4 The coefficient "effectiveness grade" as a quality parameter for a complex process of food technology (explained on the example of cooking meat)

H. NIKOLAUS, H.-J. RAEUBER

University of Technology Dresden, GDR

1. The term "effectiveness grade"

During a production process the characteristics and/or behaviours of the matter to be handled as well as a few process parameters are changing. Thus the intermediate result is at any moment a quite new ons.

If the material to be handled is one of a complex nature, as for instance meat, several behaviours are changing at the same time. There are desirable modifications (e.g. plastications of collagenic binding tissue) as well as undesirable modifications (e.g. destruction of vitamin). Furthermore process specific parameters, as for instance the energy consumption which is steadily increasing with time have to be taken into consideration.

Due to desirable and undesirable modifications, which are from time to time more or less significant, and which in complex form the result of hitherto procedure, the process result will hardly meat all, i.e. idealized requirements. Together with process period, quality of process control have an important influence. Technological knowledge, the greatest care to operation, techniques or methodology etc. are in this connection of special importance.

Here the question of comparability of the results arises. For this purpose the term effectiveness grade (symbol: EG) is introduced. The practical utility of this term can only result from a reliable quantificated statement.

In general the quality of food stuffs is quantified by means of a special system using weighted points. For accepting the product the mean of these points has to exceed a fixed minimum value /e.g. 1/.

Let ua keep this basic thought. In order to compare the whole production processes, a normalization system is recommendable. Also Braznikov /2/ considers only the modifications of the behaviours p_i of good, but by relating them by means of a suitable function f, which can be arbitrarily selected to the etalon-value p_i^{ET}, a dimensionless parameter

$$k_i = f\left(\frac{p_i}{p_i^{ET}}\right) \qquad (1)$$

comes into being, which is weighted with a factor m_i. Furthermore it distinguishes between modifications of critical, of significant, of secondary behaviours and of those, which are of less influence.

are in any case at least time depending, but there are further influencing factors. Cooking processes for instance are initiated by thermal means. The temperature T is a distributed parameter here, often existing as a threedimensional non-steady field.

For applying equation (3) for the description of the course of a cooking process, it is necessary to reify it, i.e. to "adjust" it for the procedures to be considered. This way equation (3) can be used as a model of cooking process. For this purpose it necessary to know all important material and physical reactions and interactions exactly. This condition is not satisfied. There are extensive basic research works. Suitable assertions can be reached by applying a few known regularities.

If the regularities are known, the m_i values can be calculated using integral equations. Thus complicated mathematical terms have to be handled. At the beginning a discretization with regard to time is recommendable. This way data of process can easily be included into the calculation.

If the process is connected with undesired phenomena, EG = 1 is impossible. Furthermore there is a maximum value $EG_{max} < 1$; the corresponding time is the optimum process time t_{opt}.

The spatial aspect has not been considered in the above explanations. This shortage can be conquered by determining m_i as mass weighted mean values of the single shells. If only one shell is needed for the analysis, the determination of mean value is not necessary.

Now the course of a cooking process will be appreciated by means of the parameter effectiveness grade. For modelling of process the following assumptions are made:

Material: Musculus longissimus dorsi of pork;
particle size: nearly spherical particles with an equivalent diameter of 0,01861 m;
initial temperature: 20 °C;
mass of meat: 1 kg;
mass of water: 1 kg;
dimension of pot: diameter 0,15 m, height 0,12 m;
covered pot; heat input from bottom.

At the moment $t_o = 0$ meat pieces are takan into the hot water with a temperature of 80 °C.

Only heating-up-period and time of remaining temperature constant are discussed here; the cooling-off-period is neglected due to simplicity. Such a simplification is not permissible under practical conditions, but only meaningful within these explanations.

The analysis includes the following parameters:

- core temperature of meat pieces (m_1)
- pasteurization effect within the core (m_2)
- texture effect (m_3)
- mass defect (m_4)
- total energetical efficiency (m_5).

K is equal to zero for as long as the estimation of a critical behaviour i results in $k_{a,i} = 0$, thus the good is not considered as a food stuff. When using the resulting equation for the purpose of description of process progress there an insufficiency appears. Up to a critical moment t_k, in which K becomes greater than zero, a complex analysis of the process is not possible.

With regard to that a calculation method, considering characteristics of good as well as those of process in the same manner, will be developed now. By means of the complex valuation of these characteristics the whole process progress can be reflected.

n characteristics m_i, which describe the good and/or the process are taken into consideration. They are selected in an arbitrary but reliable manner. At simple calculation of the mean value would not be meaningful, because of not containing a normalization. That is why in analogy to Braznikov the characteristic m_i is normalized in the range of 0...1 by means of a special function lev (abbreviation of "level"), which is fixed with regard to the characteristic, i.e. lev $m_i \in (0,1)$.

This value is weighted by an exponent $w_i \in (1,\infty)$. The equation based on these statements

$$y = \frac{1}{n}\sum_{i=1}^{n} (\text{lev } m_i)^{w_i} \qquad (2)$$

with a range of values $0 \leq y \leq 1$ does not reach the power of assertion of equation (2) according to Braznikov.

For being accepted, most characteristics m_i have to show a minimum of significance. Satisfying this condition may be formally described by a so called flag function

$$\text{flag } i = \begin{cases} 0 & \text{in case of} \quad \text{lev } m_i < \text{lev } m_{min,i} \\ 1 & \text{in case of} \quad \text{lev } m_i \geq \text{lev } m_{min,i} \end{cases}$$

If a condition of significance is practically meaningless, flag i = 1 for the whole process time. Thus the instruction for valuation flag and lev are specific ones depending on the characteristic to be considered itself. With regard to content they are formally connected with the characteristic m_i by means of index i. Owing to this the analysis can be carried out by a quite simple algorithm.

For the complex combination, equation

$$EG = -1 + \prod_{i=1}^{n} \text{flag } i + \frac{1}{n}\sum_{i=1}^{n} (\text{lev } m_i)^{w_i} \longrightarrow +1 \qquad (3)$$

is proposed; the range of value is $-1 \leq EG \leq +1$. The values m_i

Consideration of core temperature

Due to microbial security, in many cases a heating of meat up to a core temperature of 75 °C is required. From the microbial point of view it is not useful to exceed this value. The following instructions for analysis may be assumed:

$$m_1 = \frac{|T_t - 75\ °C|}{75\ °C - T_a}$$

T_t = temperature /°C/ at the moment t
T_a = initial temperature (75 °C < $T_a \geq$ 0 °C)

$$\text{lev } m_1 = \begin{cases} m_1 & \text{for } m_1 \leq 1 \\ 1 & \text{for } m_1 \geq 1 \end{cases}$$

$$\text{flag } 1 = \begin{cases} 1 & \text{for } T_t \geq 75\ °C,\ \text{lev } m_1 = 1 \text{ respectively} \\ 0 & \text{for } T_t < 75\ °C,\ \text{lev } m_1 < 1 \text{ respectively} \end{cases}$$

$w_1 = 1$ is choosed as a weighting exponent.

Consideration of pasteurization effects within the core

The aim might be to reduce the calculated number of vegetative microorganisms within the core by six powers of ten. This corresponds to a pasteurization effect of $L = 6 \cdot D_{65,5}$ ($D_{65,5}$ is the "decimal reduction time" at a temperature of 65,5 °C).

For $D_{65,5}$ a value of 3 minutes, for z a value of 5,5 °C may be assumed /3/. The aspired pasteurization effect is

$$L_{set} = 6 \quad D_{65,5} = 18 = 10^{(T_t - 65,5\ °C)/5,5\ °C}$$

It might be imperativaly required $L = 15 = 5 \cdot D_{65,5}$. The following instructions for analysis are proposed

$$m_2 = \frac{L_t}{L_{set}}$$

$$\text{lev } m_2 = \begin{cases} m_2 & \text{for } m_2 < 1 \\ 1 & \text{for } m_2 \geq 1 \end{cases}$$

$$\text{flag } 2 = \begin{cases} 1 & \text{for } m_2 \geq 0{,}833 = 15/18 \\ 0 & \text{for } m_2 < 0{,}833 \end{cases}$$

The weighting exponent might be $w_2 = 2$.

Consideration of texture effect

According to experimental investigations, with regard to rheological aspects a cooking time of 36 minutes may be considered as the optimum under the giving conditions (see figure 1) if the rest-over effect during cooling-off-phase is neglected. The following instructions for analysis are proposed:

$$m_3 = \frac{t}{36}$$

$$\text{lev } m_3 = \begin{cases} m_3 & \text{for } m_3 \leq 1 \\ 1/m_3 & \text{for } m_3 > 1 \end{cases}$$

The weighting exponent is $w_3 = 2$. It has to be assumed that lev m_3 - 0,75, i.e.

$$\text{flag } 3 = \begin{cases} 0 & \text{for lev } m_3 < 0{,}75 \\ 1 & \text{for lev } m_3 \geq 0{,}75 \end{cases}$$

Consideration of mass defect

Mestchen /4/ realized investigations concerning quantitative mass defect during cooking of M. longissimus dorsi of pork, depending on particle size, on temperature of water bath and on cooking time.

It may be fixed:

$m_4 = 1 - V$; (V - mass defect)

lev $m_4 = m_4$

The description of mass defect may be principally considered as a damage function. A minimum significance can not be required, because high values of mass defect do not reduce the physiological value of meat. That is why it is recommendable to fix flag 4 = constant = 1.

Consideration of the total energetical efficiency η_s

The following assumptions are made for modelling:

- The pot is supplied with the whole heating power from bottom.
- The heat-transfer coefficient at the external areas is $= 10\ Wm^{-2}K^{-1}$.
- The ambient temperature is 20 °C.
- The thermophysical parameters of muscle tissue are $a \approx 12 \cdot 10^{-8}\ m^2s^{-1}$, $\lambda \approx 0{,}49\ Wm^{-1}K^{-1}$, $c \approx 3820\ Jkg^{-1}K^{-1}$ /5/.

It is meaningful to fix

$m_5 = \eta_s$, lev $m_5 = m_5$, $w_5 = 1$.

The process will be considered as a not acceptable one, if η_s results smaller than 0,67. The flag will be fixed as follows:

$$\text{flag } 5 = \begin{cases} 0 & \text{for lev } m_5 < 0{,}67 \\ 1 & \text{for lev } m_5 \geq 0{,}67 \end{cases}$$

The dipping of the meat pieces into the tempered water bath is considered as the starting point, but also other statements would be qualified here.

Discussion

A summary about the influencing factors mentioned above and their time depending distribution is shown in figure 2.

It can be seen from this, that a new quality is reached batween 26. and 27. minute. Now there is an acceptable product and promising process parameters.

EG reaches its maximum value after 36 min; then it is decreasing again due to increasing influence of damaging influencing factors.

Thus the cooking process may be broken of after 26 minutes, but should be extended up to 36 minutes. A further extension would only result in damage or disadvantages.

This statement is only valid in case of meating the initially mentioned conditions. Other techniques or other products respectively require quite other instructions for evaluation. Nevertheless the result of the calculation is at any rate a curve, which describes the process course unique and quantitatively comparable.

The calculation method may be applied for all production processes. For its application using of electronic data processing is recommendable.

Literature

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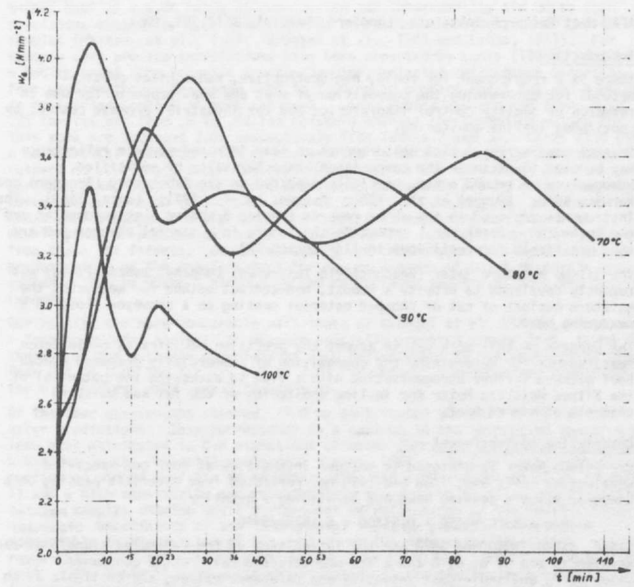

Figure 1: The influence of cooking temperature and of cooking time on the specific strain energy due to distortion, according to Wolodkewitsch on the example of M. longissimus dorsi of pork (texture effect)

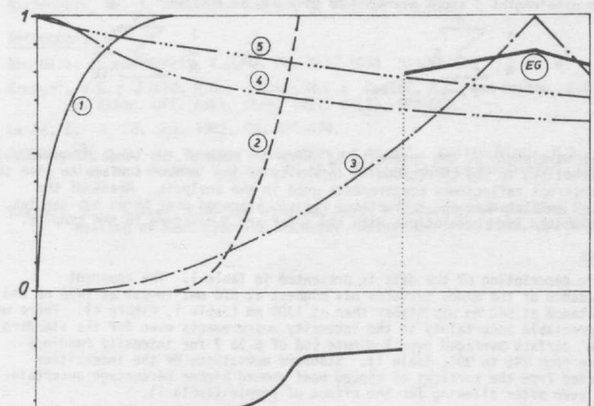

Figure 2: 1 core temperature
2 pasteurization effect within the core
3 texture effect
4 mass defect
5 total energetical efficiency