The Modified CPEM (Cooked Potato Effective Mass) Method: an Instrumental Assessment of Potato Sloughing

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Abstract

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The cooked potato effective mass (CPEM) method for potato sloughing assessment involves cooking the potato flakes on the sieve in a stirred water bath and periodically determining their effective mass during cooking. The final cooking curve divided into the cooking and breaking parts provides two parameters: the cooking time (*CT*) is the time required for starting disintegration, while the slope of the breaking part (*SBP*) describes the disintegration rate. The method enables a detailed analysis of the cooking properties in relation to the tuber density. The modified analysis of the cooking curve is based on polynomial approximation of the breaking part. It provides the time of cooking (CT_{max}) required to reach the maximal disintegration rate (*MDR*). These new parameters represent an alternative to the existing ones, their values are easier to obtain from the individual cooking curves, and therefore they can serve as a base for further development of the CPEM tests.

Keywords: potato; cooking; texture; starch; density; effective mass; sloughing

The texture of cooked potato is an important quality aspect. The texture attributes, sloughing or disintegration due to cooking are associated with the cell separation which is permitted by thermal β-eliminative degradation of pectins in the middle lamella and influenced by the starch swelling pressure (Jarvis *et al.* 1992). The influence of the cell walls and middle lamellae in determining the texture development was investigated by Marle *et al.* (1997a,b). The degree of disintegration after cooking is often correlated with the tuber density, particularly within one cultivar (Warren & Woodman 1974). However, differences in the starch properties were studied to elucidate the differences in the disintegration degree in tubers with the same density (Matsuura-Endo *et al.* 2002a,b).

The methods for the disintegration assessment are of great importance in these investigations. The degree of sloughing is often assessed in sensory tests (Matsuura-Endo *et al.* 2002a) or by various methods determining the degree of the cell separation (Marle *et al.* 1994; Matsuura-Endo *et al.* 2002b). Instrumental methods for the potato sloughing assessment are mostly based on CPM (cooked potato mass) tests which are also referred to as CPW (cooked potato weight) tests (Anonymous 1977). The CPEM (cooked potato effective mass) method was developed on the basis of the CPM tests. It consists of cooking the potato

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flakes on the sieve in a stirred water bath and of periodical determining their continuous effective mass (in relation to the outer cooking medium) during cooking (Hejlová *et al.* 2006). The shape of the resulting cooking curve corresponds with two stages of the test: no observable disintegration in the cooking part and a decrease of the sample mass in the breaking part (Figure 1). The transition between the cooking and breaking parts is termed cooking time CT (min) and means the time of cooking required for starting disintegration. The slope of the breaking part SBP (g/min) describes the disintegration rate.

The main advantage of the CPEM method lies in the possibility of precise testing small specimens and analysing their parameters in relation to the tuber density ρ (kg/m^3). Linear models of the cooking stage

$$CT = a_{CT} - b(\rho - \rho_{MV}) \tag{1}$$

related to a given density (ρ_{MV} represents the mean density value in a group of the potato specimens tested in this case), play an important role in this analysis. The regression coefficient b (min·m^3/kg) can be interpreted as CT-sensitivity to the tuber density and at the same time also to the starch content due to the known close relationship between tuber density, dry matter and starch content (Scheele *et al.* 1937). This approach serves as a basis for further theoretical research of the cell tissue properties in different potato varieties (Hejlová & Blahovec 2007, 2008; Blahovec & Hejlová 2006, 2010).

The aim of this paper was to develop an alternative analysis of individual cooking curves which would provide an easier mathematical way to obtain the cooking parameters and which would maintain the main features of the existing CPEM parameters.

MATERIALS AND METHODS

Material and CPEM method. The tested potatoes were described previously (Blahovec & Hejlová 2006; Hejlová & Blahovec 2007, 2008). Nicola and Saturna represent typical not sloughed and sloughed cultivars, respectively, Agria is a cultivar suitable for potato chips production.

The potato sample for the CPEM test was prepared from three or four tubers of approximately the same size and mean density. Rectangular slices 10 × 10 × 1.5 mm were cut mainly from the inner parenchyma. The sample, 100 g of washed and dried potato flakes, was then tested by the CPEM method (Hejlová *et al.* 2006). The test was repeated, at least 10 times, with each potato group. The potato groups were established in relation to the cultivar, the growing year, and in the case of cv. Agria also different growing conditions. All resulting cooking curves were analysed by means of the existing parameters CT and SBP (Blahovec & Hejlová 2006; Hejlová & Blahovec 2007, 2008).

Modified analysis of the breaking part. The existing analysis of the CPEM cooking curve defines CT as the intersection of two regression lines (Hejlová *et al.* 2006). In the modified analysis, the breaking part of the cooking curve (Figure 1) is approximated by the polynomial function:

$$f(t) = c_3t^3 + c_2t^2 + c_1t + c_0 \tag{2}$$

the point of inflexion

$$t_{\text{inf}} = -\frac{c_2}{3c_3} \tag{3}$$

and the first derivative are calculated

$$\frac{df}{dt}(t_{\text{inf}}) = 3c_3t_{\text{inf}}^2 + 2c_2t_{\text{inf}} + c_1 = -\frac{c_2^2}{3c_3} + c_1 \tag{4}$$

The approximations (2) are performed on several (2–5) sets of points which involve the breaking part and the transition between the cooking and breaking parts, i.e. 2–3 min before the cooking time CT. The maximal disintegration rate MDR (g/min) and the time parameter CT_{max} (min) as the time of cooking required to reach the MDR are derived as mean values of $-df/dt(t_{\text{inf}})$ and t_{inf} respectively (Figure 1).

The modified analysis was applied to the existing CPEM data (Blahovec & Hejlová 2006; Hejlová & Blahovec 2007, 2008). The polynomial approximations (2) were performed with $R^2 > 0.95$. The CT_{max} and MDR values were calculated as averages of mostly 3–4 values of t_{inf} (3) and of the derivatives $-df/dt(t_{\text{inf}})$ (4), respectively, with coefficients of variation CV in the ranges of up to 7% and 11%, respectively. (The exception was MDR values in the cv. Nicola obtained with CV 3–30%.)

Evaluation of modified parameters. The mean values and significant differences between the

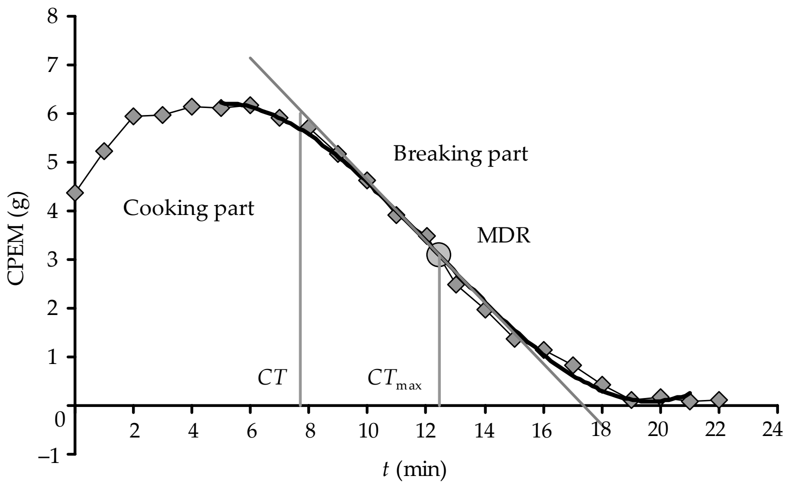

Figure 1. Modified analysis of the cooking curve

given potato groups were evaluated using the analysis of variance and were compared with the results obtained with the existing CPEM parameters (Blahovec & Hejlová 2006; Hejlová & Blahovec 2007, 2008). Both parameters were studied as functions of the tuber density. The linear regression models

$$CT_{max} = a_{CT_{max}} - b_{CT_{max}} (\rho - \rho_{MV}) \quad (5)$$

were related to the density ρ_{MV} defined as the mean value of the sample densities in individual potato groups, and were compared with the existing linear models of the cooking stage (1).

RESULTS AND DISCUSSION

The modified breaking parameters are presented and compared with the existing CPEM data in Figures 2 and 3. The highest CT_{max} and the lowest *MDR* values were observed in the non sloughed cv. Nicola. The new parameters also reflected different growing conditions (Hejlová & Blahovec 2007). A higher degree of sloughing, i.e. smaller CT_{max} and higher *MDR* values, was associated with higher tuber densities (data not shown). The parameters describing the disintegration rate *MDR* and *SBP* were very close (Figure 3). The time parameters CT_{max} and *CT* expressing the sample resistance to sloughing differed significantly and their differences were higher at higher *CT* values (Figure 2).

Linear models (5) of CT_{max} and previous models (1) of *CT* in the individual tested potato groups were compared (Figure 4). The regression coefficients $b_{CT_{max}}$ and *b* in these models express the sensitivity of the cooking properties to the changes in the tuber density. The variability was higher in the $b_{CT_{max}}$ values than in the *b* ones. All $b_{CT_{max}}$ values were higher (in some cases significantly) than the existing *b* ones. The lowest regression coefficients were observed in the non sloughed cultivar Nicola in both models. The intercepts $a_{CT_{max}}$ (min) and a_{CT} (min) represent the assessments of the sloughing properties in association

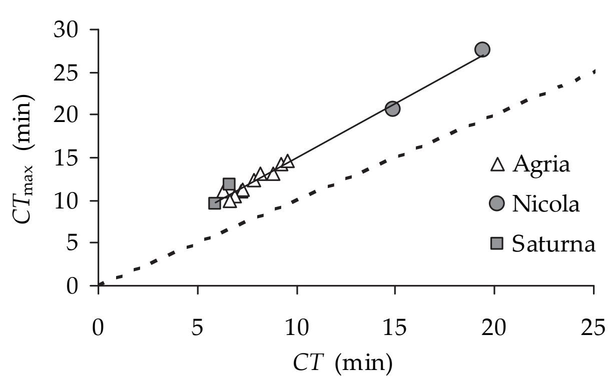

Figure 2. Comparison of *CT* and CT_{max}

CT_{max} ~ 1.28 *CT* + 2.19, R^2 = 0.986. Every point in the graph represents mean values in a tested potato group

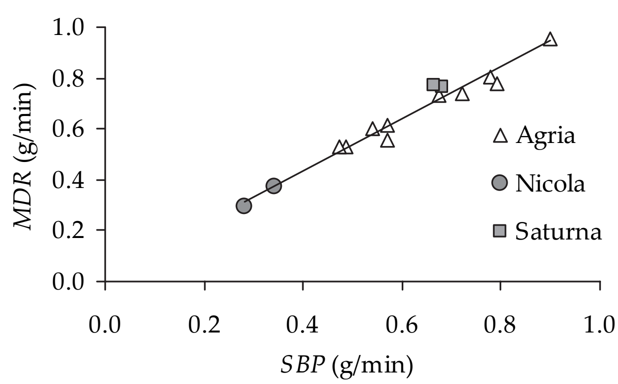

Figure 3. Comparison of *SBP* and *MDR*

MDR ~ 1.0197 *SBP* + 0.0281, R^2 = 0.964. Every point in the graph represents mean values in a tested potato group

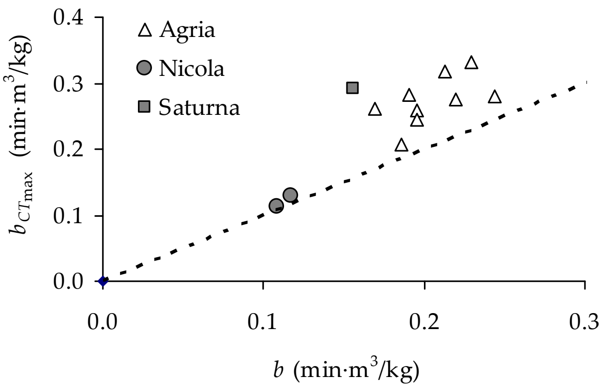

Figure 4. Comparison of regression coefficients b and $b_{CT_{max}}$ from linear models (1) and (5)

with the mean density in the given potato groups. These values are close to the CT_{max} and to the CT mean values, respectively (Figure 2). The differences $CT_{max} – CT$ were negatively correlated with density in most groups (with correlation coefficient $|R|$ = 0.5–0.9) and practically independent of density in the cultivar Nicola ($|R|$ = 0.1).

The existing parameter CT is well-defined also due to its relative independence of the experimental conditions. Unlike the first cooking part of the CPEM cooking curve, the following breaking part depends on the experimental parameters, especially on the stirring speed (Hejlová *et al.* 2006). The CT_{max} definition results from both the cooking and breaking parts of the cooking curve and therefore is more associated with the experimental conditions. This factor does not emerge under consistent maitenance of these conditions in all tests. Nevertheless, the CT_{max} definition involving the breaking part seems to be the source of differences between the models (1) and (5).

The main reason for introducing the modified parameters lies in the mathematical analysis of individual cooking curves. The existing approach defines the parameter CT as the intersection of two regression lines (Hejlová *et al.* 2006). The modified analysis (Figure 1) provides an easier mathematical way to obtain the cooking parameters. This fact can be used for possible development of CPEM tests on a modified experimental set-up.

CONCLUSIONS

The modified CT_{max} and MDR parameters could serve as an alternative set to the previously defined CT and SBP cooking parameters. The parameter CT_{max} is more sensitive to the experimental conditions than the existing parameter CT. The main advantage of using the modified parameters resides in that it is easier to obtain their values mathematically. This fact can support further development of CPEM tests.

Nomenclature

a_{CT} (min)	constant in the linear regression relation between CT and density
$a_{CT_{max}}$ (min)	constant in the linear regression relation between CT_{max} and density
b (min.m^3/kg)	slope in the linear regression relation between CT and density, CT-sensitivity to density
$b_{CT_{max}}$ (min.m^3/kg)	slope in the linear regression relation between CT_{max} and density
CPEM	"cooked potato effective mass", modified CPM test
CPM	"cooked potato mass", official test of potato sloughing
CPW	"cooked potato weight", term commonly used for CPM tests
CT (min)	"cooking time", time of cooking in a CPEM test just before indication of the disintegration process
CT_{max} (min)	time of cooking in a CPEM test required to reaching the maximal disintegration rate MDR
CV	coefficient of variations
f (g)	polynomial approximation of the breaking part in a CPEM curve
MDR (g/min)	"maximal disintegration rate", assessment of maximal slope of the breaking part in a CPEM curve with the opposite sign
MV	mean value
ρ (kg/m^3)	density
$ρ_{MV}$ (kg/m^3)	mean value of sample densities in individual potato groups
R (–)	correlation coefficient
R^2 (–)	coefficient of determination
SBP (g/min)	"slope of the breaking part", initial slope of the breaking part in a CPEM test with the opposite sign
t_{inf} (min)	point of inflexion in a polynomial approximation of the breaking part
$df/dt(t_{inf})$ (g/min)	first derivative of a polynomial approximation at the point of inflexion

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