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Alveograph characterisation of industrial samples of Danish pastry dough

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ABSTRACT

Background and objectives: Only a limited number of methods are available for the assessment of dough properties for doughs containing all the ingredients of a bakery product. The aim of this work was to analyse industrial samples of Danish pastry doughs with alveograph analysis. An adjusted protocol was developed, in which analysis conditions and data analysis were modified compared to the standard alveograph method for assessment of flour quality. A sampling and handling protocol for dough from the industrial production was also developed.

Findings: The Danish pastry doughs analysed with the adjusted protocol were more dependent on mixing time and extrusion order than the flour-water dough analysed with the standard protocol. Two different types of industrial Danish pastry dough with similar recipes could be differentiated with the adjusted protocol.

Conclusions: Industrial samples of Danish pastry dough and possibly also other full formula doughs can be analysed with alveography using the adjusted protocol, if adjustments with respect to the mixing time are made.

Significance and novelty: The findings in this work enables alveograph analysis of full formula dough, which might be used to evaluate the effects of different variables in an industrial setting.

KEYWORDS

Alveograph, bubble inflation, Danish pastry, full formula dough, industrial samples

1 INTRODUCTION

Bakery products can be differentiated from each other by parameters such as taste, appearance and texture. These differences are obtained by choice of ingredients and manufacturing process. However, the effects and the interactions between these are not fully understood (Cauvain, 2015). The design of bakery products even on an industrial level is therefore demanding and slow, as it is often based on a trial-and-error approach and relying on the know-how of experienced bakers (Kristiawan, Kansou, & Della Valle, 2017). Analysis of the dough may be used to accelerate and improve the development process, increase the efficiency during production and provide the basis for a better understanding of the properties of doughs for different types of bakery products and of how they are affected by ingredients and processing methods.

Most analyses aimed at providing data for decision making in bread baking focus on flour analysis. Empirical methods performed on dedicated flour analysis equipment are widely used to test the rheological properties of flour by attempting to simulate processes similar to breadmaking, like mixing and bubble growth (Dobraszczyk & Morgenstern, 2003). Doughs made from flour and water have also been analysed using fundamental rheological methods, including dynamic shear oscillation, creep and stress relaxation and large deformation extensional measurements, but these have primarily been used for scientific purposes (Singh & Singh, 2013; Sliwinski, Kolster, & van Vliet, 2004; Stojceska, Butler, Gallagher, & Keehan, 2007). Only a few rheological studies have been published on doughs containing all the ingredients of a bakery product. Deformation properties have been studied using texture analysis with either a probe or a Kieffer rig (de la Horra, Steffolani, Barrera, Ribotta, & León, 2015; Rezaei, Jayaram, Verstrepen, & Courtin, 2016), while mixing properties have been characterised by e.g. a farinograph (Alava, Millar, & Salmon, 2001; Oliver & Allen, 1992). In addition, most studies of doughs for bakery products are made on doughs without yeast in order to avoid the time-dependent effects of the yeast, including gas-development and production of metabolites (Rezaei et al., 2016; Verheyen, Jekle, & Becker, 2014).

Flour is usually analysed on an alveograph using a standardized protocol developed for commercial benchmarking, valuation, decision making, and comparison between laboratories (AACC, 2009b). Alveography assesses dough rheology, more specifically biaxial extension properties. As standard, the analysed dough consists of flour, sodium chloride and a fixed amount of water (Dubois, Dubat, & Launay, 2008). The standard alveograph protocol is in general used for flour analysis, although other protocols have also been developed for specific purposes (Dubois et al., 2008).

However, an alveograph protocol for analysis of full formula dough or industrial dough samples has not been made. Alveography has been used for flour analysis in order to correlate the flour properties with bread volume (Addo, Coahran, & Pomeranz, 1990; Bettge, Rubenthaler, & Pomeranz, 1989), but the prediction value is often limited (Ktenioudaki, Butler, & Gallagher, 2011). It has also been used to test how the rheology of the dough changes with different flour compositions or additives to the dough (Addo & Pomeranz, 1992; Addo, Slepak, & Akoh, 1995; Agyare, Addo, Xiong, & Akoh, 2005; Cappelli et al., 2018). However, to the best of our knowledge, no dough comprising all the ingredients for bakery products has successfully been analysed using alveography. A few previous studies investigating the biaxial extensional properties of yeasted dough have been published. Bennett and Coppock (1956) attempted to analyse a dough with yeast on the alveograph and experienced that the dough films ruptured irregularly when stretched, most likely because they incorporated a 3-hour rest period. Vanin, Lucas, Trystram and Michon (2018) analysed the biaxial extensional properties of a bread dough with yeast using lubricated squeezing flow, and their dough was therefore compressed instead of stretched. The D/R Dough Inflation System has also been used to analyse yeasted dough (Altuna, Ribotta, & Tadini, 2016; Ananingsih, Gao, & Zhou, 2013; Dobraszczyk, 1997a), however no specific countermeasures for mitigating the effect of yeast activity was mentioned.

The aim of this work was to analyse Danish pastry doughs with alveography in order to obtain quantitative, reproducible, precise and reliable measures of dough properties, with the ultimate aim to analyse dough samples taken from a Danish pastry production facility. Danish pastry is made from an underdeveloped, relatively cold dough which contains multiple ingredients (Ooms, Pareyt, Brijs, & Delcour, 2016). This dough is at a later stage laminated with fat, cut in to pieces of suitable sizes and folded into desired shapes. This work focuses on the characterisation of the dough prior to lamination. As the alveograph standard protocol is designed for flour analysis, different modifications of the protocol were necessary, as care must be taken with respect to the effects of the yeast and differences in dough development.

2 MATERIALS AND METHODS

2.1 Materials

Strong commercial wheat flour (moisture content: 13.6 %, Lantmännen Cerealia, Vejle, Denmark), margarine, improver (including taragum, enzymes and ascorbic acid) and Danish pastry dough samples were obtained from Lantmännen Unibake, Hatting, Denmark. Moisture content of the flour was determined according to AACC method 44-15.02 (AACC, 2009a). Sodium chloride was from VWR. Pasteurised eggs, sugar, compressed yeast and peanut oil were obtained from the local supermarket.

2.2 Alveograph measurements on flour

Alveograph analysis of the flour was performed on an AlveoLab (Chopin Technologies, Villeneuve-la-Garenne, France) using the standard constant hydration alveograph test (AACC method 54-30.02) (AACC, 2009b), except that different mixing times were applied. The mixing was conducted at 24 °C for 3, 4, 5, 6, 8, 10 and 14 minutes. In short, 250 g flour was hydrated using 25 g/L sodium chloride solution at 20 °C (131.2 ml at 13.6 % moisture) at the beginning of the mixing. After the first minute of mixing the bowl was scraped for 1 minute to ensure the formation of a uniform dough. At the end of each mixing, five dough pieces were extruded, rolled out and cut to produce similar-sized dough pieces, after which they were rested at 25 °C. 20 minutes after the mixing was stopped, the first dough piece was loaded into the alveograph, and a dough bubble was blown at 20 °C using a constant air flow of 96 L/hour. The overpressure was measured as a function of time until the bubble ruptured. Subsequently, the remaining dough pieces were analysed in the same way in the order they were extruded. Triplicates were made for each mixing time.

2.3 Alveograph measurements on Danish pastry dough

Danish pastry dough was mixed in the alveograph mixer bowl and analysed. The temperature of the mixing bowl and the resting chamber was set to 18 °C and the test chamber to 15 °C. The Danish pastry dough consisted of the ingredients with the following ratio: flour (100), demineralised water (50), pasteurised eggs (6.7), sugar (5.4), compressed yeast (4.1), margarine (3.5), improver (1.5) and sodium chloride (0.35). The flour was stored at -18 °C until analysis, and ice-cooled demineralised water was used. The recipe was scaled to obtain a total dough weight of 400 g. All the ingredients were added to the alveograph mixer, except water, which was automatically dosed at the beginning of the mixing. The dough was mixed for 4, 6, 8, 10, 12, 13 and 14 minutes, including a 1-minute scrapedown period after the first minute of mixing, and the dough was otherwise analysed according to the standard alveograph method with respect to extrusion, resting and bubble analysis. For each mixing time, triplicates were made.

2.4 Sampling and analysis of Danish pastry dough from industrial production

Two different types of Danish pastry dough for plait products were sampled immediately after mixing from an industrial production. Type 1 and 2 contained the same ingredients, however type 1 was mixed for longer time and contained less water than type 2. Furthermore, the two doughs were made at different days, and different batches of flour and other ingredients were therefore used. The dough was divided into samples of approximately 450 g, packed in plastic bags, rolled out to a thickness of approximately 13 mm and frozen at -18 °C allowing the dough to be stored, transported and analysed later.

Before analysis, the dough sample was thawed 3 hours at 5 °C, after which a 400 g sample was made. In the alveograph, the temperature of the mixing bowl and the resting chamber was 18 °C and the test chamber 15 °C. The dough samples were put into the alveograph mixing bowl and mixed for 2, 4, 6, 8 and 10 minutes. The bowl was not scraped during mixing. After mixing, the dough was otherwise analysed as described by the alveograph standard method. Triplicates were made for each mixing time.

2.5 Alveograph data analysis

The air pressure profile for each of the five dough pieces for each dough were automatically recorded by the AlveoLab software (version 1.1.1.14, Chopin Technologies). For a set of five dough samples, the alveograph parameters were found for the five individual curves. The alveograph parameters include the dough tenacity (P, calculated from the maximum height of the curve), the biaxial extensibility of dough (L, abscissa at bubble rupture), the deformation energy (W, related to the area under the curve) and the elasticity index (Ie, ratio of the pressure at 40 mm on abscissa to the maximum overpressure). If a curve had an Ie value of 0, caused by rupture of the dough bubble before 40 mm on the abscissa, the value was removed before data analysis. For each of the parameters, the mean and standard deviation between the five measurements were calculated for each replicate and plotted as a function of mixing time. To identify significant differences between replicates, analysis of variance (ANOVA) with Tukey's multiple comparisons tests with a significance level of 5 % were carried out.

2.6 Consistograph analysis

Consistograph analyses were made in the mixing bowl using a two-armed mixing blade and an anti-raw dough flange. The dough consistency was measured during mixing by a pressure sensor in the mixer. The same recipes for the doughs as used for the alveograph analyses were used for the consistograph analyses. The flour was analysed at 24 °C according to the standard constant hydration consistograph method (AACC method 54-50.01) (AACC, 2009c), while the Danish pastry doughs were analysed at 18 °C. The doughs were mixed for 16 minutes. In the analysis of the Danish pastry dough samples from the production, the bowl was not scraped during the mixing. The measurements were made in duplicate.

3 RESULTS AND DISCUSSION

3.1 Method development, sampling and handling

The alveograph method has in this work been used for analysis of Danish pastry dough, even though it is normally only used to assess flour quality (Dubois et al., 2008). Different modifications of the protocol were made to optimize the method for Danish pastry dough. In all steps of the alveograph protocol, the temperature was reduced compared to the standard protocol for the analysis of Danish pastry. Furthermore, some of the ingredients were cooled for the Danish pastry dough made in the alveograph mixer, and the Danish pastry dough samples from the production were thawed at 5 °C. The primary reason for the temperature reduction is that the Danish pastry dough contains yeast, which increases the volume of the gas cells in the dough during fermentation, giving the dough a foam structure (van der Sman & van der Goot, 2009). However, the alveograph method does not give satisfactory results if the foam structure is too distinct (results not shown). This correlates well with similar observations made by Bennett and Coppock (1956). The effects of yeast can be reduced by decreasing the temperature, which is well known to lower the activity of yeast, delaying gas production and foam formation (Cauvain, 2015). The temperature used during analysis was reduced to a level which is typically used for the production of Danish pastry dough (Ooms et al., 2016).

During mixing, dough is continuously developed as various reactions and processes take place, and the mixing time therefore influences dough properties (Schiedt, Baumann, Conde-Petit, & Vilgis, 2013). For standard alveograph analysis, the flour-water dough is mixed for 8 minutes before it is extruded, as this mixing time results in a dough suitable for analysis. However, dough development is affected by the ingredients in the Danish pastry dough. It has previously been shown that full recipe bread doughs have longer development times compared to flour-water doughs (Cauvain, 2015; Oliver & Allen, 1992), and this most likely also applies to Danish pastry dough. Furthermore, changes in temperature also affect the dough development, as development time has been shown to increase with decreasing mixing temperature (Farahnaky & Hill, 2007). Various mixing times, both shorter and longer than the standard mixing time, were therefore used to quantify how the properties of the dough changed. Despite samples of Danish pastry dough from the production were premixed, they were mixed again in the alveograph mixing bowl in order to increase dough temperature to the analysis temperature, and to homogenise the dough, including removal of potential incorporated air bubbles. In general, Danish pastry dough is underdeveloped at the end of mixing (Ooms et al., 2016), implying that it is possible to mix the dough further without the risk of extensive overmixing.

The Danish pastry dough samples from the production had to be stored and transported before they could be analysed, and a protocol for sampling and handing of dough from an industrial production was therefore developed. The samples were frozen as fast as possible after preparation, and the thickness of the dough samples was reduced to obtain quick freezing and uniform thawing, in order to ensure that the dough samples were as similar as possible.

It is important to notice that when analysis conditions, handling of the dough and dough composition are different, it is not possible to compare the samples. Differences in the parameters between the different types of dough might be due to e.g. analysis temperature, mixing time, addition of additional ingredients and freezing of the samples. For example, the recipes for the Danish pastry dough mixed in the alveograph and the two types of industrial Danish pastry samples were similar, except for minor differences in ingredient content and origin. However, it is not possible to know if any differences among the analysis results are caused by differences in the content (ingredients and water content) or in the processing (mixing conditions and freezing/thawing steps during sampling). If the results should be comparable, only one thing should be changed at a time. In this work, due to the nature of the industrial samples, multiple parameters are changed among the different doughs. Our aim is thus to demonstrate that the method can be applied for rheological analysis of industrial, yeasted doughs and not to study the effects of the individual parameters.

3.2 Alveograph curves

The flour-water dough, the Danish pastry dough mixed in the alveograph and the Danish pastry dough samples from the production were analysed using the alveograph. For every analysis, five pressure curves were obtained, as five dough pieces from the same dough were produced and analysed. Instead of using an average curve of the five curves for the data treatment, as it is done as standard, all five curves for each replicate were analysed, as the variation between the five curves may be used as an estimate of the rate of change of dough properties.

Examples of the alveograph curves for flour-water dough at different mixing times can be seen in figure 1. The variability between the five curves for each dough seem to decrease with longer mixing time, but in general the curves are similar. Some minor differences in the height and length of the curves among the different mixing times can be seen. The extrusion order does not seem to influence the height and the length of the curves relative to each other.

Typical alveograph curves of the Danish pastry dough mixed in the alveograph analysed with the modified protocol can be seen in figure 2. Large variability between the five curves can be observed at shorter mixing times, but the differences decrease with increasing mixing times, and at the longest mixing times, the curves are very alike. The extrusion order seems to influence especially the height of the curves, as it decreases in the same order as the dough pieces were extruded. This is especially pronounced for shorter mixing times, although the tendency can also be observed at longer mixing times, at least for the curve from the first extruded dough piece. Also the length of the curves seems to be influenced by extrusion order at shorter mixing times, as the length of the curves increases as function of the extrusion order. However, the increase in the curve length is not as pronounced or consistent as the decrease in curve height. This development of the curves by the extrusion order is suspected to be caused by dough mixing during extrusion, as the first extracted dough piece is mixed for shorter time than the fifth extracted dough piece. The variability between the curves decreases at longer mixing times, indicating that the dough at this stage does not develop as much during extrusion compared to shorter mixing times. When comparing the curves at different mixing times with each other, the average curve height decreases with increasing mixing time. This is consistent with the decreasing curve height with extrusion order.

It should be noticed that for some of the curves with a mixing time of 8 to 14 minutes, no sudden fall in the pressure curve indicating dough bubble rupture can be observed. This is caused by the alveograph software that stopped the bubble inflation before the bubble ruptured.

The Danish pastry dough that was mixed for 12 minutes or longer was difficult to handle, as the dough was sticky and soft. Oil was used for lubrication of the surfaces to avoid dough sticking and drying up. However, it was necessary to use more oil than prescribed during the extrusion to ensure the dough did not stick to surfaces. Despite the challenges with the handling of the dough, it did not seem to increase the variability in the results, as the curves are close to each other.

Examples of the alveograph curves for the Danish pastry dough type 1 sampled from the industrial production can be seen in figure 3. Many of the same tendencies, which was found for the Danish pastry dough mixed in the alveograph, could also be observed for the Danish pastry dough samples from the production. This includes large variability between the curves for the shorter mixing times and decrease of the variability with longer mixing times. Additionally, the height and the length of the curves were influenced by the extrusion order, as the first extruded dough pieces in general had higher and shorter curves compared to the dough pieces extruded in the end. Moreover, the average height of the curves decreased with longer mixing times. No rupture of the dough bubble was observed for the longer mixing time. Furthermore, the dough became difficult to handle due to increasing stickiness for longer mixing times. However, compared to the Danish pastry dough mixed in the alveograph, shorter mixing time was necessary before the above-mentioned phenomena could be observed. This was expected, since the dough was premixed and therefore already developed to some extent. Likewise, for mixing times between 6 and 10 minutes, some curves did not reach the point of rupture, as no noticeable decrease in pressure was observed. It was observed that the dough became sticky at a mixing time of 10 minutes. Similar results were obtained for the Danish pastry dough type 2 (results not shown), except that the curves were shorter and lower in general, and the premature stop of inflation occurred already at a mixing time of 4 minutes.

As the Danish pastry doughs were cold at the beginning of the mixing, and the temperature of the mixer bowl was 18 °C, it may be suspected that the variability between the curves for the short mixing times are due to temperature differences. However, temperature measurements have shown that after 2 minutes of mixing, the dough has approximately the same temperature as the mixer bowl (results not shown). Nevertheless, dough temperature increases up to 4 °C additionally (dependent on the mixing time) during mixing and extrusion for all doughs, due to the work performed on the dough by the mixer. No temperature difference between the dough pieces could be observed after the resting period (results not shown).

For standard flour analysis with a mixing time of 8 minutes, the curves are similar, and the characteristics of the curves do not depend of the extrusion order (figure 1). It is therefore acceptable to use an average of these five curves for the results. However, when Danish pastry dough is analysed, a larger variability between the curves can be observed, especially at shorter mixing times. Furthermore, the characteristics of the curves relative to each other are dependent on the extrusion order, as the dough pieces were affected by additional mixing during extrusion. The development of Danish pastry dough is different compared to flour-water dough, which is in line with previous observations showing that dough development can be affected by both additional ingredients (Cauvain, 2015; Oliver & Allen, 1992) and lowered temperature (Farahnaky & Hill, 2007), as well as dough might be premixed. A new mixing time must therefore be determined or decided upon for the individual dough and settings.

3.3 Analysis of the alveograph parameters

The parameters tenacity (P), biaxial extensibility (L), deformation energy (W) and elasticity index (Ie) obtained from the alveograph curves were used to investigate how the average and the variation between the curves change with mixing time (figure 4). For the flour-water dough, P decreases slightly with increasing mixing time, and Ie is almost constant (no significant difference between the replicates can be observed) for all the mixing times, while L and W increase and subsequently decrease with increasing mixing time, but compared to the Danish pastry doughs the changes in the parameters are minor. The parameters for the Danish pastry dough mixed in the alveograph seem to change a lot when the mixing time is increased, as P, W and Ie decrease, while L increases after which it decreases. Similar development can be observed for the Danish pastry dough samples from the production, however, the parameters do not change as much. In comparison, the flour-water dough is relatively stable, while the parameters for the Danish pastry doughs are considerably more dependent on mixing time.

The standard deviations for the parameter L are so large that significant differences could only be found between a few of the samples. Additionally, the L values for the Danish pastry doughs may be higher than reported at longer mixing times, as the alveograph probably stopped inflation prematurely. This applies to some of or all the measurements at 8 minutes or longer for the Danish pastry dough mixed in the alveograph, at 6, 8 and 10 minutes for the industrial Danish pastry dough type 1 and at 4, 6, 8 and 10 minutes for the industrial Danish pastry dough type 2. Furthermore, the parameter W is dependent on the length of the curve, and as some of the L values may be too low for several Danish pastry doughs at the longer mixing times, the W value could accordingly have been underestimated for these doughs.

The variability represented by the standard deviation between the five measurements decreases with longer mixing times until a certain level. This is observed for all the dough types for all the parameters, but different mixing times were required for the different doughs before this lower level of variation was obtained. For P and Ie, the standard deviations for the flour-water dough were smaller for the shorter mixing times compared to the Danish pastry doughs. It should be noted that the characteristics of the alveograph curves changed with the extrusion order for the Danish pastry doughs at shorter mixing times (figure 1-3). The standard deviation represents both the development of the dough due to the additional mixing during the extrusion, and the random variation between the curves. From the alveograph curves, it was observed that P and Ie have a small random variation, as the large variability is observed concomitant with the curve dependency of extrusion order, while L has a large random variation compared to the systematic variation.

As the value of the parameters often decrease simultaneously with decreasing standard deviation, it can be considered whether the variation is only dependent on the size of the values. However, when looking at the coefficient of variation, it can be seen that the this is not the case, as also the coefficient of variation decreases by a pattern similar to the standard deviation. This supports that at least some of the variability is caused by the extrusion order.

The obtained standard deviations for the standard protocol with the flour-water dough mixed at 8 minutes are in the range of 2.1-2.9 mm H_2O for P, 5.7-23.5 mm for L, 5.2-26.2 10^{-4} J for W and 0.65-0.78 % for Ie. Standard deviations for the other doughs comparable to the standard deviations for the standard method can be obtained at 10 minutes for the Danish pastry dough mixed in the alveograph (with standard deviations of 1.7-2.2 mm H_2O for P, 6.0-26.1 mm for L, 3.5-8.7 10^{-4} J for W and 1.04-1.44 % for Ie), 6 minutes for the industrial Danish pastry dough type 1 (with standard deviations of 1.1-2.1 mm H_2O for P, 11.4-18.5 mm for L, 11.4-13.2 10^{-4} J for W and 0.42-1.10 % for Ie), and 6 minutes for the industrial Danish pastry dough type 2 (with standard deviations of 1.1-2.1 mm H_2O for P, 16.0-30.5 mm for L, 11.9-21.5 10^{-4} J for W and 0.91-2.45 %

for Ie). However, this is dependent on which parameters are taken into account, as it can be seen above, the standard deviations of some of the parameters are above those for the standard protocol, while other are below.

The results for the flour-water dough, the Danish pastry dough mixed in the alveograph and the industrial Danish pastry doughs can not be directly compared as multiple variables were changed, including analysis conditions, dough composition and handling. However, as the two types of Danish pastry dough from the production were treated similarly, their results can be compared. When the two types of industrial Danish pastry dough are compared, it is observed that the type 2 dough had lower values of P and W than type 1, while lower values of L and Ie was also observed for type 2 for the longer mixing times. Differences for some of the parameters can therefore be found between the two types of industrial doughs with this analysis protocol when a suitable mixing time is used.

3.4 Dough development

Consistograph analysis of the three different dough types was made to obtain more knowledge about the dough development during alveograph analysis. The time scale is not comparable to the mixing prior to the alveograph analysis due to differences in the geometry of the mixer arm and mixing bowl. In the consistograms in figure 5, it can be observed that the curves peaks at different times. This maximum in resistance to deformation is typically referred to as the optimal dough development (Zheng, Morgenstern, Campanella, & Larsen, 2000).

The flour-water dough has a shorter development time to maximum dough resistance compared to the Danish pastry dough mixed in the alveograph. The longer development time of the Danish pastry dough could be due to the lower analysis temperature or due to the additional ingredients (Cauvain, 2015; Farahnaky & Hill, 2007). The Danish pastry dough samples from the production were not developed to maximum dough resistance when the samples were extracted, and a peak indicating optimal dough development could therefore be observed. As Danish pastry doughs in general are undermixed, allowing the dough to further develop during the lamination process (Ooms et al., 2016), this was expected. The large spike observed in the beginning of the consistograms is probably due to the low dough temperature after thawing. Differences in dough development time could be observed between the two types of industrial dough samples, as type 2 seemed to have longer development time compared to type 1. Furthermore, a lower consistency was also observed for type 2.

The differences in development time can explain why the variability among the curves decreases with longer mixing time for each dough type. Before the optimal development of the dough, large variations between the alveograph curves can be observed, especially for the Danish pastry doughs. This is supported by the dough mixing curves prior to the alveograph analysis (results not shown), in which it is observed that the variability between the alveograph curves was related to the stage of the dough development. Before optimal dough development, the dough changes with a rate that causes the properties of the dough to be affected by additional mixing during extrusion, resulting in differences in the individual alveograph curves. When the dough is optimally mixed, the variability of the characteristics of the alveograph curves is more random, and the variation among the curves is therefore most probably evidence of natural variation among the curves, i.e. it is not or only to a small degree due to development of the dough during extrusion. When the dough is overmixed, the dough does not change as fast as when it is undermixed, which can be observed as the variations for the parameters remain approximately constant.

It was observed that the Danish pastry doughs became sticky at longer mixing times. This might be due to overmixing causing release of free water (Schiedt et al., 2013). Furthermore, both a low dough consistency and the rheology of the dough can increase the perception of stickiness (Cauvain, 2015; Dobraszczyk, 1997b). The additional ingredients in Danish pastry dough may also be part of the reason, as e.g. sucrose has been shown to increase the softness and stickiness of the dough (Cauvain, 2015).

3.5 Analysis of Danish pastry dough

It is possible to use alveography to analyse Danish pastry dough, including dough samples from industrial production, if different requirements are met. As stated in the beginning of the Results and Discussion section, the analysis results from different samples can not be directly compared unless the analysis conditions and the handling of the dough are alike, as it is otherwise not possible to know which variable the differences should be assigned to. However, if the doughs are handled and analysed in the same way, such as the two types of dough from the industrial production, they can be compared.

The handling of the dough is important to ensure reliable results. The sample conditions should be as similar as possible, and extensive activity of the yeast must therefore be avoided, which is achieved by lowering the analysis temperature compared to standard protocol. In order to be able to perform the alveograph analysis of dough from an industrial production at a different time and place, dough samples were frozen. It was not possible to analyse dough samples directly after sampling to assess the effects of freezing and thawing, even though it is well known that freezing and resting time may affect the dough rheology (Newberry, Phan-Thien, Larroque, Tanner, & Larsen, 2002). Although it is not possible to know if or how this process has affected the results, the reproducibility between the samples seems to be acceptable.

Different mixing times were used in order to investigate how the dough properties changed with mixing time. It was observed that the flour-water dough is relatively stable, as the dough properties did not change much with increasing mixing time, while the Danish pastry doughs were more dependent on mixing time, as the value of the parameters changes significantly with increasing mixing time. Analysis of the Danish pastry doughs at different mixing times can therefore be used to describe how dough properties develop during mixing. Mixing curves can be used to support alveograph measurements and to determine the stage of dough development.

Characterisation of a dough at different mixing times entails an increased workload compared to the standard protocol used for flour analysis. It may therefore not be practical to analyse the dough at different mixing times in all cases. Another approach would be to select one mixing time and use this mixing time for all analyses of the dough. The mixing time selected can be based on multiple criteria, but we recommend mixing the dough beyond maximum dough resistance in order to avoid the extrusion order dependent curve characteristics. On the other hand, the dough should not be extensively overmixed, as this results in a dough, which is difficult to handle. A screening of different mixing times should preferably be performed before choosing a specific mixing time. Choice of mixing time will of cause be highly dependent on the specific questions asked, as information on the dough properties is provided at this specific mixing time, regardless of whether the dough is under- or overmixed. Nevertheless, determining (or simply choosing) a specific mixing time for a specific dough allows for further analysis of variables, e.g. the effects of ingredients and process variables on the dough properties without an overly extensive sample matrix. However, if the analysed doughs are very different they may have a different dough development and may therefore need different mixing times in order to be optimally developed for analysis. If they are analysed using the same mixing time, this may result in large variability among the curves for each replicate.

4 CONCLUSIONS

It is possible to use alveography to analyse industrial samples of Danish pastry dough, if different requirements are met. This includes lowering the analysis temperature and analysing the dough at different mixing times. Furthermore, the results must be analysed by comparison of the five individual curves for each replicate instead of just using an average curve, as this can be used as an indicator of the dough development. If the Danish pastry dough was not mixed beyond optimal dough development at the end of mixing, the characteristics of the curves were dependent on extrusion order due to additional mixing during extrusion, resulting in large variability among pressure curves. By increasing the mixing time, the variation among the curves can be lowered to a level similar to that typically obtained for the standard analysis protocol for flour.

This modified alveograph protocol can be used to analyse industrial samples of Danish pastry dough and possibly also other doughs including doughs with yeast. It was demonstrated that differences in the parameters could be found for the two distinct but relatively similar industrial samples when a suitable mixing time was used. The modified alveograph protocol facilitates detailed assessment of dough performance caused by minor differences in ingredients and water content and may thus be expected to be capable to evaluate the effects of e.g. variations in ingredients, flour type, batch and quality in an industrial setting. If different mixing times are used for the analysis, changes in dough properties at different stages of dough development can be described. Alternatively, one mixing time can be chosen to analyse the effect of variations in dough recipe or handling during production. The choice of the mixing time depends on multiple factors and must be determined for the specific dough type and production conditions. This should allow for a more precise estimation of the correlations between dough variables and dough performance compared to the traditional studies based on simple flour-water mixtures.

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Figure captions

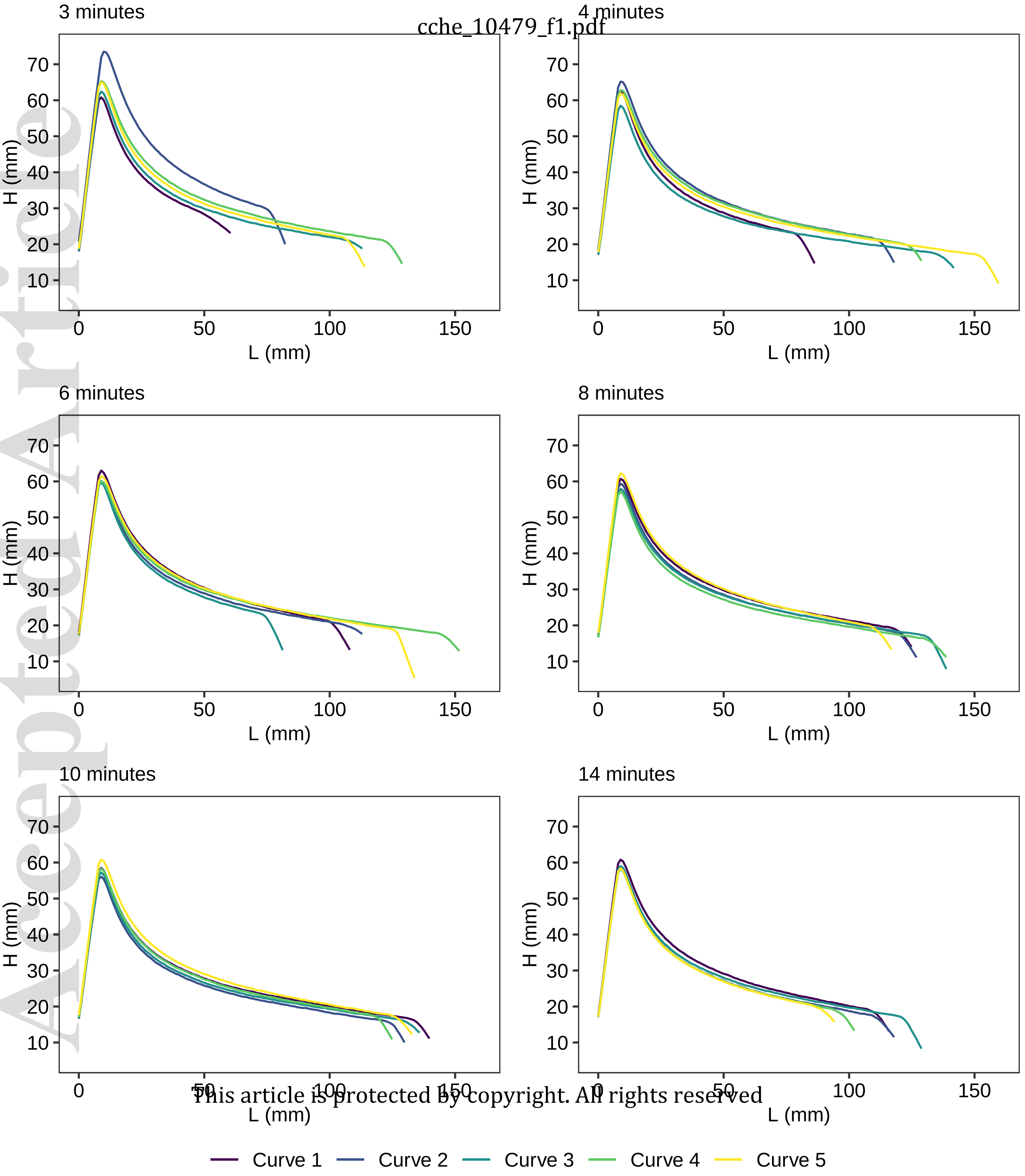
Figure 1. Examples of alveograph curves for the flour-water dough mixed for 3, 4, 6, 8, 10 and 14 minutes, respectively. The order, in which the dough pieces are extruded, are indicated by the curve number, of which 1 being the first and 5 the last.

Figure 2. Examples of alveograph curves for the Danish pastry dough mixed in the alveograph mixer for 4, 6, 8, 10, 12 and 14 minutes, respectively. The order, in which the dough pieces are extruded, are indicated by the curve number, of which 1 being the first and 5 the last.

Figure 3. Examples of alveograph curves for the industrial Danish pastry dough type 1 mixed for 2, 4, 6, 8 and 10 minutes, respectively. The order, in which the dough pieces are extruded, are indicated by the curve number, of which 1 being the first and 5 the last.

Figure 4. The mean and standard deviation for each replicate for the parameters dough tenacity (P), dough biaxial extensibility (L), deformation energy (W) and elasticity index (Ie) at different mixing times, shown for the flour-water dough, the Danish pastry dough (DPD) mixed in the alveograph and the industrial Danish pastry doughs type 1 and 2.

Figure 5. Consistograph analysis of the flour-water dough, the Danish pastry dough (DPD) mixed in the alveograph and the industrial Danish pastry doughs type 1 and 2 from the production. The dough consistency is measured by a pressure sensor inside the mixing bowl as a function of time.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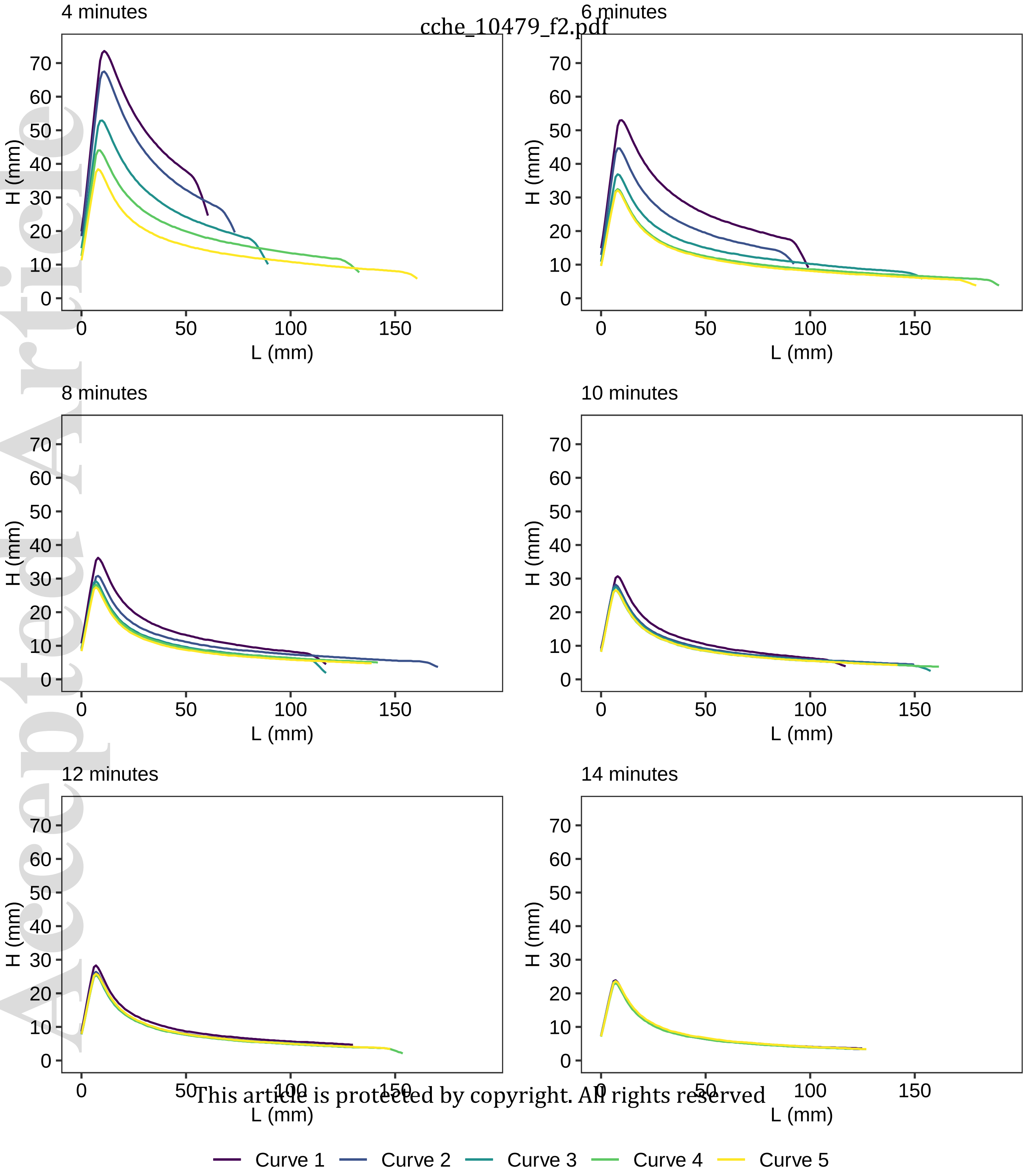
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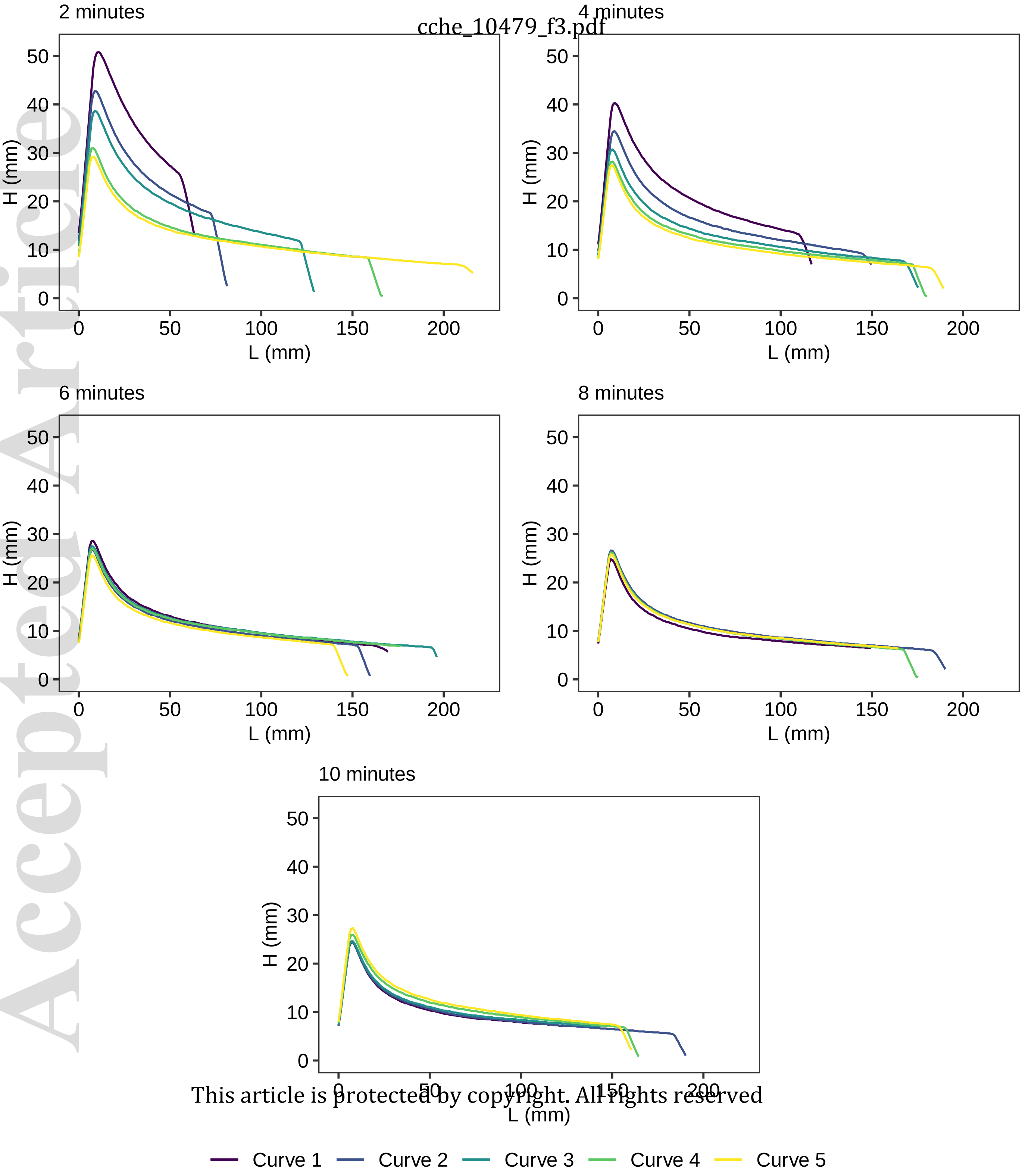
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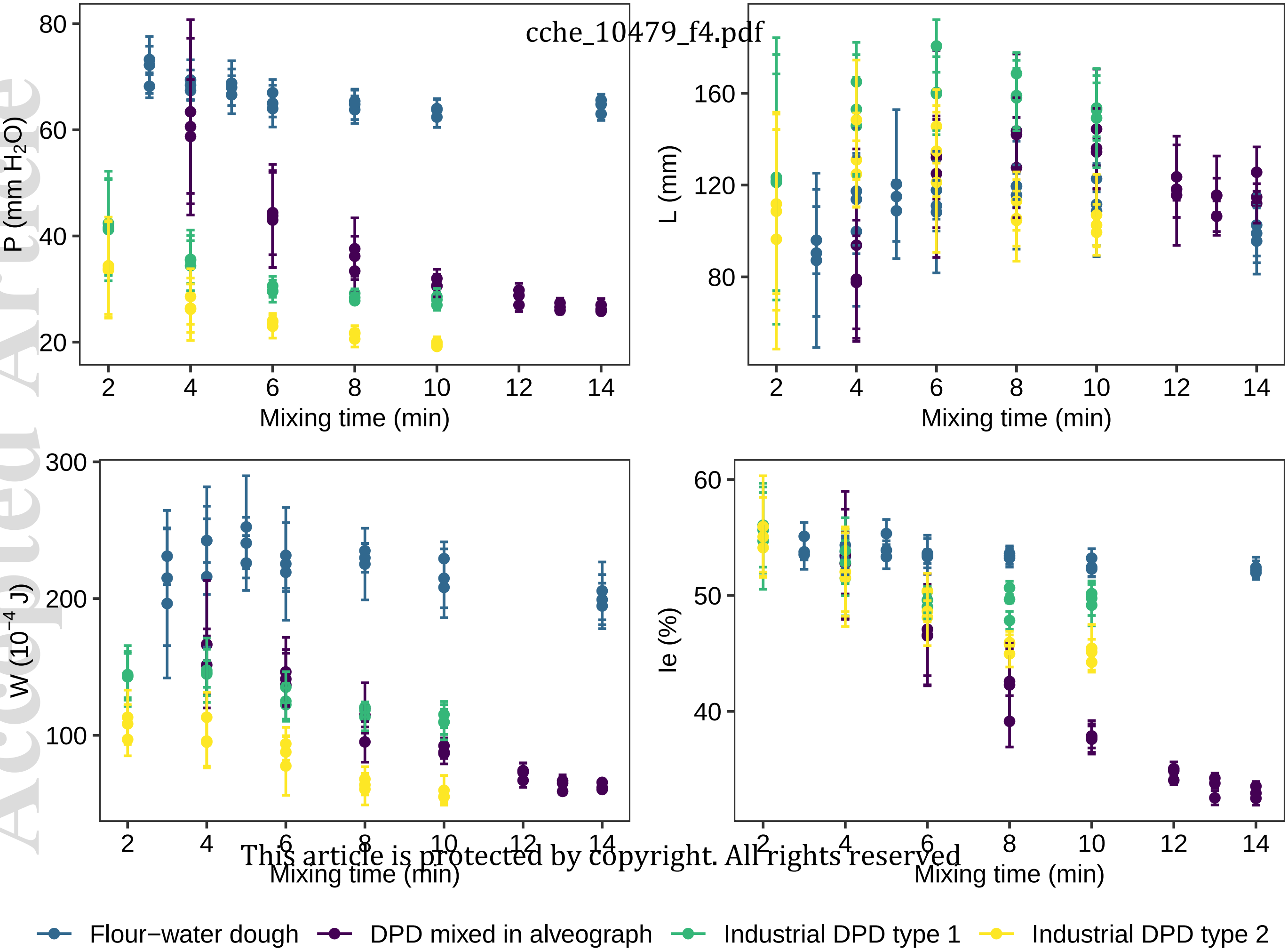

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