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Research Article

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Impact of Pressure Change during Bread Dough Mixing and Impact on Bread Properties

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ABSTRACT

Bread dough mixing is a key step in bread making process. Experiments were carried out to study the impact of pressure change in the overhead space of the dough mixer during dough mixing with a spiral dough mixer equipped with temperature and pressure control. Three pressure levels and spiral tool speed conditions were used, which were 50, 250 and 500 mbar and 100,150 and 200 RPM respectively. The objectives were to understand the effect of pressure and tool speed on dough during kneading in order to optimize dough kneading conditions. The results showed that dough aeration was proportional to the number of rotations of the spiral tool. Higher pressure and higher-speed mixing reduced the time to reach maximum power (t_{PEAK}) means duration of mixing can be reduced. Bread specific volume, porosity fraction and pore size distributions were analysed for a better understanding of the impact of high pressure on bread quality.

Keywords: *Bread dough, Pressure mixing, Porosity, Baking.*

INTRODUCTION

Mixing is an integral part of all bread making during which dough is kneaded and air bubbles introduced in the dough, helps in the formation of a smooth and homogeneous dough with a developed gluten structure. Properly mixed dough is important for the production of good quality bread. The aeration of bread dough during kneading is also a crucial aspect of modern bread making process because it is the bubble in the dough which evolve into the cells of the final bread crumb[2]. Aeration of the dough during mixing, in terms of the bubble size distribution, directly determines the structure and texture of the baked loaf, and hence its quality and appeal[1]. The degree of dough aeration can be increased using high speed mechanical dough development mixers, which will improve the dough rheology and which yields the desired baking performance. This must be achieved economically, which generally means minimising the duration of mixing and usage of energy[6].

The bread making process is based on three main steps: (1) mixing, in which ingredients are transformed into a macroscopic homogeneous medium, mainly due to the formation of gluten network;

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(2) proofing, over which dough expands due to the production of gas by yeast activity; gas holding capacity of the dough are developed during proofing period[3] which depends on the rheological properties of the gluten network formed during mixing (3) baking, which sets the cellular structure by dough/crumb transition and crust[5]. The surface properties of bread dough is important in relation to the bread making process, these properties may have effect on the pore size distribution and rheology of bread[4].

This study aims at understanding the effect of pressure and spiral tool speed during dough mixing on the time to maximum power (t_{PEAK}), dough porosity and characteristics of the final bread made with high pressurised mixing. It will also help in the design and control of dough mixing operations and in the selection of appropriate pressure and tool speed for bread preparation.

MATERIALS AND METHODS

2.1. Ingredients

The ingredients that were used for dough are wheat flour (Ash content "T55" Milling GIRARDEAU- France), salt (Les Salins du Midi- France), sugar (Beghin Say, France), sunflower oil (Transgourmet, France), IBIS improvers (Lesaffre, France): (Ingredients: Wheat flour; Emulsifier: mono and diglycerides of fatty acids; Technological auxiliary: Vegetable oil (1%); Enzymes: Alpha-amylase, Maltogenic amylase, Amyloglucosidase, Glucose oxidase, Xylanase; Flour treatment agents: ascorbic acid), water and fresh yeast :2% w/w flour basis (only for baking test). Table 1 shows the recipe followed for the experiment, whereas Table 2 shows the flour composition and rheological properties.

Table 1: Dough recipe

Ingredients	(% w/w flour basis)	Ingredients per 100 g of dough
Flour	100	60.5
Water	53.5	32.4
Sugar	4.5	2.7
Oil	4.5	2.7
Salt	1.8	1.1
Improver	1	0.605
Total	165.3	100

Table 2: Flour composition and Analytical properties obtained from Alveograph (CHOPIN) and Farinograph (BRABENDER)

Chemical analysis		
Component	Content (g)/100 g of flour	Method followed
Starch enzymatic	68.1 ± 3.4	NF V18-121
Damaged starch	23.3	NF EN ISO 17715
Moisture (%)	13.92	NF EN ISO 712
Protein Content (infrared)	12.08	Khjeldal method
Fat	1.6	EN ISO 11085
Ash	0.51	NF EN ISO 2171

Analytical Profiles

Alveograph (CHOPIN) Method: NF EN ISO 27971		Farinograph (BRABENDER)	
Pressure (mm)	80	Water absorption (%)	57.7
Length (mm)	101	Time development (min)	6.0
Swelling	22.4	Stability (min)	11.5
W area total curve (10^4 J)	254	Degree of Weakening (UF)	60
Pressure/Length	0.79		

2.2. Mixing

Mixing was done in a spiral mixer (VMI, Montaigu, France) equipped with spiral shaped tool, temperature controlled double jacketed cooling system and also has the provision to vary the overhead pressure during mixing. Mixing comprises of three steps. The first step was manual mixing of dry ingredients where homogenisation of ingredients took place. Then in the second step, homogenised ingredients were added to the water and mixing was done at lower tool speed (100 RPM for the gyratory motion of the spiral tool and 10 RPM for the rotation motion of the mixer's bowl) for 3 min. The temperature of water was set in order to keep the sum of flour, water and mixing temperature (30 °C) equal to 55 °C. Finally salt was added and the mixing was conducted at high tool speed. The experiment was conducted at three different high tool speed (200 RPM, 150 RPM and 100 RPM for the gyratory motion of the spiral tool and 20 RPM, 15 RPM and 10 RPM respectively for the rotation motion of the mixer's bowl) for 6 duration of mixing for the period of 1 min 30 s. Mixing was conducted along with air and pressure was set at three different levels (500mbar, 250mbar and 50mbar). The software facilitates to program the parameters of mixing. Also it records various parameters (power consumed by the spiral tool, temperature, pressure of tool etc.) during mixing.

2.3 Porosity Measurement

To determine dough apparent porosity sample at several duration of mixing (1 min 30 s) for each pressure level, a system based on Archimedes principle was used[7]. The setup consists of a beaker filled with 500 ml of sunflower oil, balance on which the beaker was placed and a supporting stand to hold the dough submerged at a fixed distance under the air-oil interface. The dough sample was placed on the weighing machine beside the beaker with oil and the weight was noted as, m_1, which is the mass of dough sample is and which also can be considered as a mass of the degassed dough sample. Hence, the volume of gas free dough can be calculated as,

$$V_{Dgf} = \frac{m_2}{\rho_{Dgf}} \qquad \text{...... (1)}$$

Then dough sample was dipped in the oil and the weight was obtained, m_2, corresponds to the buoyancy exerted by the volume of dough sample (V_D) i.e. the sum of the volume of gas-free dough (V_{Dgf}) and the volume of the gas entrapped in the dough (V_{gas}).

Therefore,

$$m_2 = V_D \times \rho_{oil} = \left(V_{Dgf} \times \rho_{oil}\right) + (V_{gas} \times \rho_{oil}) \qquad \text{...... (2)}$$

And, V_{gas} entrapped in the dough becomes,

$$V_{gas} = \frac{m2 - V_{Dgf} \times \rho_{oil}}{\rho_{oil}} \qquad \text{...... (3)}$$

$$\text{Finally, the porosity } (\phi) = \frac{V_{gas}}{V_{gas} + V_{Dgf}} \qquad \text{...... (4)}$$

2.4. Bread making

Mixing parameters were selected (pressure - 500mbar, tool speed 200RPM and bowl speed 20RPM) and parameters like maximum power level and the corresponding time (t_{PEAK}) were analysed to control gluten network formation. Mixing was carried out under pressurised air. The mixing process in our case was stopped just before attainment of t_{PEAK} value to avoid over mixing of dough sample. After mixing 280g of dough samples were divided and shaped it by hand so as to obtain a roll of dough.

2.4.1. Fermentation

The dough sample of 280g was weighed and formed into a cylinder shape and installed in a pan. The sample was fermented at 40^{o}C and 80% RH.

2.4.2. Baking

The fermented dough was baked in the oven (MIWE, Allemagne, Germany) at 220°C for 20 min. The dough was installed in a pan of dimensions 10 cm × 9 cm × 28 cm. Experiments were performed in triplicate.

2.4.3. Porosity measurement of bread

Helium Pycnometer (AccuPyc 1330) was used for measuring the true density of the bread sample. Bread sample was weighed and placed on the sample holder. Then the sample was kept on the Pycnometer and it was allowed to run for about 30 min. Porosity of bread can be calculated from the apparent and true density of the bread. Pycnometer gives the true density of the bread sample. While the apparent density was calculated by using the measurements from the volumeter.

$$\text{Finally, the porosity } (\phi) = 1 - \frac{\rho_{app}}{\rho_T} \quad \ldots\ldots (5)$$

Where, ρ_{app} is the apparent density (g/ml), ρ_T is the true density (g/ ml).

2.4.4. Bread volume measurement

The volumeter (TexVol BVM-L370LC) was used to measure volume and density of bread. The bread sample was cooled for about 1 hour after baking, was placed on the rotating tool. The volume was measured based on the advanced laser sensor.

2.4.5. Bread crumb structure

The bread crumb structure was determined after 24 hours of baking. Bread was sliced to a thickness of 1 cm by the help of slicer (SOFRACA- France). Then the slices were scanned with the help of flatbed scanner (EPSON perfection V37) (Fig1). The slices were taken from different locations of the bread. Then the scanned images were analysed using the image J software (Fig.2). Initially, the image was converted to 8 bit grey scale and then processed by applying threshold to identify the cells in crumb. A macro file was created to maintain the uniformity and idea about pore diameter and area were obtained.

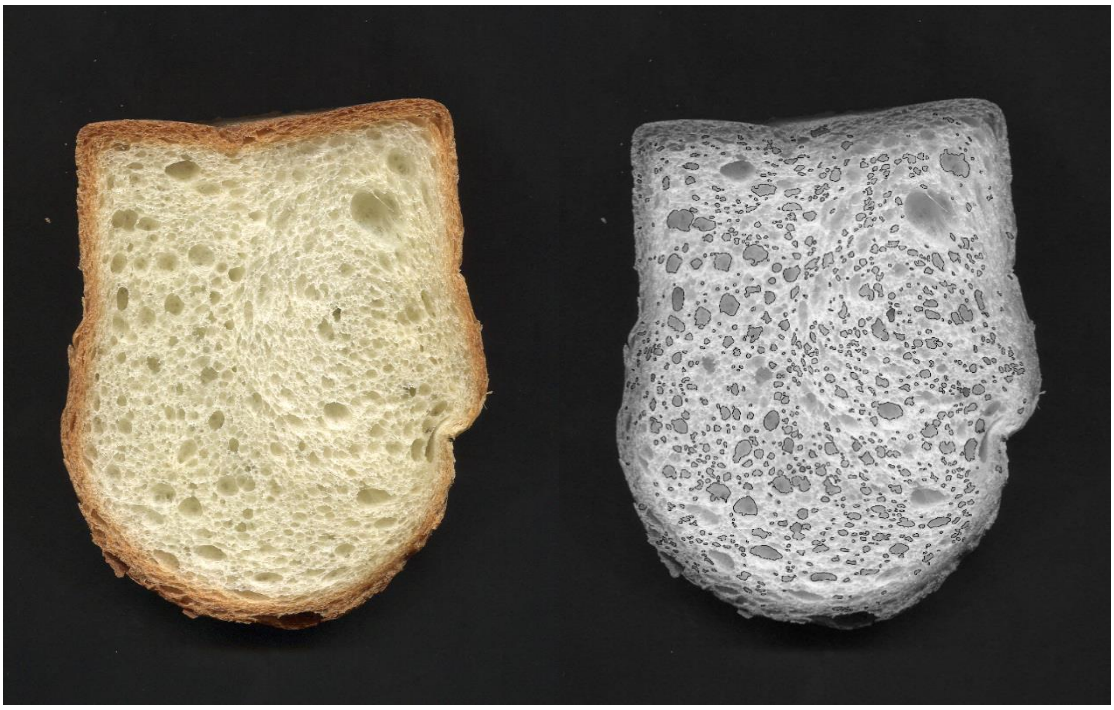

Fig.1 Crumb structure of baked bread **Fig.2 Crumb structure treated by image J**

RESULTS AND DISCUSSION

3.1. Mixing conditions

3.1.1 Pressure and spiral tool rotational effect

The effect of pressure on the maximal spiral tool power and t_{PEAK} was studied for 3 pressure levels and 3 tool speed. It was observed that the use of higher pressure and higher-speed mixing reduced the time to reach maximum power (t_{PEAK}) as shown in Fig.3. An explanation could be that a lower pressure level means less oxygen available in the mixer overhead, which results fewer oxidation. This could lead to a depolymerisation of gluten chains and to a less cohesive and weaker dough. The increase in rotation speed leads more power to the dough, which in turn increases the speed of formation of gluten network.

Fig. 4 shows that for a higher tool rotation speed, fewer spiral agitator revolutions were needed to reach the maximal power during mixing. Moreover when the specific energy is divided by the number of revolutions to reach the maximum power, it can be seen that a faster spiral agitator rotation speed delivers more energy per revolution to the dough, which makes the gluten network formation faster.

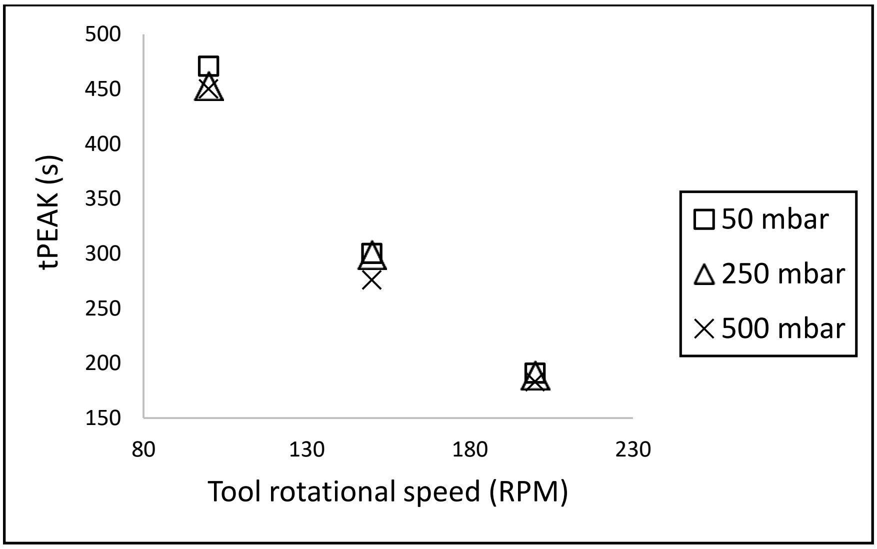

Fig. 3: Comparison of t_{PEAK} at different pressure levels

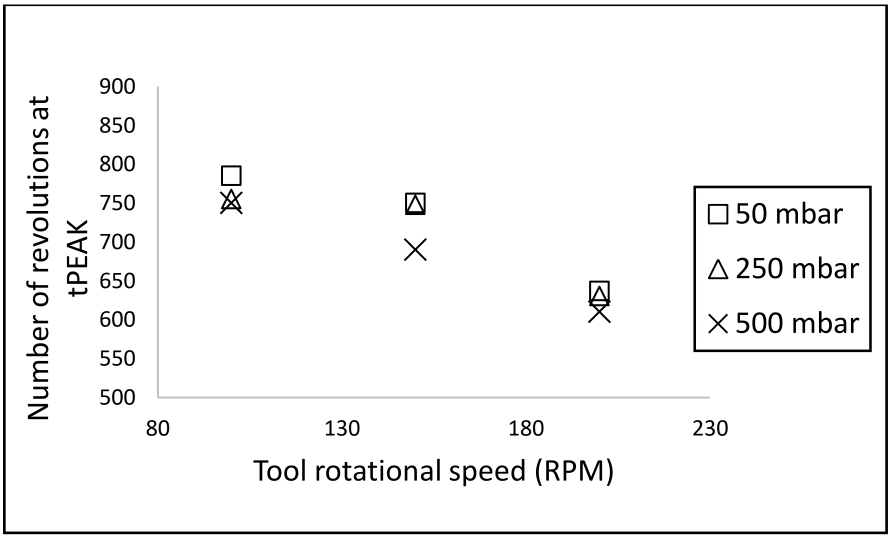

Fig. 4: Comparison of number of spiral agitator revolutions at t_{PEAK} for different pressure levels

3.2 Porosity of dough

3.2.1 Pressure and spiral tool rotational effect

The effect of spiral tool speed and pressure on porosity of dough were studied. Porosity of dough at 50mbar and 500mbar with three tool speed (100,150 and 200 RPM) were analysed during air mixing. Fig.5 shows that porosity of dough sample increases with increase in tool speed, this could be due to the shearing actions at higher tool rotation. Also higher spiral agitator rotation speed means more revolutions in the same time interval, and therefore a larger amount of incorporated air. It was observed that at higher pressure porosity of dough was more compared to low Pressurised mixing yielded the trapping of a higher amount of gas by the dough during mixing. Indeed, the entrapped air was at higher pressure in the case of higher-pressure mixing; when returning to atmospheric pressure, the entrapped air was undergoing expansion resulting in a higher dough porosity compared to mixig under lower pressure.

3.3 Specific volume porosity of bread

True density of the bread obtained by using Helium Pycnometre was found to be 1.3973g/ml. Using volumeter specific volume of baked bread obtained as 4.55ml/g. The porosity fraction was calculated by equation (5) given by ϕ = 84.26%. the higher values of porosity fraction and specific volume are due to the higher volume of CO_2 produced per gram during fermentation[3].

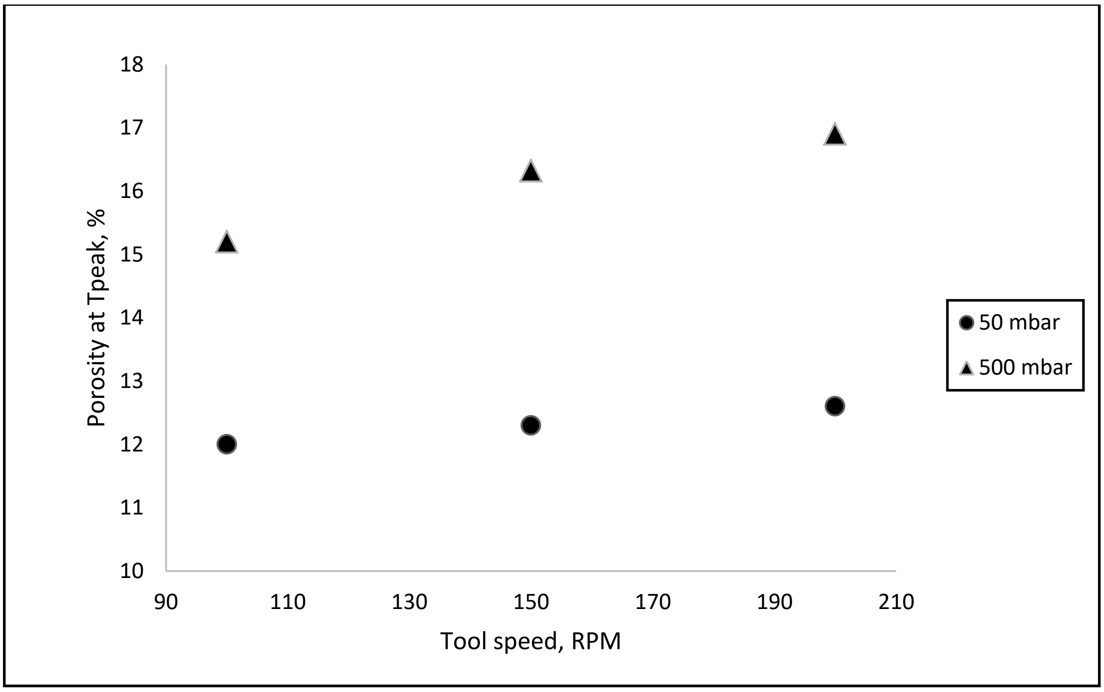

Fig. 5: Comparison of dough porosity at t_{PEAK} for different pressure levels

3.4 Final bread structure

Fig 6(a) and (b) illustrates the pore size distribution of bread from dough sample by image analysis. Pore size distribution of the bread crumb was plotted between number of bubbles and mean pore area. The pore size distribution in baked bread showed non-Gaussian fashion; because most of the cells were much smaller than the average size of the cell[3]. The pores size distribution in baked bread in present study ranged between 5 and 35 mm^2 mean pore areas (mean pore equivalent diameter between 2.5 and 15 mm). The values are higher as compared to the result obtained by[8], observed that pore size in the baked bread lies between 0.08 and 8 mm equivalent diameters, this was due to the pressurised mixing of dough.

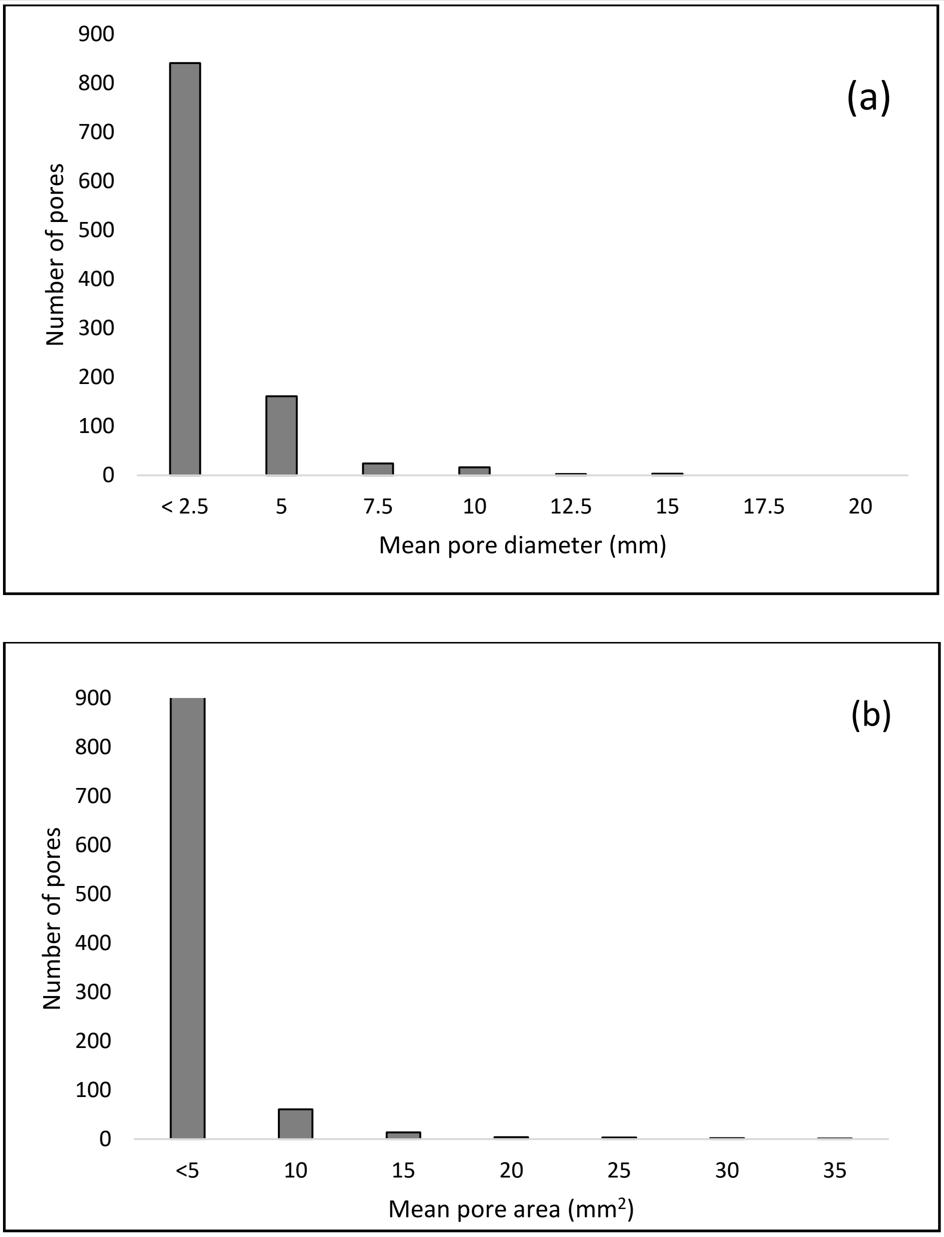

Fig. 6: Pore size distribution in bread crumb: (Mixing condition: pressure - 500mbar, tool speed 200RPM and bowl speed 20RPM): (a) Number of pores as a function of mean pore diameter. (b) Number of pores as a function of mean pore area

CONCLUSION

The impacts of dough mixing with a controlled pressure in the overhead space of the dough mixer considering different unit spiral tool speed was studied. Changes in pressure significantly affected the properties of dough and bread. The porosity of bread dough was found to be a function of pressure mixing at different tool speed. Similarly, bread properties like specific volume, porosity fraction and microstructure of bread crumb (pore size distribution in the bread crumb and median pore area) were also affected by the pressure change during mixing.

The results showed that the time required to achieve maximum power decreases with the higher spiral tool speed. Similarly porosity of bread dough increases as the increase in spiral tool speed and pressure mixing. Pore size distribution in baked bread was analysed which showed that most of the pore area are below 5mm^2 and equivalent diameter of pores were below 2.5 mm. The observed change in pore size distributions were due to the pressurised mixing of dough which will increases the incorporation of air.

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