Technological quality due to the highly advanced industrialisation of meat processing.
- Guarantees of safety and eating quality from consumers having an extensive range in choice of food commodities.
- Authenticity, a concept which includes many aspects such as adulteration, improper description of the products and the designation of origin.

Thus, the agents of the fresh meat production chain are facing a still increasing need for techniques of meat quality evaluation. In parallel, meat research has developed in tremendous proportion. In every

domain of meat science, researchers need access to new techniques in order to go deeper and faster into the comprehension of the mechanisms underlying meat quality.

Image processing, nuclear magnetic resonance, near infrared reflectance spectroscopy, ultrasound and electronic nose represents some of the new technologies for predicting the quality of meat and meat products. This review will focus on techniques intended to predict technological and sensory qualities, applicable to meat, for use in the industry as well as in research laboratories.

2. NEW APPLICATIONS FOR EVALUATION OF MEAT QUALITY

2. 1. Image Processing

Visually discernible characteristics of fat and lean indicate the eating quality of fresh meat. The difficulty in accurately estimating fat and lean within meat has led to the development of a wide range of techniques for determining fat/lean content in boneless fresh meat and processed meat products. The most accurate method of measuring fat content in meat is undoubtedly chemical analysis, but this can be both costly and time consuming.

A system using a video camera and an image analyser has been used for rapid, non-destructive measurement of visible fat and lean in fresh boneless meats and meat products (Newman, 1984).

Other than the fat and water content, the major emphasis in quality grading is placed on the muscle protein and connective tissue (Hildebrandt and Hirst, 1985). Image processing techniques can also quantitatively and consistently characterise complex colour, geometric and textural properties (Li et al., 1999). Television image analysis is a planimetric technique. Light from the objects strikes the photosensitive surface of the tube in the video camera. The individual elements of the tube become charged relative to the light intensity at that spot. An electron beam scans the tube and each individual element discharges a voltage proportional to the intensity of the light striking it. This constructs a video image composed of 600 picture lines, each containing 400 picture points. Voltages to differentiate sample from background and fat from lean are preset. Voltage comparators compare each incoming picture point voltage with the pre-set value and increase the appropriate fat/lean counter if it exceeds this value. In this way, by examining every

picture point signal, an accurate two-dimensional assessment of fat and lean within the sample image can be determined. Calibrating the system using objects of known dimensions, allows quantitative measurements to be made (Newman, 1984).

Steaks with various degrees of marbling and colour, were subjected to sensory evaluation and image processing. Image processing features accurately predicted the colour ($R^2 = 0.86$) and marbling scores ($R^2 = 0.84$) of beef steaks that were taken at the 12th and 13th rib where beef quality grades were determined in an "on-line" commercial setting (Gerard et al., 1996). In another study, objective measurements of beef rib eye steaks were investigated to determine the colour distribution throughout their interior after heat processing. Steaks from eight animals were grilled to five degrees of doneness according to internal temperature specifications. Image system can be used successfully to determine the steak doneness classes (Unklesbay et al., 1986).

Crude fat content of longissimus muscle of beef cattle was predicted from a ratio of fat area to area of rib eye muscle calculated from computer image analysis. Crude fat content as determined from chemical analysis was used as the true estimate of fat content. The results of this research indicate that, computer image analysis of cross sections of the rib eye muscle seems to have potential for prediction of crude fat content (Kuchida et al., 2000).

Texture analysis has been used to classify photographic images of meat slices. Among the multiple muscular tissue characteristics that influence meat quality, the connective tissue content and spatial distribution, which define the grain of meat, are of great importance because they are directly related to its tenderness. Connective tissue contains two important components, fat and collagen, which are variable with muscles, breed and also with age. These components are clearly visible on photographic images. Fat and collagen are particularly emphasised by ultraviolet light. Basset et al. (2000), analysed texture of photographic images using several feature extraction methods to evaluate the possibility of identifying bovine meat samples. The classification of the samples showed encouraging results. Textural features calculated on visible light and UV light images have the potential to be used as a method of indicating physical characteristic of meat samples. The possibility of certifying the origin of the meat and the kind of meat proposed to the consumer is of major interest.

2. 2. Nuclear Magnetic Resonance Imaging

Non-invasive nuclear magnetic resonance is a useful tool to evaluate the distribution of water and instrumental texture in both raw and processed meat (Tornberg et al., 2000). NMR presents several advantages over chemical techniques. It can be used *in vitro* on muscle samples, but also non-invasively *in vivo* on small and medium-sized meat animals. It avoids the variability inherent to repeated sampling (Monin, 1998). However, NMR has not been widely used in meat science, even though a broad range of applications is potentially feasible. The high cost of NMR spectrometers is a disadvantage (Laurent et al., 2000).

Nuclear magnetic resonance (NMR) imaging is widely recognised as a valuable diagnostic procedure (Duce et al., 1994). This technique provides two and three-dimensional images from large heterogeneous opaque systems, without damaging the sample. Differences in the water proton content and the NMR relaxation times of tissues permit excellent contrast between fat, muscle and various other tissues. NMR frequencies of water and lipid protons result in two peaks in frequency spectrum. The separation of the peaks is limited by the magnetic field strength of the instrument and the homogeneity of the magnetic field. The strength of the peak is used to estimate the total water or lipid content in the sample (Mitchell et al., 1991).

Changes in muscle energetics are easily monitored by ^{31}P NMR (nuclear magnetic resonance) which measures phosphorylated compounds such as ATP, creatine phosphate, sugar-phosphates and inorganic phosphate (P_i). The pH can be evaluated from the position of the P_i resonance. ^{31}P NMR makes it possible to investigate pH heterogeneity within muscle tissue. A broadening or splitting of the P_i resonance may occur in post mortem or excised muscle. It was attributed to the existence of cellular micro-compartments with different internal pH values (Monin, 1998). NMR imaging has also been used to monitor loss of adipose tissue during weight loss (Mitchell et al., 1991).

In a study, phosphorus- Nuclear Magnetic Resonance (^{31}P NMR) was used to evaluate degree of freshness of loach muscle depending on metabolic changes of high energy phosphate compounds. Changes in concentrations of creatine phosphate and its degradation products (inorganic phosphate) were examined to degree of fish freshness immediately after being caught. The energy charge determined by the ^{31}P NMR technique is found that a more reliable indicator of the degree of freshness in fish soon after they are caught than is the conventional K value. ^{31}P NMR

reflects the energy state of fish muscle and thus can be used in assessing fish quality (Chiba et al., 1991).

Fluid exudation is particularly detrimental to commercial appearance of prepacked meat, firstly pork but also beef and veal. Water holding capacity of meat depends primarily on the extent of the post mortem myofibrillar shrinkage and the correlative changes in the extracellular water compartments. NMR relaxation measurement of water protons gives information about dynamics of water (Monin, 1998). Nuclear magnetic resonance (NMR) spectroscopy has proved to be an excellent method to study the chemical state of ions, as reflected in the longitudinal relaxation time (T_1) and transverse relaxation time (T_2). Na NMR has been widely used, for example, to determine salt mobility in food or model systems and to determine the perception of saltiness in salty gum solutions. Cl NMR has been used in some biological systems. In a study, to assess the contribution of NaCl to seafood tastiness, Na and Cl nuclear magnetic resonance (NMR) spectroscopy was used to determine the mobility of sodium and chloride ions in intact snow crab (*Chionoecetes japonicus*) leg meat (Nagata et al., 2000).

2. 3. Near Infrared Reflectance Spectroscopy

Visible /NIR spectroscopy has already found considerable applications in food and meat products. Common applications with meat include the quantitative prediction of not only chemical composition, such as fat and protein, but also physical characteristics, such as hardness and tenderness (Liu et al., 2000). The technique has been employed successfully to discriminate normal and abnormal chicken carcasses, fresh and frozen-then-thawed beef, beef and kangaroo meat and broiler and local chicken carcasses (Ding and Xu, 2000).

Near-IR spectroscopy offers four principal advantages: speed (less than 3 min), simplicity of sample preparation (sometimes no sample preparation), multiplicity of analyses from a single spectrum (determination of different components at the same time), and no destruction of the sample (after analyses, the sample can be used for another purpose). Near-IR technology has two modes: reflectance and transmittance. In the reflectance approach, near- IR energy is directed against the surface of the sample. The energy scattered off the surface is measured by a suitable optical detector (usually made of lead sulphide). For meaningful measurements, the sample must be ground into a consistent fine powder. In the transmittance approach, near-IR energy intersects the surface of a

sample. A portion of this energy is transmitted through the sample and exists from the rear of the sample. A silicon detector is used to measure this exiting scattered light. Measurements using transmittance mode can be made without any sample preparation, such as sample grinding (Zhang and Lee, 1997).

In a study, near-infrared reflectance spectra were collected from beef longissimus thoracis steaks for the purpose of establishing the feasibility of predicting meat tenderness by spectroscopy. According to the results, near-infrared spectroscopy enabled the prediction of beef longissimus Warner-Bratzler shear force. Refinement of this technique may allow non-destructive measurement of beef longissimus at the processing plant level (Park et al., 1998). Various methods have been proposed in the past for identification of frozen and thawed meat, relying on electrical properties and enzyme activity determination. The suitability of NIR spectroscopy for identification of frozen and thawed beef was proved. 100% correct classification from intact beef slices was obtained (Monin, 1998).

Free fatty acids as a fish and seafood quality index has been recognized for a long time. A rapid, simple near-infrared spectroscopic method has been developed to directly determine free fatty acids in fish oil for the assessment of mackerel quality. In this research, free fatty acid change in mackerel has the same trend as hypoxanthine (Hx) change as a fish freshness index. Therefore they determined the Hx content of mackerel samples (same samples used for FFA determination) at different storage times as a comparison to FFA determination in the present research for assessing fish quality (Zhang and Lee, 1997).

2. 4. Electronic nose

Analysis of odour and flavour in food has traditionally been performed either by a trained sensory panel or by headspace gas chromatography mass spectrometry. These methods are time consuming and costly and there is a need in the food industry for objective automated non-destructive techniques that can characterise odour and flavour in food. During recent years, there has been a rapid development of a concept named electronic nose (artificial nose) based on chemical gas-sensor technology, which seems to fulfil these requirements. With the term electronic nose is understood an array of chemical gas sensors with a broad and partly overlapping selectivity for measurement of volatile compounds within the headspace over a sample, combined with

computerised multivariate statistical data processing tools. The electronic nose has derived its name because; it in several aspects tries to resemble the human nose. In principle, the primary neurones correspond to the chemical sensors of the electronic nose with different sensitivity to different odours. Chemical interaction between odour compounds and the gas sensors alter the chemical state of the sensors giving rise to electrical signals, which are registered by the instrument analogue with the secondary neurones. In this way the signals from the individual sensors represent a pattern which is unique for the gas mixture measured and is interpreted by multivariate pattern recognition techniques like artificial neural network, the brain of the instrument. When the sensor patterns for a series samples are compared, differences can be correlated with the perceived sample odour (Haugen and Kvaal, 1998).

There are a number of electronic nose systems available on the market. These utilise a range of sensor technologies either alone or in combination (Strike et al., 1999). The most frequently used sensor technologies have shown to be successful and become applicable in food analysis. Sensors can be divided into two basic groups; hot and cold sensors. Hot sensors are metal oxide semiconductors (MOS) and the metal oxide semi conducting field effect transistors (MOSFET), which operate at elevated temperatures. Cold sensors operate at ambient temperature. They consist of the conducting organic polymers (CP), oscillating sensors, optical sensors or electrochemical cells (Haugen and Kvaal, 1998).

A number of applications of the electronic nose in the food industry have been reported, as for quality estimation of ground meat, detection of boar taint in meat, detection of gender differences in meat products, estimation of fish freshness, to follow beer production, etc. (Eklöv et al., 1998). Electronic nose techniques have also been used on several applications concerned with classification of meat samples. A commercial nose (Alpha MOS Fox 2000) with an array of six semi conducting metal oxides was used to classify varieties of dry sausages and cured ham samples of different quality and 94% of the dry sausage samples were classified correctly. For the cured ham samples which consisted of two groups of samples, respectively normal samples and abnormal samples with an aroma defect after slicing, 87 % of the samples were correctly classified (Haugen and Kvaal, 1998).

Electronic nose, solid-phase micro extraction (SPME) and gas chromatographic mass spectral (GC-MS) analysis of the headspace volatile organic compounds were done to compare bacterial species

important for food safety and common to biofilms in the poultry processing environment. Results showed that, electronic nose was sufficiently sensitive to measure the volatiles in the headspace of bacterial samples, and the method was reproducible within the limits of the analyses (Arnold and Senter 1998). Lipid oxidation during storage of fish is well known, and many volatile compounds have been suggested as indicators of spoilage. Electronic nose measurements were compared to measurements of total volatile bases (TVB), gas chromatography of volatile compounds and sensory analyses. The results indicate that rapid electronic nose measurements that require no sample preparation can be used to predict the TVB value of the raw material stored under different conditions (Olafsdottir et al., 2000). The gas sensor array technology may as well be interesting to use in the monitoring of food processing, especially for sausage fermentations to monitor volatile compounds during the fermentation process (Eklöv et al., 1998).

2. 5. Ultrasound technology

Ultrasound technology has been used to predict live animal and carcass traits for many years. Ultrasonic techniques have the greatest practical value in predicting carcass composition of live animals (Smith et al., 1992).

Ultrasound analysis is recognised as displaying many advantages: it is accurate, rapid, non-destructive, non-invasive, relatively inexpensive and suitable for on-line industrial applications. Ultrasonic images are a record of sound waves interacting with physiological properties of a sample (Abouelkaram et al., 2000).

The usefulness of A mode (amplitude, one dimensional representation), B mode (brightness, two dimensional gray-level imaging) and real-time scanning has been well documented. Information from echoing ultrasonic pulsations, generated by piezoelectric crystals in a transducer and received by either the same (pulse-echo) or different crystals (through transmission), is used to describe the mechanical properties of scanned meat samples.

Ultrasonic waves possess no apparent hazards at the levels used in imaging because the waves are nonionizing emission. However at higher acoustic energy levels or if exposed for extended time periods, safety concerns could exist because ultrasound may induce thermal heating within tissues, cause cavitation (micro bubbles of gas), or

result in other disruptive occurrences affecting genetic replication and other cellular functions.

A-Scanning : Most basic A-mode research related to the use of ultrasound in prediction of composition and palatability traits is conducted to characterise fundamental theoretical parameters. These data aid in the future development of instruments specifically for use in carcass grading and evaluation.

B- Mode and Real-Time Scanning: In B-scan imaging, ultrasonic signals are ultimately digitalized, displayed and stored as an image. Digital processing allows for a dynamic range of acoustic signals to be mapped as image-brightness or gray-scale pictorial data. Gray-scale levels of intensity for an image correspond with individual elements of a picture. These elements are referred to as pixels. Evaluation of digitalized pixel data allows the development of quantitative models from which composition of a biological sample can be predicted.

Various characteristics related to the use of A-mode scanning to detect palatability traits were studied. In those studies, the speed at which an ultrasonic wave travels away from the origin was influenced by fat and moisture content. Strong correlations were documented between longitudinal ultrasonic velocity and moisture content such that decreased velocity was associated with increased fat concentrations and increased velocity was associated with increased moisture content (Cross and Belk, 1992).

The use of ultrasound to aid in livestock selection and in ultimate prediction of carcass cutability continues to be one of the current areas of interest to the beef industry. Functional value-based marketing system must have a means of identifying the value of animals or carcasses. Determining the value of cattle, especially with the hide still on them, gives greater comfort to producers than if value is only determined on chilled carcasses. Ultrasound technology may be the answer to this need (Griffin et al., 1999). With continued improvements in ultrasound technology, it may be possible to implement ultrasound evaluation at key points along the marketing chain (May et al., 2000).

3.CONCLUSION

As a conclusion, introducing a new technology into meat industry at the level of slaughtering, meat cutting and distribution is not easy. These new techniques have the great advantage of being accurate as well as robust and were mostly non-

invasive. But they are often expensive and in some cases too sophisticated to be used as a routine part of normal commercial processing. New researches should be made to simplify these techniques, so that every related person can easily apply them. Also cost of investment of these techniques should be reduced. Beside these, it is important to introduce clearly these techniques to meat processors and researchers.

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