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AN APPROACH TO ON-LINE AUTOMATIZED COOKING PROCESS OF WHOLE MEAT PRODUCTS

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SUMMARY

The optimization and the automation of cooking process of whole meat products is necessary, because the importance of catering is permanent increasing.
The actual used possibilities of automation base on the experience, for instance: time-temperature-regimes. The actual biochemical and physical changes of meat during the cooking process are not used as control parameters. Other problems are the missing of an universal mathematical model of cooking process and a universal sensory analysis for cooked whole meat products.
The problem was to find a measuring method, which signals the readiness of meat.
A special consumer analysis has shown, that the chewability and tenderness of cooked meat are the most important sensory factors. An adapted sensory evaluation scale has been composed.
Chewability and tenderness correlate with the rheological property elasticity. A process measuring device has been built, which measures the elasticity in a nondestructive way during the cooking process in the oven. It realices a vibration measurement, which is based on the resonance of the meat. Resonance frequency an the so named "quality" of the vibration perceed a sinus like curve during cooking time. That meat got the highest evaluation, if the process was interrupted at reached constant resonance frequency and "quality". This is the point of readiness of meat which is measurable electrically and so giving a criterion for process control.

INTRODUCTION

The importance of catering for the provisioning of the people is permanent increasing. The production of food is based on the use of traditional production production methods. Optimization and automation of these methods are badly needed.

For the production of food thermal treatment is a basic process, 95 % of all foods pass through a cooking process. The cooking process of whole meat products is an important and complicate one, but this process is else recently based on individual methods. The result is often a product with unreliable quality, high mass loss, high energy consumption and a low nutritive value.
The following variants of automatic control are used:

- temperature-time-regimes for every special product
- measurement of core temperature and control of air temperature (f.i. delta-T-process) /2/
- measurement of air humidity in the oven, of level of crust colour and of the gas composition of the atmosphere in the oven and control of time, temperature and humidity of air in the oven /5/.

The tendency of using microelectronic and programmable systems is growing, but the basis for automation are experiences of the practice. Exterior physical parameters are controlled.
The raw material itself with its biochemical changes during the cooking process is not used as a source of signals. The possibilities of automation mentioned above don't guarantee finding the readiness of whole meat products. The mainly used parameters cooking time and temperature disregard the different properties of meat, for instance the meat qualities like normal, PSE and DFD-quality. These parameters only loosely correlate with the sensory evaluation. The programms for the cooking process can not be universal.

Important for the automation is also the development of a mathematical model. With the help of such a model it is possible to describe the cooking process as function of measurable parameters in fixed limits. For the cooking process is not existing a universal model. During the cooking process in the meat are going on complex chemical, biochemical and physical processes and their effect on the measurable properties is often counteracting each other, e.g. the denaturation of the meat proteins and collagens related with the texture of meat. The Knowledge about the changes in the meat is not well enough known to solve this problem.

An other problem is the fact of missing a universal sensory analysis for cooked whole meat products.

Our problem has been to find a measuring method, which objectively signals the readiness of meat, and to automate this method.

It is necessary to look for a measurable parameter, which correlates with sensory evaluation and which fulfills following tasks:

- Parameters change over time and space in dependence of thermal treatment.
- The measurable parameter possesses characteristic points in its curve.
- The measurement going on is not impairing the quality of meat.

Experiments showed two different fundamental results:

1. Rheological parameters have an oscillating curve during the cooking time.
2. Efficiency parameters, e.g. core temperature and mass loss are represented in an exponential curve.

These efficiency parameters are not sufficent for whole meat process control. They only loosely correlate with the sensory evaluation. An other result is, that the absolute level of rheological parameters does not play an important role in the estimation of the readiness. Important are characteristic points and parts in the curve due to the oscillating curve mentioned above.

A supposition is also to define the readiness of whole meat. With the help of sensory evaluation can be described the readiness of meat.

MATERIALS AND METHODS

A special consumer analysis has shown that the chewability and tenderness of cooked meat are the most important sensory factors. An adapted sensory evaluation scale with three parts (colour in the core of the meat; juiciness; chewability/tenderness) has been composed /3/. The meat was tested by a well trained panel. The summary of the results of the sensory evaluation is calculated in a quality coefficient PQ.

$$PQ = \sum_{i=1}^{n} I_n \cdot W_n \qquad (1)$$

I_n - average intensity of one property

W_n - weighing factors

Chewability/tenderness - $W_1 = 0,7$

Juiciness - $W_2 = 0,3$

These weighing factors express the importance of chewability and tenderness.

Chewability and tenderness correlate with rheological properties, for instance elasticity and hardness. Meat is a viscoelastic material and consists theoretically of a mass-element, a spring-element and a damper element. For this reason a process measuring device has been built, which measures the elasticity properties in a nondestructive way during the cooking process in the oven. It is a vibration measurement. This method does not influence the meat and its cooking properties. Changes of elasticity can be described well by this method.

The vibration measurement is based on the measurement of resonance of the material. Two different impacts can be used:

- generation of a sinus vibration by means of a vibration generator
- generation of the vibration by means of a shock.

In the first variant meat underlies a sinus vibration with a constant amplitude. It is a damped, forced vibration. Following characteristic parameters of the vibration are to be decribed: resonance frequency, quality, band width, phase lag and the oscillation time. Simply to measure are resonance frequency and the quality. The resonance frequency is readed, if the characteristic frequency of meat is equal to the exciting frequency. The amplitude of the response vibration in this point reaches a maximum value. The resonance frequency is a characteristic parameter of the material (meat).

The quality is the peak of the amplitude on the place of the resonance frequency /1/. The resonance frequency and quality are measured in a time interval of 1 min. All experiments have been carried out in a convection oven "Unigar 4260" of the

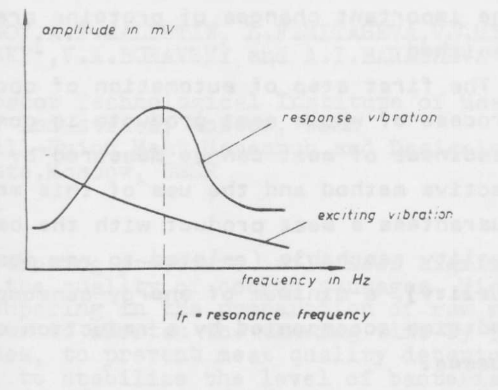

Figure 1: Amplitude-frequency-characteristic with resonance

equipment deliverer "NAGEMA". Air temperature in the oven was at 200 °C. As material we used meat of musculus longissimus dorsi with a mass of 200 gramms. It is possible to say, that this meat was quite homogeneous. For measuring process, data acquisition and analysis was used a microcomputer MC 80.

The exact evaluation of raw meat quality (PSE, DFD, normal) was possible by the method of SCHÖBERLEIN/RICHTER /4/ - the measurement of impedance of meat 24 hours post mortem at the musculus longissimus dorsi.

Raw meat quality	impedance h-value	pH-Value	drip-loss in %
Normal	50	5,6 - 5,8	6,0
PSE	30	5,6	6,0
DFD	50	6,1	1,0

Table 1: Criterions of raw meat quality evaluation

The measurement procedure sampled the frequencies between 11,5 and 60,0 Hz, this is the frequency-band. Meat underlied a sinus vibration with a constant amplitude by a vibration generator. A vibration detector translated the modified response vibration (after the transition through the meat) to the computer. It resulted a curve with a maximum, this is the place of resonance frequency. The measured resonance frequency was memorized in the computer. The numerical values were no very interesting for this special research, but the characteristical parts in the curve.

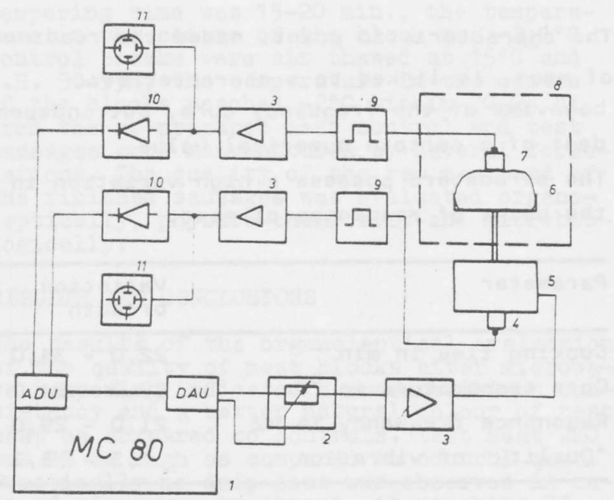

Figure 2: Structure of measurement procedure
1 - microcomputer; 2 - feedback control system; 3 - power amplifier; 4 - vibration detector; 5 - vibration generator; 6 - meat; 7 - vibration detector cooled by water; 8 - convection oven; 9 - band-pass filter; 10 rectifier; 11 - oscillator

RESULTS AND DISCUSSION

The development of resonance frequency and quality show an oscillating characteristical curve during the cooking time. The numerical values of these parameters show great variations.

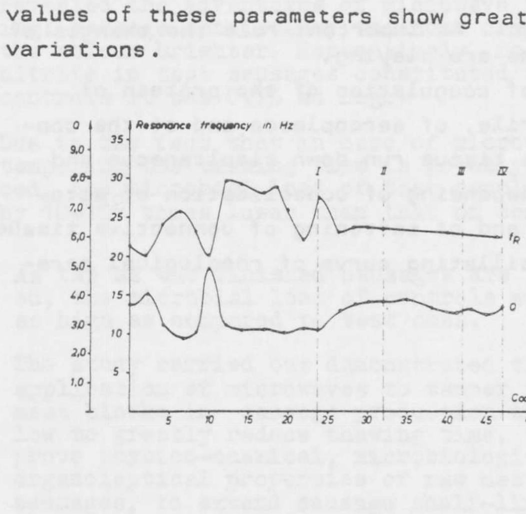

Figure 3: Typical curve of resonance frequency and correlated quality

The sensory evaluation of meat was carried out for different points of the curve of resonance frequency and quality. The meat received the highest evaluation, if the resonance frequency and the quality remained constant during 3 measuremtns, steps of 1 min each. This is the point of readiness of meat and the cooking process is to be finished.

The characteristic point, named the readiness of meat, is linked to a characteristic behaviour of the frequency cure, but independent of a certain numerical value.
The parameters possess a high variation in the point of readiness of meat.

Parameter	Variation broadth
Cooking time in min	22,0 - 34,0
Core temperature in °C	62,0 - 84,0
Resonance frequency in Hz	21,0 - 29,0
"Quality" of vibration	1,3 - 3,7

Table 2: Variation broadth of measured parameters at the point of readiness of meat

Main advantage is, that the point named readiness of meat is an universal criterion for the cooking process. The criterion is valid independent of raw meat quality (PSE, normal, DFD), of cooking conditions and of cooking equipment.
The reasons of oscillating behaviour of the curve of rheological parameters and the high variation of these parameters are the complex changes of the meat during the heat treatment. An important role the changes of proteins are playing.
Steps of coagulation of the protein of myofibrils, of sarcoplasma and of the connective tissue run down simultaneous and cause depending of consolidation of actomyosin and of softening of connective tissue the oscillating curve of rheological parameters. If the readiness of meat is readed, the important changes of proteins are finished.

The first step of automation of cooking process of whole meat products is gone, the readiness of meat can be measured by an objective method and the use of this method guarantees a meat product with the best quality reachable (related to raw meat quality), a minimum of energy consumption and time accompanied by a reduction of mass losses.

Next steps should lead to reliable industrial devices and to better knowledge on raw material preconditions for high product quality.

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