A method for predicting baking performance through evaluation of short crust dough

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Abstract
The three major components of short-crust cookie dough are flour, sugar, and fat. Since high fat contents have been shown to have a major effect on the development of the gluten network, studying how these ingredients could affect the texture of the dough and the baked product became interesting. In addition, there are no existing methods on short crust cookie dough that allow predicting the characteristics of the baked product based on those of the dough. Therefore, the task was to study whether developing such a method is possible or not. In this paper, the amount of ingredients was varied and textural analyses were run on dough and baked samples. The results were analyzed using chemometrics and statistical tools and different graphs were plotted to visualize the relations between the variables and parameters. The analyses showed that the fat and egg amounts have a significant effect on the texture of the dough in terms of hardness and gumminess. In addition, the hardness of the baked product was shown to be positively correlated with dough hardness and gumminess, which in turn can be controlled by the addition of fat and/or eggs according to requirements on the final product. Thus, prediction of baking performance based on dough characteristics was shown to be possible.

Keywords: short crust dough, rheology, textural characteristics, texture, shortening, margarine, texture analyzer, baking

Introduction
In daily life, at least at home, no more than basic knowledge is required to be able to produce bread and other bakery products. However, in order to improve such production, especially in industrial processing and applications, proper scientific understanding of the components and their interactions is a priority. Taking this to another level, it is valuable to be able to predict baking performance and the characteristics of the finished product based on those of the dough. This will help improve production in terms of quality and quantity, since time and materials will be saved. While methods for predicting bread-baking performance through dough evaluation already exist, no such methods have been developed for short crust dough. Therefore AAK suggested a study on the possibility of developing such a method.

Short-crust pastries are considered one of the most popular groups of baked products (Kweon et al. 2014) (Miskiewicz, Nebesny & Rosicka-Kaczmarek 2013). Proper selection of the ingredients and their quantity determines the quality and stability of the final product even during storage, such as fragility and oxidation. Besides the sensory properties, the quality is also determined by the chemical properties of the ingredients (Miskiewicz, Nebesny & Rosicka-Kaczmarek 2013) (Pareyt & Delcour 2008). Flour, sugar, and fat are the three major components that short crust cookies consist of (Zucco, Borsuk & Arntfield 2011). Fat could be added as butter, shortening, or margarine. The high content of fat increases the air incorporation in the dough especially when subjected to a creaming stage. In addition, fat act as a lubricant and competes with the aqueous phase and limits the gluten formation (Maache-Rezzoug 1998) (Wade 1990) (Slade 1994). However, during baking fat melts and together with sugar they increase the mobility of the dough and hence result in larger dough spread (Pareyta et al. 2009). The dough components thus influence the dough rheology, dough making and handling, and baking quality that influence the rheology characteristics (Pedersen et al. 2004).

According to Bourne (1990) methods such as compression, bending-snapping, and puncture principle have been used to study rheological and textural properties of dough and baked product.

Materials and Methods
Materials
Wheat flour produced by Nord Mills (moisture content less than 15,5%; Kärnvetemjöl (ARTNR 140233)), normal granulated sugar from Nordic Sugar, egg powder (1531006-105 heläggspulver) produced by Källbergs Industri AB with a water content of 4%, protein content of 48%, and 43% fat, and cold drinkable tap water. Four types of fat based on S100 were used in the experiments that were especially produced at AAK for this study: (1) shortening, (2) shortening with 2% emulsifier, (3) margarine, and (4) margarine with 2% emulsifier.

Dough preparation
Mixing: sugar, fat, and egg powder were mixed at low speed (60 RPM) in a mixer (Hobart N50 5-Quart Mixer) for 30 sec, scraped down, water was added, ingredients creamed for additional 30 sec, and the content was scraped down. The speed was increased to 124 RPM and creaming was allowed for 4 minutes. The cream was scraped down, flour was added, and the content was mixed at 60 RPM for 90 sec. the content was then scraped down, speed was increased to 60 RPM, and the content was mixed for 3 minutes and 30 sec. Note that when margarine was used instead of shortening, in the first step the content was mixed for 60 sec instead of 30, and no water was added since margarine consists of 20% water.

Sheeting: Two rulers of the same height were placed on each side of a baking paper, and the sheeting was performed by allowing the edges of a rolling pin to roll on the rulers so that the dough will obtain a standardized height of 6 mm.

Sampling: a mold with a diameter of 42 mm was used to cut the samples. The excess dough surrounding the samples was carefully removed by lifting or pushing away. Using a knife, the baking paper was cut around the sample and a thin pie lifter was used to lift the samples with the baking paper and transfer onto a small petri dish. In this way sample deformation would be avoid and thus obtaining a standardized method. The samples were then divided into three different groups (baking, compression, and holding) composing of five samples in each group.

Baking: The samples in the baking group were weighed and using a caliper the diameter was measured. A baking tray covered with baking paper was prepared and samples were lifted and tilted over (upside-down). The small piece of baking paper was gently removed to avoid deformation. The samples were baking for 20 min at 180 °C, and stored for at least 2 weeks before analyses.

Color and textural measurements

Color measurements: the color was measured as brightness using a color measuring instrument (CR-400 Chroma Meter, Konica Minolta).

Textural measurements: to determine the textural characteristics of the samples TexVol Texture Analyzer TVT-300XP was used. Three different methods were used, method (1) and (2) were used on dough and (3) on baked product.

1. Double compression: double compression cycle with compression 4 mm over plate and 50 sec pause between cycles. Probe P-Cy75A was used and the pre-test, test-, and post-test speed was set to 0.2 mm/s.
2. Hold until time: a single cycle with compression 4 mm over plate and holding time 62 seconds. Probe P-Cy75A was used and the pre-test, test-, and post-test speed was set to 1.0 mm/s.
3. Three point bend: a single cycle that breaks the sample with a compression of 10%. Probe P-BP70A and rig R-TPBR were attached and the pre-test, test-, and post-test speed was set to 1.0 mm/s.

Statistics and Chemometrics

Experimental design: in order to detect the effect of the different ingredients as well as the interactions between them, a central composite design known as CCD was used. It consists of a complete factorial design combined with replicates in the centrum (Brereton 2003). The variables were varied at 3 levels (-1 0 +1), which allow neglecting triplicates (Miller & Miller 2010).

Statistical analysis: to analyze data obtained from the different measurements, different tools were used:

- PCA: consists of multivariate projections of the observations onto a two-dimensional plane. This enables visualization of the structure of the investigated data set and reveals the relationships between variables and observations as well as the relationships within the variables themselves (Brereton 2003) (Eriksson et al. 2001).
- PLS2: a projection method as PCA that handles complex models and strongly correlated responses or parameters (Eriksson et al. 2001) (Brereton 2003). This method was used to observe relations between variables and parameters as well as within parameters themselves.
- ANOVA: a tool used to study the significance of the differences between two or more vectors.
- Linear regression.

To be able to plot the ingredient variations when using PCA, the different ingredients were assign different abbreviations in the positions ABCDE. Position A was assigned with the letters S or M, depending on the type of fat used (<u>S</u>hortening or <u>M</u>argarine). Positions BCDE were assigned with the letters L (low level), M (medium level), or H (high level) depending on the levels used for sugar, fat, egg powder, and emulsifier respectively.

Results and Discussion

Effect of ingredients on characteristics of dough and baked product

PCA was used to analyze the effect of ingredients on the textural parameters. Figure 1 below shows that the gumminess (DBGumminess), elasticity (HUTElasticity), hardness (DBForceA), and cohesiveness (DBCohesiveness) of the dough are positively correlated with low fat amount (shortening or margarine) and high egg powder content (SHLHH and SHLHL). In addition the brightness of the baked product showed a relation to the amounts of fat and egg powder (SLHLL, SHHLL, MHHLL, SHLHH, SHLHL). If the egg amount was reduced and the fat amount was increased, then the brightness decreases. This could be interpreted since the angles between the vectors to TPBBrightness (the orange arrow) and to the scores (the purple arrows) were either much greater or smaller than 90°. In addition, these vectors are almost of the same lengths.

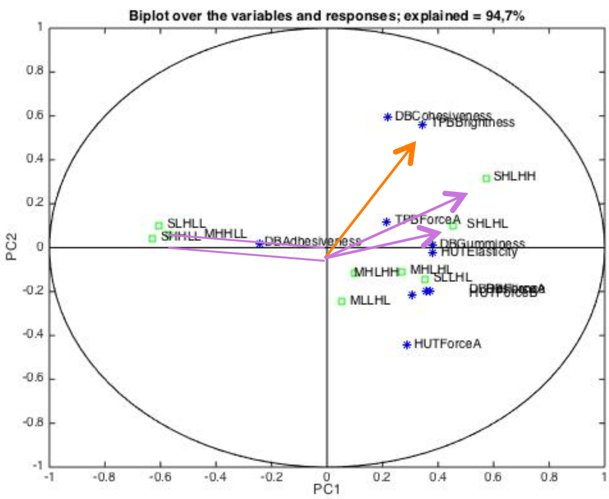

Figure 1 Relations between ingredients and textural parameters using PCA.

In order to study the relations between the ingredients and the textural parameters, PLS2 was used. Figure 2 shows that egg powder positively affected the resilience (DBResilience) and gumminess of the dough as well as the hardness (DBForceA, HUTForceA, and HUTForceB) obtained by the two textural methods used (double compression and hold until time). This could be due to the increased protein content of the dough when using egg powder, which gives a firmer structure to the dough samples. The figure obtained also showed that the fat amount had a negative effect on the previously mentioned parameters but a positive one on the adhesiveness (DBAdhesiveness), springiness (DBSpringiness), and stringiness (DBStringiness) of the dough.

Figure 2 also showed that the brightness of the baked products (TPBBrightness) showed a strong positive relation to fat amount but a negative one to egg powder, strengthening the relations observed in Figure 1. This is due to that the fraction of proteins available in the product is low in addition to the high fat content which cotes these proteins (Maache-Rezzoug 1998) (Wade 1990) (Slade 1994) (Manohar & Rao 1999). This coating may result in unavailable amino groups especially those in the side-chains of the proteins. These amino acids are the most often ones to be involved in Maillard reactions in the presence of reducing sugars (Coultate 2009) (Maillard 1912), thus a shortage in them results in a brighter product upon heating (baking). However, when adding egg especially in higher amounts, the amount of available proteins or side chains increases enhancing the Maillard reactions and thus giving a darker product.

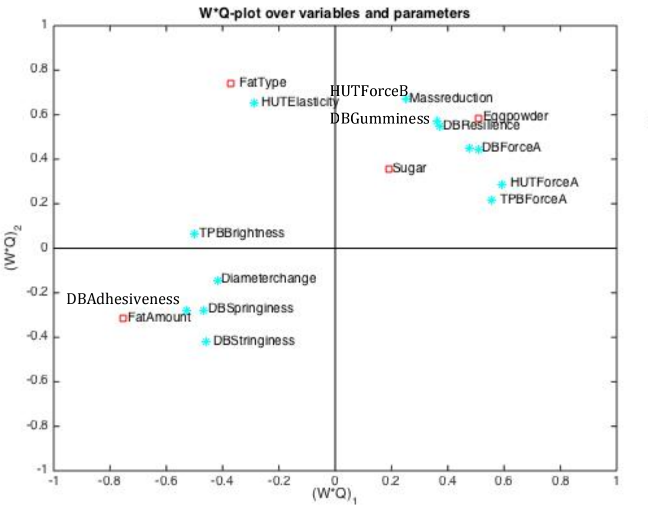

Figure 2 Relations between ingredients and textural parameters using PLS2.

The fat amount and fat type showed a negative relation to the hardness of the baked product (TPBForceA). It means that the margarines (S100M0AAK, S100M1AAK, and S100M2AAK) gave harder cookies than what shortenings (S100S0AAK, S100S1AAK, and S100S2AAK) did. Interestingly, this negative effect has also been observed in many other studies (Manohar & Rao 1999) (Pareyt, Brijs & Delcour 2010) (Pareyt et al. 2009) (Baltsavias, Jurgens & Vliet 1999) (Sudha et al. 2007) and has been related to the influence of the fat on the internal cookie structure. The analysis also showed that the fat amount used in the dough had a positive relation to the Diameterchange of the dough (the spread during baking), which has also been stated in other studies (Maache-Rezzoug 1998) (Pareyt et al. 2009) (Manohar & Rao 1999) and said to be related to the increase in system mobility upon melting of fats during baking.

Relations between dough characteristics and those of the baked products.

From the previous W*Q-plots such as Figure 12 it could be seen that the textural parameters were divided into two groups that fell in opposite quadrants. For instance, the hardness of the final product (TPBForceA) showed a positive relation to the hardness (DBForceA), resilience (DBResilience), and gumminess (DBGumminess) of the dough. Figure 3 showed that these observations were still valid. In addition, the hardness, resilience, and gumminess of the dough positively affected the moisture loss (Massreduction) but negatively the cookie diameter (Diameterchange). This means that if the hardness of the final product and the total moisture loss was to be increased, then the hardness, resilience, and gumminess of the dough should be increased. However, if the cookie diameter was to be increased, then these parameters should be decreased. Since the hardness, gumminess, and resilience of the dough have shown to be negatively affected by the fat amount and positively by the egg powder content in the dough, the fat and egg amounts could be adjusted after desire to achieve a product with required diameter and hardness properties.

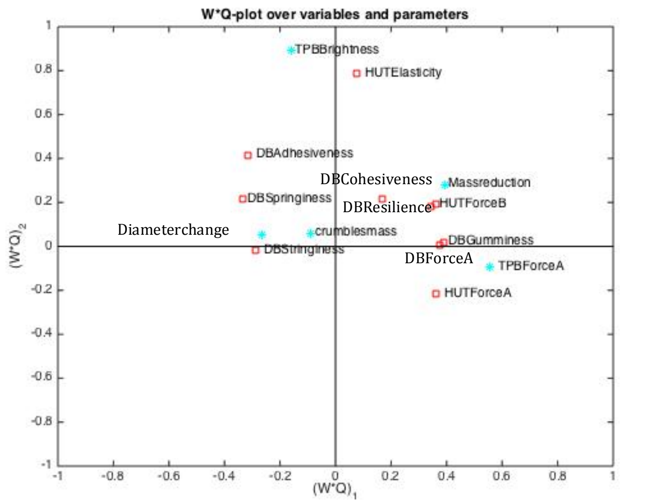

Figure 3 Relations between the textural parameters of the dough against the textural parameters of the baked product, using PLS2.

In order to study if these relations correspond to the actual data obtained from the measurements, as recommended by Bourne (1990), the data points were plotted and linear regression was applied to each pair of parameters that seemed to be related to each other in order to be examined for trend lines (Bourne 1990).

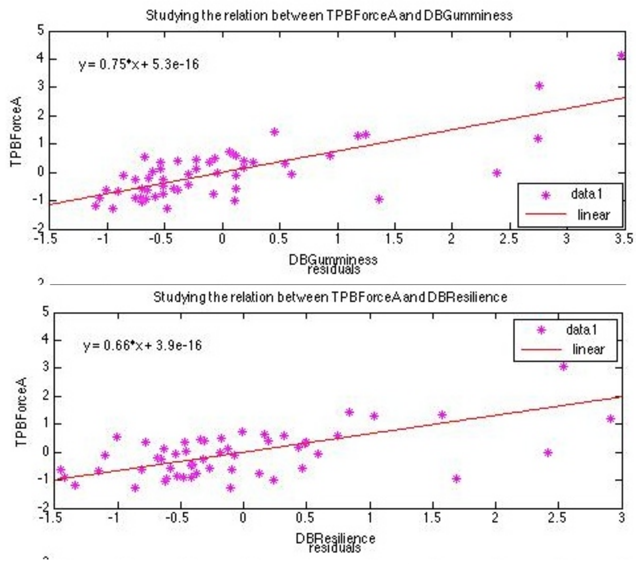

Figure 4 linear regressions applied to pairs of parameters that were seen to be related to each other.

The slope of the linear regressions applied to the data matched the relations observed in Figures 2 and 3, e.g. TPBForceA had a positive relation to DBGumminess that had also been seen by linear regression since the slope was positive (see Figure 4). In order to study if these relations were significant, Pearson correlation was applied to calculate a correlation coefficient (R) on 95% significance level. The R2-value was then calculated and the different values are compiled in Table 1.

Relation	R (Correlation coefficient)	H_0	R^2
TPBForceA vs. DBGumminess	0,75326	Rejected	0.5674
TPBForceA vs. DBResilience	0,65918	Rejected	0.4344
TPBForceA vs. DBSpringiness	-0,65158	Rejected	0.4246
TPBForceA vs. DBForceA	0,72816	Rejected	0.5302

The calculations showed that at least the relations between TPBForceA to DBGumminess and DBForceA is high enough to say that by knowing the hardness and Gumminess of the dough samples, it is possible to predict the hardness of the finished products.

Conclusions

The fat type showed a negative effect on the hardness of the baked product but a positive effect on the springiness of the dough. This means that shortening gives harder cookies with lower springiness than what margarine does. The fat and egg amounts used affected the color of the baked product in opposite manners, fat increased the brightness of the cookies but egg powder decreased it. The fat and sugar amounts affected the cookie spread during baking positively, i.e. increasing the sample diameter. In addition, sugar content increased the moisture loss during baking resulting in a lighter cookie mass. High fat amounts increased the springiness of the dough, but decreased gumminess. In addition, hardness and resilience of the dough decreased with increased fat amounts as well as the hardness of the finished product. The analysis also showed that by knowing the hardness and/or the gumminess of the dough sample, it is possible to predict the hardness of the finished product.

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