Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.7601

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2019) *7*(4), 269-276

Research Article

Indian Journal of Pure & Applied Biosciences

Assessment of Dough Rheological Characteristics with Mixing Time

Niveditha A. and Chidanand D. V.*

Indian Institute of Food Processing Technology, Thanjavur, India

*Corresponding Author E-mail: chidanand@iifpt.edu.in

Received: 28.06.2019 | Revised: 30.07.2019 | Accepted: 8.08.2019

ABSTRACT

Mixing is an important primary unit operation in bread making. The optimum mix (t_{PEAK}) of the dough is a crucial factor that decides the final quality of dough. At the optimum mix the dough will be viscoelastic with high porosity which gives the bread its final structure. Determining and characterizing this tPEAK is essential in producing good quality bread. The assessment of the optimum mix of dough through rheological characterization was done by means of rheological instruments such as texturometer and rheometer and compared with the amount of power consumed by the spiral tool during mixing. The nature of dough rheological characteristic was tested using texturometer and rheometer. The rheological properties of dough were observed by conducting experiments on frequency sweep and creep recovery tests. The textural properties of bread dough like the young's modulus and firmness characteristic have been also studied with mixing time. The rheological properties of the dough like storage modulus (G'), loss modulus (G") and young's modulus, firmness from rheometer and texturometer, respectively, increased with mixing time and was maximum at t_{PEAK} after which it decreased. Similar trends were seen in tool power curve obtained from spiral mixer.

Keywords: *Bread, Viscosity, Colour, Temperature*

INTRODUCTION

Bread is a commodity consumed by people all around the world. The bread making mainly involves weighing, mixing, proofing and baking. Among this the preliminary step of mixing plays a major role in characterising the bread and dough quality. The dough is a wet mass which is prepared by the mixing water, wheat flour and other ingredients. The proper mixing of all the ingredients in the correct ratio in an accurate equipment determines the quality of dough which eventually decides the final bread characteristics. The dough development process begins with addition of water and the establishment of proper mixing operation. We will notice various changes during the mixing process, including viscosity increase, the nature of dough changes from sticky to non-sticky, the colour changes, temperature increase etc. Each of these parameters play a major role in deciding the optimum mix of dough (t_{PEAK}). At the optimum mix the dough behaves both elastic as well as viscous i.e. it demonstrates a viscoelastic behaviour.

In the baking industry, the assessment of dough rheology is very challenging; its physical properties depend on each processing steps.

Cite this article: Niveditha, A., & Chidanand, D.V. (2019). Assessment of Dough Rheological Characteristics with Mixing Time, *Ind. J. Pure App. Biosci.* *7*(4), 269-276. doi: http://dx.doi.org/10.18782/2320-7051.7601

When a force is applied, the mechanical response obtained is particularly relevant to study the dough macroscopic physical characteristics (Amjid et al., 2013). These measurements are generally categorized under the scientific field of rheology. Its principles and theory are often used in the bakery industry to simulate and predict the dough response to the complex flow and deformation conditions that can be found during a bread-making process (Dobraszczyk & Morgenstern, 2003). Indeed, the dough is a complex mixture of flour, water, salt, yeast and other ingredients that are processed according to three main steps: kneading, fermentation, and baking. Kneading is often considered the most crucial step as several physicochemical modifications occur during this phase; the hydration of gluten proteins results in the formation of a continuous viscoelastic network. This gluten network will contribute to gas holding capacity during fermentation and baking (Bloksma, 1990).

For ideal bread making, particular dough viscoelastic properties are required; assessing it is a quite difficult task. Proper mixing depends on various factors such as the ingredients, aeration, the power of the tool, rheological characteristics etc. The building up of bubbles inside is a unique characteristic that gives the bread its structure. The dough as it mixes builds its structure with gluten network becoming more and more viscoelastic. For many years, several efforts have been made in improving effective approaches to make a meaningful estimation of rheological properties. Most of the instruments used in industries are empirical. In empirical tests, the foods are subjected to mechanical deformation, which applies a sequence of stresses over a time needed to deform dough. This types of tests are quite rapid, easy to perform and do not require highly skilled technical persons, which makes them accessible in industries. Texturometer or texture analyzer is one of the empirical instrument that is widely used by food industries to characterize dough rheology. Texture analyzers are used to characterize dough rheology with units that have been defined by the equipment manufacturer. However, the experiments with texture analyzers should have definite information on the sample dimension; which in the case of dough is difficult because of its uneven structure. Rheometric tests are also used to observe dough rheology, which is classified under fundamental test. These tests include the deformation of a sample at known parameters and evaluating the results with rheological theories. In practice, rheometric tests have been much used by researchers as it gives well defined physical properties of food samples. The disadvantage concerning this type of analysis is the sophisticated instrumentation (which makes them expensive), the time consumption, the difficulty in maintaining in an industrial environment and the requirement of high levels of technical skill. Moreover, they often give inappropriate deformation conditions and methodological issues like the slip and edge effects during testing making the result difficult to interpret (Dobraszczyk & Morgenstern, 2003). Owing to all these predetermined data we have thought of analyzsing the dough rheological characteristics using empirical and fundamental instruments like texturomter and rheometer and compare it with the power curve obtained from mixer tool. The effect on dough rheology characteristics with mixing time has been widely studied by various authors (Campos et al., 1997, Contamine et al.,1995, Lee et al., 2001, Maache-Rezzoug et al., 1998)., but a comparison with rheological values between rheometer, texturometer and power curve seems to be rare. Here, we have characterized the dough mixing with rheological characteristics and power curve obtained from the mixer and compared with textural properties obtained from texture analyzer and rheometer. The study also focuses on estimating the optimum mixing time using the three techniques and compares their ability in determination.

MATERIALS AND METHODS

2.1 Sample

The dough sample is prepared by three ingredients namely flour, water and salt. The salt content is kept at 1.8% flour basis. The water percentage is unchanged, kept at 62%

flour basis. The flour moisture content was estimated as 12.5% on wet basis. The flour (Type 55) was provided by Minoterie GIRARDEAU, France. The flour was stored at 4℃ and later brought to room temperature before preparation.

2.2 Mixing

The mixing process was done in a spiral mixer (SP11, VMI, France). The mixer consists of a spiral tool and a rotating bowl. The spiral tool follows a gyratory motion while the bowl follows a rotational motion. Both these motions help the mixer to come in contact with the entire volume of dough. The weighed ingredients are emptied into the bowl in the order, water first then the other ingredients are added. A sensor is attached beside the tool for sensing the temperature during mixing. The mixer can be operated both semi-automatically and automatically. The mixer tool and bowl were operated at 10 and 100 rpm for the premixing whereas for mixing it was 20 and 200 rpm, respectively.

The recorded output parameters from the software include temperature, tool power, and energy consumed. The mixing time was optimized based on the time needed to reach the maximum dough consistency obtained for the maximum consumed power by the spiral tool (t_{PEAK}) (Sadot et al., 2017). One can find out the optimum mixing time (t_{PEAK}) from the tool power curve. The peak in the power curve signifies the optimum mixed dough. The optimum mixing time of dough was attained at the time interval of 390-420s. The mixer is operated at a tool clearance of 4 mm from the bottom of the bowl. It was kept as a constant for all the trials. All the samples were tested as replicates of five.

Sampling was done during mixing to monitor the evolution of the dough rheological parameters during mixing. Sampling is one of crucial process concerning the dough. During sampling, extra care is given not to touch the dough as it could destroy its natural structure. When the mixer is stopped for sampling, a small portion of dough is scooped out using a baker's pad. A small cylinder like structure having 2.5cm dia was used for sampling the dough for rheometer and texturometer. For rheometric test the samples were stored under refrigeration at -20^{0}C, later brought to room temperature before testing. For texturometer fresh samples were utilized.

2.3 Rheometer

The fundamental rheological measurements for measuring the viscoelastic properties of the dough were done in a 40 mm serrated parallel plate rheometer (AR 1000, TA instruments Division de Waters SAS, France) at 30^{0}C maintained using a water bath. The samples kept under refrigeration was brought to room temperature and then tested for rheometry. Each sample is placed one by one in a sealable airtight cover and is kept under room temperature for 30 min. The dough was then tested for frequency sweep test and creep recovery test. The sample was tested at a thickness of 1mm. The excess materials from the sides of the parallel plates were trimmed, and to prevent drying by oxidation the external sides of the dough under the rim were coated with paraffin oil. Frequency sweep and creep recovery tests were carried out at 10 Pa shear stress. For the frequency sweep test, the storage and loss modulus were calculated for an oscillating frequency (0.1-50 Hz) under a constant stress of 10 Pa. Creep recovery test were done at 10 Pa for 3min in creep and without stress in recovery for 3min (by conducting preliminary studies).

2.4 Texturometer

The texture analyzer (Lloyd Ametek, France) is a commonly used instrument in industries to measure rheological properties of dough. The TPA measurement mimics the action of mouth. A 20mm diameter flat plate was used to do the TPA for dough. To avoid stickiness, the dough surface was covered with a thin polyethylene film. The experiments were carried out with a load cell of 50 N for 180s. A resting period of 150 sec was set between each load phase. In TPA the mechanical properties such as hardness, cohesiveness, viscosity, elasticity, and adhesiveness can be found. For dough rheology, the main characteristics that are compared here are young modulus (Elasticity) and firmness. The analysis was replicated five times for dough sampled at each mixing phase.

2.5 Statistical Analysis

All the data were tabulated and subjected to one-way analysis of variance (ANOVA) for determination of significant difference between the dough rheology as a function of mixing time using STATGRAPHICS XVII-X64. Fishers's least square difference (LSD) method was followed to determine highly significant difference between dough rheology at different mixing time.

RESULTS AND DISCUSSION

3.1 Evolution of power curve and temperature on dough mixing

The Spiral mixer records the tool power and temperature over kneading time. Fig. 1 represents the tool power, average power and temperature over mixing time. The power required for mixing increased with mixing time and further mixing results in the drop of the power curve. The power needed for optimum dough development is marked as a peak in the fourth phase of mixing (500-550W) further which the curve drops due to over mixing. This is a general phenomenon observed by bakers for the calculation of optimum dough development. The reasons for this can be explained as; when the kneading begins the flour and the water molecules start to mix. In the beginning, the dough resistance to an extension is low, so the power curve is low. Gluten is a protein when dry is a glassy polymer, but as it takes up water, it undergoes a glass transition (Hoseney, 1986). As the kneading continues the protein fibrils get hydrated rapidly and the amount of free water in the system decreases. Moreover, the strength of cross-linking between the protein fibrils increases making the dough stronger. At optimum kneading, the dough will have the maximum strength and maximum resistance to extension. This resistance to extension will be reflected as peak height in the power curve. Once, all the protein is hydrated there won't be any increase in the power curve resulting in its fall.

The dough temperature increased with an increase in mixing time. The rise in dough temperature can be attributed to two reasons, i.e., heat generated by frictional force and the heat generation due to the hydration of flours. The frictional heat produced is the result of the mechanical stress possessed by the tool to overcome the internal and external friction during the dough mixing process. The amount of friction to overcome depends upon the water absorption and gluten development. The heat of hydration is the amount of heat generated when a substance absorbs water. The amount of hydration varies upon the degree of water absorbed. On considering soluble substances, energy is needed for dissolving them so that the change in energy level is in the negative nature. Thus, the amount of heat is withdrawn from the system. In this way the temperature increases. The temperature at optimum mixing was 27 ^{0}C, above which the dough over mixed and behaves in a sticky manner.

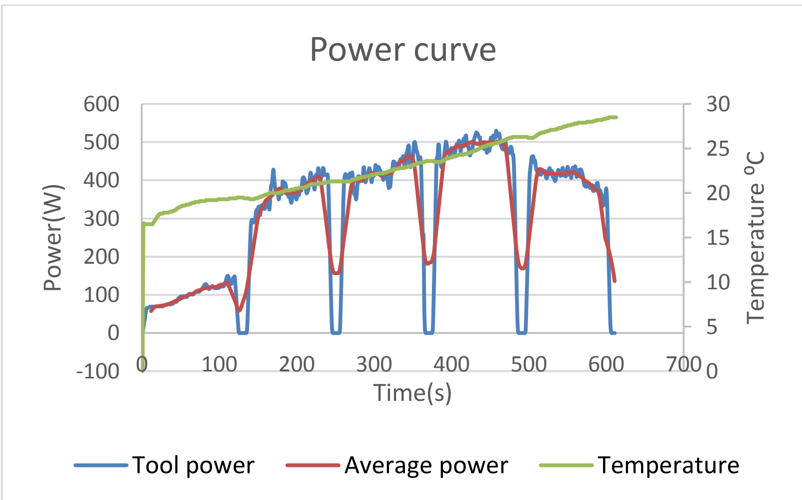

Fig. 1: Progression of the power curve in watts and temperature (˚C) with mixing time of dough

3.2 Rheometer

3.2.1 Frequency Sweep Test

The values of storage (G') and loss (G") modulus at a frequency of 1Hz with mixing time is illustrated in Fig.2. Despite the considerable variation in the values, storage and loss modulus show a similar curve as power curve following the elastic network build-up possibly due to protein interactions. However, the values decreased after the peak. Many authors have observed parallel changes in rheological parameters with power consumption (Dobraszczyk & Morgenstern, 2003). The variation in values measurement issue is due to the high sensitivity of the dough in handling of the samples and is notified by numerous authors (Zheng et al., 2000).

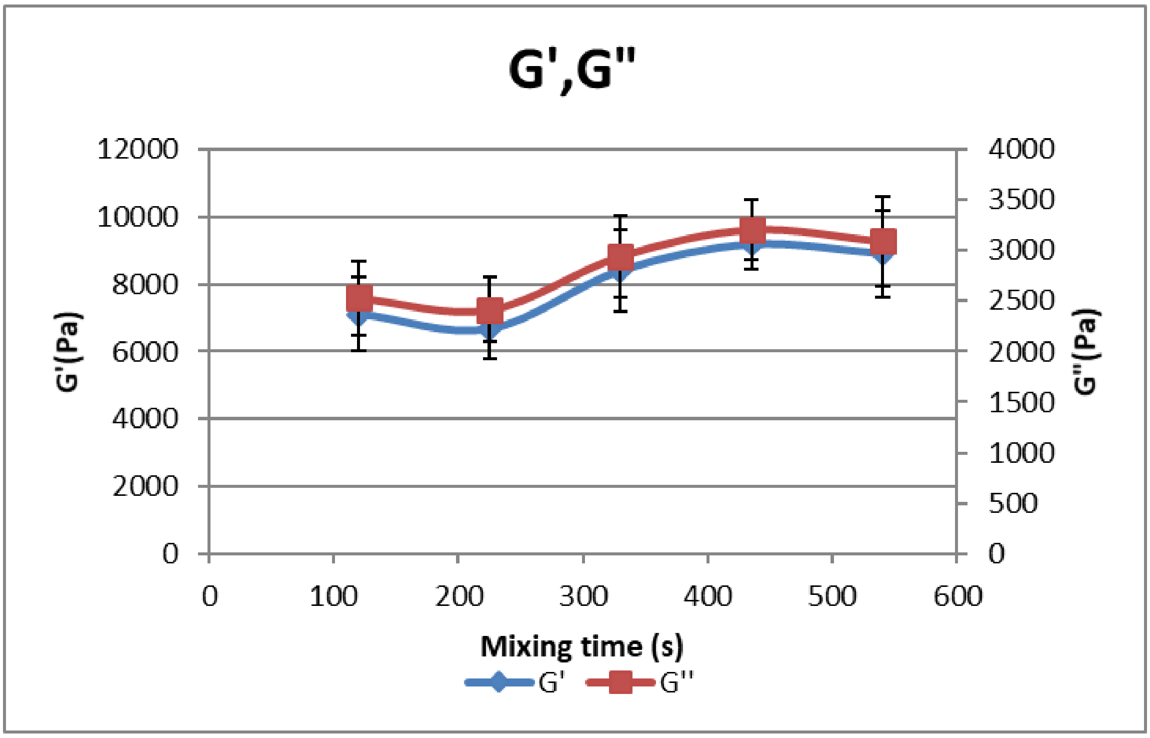

Fig. 2: Storage modulus G' and loss modulus G", (Pa) changes in the dough with mixing time(s) from frequency sweep test performed in the rheometer

3.2.2 Creep Recovery

The curves were modeled by using the same 3-elements KV model. The creep-recovery test was conducted here to judge the difference in rheological properties of dough along with the kneading time. Fig. 3 demonstrating creep recovery illustrates the considerable difference in dough rheological characteristics at each phase of mixing. Phenomena of creep and recovery are caused by the reorientation of bonds in viscoelastic material (Onyango et al., 2010). With each sampling phase, the maximum deformation decreases indicating higher elastic recovery. The viscosity of the sampled dough show high viscosity for dough sampled at t_{PEAK} representing optimum mixed dough. However, there is no significant difference between the viscosities of both samples i.e. at the phase of optimum and over mix, indicating the inaccuracy of the instrument. On comparing other modeled values (Young's Modulus and Compliance) from table 1, we see that the standard deviation is quite high. Even though creep recovery measurements are small deformation tests; the fact that the values showing high standard deviation cannot be ignored. This deviation might be due to irregular structuring of dough. The creep test clearly indicates a stiffer behaviour along the mixing, but the accuracy of the test is insufficient to "capture" the t_{PEAK}.

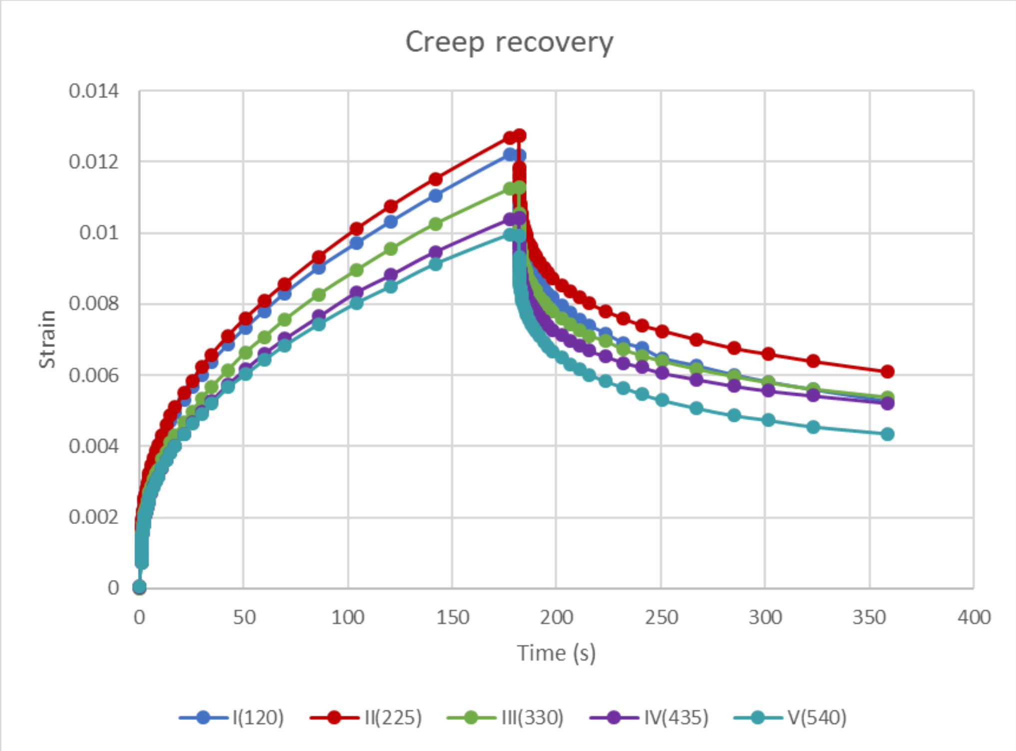

Fig. 3: Effect of mixing time(s) on creep recovery of dough

Table 1: Modeled values of creep recovery obtained from rheometer

Parameter	Symbol	Unit	I(120)	II(225)	III(330)	IV(435)	V(540)
Youngs Modulus 1	G_1	Pa	3596.186	3411.666	3695.187	3735.245	4023.293
Retardation time	θ_1	s	14.10181	17.84331	18.09887	16.64578	13.84254
Youngs Modulus 2	G_2	Pa	3330.979	3145.075	3640.269	3890.937	3951.291
Retardation time	θ_2	s	15.72743	18.27709	19.82865	32.45507	19.3436
Flow viscosity	η_0	Pa.s	2.78E+05	2.63E+05	3.06E+05	3.36E+05	3.42E+05
Compliance 1	J_1	Pa^{-1}	3.02E-04	3.09E-04	2.87E-04	2.73E-04	2.59E-04
Compliance 2	J_2	Pa^{-1}	8.30E-04	9.21E-04	8.39E-04	8.30E-04	7.24E-04

3.3 Texturometer

The texturometer was used to measure the young's modulus and firmness values. The values showed an increase with an increase in mixing time with applicable variation between different phases of mixing. The increase in young's modulus values indicates an increase in elasticity while a similar trend in firmness indicates the lower resistance to an extension with the function of mixing time. It also points out the development of gluten network, which offers strength with each phase of mixing. However, in spite of good results the texturometer being an empirical test cannot provide the fundamental details of dough rheology. Moreover, the increase in firmness and young's modulus even after t_{PEAK} creates confusion in the proper evaluation of optimally mixed dough.

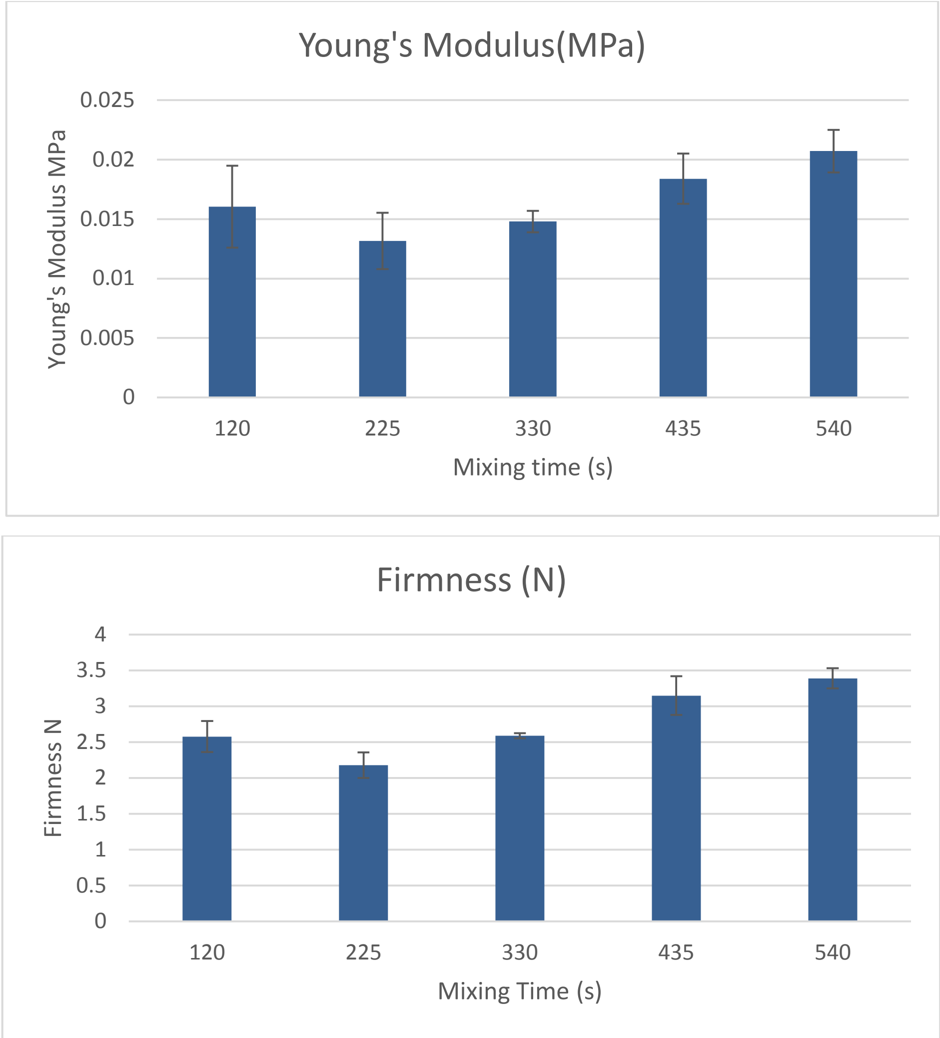

Fig. 4: Development of young's modulus (MPa) and firmness (N) with mixing time of dough (in sec) from TPA

CONCLUSION

The evaluation of dough rheology with mixing time was done using rheometer and texturometer and compared with power curve obtained from the spiral mixer. From the results of power curve, the optimum mixing of dough can be distinguished perfectly by the peaks of the graph. The dough at optimum mix has the maximum power which reflected the viscoelasticity of the dough. Beyond that point, the gluten network breaks, weakening viscoelstic nature ultimately declining tool power, making the dough sticky and unusable. A KV model was used to find out different parameters of dough rheology from the deformation curve obtained from the rheometer. The modeled values witnessed a trend illustrating the development of dough viscoelasticity with an increase in mixing time. Even though the values of rheometer looks little convincing in determining the optimum mix of dough, the results of TPA does not, which could be due to uneven dough structure. As a whole the rheological instruments used here for determining the optimum mix of the dough seems to be dubious and time consuming. For future works a rheological instrument which can assess the dough rheology instantly and accurately with mixing time can be developed which can provide better insights to industries and researchers.

REFERENCES

Amjid, M. R., Shehzad, A., Hussain, S., Shabbir, M. A., Khan, M. R., & Shoaib, M. J. P. J. O. F. S. (2013). *A comprehensive review on wheat flour dough rheology*. *23*(2), 105-123.

Bloksma, A. (1990). Rheology of the breadmaking process. *Cereal Foods World, 2*(35), 228-236.

Campos, D. T., Steffe, J. F., & Ng, P. K. J. C. C. (1997). *Rheological behavior of undeveloped and developed wheat dough*. *74*(4), 489-494.

Contamine, A., Abecassis, J., Morel, M., Vergnes, B., & Verel, A. J. C. C. (1995). *Effect of mixing conditions on the quality of dough and biscuits*. *72*(6), 516-522.

Dobraszczyk, B., & Morgenstern, M. J. J., o. c. s. (2003). *Rheology and the breadmaking process*. *38*(3), 229-245.

Hoseney, R. (1986). *Component interaction during heating and storage of baked products.* Paper presented at the Chemistry and physics of baking: materials, processes, and products: the proceedings of an int. symposium held at the School of Agric., Sutton Bonington, 10th-12th April 1985/edited by JMV Blanshard.

Lee, L., Ng, P., Whallon, J., & Steffe, J. J. C. C. (2001). Relationship between rheological properties and microstructural characteristics of nondeveloped, *partially developed, and developed doughs*. *78*(4), 447-452.

Maache-Rezzoug, Z., Bouvier, J. M., Allaf, K., & Patras, C. J. J. O. F. E. (1998). *Effect of principal ingredients on rheological behaviour of biscuit dough and on quality of biscuits*. *35*(1), 23-42.

Onyango, C., Mutungi, C., Unbehend, G., & Lindhauer, M. G. J. J. O. F. E. (2010). *Rheological and baking characteristics of batter and bread prepared from pregelatinised cassava starch and sorghum and modified using microbial transglutaminase*. *97*(4), 465-470.

Sadot, M., Cheio, J., & Le-Bail, A. J. J. O. F. E. (2017). *Impact on dough aeration of pressure change during mixing*. *195*, 150-157.

Zheng, H., Morgenstern, M., Campanella, O., & Larsen, N. J. J. O. C. S. (2000). *Rheological properties of dough during mechanical dough development*. *32*(3), 293-306.