Welcome

Welcome to the 12th issue of Perten Science World.

The first article in this issue is a summary of a paper presented earlier this year at the 65th Australian cereal Chemistry Conference. Due to an increasing use of high-energy dough mixers in commercial bakeries, traditional techniques to measure dough rheology have become limited. Therefore, a comparison of old and new dough mixing methods and their utility in predicting bread quality was performed using a doughLAB and micro-doughLAB from Perten Instruments, and a Mixolab from Chopin Technologies.

In the second article, the quality of potatoes in terms of surface toughness is evaluated. Pre-peeled potatoes served in schools and canteens etc. tender to get an increased surface toughness during warm keeping. The surface texture of industrial pre-treated potatoes and hand peeled references were compared for two different cooking procedures, namely steam cooking and conventional boiling.

In the last article, the texture and color of crisps are measured in relation to sugar and acrylamide content during storage. Acrylamide is formed during the frying process by a chemical reaction called Maillard reaction, which contributes to the color of the crisps. Acrylamide is considered to be a carcinogenic substance to humans.

I hope you find this 12th issue of Perten Science World interesting, useful, and stimulating. Enjoy your reading!

Dr. Jeanette Purhagen
Editor in Chief

www.perten.com
Comparison of Old and New Dough Mixing Methods and their Utility in Predicting Bread Quality

J.M.C. Dang*1 and M.L. Bason2

1Perten Instruments of Australia Pty. Ltd., Macquarie Park NSW 2113, Australia
2Perten Instruments AB, Hägersten, SE-12609, Sweden
*Corresponding author: jmdang@perten.com

Summary of the paper presented at AGSA 2015, 65th Australian Cereal Chemistry Conference, 16-18 September 2015, Crowne Plaza Coogee Beach Hotel, Coogee NSW.

Introduction
The need for relevant and timely flour quality information in modern flour mills and bakeries is an ongoing challenge for instrument producers and users. High-energy commercial dough mixers, now in common use in bread bakeries around the world, provide better process relevance for rapid bread making systems. Traditional techniques to measure dough rheology have many drawbacks - slow tests, poor process relevance, limited sample types, and results that are usually limited to either the mixing or end-use quality of bread flour. Recent methods from Perten Instruments (doughLAB [dL] and micro-doughLAB [mdL]) and Chopin (Mixolab) have addressed some of these concerns. This study compared the recently developed mixing methods and their capabilities in predicting bread quality.

Materials and Methods

Samples and treatments
61 wheat flours with diverse properties were obtained from various Australian flour mills (Allied Mills, Ben Furney Flour Mills, Laucke Flour Mills, Manildra Group, Millers Foods, Tasmanian Flours Ltd, and Weston Milling). Samples were stored in airtight containers in a cool (18°C) dry environment until analysis.

Sample analyses
The moisture content of each flour was determined by AACC Method 44-15.02 (AACC International, 2014). Mixing properties were determined on the Mixolab (Chopin Technologies, Villeneuve-la-Garenne, France), dL and mdL (Perten Instruments Australia, Macquarie Park, Australia). For Mixolab tests, samples (50.00 ± 0.01 g, 14% moisture basis, adjusted for moisture content and to a constant dough mass of 75.00 g) were mixed in duplicate to optimum consistency according to the manufacturer’s "Chopin+" protocol (Table 1, AACC Method 54-00.01). Samples for the dL (300.0 ± 0.01 g) and mdL (4.00 ± 0.01 g) were mixed in duplicate to optimum consistency with the manufacturer’s protocols at slow (63 rpm, AACC Method 54-21.01) and fast (120 rpm, AACC Method 54-70.01) speeds (Table 1). In addition, samples were tested in duplicate on the mdL using the manufacturer’s cooking protocol (Table 1) using optimum water absorption achieved in the mixing tests. Extensograph testing was performed according to AACC Method 54-10.01, in duplicate, on doughs prepared from the dL. Duplicate volume measurements were determined on duplicate pur loaves (250 g, rapid dough protocol), according to AACC Method 10-05.01.

Statistical analyses
Mixing properties were determined from the Mixolab, dL and mdL mixing curves as defined in Figure 1, and compared to Extensograph and baking data by univariate (UVA) and multivariate (MVA) analyses. Univariate comparisons of mixing properties between methods were performed by regression analyses (Minitab ver. 13) on all samples (n = 61). Method precision was evaluated from one-way analysis of variance of data as the root mean square of the error term (RMS) and the coefficient of variation (CV). Torque/time spectra at one-second intervals from the dL and mdL were exported from the dL for Windows (DLW) software (v. 1.4, Perten Instruments, Macquarie Park, Australia) in ASCII format into the Unscrambler software (v. 10.3, CAMO ASA, Oslo, Norway) for MVA against Mixolab, Extensograph and baking reference data. All samples (61) were used to generate
partial least squares (PLS) regression calibration models between the reference values and dL/mdL analysis parameters for data regions between 20-600 s. Statistics calculated for each data region included the root mean square error of cross-validation (RMSECV) and the coefficient of determination (R$^2$).

**Table 1: Dough mixing configurations**

<table>
<thead>
<tr>
<th>Mixolab Chopin+</th>
<th>dL / mdL slow mix</th>
<th>dL / mdL fast mix</th>
<th>mdL cook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time mm:ss</td>
<td>Temp °C</td>
<td>Speed rpm</td>
<td>Time mm:ss</td>
</tr>
<tr>
<td>00:00</td>
<td>30</td>
<td>80</td>
<td>00:00</td>
</tr>
<tr>
<td>08:00</td>
<td>30</td>
<td>-</td>
<td>20:00</td>
</tr>
<tr>
<td>23:00</td>
<td>90</td>
<td>-</td>
<td>10:00</td>
</tr>
<tr>
<td>30:00</td>
<td>90</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>40:00</td>
<td>50</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>45:00</td>
<td>End</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Premix</td>
<td>30°C</td>
<td>80 rpm</td>
<td>1 min</td>
</tr>
<tr>
<td>Target</td>
<td>1100 ± 50 mNmm</td>
<td></td>
<td>4902 ± 196 / 100 ± 4 mNmm</td>
</tr>
<tr>
<td>Sample</td>
<td>75.0 g dough</td>
<td></td>
<td>300.0 g / 4.00 g flour</td>
</tr>
</tbody>
</table>

*Chopin+, slow mix and fast mix configurations according to AACC methods 54-60.01, 54-21.01 and 54-70.01 respectively. Sample weights were corrected to 14% moisture basis. End = end of test.*

**Figure 1:** Commonly measured parameters from the Mixolab (A), dL/mdL standard mixing (B), and mdL cooking curves (C).

In Figure 1, C, T, and T°C are torque, time and temperature values, respectively, at the five stages of the Mixolab curve: C1-dough development, C2-protein weakening, C3-starch gelatinization, C4-gel stability and amylase activity, and C5-starch retrogradation. dL/mdL mixing parameters include peak torque, dough development time (DDT), stability, softening at 5 min (120 rpm) or 12 min (63 rpm) after peak and accumulated energy at peak torque (Wh/kg). Water absorption (WA) is derived from the peak torque and amount of water added during the test. mdL cooking parameters (similar to those of the Mixolab) include Peak1, Hold1, Peak2, Hold2, Final torques and associated times at the five stages of the mdL cooking curve.
Results and Discussion

Mixing Methods

The faster dL and mDL methods (120 rpm) had better precision, with lower coefficients of variation (CV), than the Mixolab and slower (63 rpm) dL methods (Table 2). The high CV for C1 time (dough development time) in the Mixolab method was probably due to the inconsistency of the software in differentiating hydration (generally first) and true mixing (generally second) peaks in duplicate analyses, in cases where two peaks were observed.

The results show good univariate correlations between all mixing methods for water absorption (WA), with the dL 120 rpm method giving the closest correlation to the 63 rpm method (Table 3). Univariate correlations for dough development time (DDT) and stability were reasonable between dL and mDL, but poorer between these instruments and Mixolab (results not shown). Correlations to 63 rpm mixing parameters improved with MVA of data, with lower RMSECVs and higher R²'s. Perten Instruments software (Prediction Pack) has been developed to allow these calibrations to be applied in the dL and mDL.

Table 2: Summary of mixing properties of wheat flour doughs tested on the Mixolab, dL and mDL using manufacturer's standard protocols, compared to the traditional mixing method (63 rpm).¹

<table>
<thead>
<tr>
<th>Mixing Parameters</th>
<th>63 rpm</th>
<th>Mixolab 80 rpm</th>
<th>dL 120 rpm</th>
<th>mDL 120 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>RMS</td>
<td>CV</td>
</tr>
<tr>
<td>WA (%)</td>
<td>62.6</td>
<td>62.4</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>C1 Time or DDT (min)</td>
<td>8.8</td>
<td>5.7</td>
<td>1.1</td>
<td>19.9</td>
</tr>
<tr>
<td>Stability (min)</td>
<td>20.0</td>
<td>10.0</td>
<td>0.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Energy (Wh/kg)</td>
<td>8.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

¹RMS = root mean square of the error term. CV (%) = coefficient of variation (relative repeatability standard deviation).

Table 3: Univariate (linear) and multivariate (partial least squares) regressions of Mixolab, doughLAB and micro-doughLAB mixing results with those from the 63 rpm method.

<table>
<thead>
<tr>
<th>63 rpm parameters</th>
<th>Calibration</th>
<th>Mixolab</th>
<th>dL120</th>
<th>mDL120</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMS</td>
<td>R² (%)</td>
<td>RMS</td>
<td>R² (%)</td>
</tr>
<tr>
<td>WA (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariate</td>
<td>1.5</td>
<td>89.8</td>
<td>1.0</td>
<td>95.6</td>
</tr>
<tr>
<td>DDT (min)</td>
<td>3.8</td>
<td>37.7</td>
<td>3.2</td>
<td>56.2</td>
</tr>
<tr>
<td>Stability (min)</td>
<td>11.1</td>
<td>24.0</td>
<td>10.4</td>
<td>34.0</td>
</tr>
<tr>
<td>Energy (Wh/kg)</td>
<td>3.3</td>
<td>54.0</td>
<td>3.3</td>
<td>54.0</td>
</tr>
</tbody>
</table>

| WA (%)            | Multivariate (PLS) | RMS | R² (%) | RMS | R² (%) | RMS | R² (%) |
|                   | RMSECV | 1.7  | 85.5   | 0.8  | 97.1   | 1.3  | 92.0   |
| DDT (min)         | 2.7     | 59.7 |        | 2.0  | 79.3   | 2.7  | 60.3   |
| Stability (min)   | 8.3     | 41.1 |        | 7.3  | 53.5   | 8.7  | 34.2   |
| Energy (Wh/kg)    | 2.7     | 54.5 |        | 1.9  | 78.3   | 2.9  | 50.4   |

⁻R² = coefficient of determination, is the estimate of the variability accounted for by the regression; RMS = root mean square of residuals of the linear fit; n = 61;

⁻RMSECV = root mean standard error of cross-validation between analysis results from the various mixing methods and the 63 rpm method; PLS = partial least squares regression; n = 61.
Cooking Methods

The mL cooking method had better precision - with generally lower CVs - than the Mixolab method (Table 4).

There was a good univariate correlation ($R^2 = 83.0\%$) between mL and Mixolab cooking methods for WA. Weaker correlations were observed between mL DDT and Mixolab C1 time ($R^2 = 50.7\%$), and mL Hold1 and Mixolab C2 ($R^2 = 53.9\%$) (results not shown). For approximately 10% of the samples, the Mixolab curves showed cavitation of torque following the hot peak that were absent from mL curves for the corresponding samples (Figure 2). In both methods, the cooked dough became rubbery and exhibited a ‘shark skin’ effect, this is indicative of flow fracture, where the dough loses the ability to comply to large deformations (Bason, et al., 2007). Torque cavitation in the Mixolab curve was mainly attributed to the higher maximum temperature (90°C) of the Mixolab method compared to that used in the mL cooking method (80°C). When the maximum temperature in the Mixolab was reduced to 80°C, a smooth torque curve was observed with no cavitation (results not shown).

![Figure 2: Mixing curve of a weak flour tested using the Mixolab method with 90°C maximum temperature (A) and micro-doughLAB cooking method with 80°C maximum temperature (B). The cavitation in torque (circled) in the Mixolab curve following the hot peak was absent in the micro-doughLAB curve where a lower maximum temperature was employed.](image)

Table 4: Summary of cooking properties of wheat flour doughs tested on the Mixolab and mL using manufacturer’s protocols.

<table>
<thead>
<tr>
<th>Cooking Parameters</th>
<th>Mixolab 80 rpm</th>
<th>mL 120 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>RMS</td>
</tr>
<tr>
<td>WA (%)</td>
<td>62.4</td>
<td>1.7</td>
</tr>
<tr>
<td>C1 time/DDT (min)</td>
<td>5.7</td>
<td>1.1</td>
</tr>
<tr>
<td>C2 torque/Hold1 (mNm)</td>
<td>556.6</td>
<td>20.0</td>
</tr>
<tr>
<td>C2 time/Hold1 time (min)</td>
<td>17.7</td>
<td>0.3</td>
</tr>
<tr>
<td>C3 torque/Peak2 (mNm)</td>
<td>1924.2</td>
<td>28.1</td>
</tr>
<tr>
<td>C3 time/Peak2 time (min)</td>
<td>25.2</td>
<td>0.6</td>
</tr>
<tr>
<td>C4 torque/Hold2 (mNm)</td>
<td>1778.0</td>
<td>33.9</td>
</tr>
<tr>
<td>C4 time/Hold2 time (min)</td>
<td>30.2</td>
<td>0.5</td>
</tr>
<tr>
<td>C5 torque/Final (mNm)</td>
<td>2847.2</td>
<td>118.7</td>
</tr>
</tbody>
</table>

1RMS = root mean square of the error term. CV (%) = coefficient of variation (relative repeatability standard deviation).
Correlation to Extensograph and Bake Volume

Mixing parameters DDT and energy at peak torque from the dL and mdL fast methods, and C1 time from the Mixolab method gave weak univariate correlations to Extensograph parameters (extensibility and maximum resistance at 45 and 135 minutes) and bake volume ($R^2 < 57.4\%$, results not shown). There was also no correlation ($R^2 < 21.9\%$) between Extensograph results and bake volume. The results suggest that mixing parameters of flour-water doughs are poor indicators of end-use quality. The correlations may improve with full-formulation doughs (Oliver & Allen, 1992).

Conclusions

This study used univariate and multivariate analyses of data from recently developed mixing methods to compare them with the traditional mixing method and to assess their capabilities in predicting end-use quality.

The doughLAB rapid (120 rpm) method had better precision among the methods, and produced results that best correlated to the traditional 63 rpm method. Correlations generally improved with multivariate analysis of data, regardless of the mixing method used. However, all methods and mixing parameters showed weak to poor correlation to Extensograph and bake volume. The results suggest that mixing parameters of flour-water doughs are poor indicators of bread making quality.

Further studies are being conducted using a stress-decay test on the micro-doughLAB to study the elasticity of dough, and using this information to predict bake volume. The mdL stress-decay test showed potential to provide data on mixing characteristics and viscoelastic properties of a dough (Dang & Bason, 2013). When combined with the predictive capability of the Prediction Pack software, the stress-decay test on the mdL can potentially be a useful one-stop instrument for bakers, breeders and researchers.

Acknowledgements

The authors would like to thank Sam Bason of Perten Instruments of Australia for assistance with sample testing.

References

AACC International. (2014). Approved Methods of Analysis, 11th Ed., Approved Methods 16-05.01, 44:5.02, 54-10.01, 54-21.01, 54-60.01, 54-70.01. AACC International, St. Paul, MN.


Evaluation of Tough Surface of Potatoes Served at Swedish Schools

Klara Sjölin*¹ and Dr. Jeanette Purhagen¹²

¹ Lund University, Department of Food Technology, Engineering and Nutrition, Lund, Sweden
¹² Pertem Instruments AB, Garnisonsgatan 7a, 254 66 Helsingborg, Sweden
*Corresponding author: klara.sjolim@food.lth.se

Abstract
Potatoes served at Swedish schools sometimes develop a tough surface, which is considered impaired quality. In this study, the tough surface of industrially pre-treated potatoes of the Falke variety were prepared by steam cooking or conventional boiling and evaluated by texture analysis. Depending on whether the results are analyzed based on peak force, gradient, or peak distance, the results differ. In total the results show that pre-treatment has more impact on quality than cooking method. However, further studies need to be done to identify the exact parameters that consumers perceive as reducing quality.

Introduction
In Sweden, all children are served a free hot lunch every day. Several times per week potatoes, which are a staple food in Sweden, are one of the main components of the meal. In recent years the overall consumption of potatoes in Sweden has decreased, and it also has at Swedish schools (Jordbruksverket & Statistiska Centralbyrå, 2012). One reason for this is most likely the increasing awareness of quality. Unfortunately, the quality of potatoes served at Swedish schools is often considered poor, which increases the risk of unnecessary food waste and reduced nutritional intake among Swedish children (Svensk Potatis AB, 2015).

The potatoes are usually prepared in large-scale kitchens. The type and condition of the equipment varies. Usually, the potatoes are prepared by steaming cooking (SC), since the handling is easier compared to conventional boiling (CB) in a boiling vessel. It has been shown that SC gives rise to a firmer texture than CB in general (Thybo, et al., 1998), and the general opinion in Sweden is that SC also contributes to a tougher surface (Svensk Potatis AB, 2015).

To increase the efficiency of the cooking, the potatoes are usually industrially pre-peeled a few days before being delivered to the kitchens. Pre-peeling and storage temperature affects susceptibility to enzymatic browning caused by polyphenol oxidase for several kinds of fruits and vegetables, including potatoes (Kahn, 1977, Vitti, et al., 2011). One method to avoid enzymatic browning is treatment with preservatives. Different kinds of acids and/or sodium metabisulphite (SMS) are commonly used. The acids reduce the pH and have an antioxidant effect. SMS also causes a slightly reduction in pH and acts as an antioxidant in combination with a bleaching effect. SMS has been used widely due to its efficiency and low price. In the past years though, health risks and allergies connected to sulfites have been studied, which resulted in restrictions in use of sulfites as a preservative (FDA, 1994).

Another drawback with pre-peeling is that the quite rough peeling methods, eventually in combination with preservatives, might cause an unpleasant, tough layer at the surface of the tuber. According to Kaack, Kaaber, et al.
(2002), subsurface hardening depends on formation of suberin at the surface, which seems to increase if the tubers are treated with acids. Svensson (1971), on the other hand, suggests that SMS prevents the formation of suberin, but the tough layer is still formed. One theory is that the activity of the enzyme pectin methylesterase increases, which causes cross-linkage of pectin causing the tough surface (Kaafer, et al., 2007).

The tough surface of potatoes can be evaluated by sensorial analysis by a panel or mechanically by a texture analyzer. To evaluate the cooked potatoes mechanically, the peak force is usually used to determine the hardness of the surface (Calder, et al., 2011, Kaafer, Larsen, et al., 2002, Ross, et al., 2010), but other parameters such as peak distance and gradient could be used to evaluate the quality.

The aim of this study was to evaluate subsurface hardening as a measurement of quality of boiled and steam-cooked potatoes by using a texture analyzer. Both industrial and hand-peeled tubers were investigated.

**List of abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>steam cooking</td>
</tr>
<tr>
<td>CB</td>
<td>conventional boiling</td>
</tr>
<tr>
<td>SMS</td>
<td>sodium metabisulfite</td>
</tr>
</tbody>
</table>

**Materials and Methods**

**Potato samples**

Potatoes of the variety *Solanum tuberosum* cv. Fakse were used for analysis. All tubers were grown in the south of Sweden in the same field.

**Preparation of samples**

The tubers were pre-treated with similar equipment as for industrial pre-treatment, but on a smaller scale. The tubers were washed and then peeled with an abrasion peeler for 2 min, followed by peeling with a knife peeler for 40 s. The tubers were then treated with a solution consisting of 0.1% citric acid and malic acid at 8°C for 20 min, followed by treatment with 1.5% SMS for 30 s at 14°C. The tubers were stored in plastic bags at 8°C for 24 h until analysis. As reference, tubers were hand-peeled right before analysis.

**Cooking techniques**

**Steam cooking**

A combi-steamer (SCC WE 61, RATIONAL AG) was preheated to 100°C with 100% steam. The industrially pre-treated tubers and the reference tubers were loaded into the oven, and cooked until the center had reached 96°C. The temperature was monitored both with the built-in temperature sensor and by external thermocouples (type K).

**Conventional boiling**

Industrially pre-treated and reference tubers were soaked in boiling water in lab scale, and cooked until the center had reached 96°C. The temperature was monitored by thermocouples (type K).

**Texture analysis**

Texture analysis was performed with TVT-300XP (Perten Instruments AB) equipped with a 7 kg load cell. The tubers were cut on one side, and the flat side was placed downwards on the instrument board. A 2 mm cylindrical probe was used to penetrate the tuber 9 mm with a rate of 1 mm/s. The required force was monitored. For each variety and treatment, 5 tubers were analyzed with 5 or 6 tests per tuber.

**Results and Discussion**

In Figure 1, two industrially pre-treated tubers cooked with different cooking techniques can be seen.

**Figure 1**: Industrially pre-treated tubers cooked with different cooking techniques: CB to the left and SC to the right.
A layer separating from the rest of the tuber can be seen on the surface of the conventionally boiled tuber. This was not detected for the steam-cooked tubers on a visual inspection.

An example of the results from the texture measurements of a steam-cooked reference sample can be seen in Figure 2. The peak force was observed within 3 mm from the surface of the tuber. For some of the samples there were difficulties in determining the correct peak force due to non-specific peaks. In total 106 measurements were performed. For 7 measurements the peak force could not be determined properly, and therefore the data was excluded from the study. The number of data points for each set-up ranges from 21 to 26.

The results were evaluated in terms of peak force, gradient for the first third of the slope until the peak force, gradient to peak force and peak distance, see Figure 2. The results are presented in Table 1. Depending on the chosen evaluation criteria, the results differ. According to peak force, the industrially pre-treated tubers cooked by CB have a significantly harder surface, while evaluation of the gradient shows that it is the industrially pre-treated tubers cooked by SC that differ. According to peak distance, there is a difference depending on pre-treatment, showing that industrially pre-peeled tubers get a more elastic surface, while cooking method does not affect the result.

As can be seen in Table 1, the gradient differs for some set-ups depend on which part of the curve is studied. In the graph in Figure 1, it is clear that the slope decreases closer to the peak force. At this position, the probe is probably affected by the texture underneath the tough surface. This part of the potato is softer, and therefore requires less force to penetrate, which results in a lower gradient closer to the peak.

Since the gradient is the ratio of peak force and peak distance, and both of these are supposed to be small to obtain a high quality, there is most likely an optimum for the value of gradient. However, tubers of poor quality, where both peak distance and peak force have larger values, can still have the optimum gradient. The gradient is therefore not suitable for determining the quality of boiled potatoes.

**Figure 2:** Example graph from steam-cooked reference sample

**Table 1:** Evaluation of subsurface hardening based on peak force, gradient for the first third and the total gradient of the slope until peak force, and peak distance. Means of 21-26 replicates.

<table>
<thead>
<tr>
<th></th>
<th>Peak force (g)</th>
<th>Gradient 1/3 (g/mm)</th>
<th>Gradient total (g/mm)</th>
<th>Peak distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB Ref</td>
<td>95.1a</td>
<td>78.3ab</td>
<td>66.8a</td>
<td>1.45a</td>
</tr>
<tr>
<td>Ind pre-treatment</td>
<td>120.0b</td>
<td>81.8ab</td>
<td>67.3b</td>
<td>1.83b</td>
</tr>
<tr>
<td>SC Ref</td>
<td>89.3bc</td>
<td>80.9bc</td>
<td>66.9c</td>
<td>1.37c</td>
</tr>
<tr>
<td>Ind pre-treatment</td>
<td>88.0bc</td>
<td>60.4ab</td>
<td>49.6ab</td>
<td>1.81ab</td>
</tr>
</tbody>
</table>

Values within a column not having the same letter (a-b) and a row (x-y) are significantly different (p<0.05).
Even if the evaluation of the tuber based on peak force and peak distance does not agree completely, it is clear that the tough surface depends more on pre-treatment than cooking method, and that it is increased by industrial pre-treatment.

Conclusions
Pre-treatment and cooking methods affect different properties of the tuber. Therefore it is critical to identify the purpose of the analysis in detail, and also which parameters represent quality, and thereafter select one or several of them. Probably both elasticity and hardness are related to quality loss, but this has to be confirmed by sensorial analysis where the consumer determines the quality of the tubers in combination with mechanical analysis.

References


Texture and Color of Crisps in Relation to Sugar – and Acrylamide Content during Storage

Mariane Lakehal-Ayat,¹ Prof. Eva Tornberg*¹ and Jeanette Purhagen¹²

¹Lund University, Food Technology, Engineering and Nutrition
²Perten Instruments AB, Garnisonsgatan 7a, 254 66 Helsingborg, Sweden
*Corresponding author: eva.tornberg@food.lth.se

Abstract
During potato crisp production, the raw material changes in both texture and color. These changes depend on both potato cultivar and process parameters. In this study, the texture and color of crisps processed from potatoes with different sugar contents were analyzed. The acrylamide content, which is related to sugar content and the color of the crisps, was also measured. To see whether the properties change over time, the crisps were measured during a storage time up to eight weeks. The results showed that the sugar content was the main factor governing the quality aspects of the crisps. The brightness (L) decreased, while the redness (a) increased with increased sugar content. Also, the acrylamide formation increased with the sugar content. The texture seemed to be the only parameter affected by both the sugar content and the storage time, requiring higher break forces and longer breaking distances for crisps with low sugar content, and a decrease in firmness after eight weeks of storage.

Introduction
Crisps are a common snack food around the world and are most often produced from potatoes. The quality and consumer acceptance of crisps in terms of texture and color depend on both the raw material and the production process. Crisps and color have been shown to be the most important parameters for consumer perception (Krokida, et al., 2001, Pedreschi, et al., 2005, Santis, et al., 2007, Segnini, et al., 1999, van Vliet, et al., 2007).

The texture and color parameters (i.e. lightness (L), redness (a), and yellowness (b)) have been found to be influenced by both the production parameters, such as frying medium, temperature, and slice thickness, as well as by the potato cultivars (Abong, et al., 2011, Kita, 2014).

During the frying process, the water decreases from around 75% in the fresh potato slices to 2–3% in the crisps (Viklund, 2007). The water is then partly replaced by oil, which can constitute up to 40% of the finished product, which in turn affects the texture (Kita, et al., 2007, Lisinska & Leszcynski, 1989). How much oil is absorbed during the frying partly depends on the frying temperature, which influences the length of the process (Dobarganes, et al., 2000, Gamble, et al., 1987, Mellema, 2003, Moreira, et al., 1997, Saguy & Dana, 2003). In addition, crisps are generally fried at high temperatures (175–190°C), which is a favorable temperature range for acrylamide formation (Gertz & Klostermann, 2002, Grob, et al., 2003). Acrylamide is formed in foods containing reducing sugars (glucose and fructose) and amino acid (asparagine) at high temperatures and is considered to be a carcinogenic substance to humans (Codex Alimentarius, 2009, Napolitano, et al., 2008, Rodriguez-Ramiro, et al., 2011). There are several acrylamide formation mechanisms; however, the main pathway seems to be based on a chemical reaction called the Maillard reaction, which contributes to the color of the crisps. It has been shown that the formation of acrylamide can be reduced (about 73%) by washing the potatoes in water, however, this method causes a negative impact on the final product, resulting in less crispness (Viklund, 2007).

In this paper, the texture and color of crisps during storage was investigated in relation to sensory analysis and the amount of acrylamide formation at different sugar contents.
Material and Methods

Material
Potatoes stored at 8°C (10°C during 8 hours of transfer) and sunflower oil, supplied by a commercial producer, were used.

Crisp production
Washed non-peeled potatoes were cut into slices of 2 mm thickness with a slicing machine (Berkel 800, The Netherlands). About 50 g of potatoes were used for each batch (about 8 to 16 slices).

For frying, a Julabo HC was used with an oil temperature of 156°C for 6 min. For each of the sugar contents (SC), the oil was changed. After frying, crisps were cooled down and the excess grease was eliminated with air and absorbent paper. Samples were put into aluminum bags and sealed with heat for storage measurements. The samples were stored in ambient temperature except for the samples where the amount of acrylamide should be determined. These ones were stored at -18°C (Viklund, 2007). Analyses were performed after 0, 2, 4, 6, and 8 weeks of storage.

Dry matter determination
The dry matter of the potato slices was measured before and after frying for each SC for week 0 and week 8. 5 g of potatoes slices were put into a metal cup and then placed in an oven (Termaks) for 18 h at 105°C, while 2 g of crushed crisps were put into a metal cup and placed in the oven for 5 h at 105°C.

Glucose measurement
A diabetic machine (Accu-Check sensor blood glucose meter) was used to measure the concentration of glucose in the potatoes. Five randomly chosen potatoes were tested for each range of concentration. A slice was cut in the middle of the potato (the glucose is unevenly distributed in the potatoes, so the same part of the potatoes was always tested). The slice was crushed with a mortar and the juice was tested five times for each potato.

Color determination of crisps
A spectrophotometer ‘L.a.b’ (CM-700d) was used to determine the color of the crisps. It is a non-destructive machine and so the crushed crisps were then used for other analysis. Crisps were crushed and put into metal cups; a plastic film was used to protect the spectrophotometer. Five replicates were done for each sample.

Acrylamide measurements
The acrylamide determination was performed in an external lab according to the LC MS/MS method (Chromedia, 2015). The sample endures a solid phase extraction (SPE) before the separation unit with a liquid of chromatography (LC). The final measure of the acrylamide was done with a mass spectrometry (MS).

Texture measurements
A TVT-texture analyzer (Perten Instruments, Sweden) equipped with a three-point bend rig and break probe was used to determine the fracture behavior of the crisps by using a single cycle compression method. The maximum peak force and the fracture distance was determined, Figure 1. Profile settings are displayed in Table 1.

Sensory analysis
Two crisps were tested for each of the two sugar contents (Low and High) after 0, 5, and 8 weeks of storage. An untrained panel was used and the sensory parameters were color, crispness, off-favor, and total impression. The grading was 1–9 where 1 corresponded to ‘none’ and 9 to ‘very high’.

![Figure 1: Texture parameters.](image-url)
Table 1: Profile settings for texture measurements.

<table>
<thead>
<tr>
<th>Setting Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single cycle compression</td>
<td></td>
</tr>
<tr>
<td>Sample height (mm)</td>
<td>2.0</td>
</tr>
<tr>
<td>Starting distance from sample (mm)</td>
<td>8.0</td>
</tr>
<tr>
<td>Compression (mm)</td>
<td>8.0</td>
</tr>
<tr>
<td>Initial speed (mm/s)</td>
<td>3.0</td>
</tr>
<tr>
<td>Test speed (mm/s)</td>
<td>1.0</td>
</tr>
<tr>
<td>Retract speed (mm/s)</td>
<td>10.0</td>
</tr>
<tr>
<td>Trigger force (g)</td>
<td>5</td>
</tr>
<tr>
<td>Data rate (pps)</td>
<td>200</td>
</tr>
</tbody>
</table>

Results and Discussion

Dry matter content and glucose determination

The dry matter content of the potato slices and crisps can be seen in Table 2 together with the glucose determination of the potato slices. No clear correlation is seen between the dry matter content and the sugar content. In addition, the storage time does not seem to influence the dry matter.

According to a study by Williams (2005), glucose concentration in raw potatoes is correlated with the acrylamide level in fried crisps with $R^2 = 0.97$. In that study, no correlation was found between asparagine and acrylamide concentration. That means that as long as asparagine is present, the concentration of reducing sugars is the limiting factor in formation of acrylamide. The importance of using potatoes with low sugar content is thus the main factor. Only potatoes with $SC_{low}$ and $SC_{medium\ low}$ can be used to cope with the recommendations of less than 1 g/kg fresh weight (Biedermann-Brem, et al., 2003).

Color measurements

The brightness of the crisps decreased with increased sugar content, which was expected since sugar is the main reacting compound in the Maillard reaction, resulting in brown pigments and a more colorful product, hence an increase in redness, Figures 2 and 3. Furthermore, in most cases both the brightness and the redness decreased in the samples during storage. Figure 4 shows the difference ($Δ$) between week 8 and week 0 for the different sugar contents.

![Figure 2: A – sugar content Low, and B – sugar content High.](image)

![Figure 3: Brightness and redness for different sugar contents (L low, M-L medium-low, M-H medium-high and H high).](image)

Table 2: Dry matter and glucose level in potato slices and crisps at four different sugar contents.

<table>
<thead>
<tr>
<th>Sugar concentration</th>
<th>Potato slices</th>
<th>Crisps</th>
<th>Crisps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry matter*</td>
<td>mg glucose/ g dry matter</td>
<td>Dry matter*</td>
</tr>
<tr>
<td>SC_{low}</td>
<td>26.5 ± 1.0</td>
<td>1.5</td>
<td>SC_{low}</td>
</tr>
<tr>
<td>SC_{medium\ low}</td>
<td>25.0 ± 0.0</td>
<td>2.9</td>
<td>SC_{medium\ low}</td>
</tr>
<tr>
<td>SC_{medium\ high}</td>
<td>31.4 ± 0.9</td>
<td>12.4</td>
<td>SC_{medium\ high}</td>
</tr>
<tr>
<td>SC_{high}</td>
<td>21.5 ± 1.0</td>
<td>19.8</td>
<td>SC_{high}</td>
</tr>
</tbody>
</table>

* mean and std dev
firmness in week 8 compared to their maximum firmness from the storage time. Since no differences were found in dry matter between week 0 and week 8, water absorption from the air within the sealed bags could not solely explain the decrease in firmness. It is therefore likely that a water distribution of the unbound water within the crisps occurred. Furthermore, crisps from the sugar content Low required significantly higher forces and a longer distance to reach the break point compared to crisps with sugar content High.

**Figure 5**: Acrylamide formation at different sugar contents (L low, M-L medium-low, M-H medium-high and H high).

**Texture of the crisps**
The crisps were not equal in shape and some were more homogenous than others, which resulted in different types of fracture behavior. Two different example graphs can be seen in Figure 6. The blue curve crisp had a sharp break point while the red curve crisp displayed several smaller fractures before the break point.

The sugar contents gave different behaviors for the fracture during storage, with their maximum firmness between week 2 and week 6. However, all sugar contents had a decreasing

**Sensory analysis**
The sensory panel gave higher color scores to the crisps with the sugar concentration High than for crisps with sugar concentration Low. This is in agreement with the instrumental results which displayed a decrease in brightness and increase in redness for the higher sugar content.

The crispness tended to decrease with increased sugar content while the off-flavor seemed to increase. However, the variations in scores are largely due to the fact that the panel is untrained. The total impression corresponds to overall appreciation and includes the color, the crispness, the off-flavor, and the crisp appreciation, which seemed to decrease with higher sugar concentrations.
Conclusions
Quality aspects of crisps have been analyzed concerning sugar content of the potato and the storage time. The results showed that the sugar content was the main factor governing the quality aspects of the crisps. The brightness (L) decreased, while the redness (a) increased with increased sugar content. Also the acrylamide formation increased with the sugar content. The texture seemed to be the only parameter affected by both the sugar content and the storage time, requiring higher break forces and longer breaking distances for crisps with low sugar content, and a decrease in firmness after eight weeks of storage.

References


BVM


DA 7000 and 7200


RVA


**Falling Number**


**TVT**


Come and see Perten Instruments products and meet Perten Instruments representatives.