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Predicting farinograph parameters by rapid visco analyser pasting profile using partial least square regression

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RESEARCH ARTICLE

Abstract

Farinograph parameters are widely used to predict flour and dough functionality. Accurate prediction of farinograph parameters using other instruments would provide key information in determining cereal products quality and functional properties. This study was undertaken to provide calibration models using rapid visco analyser (RVA) to predict farinograph flour parameters and dough end-use functionality. A total of 267 samples consisted of wheat flour substituted with various ratios of disrupted chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) flours were used in this study. Samples (n=237) were randomly selected and used to develop calibration models of farinograph parameters using RVA profile. Another sample set consisting of 30 flour samples were used to validate the developed models. The partial least squares regression method using the RVA profile was used to develop prediction models for farinograph parameters treatments. Farinograph parameters (water absorption, peak time, mixing tolerance index, stability, arrival and departure times) were moderately fitted with a coefficient of determination (R^2) of predicted and measured values of 0.881, 0.911, 0.903 and 0.913, 0.751 and 0.824, respectively. Root mean square of calibrated and predicted models for farinograph parameters ranged from 0.083 and 5.687 and from 0.090 to 6.215, respectively, indicating the fitness of the developed model in predicting farinograph parameters. Results further indicated satisfactory developed models in predicting farinograph parameters except arrival time.

Keywords: rheology, wheat

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1. Introduction

Rheological characteristics of flour such as its water absorption capacity, optimum dough consistency, dough development time and stability, extensibility and elasticity are examples of predictors for wheat flour baking performance (Codina *et al.*, 2010). Such dough performance during testing are mostly associated with transformations occurring to flour chemical composition and its structural changes including gluten network formation (i.e. functional properties of gliadin and glutenin and the hydration kinetics of flour particles (i.e. functional properties of amylose and amylopectin wheat starch) (Amjid *et al.*, 2013; McCann and Day, 2013; Shewry *et al.*, 2001). The net effect of these changes during mixing results in dough acquiring its viscoelastic structure and the specific properties.

Farinograph is considered one of the major instruments used in the bakery industry to allow flour classification according to the above mentioned factors namely gluten strength and the power of water hydration (Lons, 2009; Nikolić *et al.*, 2013). Furthermore, the instrument measures the plasticity and the mobility of dough when subjected to a prolonged, relatively gentle mixing action at a constant temperature and speed (Amjid *et al.*, 2013; Codina, 2010; Lons, 2009).

Farinograph parameters include: (1) arrival time that is used as an indication of water uptake rate and protein content of flour; (2) dough development 'peak time' that is used as an indication of development or mixing time of the flour; (3) mixing tolerance index; (4) departure time; and (5) dough stability are all indications of flour tolerance to mixing (Lons, 2009).

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Viscosity and pasting properties are also important for the milling and baking industries and are used to predict various processing parameters of dough as well as the quality of baked products (including their ability to withstand heating and shear stress) (Amjid *et al.*, 2013; Fitzgerald *et al.*, 2003). The formation of paste viscosity curve, for instance, involves a transition of flour from semi-crystalline polymers to a paste of gelatinised and denatured polymers (Fitzgerald *et al.*, 2003). This state transition occurs in the presence of an excess amount of water and usually takes place at temperature range of 60-75 °C; the temperature at which proteins hydrate and amylopectin starts to melt (Fitzgerald *et al.*, 2003). Starch granules swelling, amylose leaching, formation of amylose lipid complexes and protein denaturation are transformations that usually take place during pasting measurements (Amjid *et al.*, 2013; Fitzgerald *et al.*, 2003; Jekle and Becker 2012; Mirsaeedghaz *et al.*, 2014; Reddy *et al.*, 1994; Sowbhagya and Bhattacharya 2001). The use of a rapid visco analyser (RVA) to predict farinograph parameters would decrease the required sample size to 3 g compared to the 300 g during farinograph testing as well as decreasing the measurement duration of more than 30 min for farinograph to approximately 12 min for RVA.

Since physicochemical characteristics of cereals are strongly correlated with its processing characteristics, number of instruments (farinograph, mixograph, extensigraph, alveograph, falling number, gluten tester, maturograph as well as near infrared spectroscopy) are currently in use to predict cereals flour and dough functional properties (Amjid *et al.*, 2013; Dapcevic *et al.*, 2009; Dowell *et al.*, 2006; Hruskova and Famrra, 2003; Hruskova and Skvrnova, 2003; Lons, 2009). Furthermore, correlations of several instruments in measuring cereal functionality are reported. Rheological quality of wheat dough and bread making parameters were predicted using near-infrared spectroscopy (Dowell *et al.*, 2006; Hruscova *et al.*, 2003). The studies reported the potential for predicting wheat chemical and quality parameters including protein and moisture contents, colour, total gluten content as well as mixograph, farinograph, alveograph parameters and loaf volume and baking water absorption. The authors showed that the predicted parameters were highly correlated with protein content. The accuracy of the predicted parameters was indicated to be suitable only for rough screening purposes (Dowell *et al.*, 2006; Hruscova *et al.*, 2003).

Dapcevic *et al.* (2009) studied the relationship between Mixolab (CHOPIN Technologies, Villeneuve-la-Garenne, France), farinograph and amylograph parameters among flour samples of different quality. The authors reported significant correlations between farinograph, including water absorption (r=0.9816), dough development time (r=0.9668) and the degree of softening (r=0.8504) with Mixolab parameters (level of significant of $P<0.05$). The authors also indicated a weak dough stability correlation (r=0.7484) between farinograph and that of Mixolab. Hruskova and Skvrnova (2003) and Vizitiu and Danciu (2011) also reported an acceptable correlation for the mixing parameters of flours using by Maturograph (Brabender® GmbH & Co. KG, Duisburg, Germany) and Mixolab, respectively, with that for farinograph.

Although researchers have examined the potential for using various instruments to predict flour and dough quality parameters, most studies were limited in their small sample size (n=10 in Vizitiu and Danciu (2011), n=19 in Dapcevic *et al.* (2009), and n=30 in Hruskova and Skvrnova (2003)) or used pure cultivars and sample treatments with limited variability; a restriction of predicted models. In addition, no studies were reported on the use of viscoelastic profile for rapid assessment of flour parameters. Therefore, the objective of this research was to evaluate the potential of developing predicting farinograph parameters of variable samples produced by partially substituting wheat flour with disrupted chickpea and lentil flours using pasting viscosity profiles.

2. Materials and methods

Materials

Commercial all-purpose wheat (Al-Arabia Wheat Flour, Co., Tanta, Egypt), whole chickpea and lentil (Gardenia; Lebanos Food Trading Ltd, London, UK) were purchased from a local market. A cyclone sample mill (UDY Corporation, Fort Collins, CO, USA) fitted with a 100-mesh sieve was used for grinding chickpea and lentil samples to produce flours. Treatments of fractional substitution of all purpose wheat flour with disrupted and non-disrupted chickpea and lentil flours were used in this study. Treatments of fractional substitution using non-disrupted chickpea and lentil flour and 100% wheat flour were included in this study as the control samples. Moisture contents of the flours used were adjusted to equilibrium moisture content of 12% (wet basis).

Experimental design

Treatments of fractional substitution of all purpose wheat flour with disrupted and non-disrupted chickpea and lentil flours were used in this study to increase sample variability to predict the farinograph parameters. Two acid (HCl, 0.01 and 0.1 N) and two alkaline (NaOH, pH=8 and 10), levels and four different enzymes were also used to disrupt chickpea and lentil flours. Protease disruption treatment includes protease from *Rhizopus* spp. (EC 3.4.23.21 – rhizopuspepsin, P0107-5G; Sigma-Aldrich, St. Louis, MO, USA), protease from *Aspergillus saitoi* (EC 3.4.23.18 – aspergillopepsin I, P2143-25G; Sigma-Aldrich), protease from *Aspergillus melleus* (EC 232-642-4, P4032-25G; Sigma-Aldrich) and papaya proteinase (EC 3.4.22.2 – papain, P3250-25G; Sigma-Aldrich).

Sequential acid, alkaline and enzymatic treatments were performed to disrupt legume flours as indicated by sodium dodecyl sulfate polyacrylamide gel electrophoresis (data not shown) to increase treatment variability. For treatment formation, flours disrupted and non-treated chickpea and lentil flours were used to replace whole purpose wheat flour at a ratio of 5, 10, 15 and 20%. A control sample with no replacements (i.e. 100% wheat flour = 0% replacement) was also included in the sample set. Replacements of more than 20% of the wheat flour by treated or non-treated chickpea or lentil flour was not included in this study since greater replacement was expected to be detrimental to flour functionality provided by its gluten properties. Treatments were mixed thoroughly using a household kitchen aid mixer (KitchenAid, St. Joseph, MI, USA) before measurements were performed.

Combinations of acid, alkaline and sequential disruption using acid, alkaline and enzyme as well as non-disrupted chickpea and lentil flours were used to create fractional replacement (i.e. 5, 10, 15 and 20%) of wheat and were used as calibration and validation sample sets. In brief, samples used in this study formed a combinations of a total of 267 samples of the following: (1) not disrupted legumes × fractional replacements = 8; (2) enzymatic treatments × fractional replacements = 32; (3) acid + enzyme combination × fractional replacements = 64; (4) alkaline + enzyme combination × fractional replacements = 64; (5) acid + alkaline+ enzyme combination × fractional replacements = 66; (6) acid treatments × fractional replacements = 16; (7) alkaline treatments × fractional replacements = 16; and (8) wheat flour control = 1. Samples were randomly divided into two sample sets where a total of 237 samples out of the 267 samples were used to develop calibration models of farinograph parameters using the RVA profile and another set of 30 samples was used to validate the calibration models developed using the first sample set.

Acid hydrolysis of chickpea and lentil flours

Chickpea and lentil flours were acid treated according to the method described by Lee *et al.* (2001). In brief, chickpea and lentil flours were suspended in distilled water in a ratio of 5:1 water to flour and held in a water bath at 40 °C for 30 min. HCl was used to hydrolyse flour by adjusting the pH of the solution to achieve the concentration in the reaction medium of 0.1 N HCl. The suspension was then incubated at 45 °C with continuous agitation for 3 h. Acid hydrolysed flour was then terminated by cooling the solution for 30 min to room temperature (approximately 23.2 °C) and by adjusting the pH to 6.0-6.2 using 0.1 N NaOH.

Enzymatic hydrolysis of chickpea and lentil flours

Prior to enzymatic treatment, a suspension of acid treated flour was prepared by adding 250 ml of distilled water per 50 g flour. Enzymatic hydrolysis was then carried out in the optimum pH (2.5-7.5) and temperature (30-55 °C) for each enzyme using a temperature controlled water bath. Enzymatic treatment durations varied according to the optimum activity for each enzyme as described by the manufacturer. Enzymatic reactions were terminated by adjusting the pH of the solution using NaOH and HCl solutions depending on the operating conditions of each enzyme.

Alkaline treatment of chickpea and lentil flours

Alkaline treatments (pH=10) were carried out on acid and enzymatic treated chickpea and lentil flours. In brief, enzyme treated chickpea and lentil flours were suspended in distilled water at a ratio of 5:1 water to flour ratio and held at 40 °C for 30 min using a water bath. NaOH solution was then added to achieve the concentration in the reaction medium to 0.1 N NaOH (pH=10). The suspension was then incubated at 40 °C with continuous agitation for 2 h. Alkaline treatments were terminated by cooling the solution for 30 min at room temperature (approximately 23.2 °C) and adjusting the pH to 7.0 using 0.1 N HCl. Samples were then dried at 40 °C using a drying oven.

Farinograph measurements

Farinograph measurements were performed according to the AACC method 54-21.02 (AACC, 2000) using a farinograph (Brabender® GmbH & Co. KG). In brief, treatments of 300 g samples (on a 14% moisture content wet basis) were weighed and placed into the corresponding farinograph mixing bowl. Water was then added to the flour and mixed to form dough and the amount of water added (i.e. water absorption) resulted in a Brabender Unit (BU) of 500 was recorded as the amount of water absorption. The curve was centred on the 500-BU line ± 20 BU by adding the appropriate amount of water and was run until the curve leaves the 500-BU line (Shewry *et al.*, 2001).

Farinograph parameters including water absorption (i.e. the amount of water required to centre the farinograph curve on the 500-BU line), peak time (i.e. the time in min required to reach maximum consistency, arrival time (i.e. the time in minutes when the top of the curve touches the 500-BU line), departure time (i.e. the time in minutes when the top of the curve leaves the 500-BU line), stability (i.e. the difference in time between arrival time and departure time and mixing tolerance index (i.e. the difference in BU value at the top of the curve at peak time and the value at the top of the curve 5 min after the peak).

Pasting profile and viscosities measurements

Pasting profile and viscosities (peak, trough, setback, breakdown and final) and pasting temperature of flour treatments were assessed and recorded with a RVA (RVA-4 Rapid Visco Analyzer; Foss North America, Eden-Prairie, MN, USA) following approved method AACC 61-02 (AACC, 2000). Approximately 3 g (hence; the weight was corrected based on the moisture content (12% wet basis) of the sample and was calculated using the RVA software) of flour samples were mixed with 25 ml of distilled water. The slurry was then mixed at 50 °C for 1 min at 160 rpm before being heated from 50 to 95 °C at a heating rate of 12 °C/min. The hot paste was then held at 95 °C for 2.5 min and then cooled down to 50 °C at a cooling rate of 12 °C/min and typical RVA parameters will be extracted. Parameters recorded were peak viscosity, trough viscosity, final viscosity, breakdown, setback, peak time and pasting temperature. RVA pasting profile for each treatment was used for predicting farinograph parameters.

Statistical analysis

Pasting properties profile treatment

Pasting profile for each flour sample was recorded during pasting using RVA. Flour pasting profiles were recorded at 4 s increments and collected over a range of 8-780 s (194 data points were recorded). Three pasting measurements were conducted on each sample and data were averaged before data analysis.

Calibration model development and data analysis

Calibration samples (n=237) were measured in duplicate totalling a 474 measurement. For each treatment, replicate farinograph parameters (water absorption and departure, peak, arrival and mixing tolerance time and stability index) were averaged resulting in 237 samples that were used to develop calibration models to predict these parameters using the RVA pasting profile data. Using multivariate regression software (Unscrambler, v. 9.2; Camo, Oslo, Norway), partial least squares (PLS) (where more than one variable is modelled) was performed to develop prediction models for farinograph parameters (y-variables). Pasting profile values (x-variables) were transformed using first derivative and were standardised by weighting each with the standard deviation so that all variables were given equal influence on the predicted variables.

Full cross validation was employed to validate the predictive ability of the calibration models. In this approach, each sample was used to test the model derived from all other samples. The deviation from the expected value as a result of excluding each sample from the models was measured. This process was repeated so that each calibration value was excluded once, to test whether its removal had seriously affected the model. A root mean square error (RMSE) of cross-validation was then calculated. The uncertainty test was also performed during the full cross-validation computation to assess stability of the results. These procedures allowed for the removal of predicted variables that either did not influence the prediction or created interference in the model. This technique has also reduced the uncertainty in the prediction models and, in most cases, improved the validation statistics. The number of principle predictors used in the PLS calibration models were selected as suggested by the Unscrambler software (n=9). Calibrated and validated coefficient of determinations (R^2) and RMSE values were also obtained to evaluate each calibration model.

Validation of farinograph parameters using calibration models

Another sample set of 30 flour treated samples; not included in building the calibration models were used to validate the calibration models developed using the first sample set. The pasting profile and farinograph measurements of these samples were measured using the farinograph and RVA as described previously. Farinograph parameters were predicted using the models developed earlier using the prediction option provided by the Unscrambler software.

Calibrated and predicted root mean square error (RMSEC and RMSEP, respectively), standard error of prediction (SEP), R^2, bias (indicating systematic errors) of measured and predicted values, and the relative ability of prediction (RPD) (also known as the discrimination index, where RPD = SDc/SEP) (SDc is the standard deviation of each farinograph parameter) were used to assess the prediction accuracy of the calibration (Locher *et al.*, 2005).

3. Results and discussion

Farinograph parameters calibration models

Scatter plots of measured and predicted farinograph parameter values of treated flour samples used to develop calibration models using RVA pasting profile are shown in Figure 1. Results indicated a well fitted correlation of measured and predicted farinograph parameters using RVA profile. Developed model statistics are further presented in Table 1. Water absorption, peak time, mixing tolerance index, stability, and arrival and departure times of treated samples ranged from 60.11 to 70.25%, 1.69 to 7.85 min, 15.32 to 120.59 min, 5.81 to 15.10 min, 0.79 to 2.98 min and from 8.06 to 13.43 min, respectively. Table 1 also presents calibrated and validated correlation coefficients for farinograph parameters. Results indicated that calibrated (R_c) and validated (R_v) correlation coefficients ranged from 0.751 for arrival time to 0.913 for stability time. The correspondent RMSEC and RMSEP for arrival time and

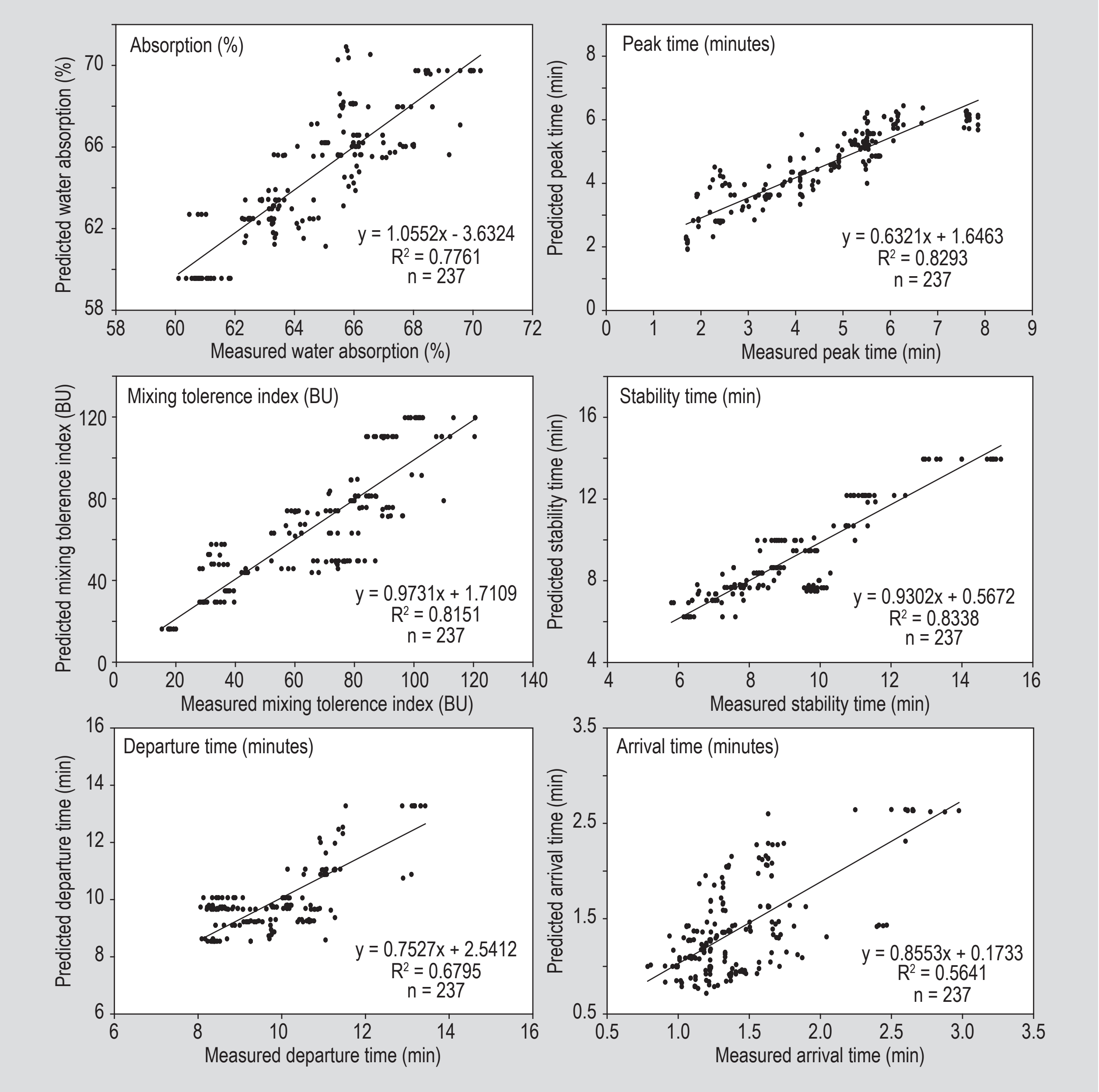

Figure 1. Predicted versus measured (A) water absorption (%), (B) peak time (min), (C) mixing tolerance index (BU), (D) stability (min), (E) arrival and (F) departure time (min) of wheat treated samples (n=237) used to build prediction models for farinograph parameters.

stability time are 0.083 and 0.090, and 2.089 and 0.623, respectively. Water absorption ratio, peak, mixing tolerance index and departure time had R_c values of 0.881, 0.911, 0.903 and 0.824, and R_v values of 0.852, 0.893, 0.880 and 0.813, respectively. RMSEC and RMSEP further indicated the fitness of the developed model in predicting farinograph parameters (Table 1).

Model statistics of the PLS regression developed using pasting profile of treatments (Table 1) were comparable to results reported by Dapcevic *et al.* (2009) and better than those reported by Vizitiu and Danciu (2011). These results were attributed to the differences between instruments used where Vizitiu and Danciu (2011) and Dapcevic *et al.* (2009) used Mixolab, the smaller sample size used by both authors (n=10 and 19, respectively) compared to the large sample size (n=237) used in this study and to the data analysis protocol. Hruskova and Skvrnova (2003) also used Maturograh to predict farinograph parameters using 30 commercial wheat samples. The number and variability of samples used in this study (wheat flour replaced with various ratios of disrupted and non-disrupted chickpea and lentil flour) further resulted in great predictability of the models developed. Furthermore, Vizitiu and Danciu

Table 1. Model statistics for prediction of farinograph parameters (water absorption, peak time, mixing stability index, stability, arrival and departure time) using rapid visco analyser (RVA) pasting profile.[1]

Parameters[2]	Water absorption (%)	Peak time (min)	Mixing tolerance index (BU)	Stability time (min)	Arrival time (min)	Departure time (min)
Calculated						
Max. value	70.25	7.85	120.59	15.10	2.98	13.43
Min. value	60.11	1.69	15.32	5.81	0.79	8.06
R_c	0.881	0.911	0.903	0.913	0.751	0.824
RMSEC	0.523	1.551	5.677	2.089	0.083	0.495
SEC	0.052	1.558	5.687	2.099	0.083	0.496
Bias	0.000	0.000	0.000	-0.008	0.000	0.000
SD_c	2.454	1.687	27.831	2.013	0.455	1.138
Validated						
Max. value	70.91	7.85	120.59	15.10	2.98	13.28
Min. value	59.56	1.69	15.32	5.81	0.79	8.54
R_v	0.852	0.893	0.880	0.909	0.743	0.813
RMSEP	0.575	1.730	6.215	0.625	0.090	0.569
SEP	0.575	1.738	6.224	0.626	0.090	0.570
Bias	0.012	0.023	-0.082	0.006	0.001	0.005
SD_v	2.934	1.171	29.998	2.051	0.521	1.203
RPD_c	4.268	0.971	4.472	3.216	5.056	1.997

[1] Using RVA profile (n=237; calibration sample set).

[2] Rc = calculated correlation; RMSEC = calculated root mean square error; SEC = standard error of calculation; SDc = calculated standard deviation of each farinograph parameter; Rv = validated correlation; RMSEP = predicted root mean square error; SEP = standard error of prediction; SDv = validated standard deviation used to build calibration models to predict farinograph parameter; RPD = relative ability of prediction, a discrimination index (RPD = SDc/SEP).

(2011), Dapcevic *et al.* (2009) and Hruskova and Skvrnova (2003) performed correlations of data compared to more robust multivariate regression analysis used in this study. The accurate predictability of farinograph parameters using pasting profile data were attributed mainly to the influence of flour chemical composition on physical characteristics of paste and dough. For instance, water absorption was indicated to measure the potential of protein molecules to absorb added water, therefore changes in proteins content as well as structure as a result of flours disruption would influence the rate of water absorption, thus flour and dough physical properties (Haraszi *et al.*, 2004; Van Lill *et al.*, 1995). Wang *et al.* (2013) has recently reported strong correlations between RVA and farinograph parameters that were related to protein functional properties. The authors reported a significant correlation ($P<0.05$) between development time with peak viscosity and breakdown.

Our results are in accordance with Turner and Bason (1997) reports where significant correlations between rheological (RVA) and flour baking qualities was reported. In particular, the authors reported correlations between breakdown and each of farinograph dough development time (r=-0.66), stability (r=-0.78) and time to break down (r=0.61). The authors claimed that these correlations were superior and indicated the potential utilizing the method for assessing wheat quality. Farinograph parameters (dough development and stability time) were further reported to be affected by water absorption and flour constituents to form a smooth and homogenous dough appearance (Vizitiu and Danciu, 2011). The authors reported the suitability of farinograph and Mixolab in predicting water absorption, of the flours obtained by Mixolab (R^2=0.6303) and farinograph (R^2=0.7314). Starch content was also reported to influence water absorption during dough and pasting development (Fitzgerald *et al.*, 2003; Saleh and Meullenet, 2013; Sowbhagya and Bhattacharya 2001).

Fu *et al.* (2008) also reported influence of resistant starch on the pasting properties and the viscoelasticity of various gluten strength wheat flour blends substituted with 5, 10, 15 and 20% resistant starch on farinograph dough breakdown time, stability, development time and mixing tolerance index parameters. Furthermore, the authors indicated that RVA peak, trough, breakdown, final, and setback viscosities were all also influenced by the starch substitution for all replacement ratios used.

Predicted and measured farinograph parameters had relative ability of prediction (RPD) values of greater than

2.00 (water absorption = 4.268, mixing tolerance index = 4.472, stability = 3.216, arrival time = 5.056 and departure time = 1.997) except for peak time (0.971) indicating that the range of variation in each parameter was significantly greater than the prediction error. These results are sufficiently high to predict farinograph parameters. Several authors indicated that RPD values >2.0 are acceptable (Saleh *et al.*, 2008; Sitakalin and Meullenet, 2000).

Models validation using treated chickpea and lintel flour samples

Model statistics of water absorption, peak time, mixing tolerance index, stability, and arrival and departure times of treated samples as predicted using previously developed models are shown in Table 2. Measured farinograph; water absorption, peak time, mixing tolerance index, stability, arrival and departure times, range from 59.26 to 71.95%, 1.69 to 7.85 min, 17.47 to 126.60 BU, 5.04 to 17.03 min, 0.91 min and from 7.89 to 17.87 min, respectively.

Farinograph parameters, except arrival time, were well predicted using the developed model with a highly significant ($P<0.05$) R_v ranging from 0.720 for mixing tolerance index to 0.882 for the water absorption. The corresponding RMSEP and SEP values ranged from 0.228 to 14.336 and from 0.230 to 13.359, respectively, across farinograph parameters. The limited predictability of arrival time was attributed to the fact that arrival time is an indication of the rate of water absorption of flour; an attribute that may not clearly detected by RVA due to the small sample size requirement compared to farinograph.

A scatter plot of measured and predicted farinograph parameters values using our developed calibration models is shown in Figure 2. Predicted and measured values were highly correlated, with R^2 of 0.696, 0.542, 0.518, 0.625, 0.459 and 0.096, respectively, for water absorption, peak time, mixing tolerance index, stability and arrival and departure times.

These results indicate acceptable models developed in providing accurate prediction of farinograph parameters. Although different instruments were also used to predict farinograph parameters; reported literature data was either reported on a very small sample set or no samples used for model verifications (Dapcevic *et al.*, 2009; Dowell *et al.*, 2006; Hruscova *et al.*, 2003; Vizitiu and Danciu, 2011) compared with a larger sample size and wider sample variability used in this study.

4. Conclusions

The predictability of farinograph parameters using RVA pasting profile was evaluated in this study. Variability of samples used, sample size and multivariate analysis technique performed using RVA profile data produced a satisfactory prediction models for farinograph parameters. Previous methods used for predicting farinograph parameters had a very small sample set with limited variability or used simple correlation technique that in many cases affected the predictability performance. In this study, a large sample number with a wider variability using the complete pasting profile range was used to maximise calibration robustness of the developed models.

Table 2. Validation model statistics for predicting farinograph parameters (water absorption, peak time, mixing stability index, stability, arrival and departure time) using previously developed models.[1]

Parameters[2]	Water absorption (%)	Peak time (min)	Mixing tolerance index (BU)	Stability time (min)	Arrival time (min)	Departure time (min)
Calculated						
Max. value	71.95	7.85	126.60	17.03	1.77	17.87
Min. value	59.26	1.69	17.47	5.04	0.91	7.89
SD_c	2.544	1.619	28.893	2.174	0.379	1.288
Validated						
Max. value	69.74	6.44	119.66	13.95	2.65	13.33
Min. value	59.56	1.92	16.21	6.23	0.96	8.34
R_v	0.882	0.737	0.720	0.791	0.310	0.822
RMSEP	0.954	1.044	14.336	1.034	0.228	0.656
SEP	0.889	0.996	13.359	0.858	0.230	0.547
Bias	0.370	0.346	5.564	0.591	-0.003	0.370
SD_v	2.423	1.142	28.397	2.117	0.371	1.192

[1] Using RVA profile (n=30; validation sample set).

[2] SDc = calculated standard deviation of each farinograph parameter; Rv = validated correlation; RMSEP = predicted root mean square error; SEP = standard error of prediction; SDv = validated standard deviation used to build calibration models to predict farinograph parameter.

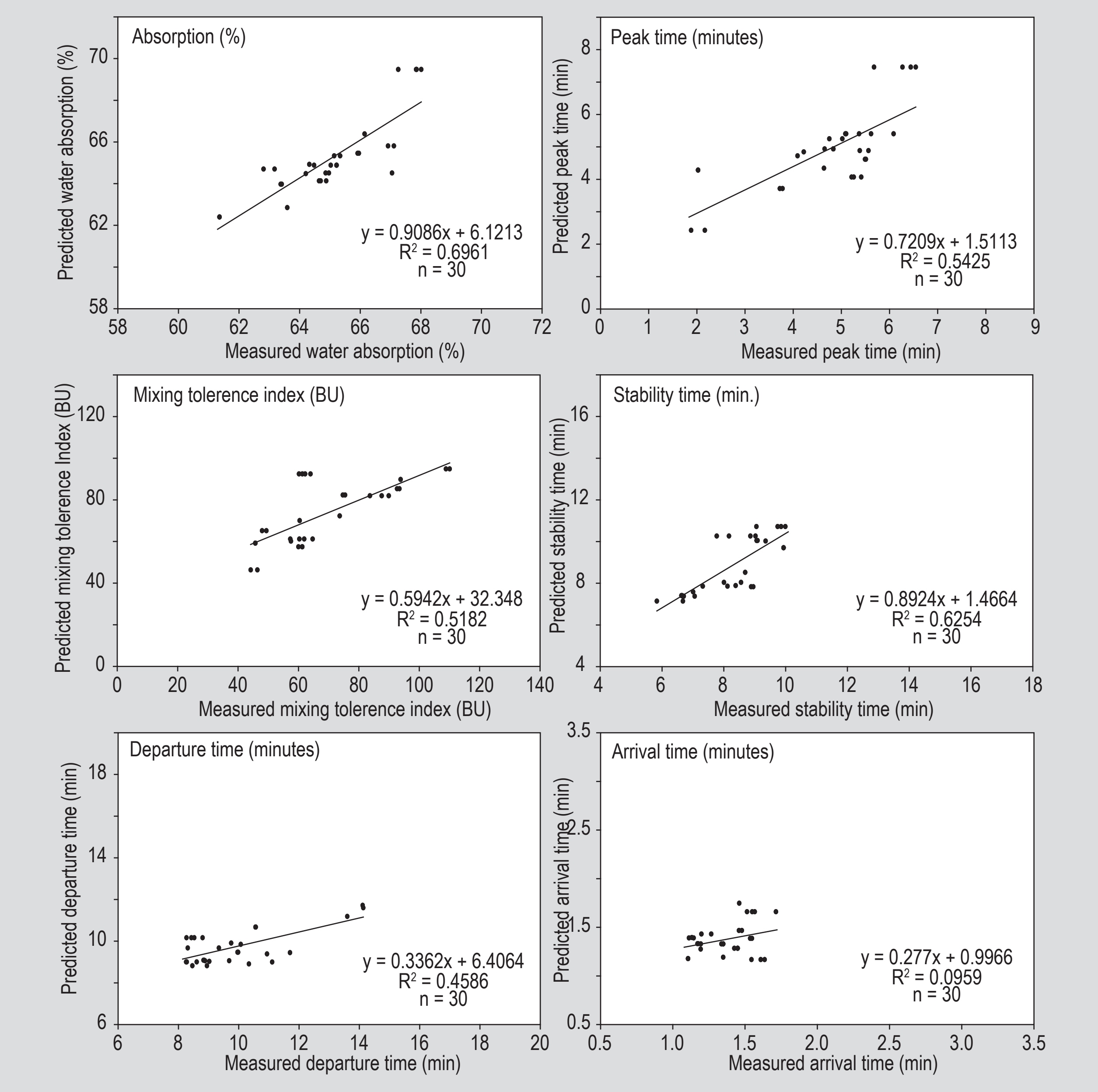

Figure 2. Predicted versus measured (A) water absorption (%), (B) peak time (min), (C) mixing tolerance index (BU), (D) stability (min), (E) arrival and (F) departure time (min) of treated samples (n=30) predicted using calibration models generated using rapid visco analyser pasting profile of 237 wheat treated samples.

The use of RVA profile provided a reasonable prediction models for most of the farinograph parameters; thus flour functionality. The use of the RVA profile for predicting flour functionality would provide an initial discrimination in providing useful information that can be applied to flour baking characteristics.

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