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Full length Research Paper

Optimization of Cup Bread Baking in Household Electric Oven

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In bread making, baking is a key step in which the raw dough piece is transformed into a light, porous, readily digestible and flavourful product. Bread baking is a low margin scale industry so it is a challenging task to produce a large quantity of good quality breads with low cost. To hasten the baking process in a normal Household oven, optimization of operating parameters is needed. In this study wheat flour, sugar, salt, yeast (*saccharomyces cerevisiae*), ghee and water mixed and made into cup breads. These breads were baked in house hold conventional oven at three different temperatures 175 °C, 200 °C and 225 °C for 5 to 30 min with an increment of 5 min at each temperature. After baking the crumb moisture content, crust hardness, colour was determined and sensory evaluation was also carried out. From results, the optimized operating parameters were found as at 175 °C, baking time is 30 min; at 200 °C, baking time is 25 min and at 225 °C the baking time is 20 min.

Key words: Bread; optimization; baking time; baking temperature; Household conventional Oven.

INTRODUCTION

Bread is one of the oldest prepared foods, dating back to the Neolithic era. Although people have practiced baking for a long time, the understanding of the whole process is not very clear. One of the possible reasons for this is that several fundamental complex physical processes are coupled during baking like evaporation of water, volume expansion, gelatinization of starch, denaturation of protein, crust formation etc. The bread consists of two

parts one is crust i.e. outer surface of bread and another one is crumb. The crust plays a vital role in moisture evaporation and transfer of heat from outer surface to inner side of the bread. Temperature is the dominating factor on baking mechanism including gelatinisation, enzymatic reaction and browning reaction, therefore the final bread quality. The crumb temperature increases up to 98.4-98.9 °C and remains constant but the crust temperature increases up to oven temperature. At this temperature, all reactions are maximised, including moisture evaporation, starch gelatinisation, and protein coagulation. A typical browning crust can be observed when crust temperature reaches 150-205 °C. The vital

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Figure 1. cup bread before baking.



Figure 2. Household conventional oven.

influence on final product quality includes amount of heat application (baking temperature) and baking time. Bread baking is a low margin scale industry so it is a challenging problem to small scale industries to produce large quantity of good quality breads with low cost. To hasten this process in house hold oven it is necessary to optimization of operating parameters. To achieve optimal baking, the common industrial practice is to bake bread in the oven controlled at a constant temperature. This paper aims to describe the effect of baking temperature and time on the bread quality attributes including crust colour, Texture and minimum weight loss. The operating parameters were optimized based on crust colour, texture and crumb moisture content.

Material and Methods

Dough Preparation

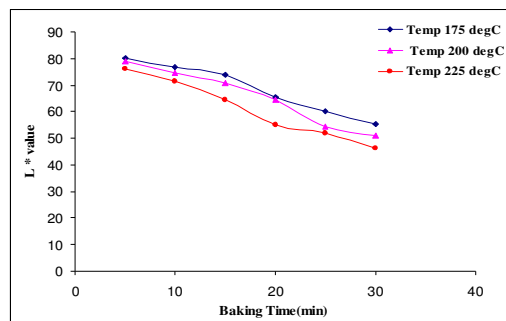
The basic ingredients Wheat flour (40 g), Sugar (2.5 g), Salt (0.48 g), yeast (*saccharomyces cerevisiae*)(0.8 g), ghee (1.08 g) and water (24 g) were taken and mixed properly on an enamel pan till it achieves uniform consistency and a smooth texture. Here 68.86 g dough was used to make cup bread. The dough was placed on the pan and covered with wet cloth. The cloth was kept because the R.H of the air around the dough has to be maintained at about 75 to 85%. The dough was allowed

to rest for 90 min. During this time the volume increased due to the action of yeast. The formation of air cells takes place because of release of CO₂ in fermentation. The dough was re kneaded at the end of 90 min. The dough was moulded into smooth ball and fitted it into an Aluminium cup. The Aluminium cup was covered by wet cloth and left for another 30 min for final rising (proving/proof). After 30 min this dough was ready for baking as shown in Figure 1. Here the Aluminium box used for baking had an average diameter of 7 cm and height 3.5 cm.

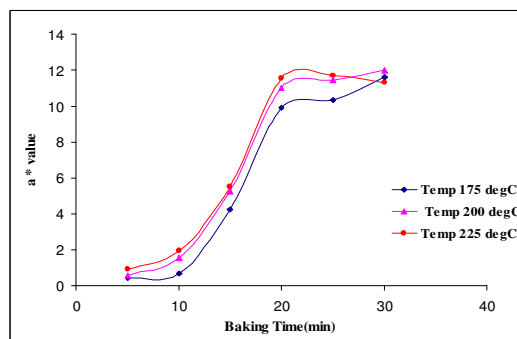
Baking

A key parameter of loaf quality is to achieve a core temperature of about 92-96 °C by the end of baking to ensure product structure is fully set. As dough warms up, it goes through a complex progression of physical, chemical and biochemical changes. Crust browning occurs due to maximum evaporation of water from the top surface and also when the temperature is greater than 110 °C. Browning is mainly the result of a Maillard type browning reaction between amino acid and sugar which finally leads to formation of brown nitrogenous polymers and melanoidins.

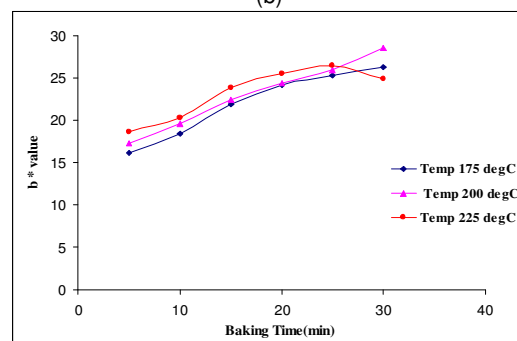
At the end of proof stage, the Aluminium box with fermented dough was kept on baking tray in the household conventional oven, which was set at



(a)



(b)



(c)

Figure 3. Changes in color of cup bread baked at different temperatures in terms of L^* , a^* and b^* with baking time - (a) L^* vs. baking time; (b) a^* vs. baking time; (c) b^* vs. baking time.

predetermined temperature. Following baking, the Aluminium cup was removed and cup shaped bread was cooled to room temperature over 45 min and sealed in metalized plastic bag (100 μ m thick) until further analysis.

Household Conventional Oven

The bread baking experiments were done in household electrical oven (Bajaj India) shown in Figure 2, with inside chamber (400 x 350 x 300 mm) having temperature range of 50-300 $^{\circ}$ C. This oven had temperature regulator and timer to change the baking temperature and time. The heating element which is placed at the top of inside

of the oven and there is a removable non stick and scratch resistant baking tray made with aluminium. A bright lamp was provided inside the oven permits one to observe the cooking in progress through the high visibility door. In this oven, different heat transfer mechanisms act together onto the product being baked. These are heat convection from the high temperature air in the oven, thermal radiation from the heating surfaces and heat conduction from trays to the product's lower and lateral surfaces. The heat transfer into the product from upper, lower and lateral surfaces creates a cold layer (thermal centre) at some distance from the surfaces. Simultaneous to these, internal moisture (liquid or vapour) diffuses towards the cold centre in negative

Table 1. L*, a* and b* values of cup bread baked at different temperature and time combinations

Baking Time		5 min	10 min	15 min	20 min	25 min	30 min
Baked 175°C	at	L* = 80.26	L* = 76.77	L* = 73.90	L* = 65.43	L* = 60.04	L* = 55.45
		a* = 0.45	a* = 0.68	a* = 4.23	a* = 9.92	a* = 10.36	a* = 11.60
		b* = 16.11	b* = 18.44	b* = 21.89	b* = 24.16	b* = 25.30	b* = 26.24
Baked 200°C	at	L* = 78.87	L* = 74.57	L* = 70.68	L* = 64.46	L* = 54.47	L* = 50.88
		a* = 0.57	a* = 1.56	a* = 5.28	a* = 11.04	a* = 11.48	a* = 11.98
		b* = 17.27	b* = 19.63	b* = 22.40	b* = 24.39	b* = 25.90	b* = 28.54
Baked 225°C	at	L* = 76.27	L* = 71.44	L* = 64.57	L* = 55.06	L* = 51.77	L* = 46.13
		a* = 0.94	a* = 1.95	a* = 5.52	a* = 11.55	a* = 11.7	a* = 11.30
		b* = 18.60	b* = 20.27	b* = 23.88	b* = 25.56	b* = 26.43	b* = 24.90

radial and upward directions; from there, it draws its way to the open top surface, and finally the moisture leaves the surface by convective mass transfer.

0.5mm/s, distance of 30% strain and load cell of 5 kg. Hardness value was considered as mean compression force and expressed in Newton.

Experimental Design

Experimental plan for optimizing the process parameters during baking constituted two independent parameters viz., baking temperature and baking time and five dependent variables viz., texture, crumb moisture content and colour variables in terms of L*, a* and b* of bread. Cup breads were baked at three different temperatures 175 °C, 200 °C and 225 °C for 5, 10, 15, 20, 25 and 30 minutes at each temperature. Total 18 experiments were conducted and number of repetitions was two.

Analysis of Process Parameters

Analysis of Colour

Colour is an important quality of food. Colour is the most important thing on the basis of which the food product is accepted. Respect to regulation, theCodigo Alimentario Argentino (ANMAT, 2004) establishes that bread crust must present a uniform golden brown colour. Hence, the crust colour appears as a critical factor in the bread baking process. Colour measurement is used to control the quality of food. The colour is measured by using Minolta Colorimeter. Colour was measured in terms of L*, a* and b*. The colour was defined by three coordinates: L* (lightness), a* (redness) and b* (yellowness).

Texture Analysis

The texture characteristics of cup breads in terms of hardness was measured using a stable micro system TA-XT2 texture analyzer (Texture Technologies Corp, UK) fitted with a 10mm ϕ cylindrical probe. The studies were conducted at a pre test speed of 1.00mm/s, test speed of

Analysis of Moisture Content

The crust was removed and the sample of bread crumb was taken in an Aluminium moisture content determination box. The box was kept in the hot air oven for 24 hrs at 105°C. The moisture content (m.c.) was calculated as

Crumb m.c. (w.b.) % = wt of moisture evaporated / wt of sample taken

Sensory Evaluation

The sensory evaluation was carried out on nine point Hedonic scale as shown in Appendix with '1' being lowest possible value and '9' being highest possible value. It includes evaluating product quality based on colour, texture, flavour and overall acceptability of the product. This sensory evaluation was carried out to only those breads colour was near to golden brown by visual observation.

RESULTS AND DISCUSSION

Colour Analysis

The colour of cup breads was measured in terms of L*, a* and b*. The L* values decreased with increasing of baking time and baking temperature as shown in Figure 3(a). Approximately equal L* values 55.45, 54.47 and 55.06 were recorded at 175 °C, 200 °C and 225°C for 30, 25 and 20 min baking times respectively.

During baking, the a* and b* values were also increased with increasing of baking temperature and baking time as shown in Figure 3(b) and Figure 3(c) respectively. That means the redness and yellowness of

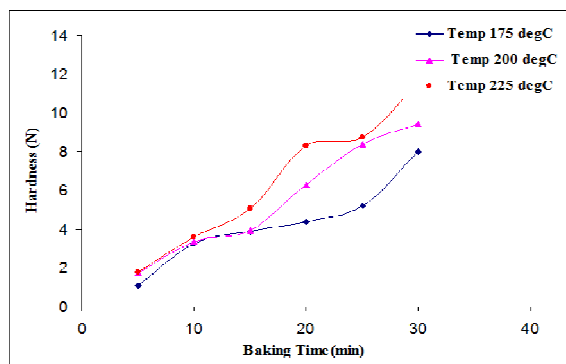


Figure 4. Hardness of Cup Bread baked at different temperatures for different times.

Table 2. Comparison of colour values of cup breads

Temp(°C)	Time(min)	L*	Diff in L*	a*	Diff in a*	b*	Diff in b*
175	25	60.04	4.59	10.36	1.28	25.30	0.94
	30	55.45		11.64		26.24	
200	20	64.46	9.99	11.04	0.44	24.39	1.66
	25	54.47	3.59	11.48	0.5	26.05	2.49
	30	50.88		11.98		28.54	
225	15	64.57	9.51	5.52	6.03	23.88	1.68
	20	55.06	3.29	11.55	0.15	25.56	0.87
	25	51.77		11.7		26.43	

bread increased with increasing of baking temperature and time. Approximately equal a^* values 11.60, 11.48 and 11.55 and equal b^* values 26.24, 25.90 and 25.56 were recorded for the cup breads baked at 175 °C, 200 °C and 225 °C for 30, 25 and 20 min baking time respectively. During baking the bread colour changed from light brown to golden brown and it was become dark brown on overbaking that is why a^* and b^* values decreased at 225 °C, 30 min baking time. The experimental colour values were shown in Table 1.

The bread colour in terms of L^* , a^* and b^* were compared mathematically as follows shown in Table 2.

Difference between any two L^* values, a^* values and b^* values recorded in this experiment were not less than the following difference values.

Difference in L^* (L^* at 175 °C; 30 min - L^* at 200 °C; 25 min) = 0.98

Difference in L^* (L^* at 200 °C; 25 min - L^* at 225 °C; 20 min) = 0.59

Difference in a^* (a^* at 175 °C; 30 min - a^* at 200 °C; 25 min) = 0.16

Difference in a^* (a^* at 200 °C; 25 min - a^* at 225 °C; 20 min) = 0.07

Difference in b^* (b^* at 175 °C; 30 min - b^* at 200 °C; 25 min) = 0.19

Difference in b^* (b^* at 200 °C; 25 min - b^* at 225 °C; 20 min) = 0.34

That means the L^* , a^* and b^* values recorded at 175 °C; 30 min, 200 °C; 25 min and 225 °C; 20 min were almost same because the breads baked at these temperature and time combinations attained the golden brown colour due to completion of baking. According to the colour, the breads were completely baked at these operating parameters 175 °C; 30 min, 200 °C; 25 min and 225 °C; 20 min.

Texture Analysis

The hardness of cup bread increased with increasing of baking time and baking temperature as shown in Figure 4.

The hardness depends on crust thickness. As the baking proceeded, the crust thickness increased because of evaporation of moisture from the surface of the bread. The minimum hardness of the cup bread 1.102 N was recorded at 175 °C and 5 min baking time; and the maximum hardness 11.6 N was recorded at 225 °C and 30 min baking time. Approximately equal hardness values 8.0 N, 8.38 N and 8.3 N were recorded for cup

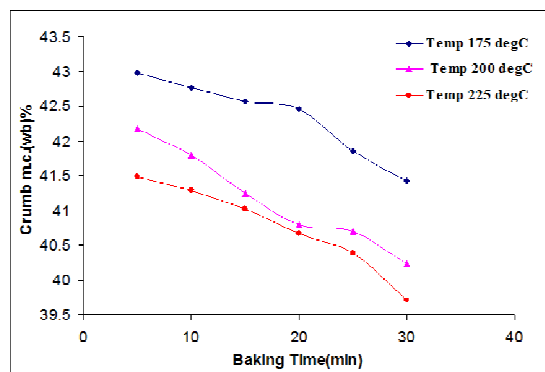


Figure 5. Variation of bread crumb mc (w.b) % with baking time at different temperatures.

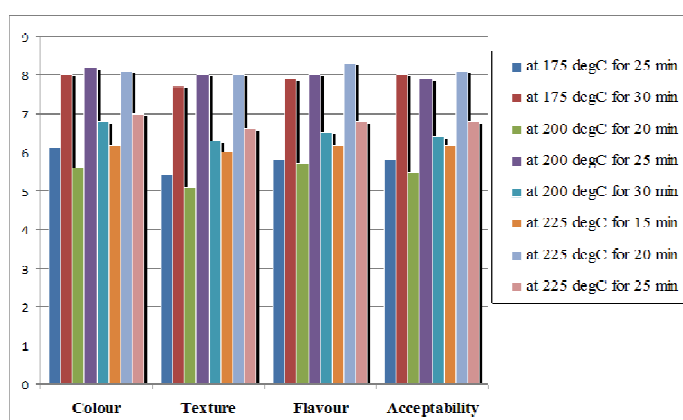


Figure 6. Comparison of sensory attributes of breads baked at different temperature for different times

bread baked at 175 °C for 30 min; at 200 °C for 25 min and 225 °C for 20 min respectively.

Moisture Analysis

The Figure 5 shows that the crumb moisture content decreased with increase of baking time and baking temperature. Initially before baking, the dough had approx. 44.6 % (w.b.), later on as the baking continued the moisture content decreased. Initially the moisture evaporated easily from the top surface of the bread and formed a crust around the bread. This crust acted as a barrier to the moisture to evaporate from the crumb. So very small quantity of water evaporated from the crumb even the baking process was continued for a long time. The moisture content of cup bread baked in Household oven at 175 °C for 30 min; at 200 °C for 25 min and at 225 °C for 20 min was 41.43 % (wb), 40.692 % (wb) and 40.674 % (wb) respectively.

To compare the m.c. of crumb values with standard bread available in the market, the market bread m.c. was

also found. Market bread (diamond bakery) crumb moisture content- Sample 1 = 40.99 % (wb) and Sample 2 = 40.25 % (wb) so the avg. crumb m.c. of market bread was 40.62% (wb) so the experimental values well matching with market bread crumb m.c. value.

Sensory Evaluation

Nine point Hedonic scale was used for bread quality evaluation on the basis of colour, texture, flavour and overall acceptability. The sensory evaluation was conducted through ten trained evaluation team with standard format of sensory evaluation score card was used. The Figure 6 shows the Mean sensory attributes of breads baked at different temperatures for different times.

The highest mean score in colour, texture, flavour and acceptability been recorded for the breads which were baked at 175 °C for 30 min; at 200 °C for 25 min and at 225 °C for 20 min. From this sensory evaluation it was noticed that the baking time and baking temperature affected the final bread quality.

CONCLUSION

The results showed that the weight loss and texture (hardness) increased with increase of baking temperature and time. The crust colour turned from white to golden brown up to complete baking of bread and then after it became dark brown on over baking, Approximately equal values of colour in terms of L^* , a^* and b^* and bread hardness were recorded at temp 175°C ; 30 min, 200°C ; 25 min and 225°C ; 20 min.

According to colour, texture and minimum weight loss of bread by mathematical calculation and sensory evaluation, the following operating parameters combinations were optimized.

1. At 175°C baking temperature the optimum baking time is 30 min
2. At 200°C baking temperature the optimum baking time is 25 min
3. At 225°C baking temperature the optimum baking time is 20 min

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