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A Simple Laboratory Technique for Comparing Performance of Baking Powders

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A very simple and low cost laboratory technique that could be used on routine basis to monitor and control the quality of baking powders was studied. This technique did not require preparation of any dough or solution prior to analysis. Simply by measuring the volumetric flow rate of liberated CO_2 gas; the baking powders with different leavening acid compositions could be compared and thereby classified into slow and fast acting baking powders.

Key Words: Baking powders, Leavening acids, Carbon dioxide, Volumetric flow rate.

INTRODUCTION

Leavening agents are extremely important for the light and puffed texture of bakery products. The history of leaveners dates back to 2300 B.C., when Egyptians leavened their breads using wild yeast. However, this biological method of CO_2 production is mainly restricted to hard wheat products, as it is known to affect the dough rheology[1].

Chemical leaveners commonly known as 'baking powders' are incorporated in soft wheat products like cakes and cookies, *etc*. The first chemical leavener was patented in 1838 in England[2]. The three major components of a baking powder are: (a) CO_2 carrier or base (b) acidic salt (c) and inert filler *e.g.* starch. The two most commonly used parameters for the formulation and evaluation of baking powders are neutralization value (NV) and dough reaction rate (DRR), respectively. Using neutralization value (parts of bicarbonate that can be neutralized by 100 parts of acid) of the leavening acid, the correct ratio of acid and base for a particular baking powder is calculated so that it may produce a neutral pH[3]. If the pH is not neutral it may affect the colour, flavour, crumb texture and gluten strength of the baked goods. Dough reaction rate categorize baking powders into fast acting and slow acting based on the rate of CO_2 gas liberated from a baking powder under standardized conditions. The dissociation constant of a leavening acid governs the rate of CO_2 production.

Though a lot of patenting has been done by different inventors[4-11] to formulate baking powders with unique compositions and novel ingredients inorder to have a better control over the release of CO_2 gas, which in turn improves the bench tolerance. However, little work has been done so far to develop rapid and easy techniques to evaluate the performance of baking powders.

The purpose of the present study was to introduce an easy and less time consuming procedure to compare the gas producing ability of chemical leaveners made with different acidic salts.

EXPERIMENTAL

Sodium acid pyrophosphate (SAPP) and anhydrous monocalcium phosphate (MCP) with brand names perfection and V-90, respectively were purchased from Rhodia Foods, (USA). Analytical grade sodium bicarbonate was purchased from Merck Darmstadt, Germany.

Methods

The apparatus assembly used for the measurement of volumetric flow rate of CO_2 gas liberated as a result of reaction between sodium bicarbonate and leavening acid is shown in Fig. 1. The assembly consisted of a 14 inch long, open ended, narrow glass tube with an internal diameter of 0.35 inches. The glass tube had two marks 'A' and 'B' separated by a distance of 0.05 m. The tube had a small outlet at point C which was connected to a 500 mL suction flask through a rubber tubing. The flask was placed over a magnetic stirrer. A rubber bulb filled with detergent solution was attached at the lower end of the tube.

Procedure: The rubber bulb was pressed to create a bubble at point 'C'. Ten g of baking powder followed by the addition of 100 mL water, was sealed in the suction flask placed over a magnetic stirrer. The time taken by the bubble to move from point 'A' to point 'B' was noted using a stopwatch. Ten

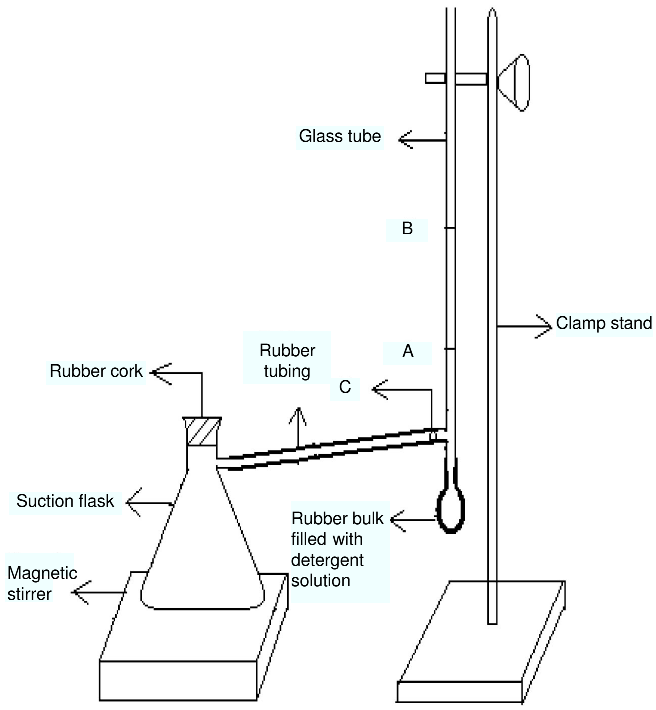

Fig. 1. Apparatus assembly to evaluate baking powders

consecutive readings were recorded by creating a bubble every time at point 'C'. The velocity of the bubble was calculated for the ten consecutive readings. Velocity of the bubble represented the velocity of CO_2 gas evolved. Volumetric flow rate of CO_2 gas was calculated using the following formula:

$$V_f = V \times A$$

where, V_f = Volumetric flow rate; V = velocity of bubble; A = inner cross sectional area of the glass tube = πr^2

Composition of baking powders: Baking powders namely; BP-1, BP-2 and BP-3 with three different leavening acid compositions (Table-1) were formulated using the following equation:

$$\text{Acid (g)} = \frac{\text{Soda (g)}}{\text{Neutralization value of leavening acid}} \times 100$$

TABLE-1
COMPOSITION OF BAKING POWDERS

Baking powders	$NaHCO_3$ (%)	Corn starch (%)	SAPP (%)	MCP (%)
BP-1	30.00	28	42.00	–
BP-2	35.60	20	–	44.40
BP-3	35.00	18	37.60	9.40

Specific neutralization values of leavening acids were supplied by the manufacturer. Sodium acid pyrophosphate and anhydrous monocalcium phosphate were used as leavening acids in BP-1 and BP-2, respectively. BP-3 was formulated with an acidic blend of sodium acid pyrophosphate and monocalcium phosphate in a ratio of 80:20.

Statistical analysis: Analyses were done in triplicate. The data was subjected to one way ANOVA followed by least significant difference test at a significance level of $p < 0.05$ using SPSS software (SPSS version 11, Inc. USA).

RESULTS AND DISCUSSION

The volumetric flow rates of BP-1, BP-2 and BP-3 are shown in Table-2. Volumetric flow rate of all the three baking powders decreased progressively as the consecutive readings were recorded. On the basis of measured volumetric flow rate, baking powders can be evaluated and compared. For all the ten consecutive readings, V_f of BP-1 > BP-3 > BP-2, showing that BP-1 is a fast acting baking powder as V_f of the liberated CO_2 gas was comparatively higher than the other two baking powders, whereas BP-2 made with anhydrous monocalcium phosphate is a slow acting baking powder, which is evident by its very low 'V_f' for all the ten consecutive readings. Slow acting, anhydrous monocalcium phosphate with improved bench tolerance is commercially available in coated form. Uncoated monocalcium phosphate is highly hygroscopic and hydrates fast to release all CO_2 prior to baking stage. Monocalcium phosphate is either coated with a mixture of potassium, calcium, magnesium and aluminum metaphosphates[12] or heated at elevated temperature[13] to delay the release of CO_2 gas. BP-3 showed performance intermediate between BP-1 and BP-2. The release of CO_2 at a slower rate in BP-3 as compared to BP-1 is due to calcium ion effect. Stokes and Wright[14] studied that baking powders made with monocalcium phosphate in addition to sodium acid pyrophosphate had a retarding effect on CO_2 liberation as compared to chemical leaveners made with sodium acid pyrophosphate alone. On the basis of this technique one can evaluate whether the leavening acid present in the baking powder would release the gaseous CO_2 from sodium bicarbonate at a slow or fast rate and thereby speed of reactivity of different baking powders could be compared. The delayed or quick release of CO_2 depends on the solubility of acidic salt or salts used. If the acidic salt hydrates quickly to release the acid then liberation of CO_2 would be prompt and initial volumetric flow rate would be higher, which

TABLE-2
VOLUMETRIC FLOW RATE (m^3/s) FOR BP-1, BP-2 AND BP-3

	BP-1	BP-2	BP-3
1	$1.18 \times 10^{-5} \pm 9.41 \times 10^{-6}_{b}$	$2.46 \times 10^{-7} \pm 1.03 \times 10^{-8}_{a}$	$8.89 \times 10^{-6} \pm 1.59 \times 10^{-6}_{bc}$
2	$9.42 \times 10^{-6} \pm 2.35 \times 10^{-6}_{b}$	$2.36 \times 10^{-7} \pm 1.02 \times 10^{-8}_{a}$	$7.09 \times 10^{-6} \pm 6.84 \times 10^{-7}_{bc}$
3	$5.96 \times 10^{-6} \pm 7.22 \times 10^{-7}_{b}$	$1.94 \times 10^{-7} \pm 3.44 \times 10^{-9}_{a}$	$4.35 \times 10^{-6} \pm 1.16 \times 10^{-6}_{bc}$
4	$4.42 \times 10^{-6} \pm 3.99 \times 10^{-7}_{b}$	$1.56 \times 10^{-7} \pm 2.66 \times 10^{-9}_{a}$	$2.36 \times 10^{-6} \pm 2.90 \times 10^{-7}_{c}$
5	$4.44 \times 10^{-6} \pm 2.01 \times 10^{-6}_{b}$	$1.18 \times 10^{-7} \pm 1.85 \times 10^{-9}_{a}$	$1.47 \times 10^{-6} \pm 7.37 \times 10^{-8}_{ab}$
6	$2.36 \times 10^{-6} \pm 1.89 \times 10^{-6}_{a}$	$8.46 \times 10^{-8} \pm 1.53 \times 10^{-9}_{a}$	$1.30 \times 10^{-6} \pm 6.15 \times 10^{-8}_{a}$
7	$1.83 \times 10^{-6} \pm 1.68 \times 10^{-7}_{b}$	$5.71 \times 10^{-8} \pm 7.64 \times 10^{-10}_{a}$	$7.62 \times 10^{-7} \pm 1.02 \times 10^{-7}_{c}$
8	$1.03 \times 10^{-6} \pm 5.34 \times 10^{-8}_{b}$	$4.01 \times 10^{-8} \pm 1.36 \times 10^{-10}_{a}$	$5.52 \times 10^{-7} \pm 9.24 \times 10^{-8}_{c}$
9	$7.99 \times 10^{-7} \pm 4.94 \times 10^{-8}_{b}$	$4.01 \times 10^{-8} \pm 1.54 \times 10^{-10}_{a}$	$5.42 \times 10^{-7} \pm 1.16 \times 10^{-7}_{c}$
10	$7.25 \times 10^{-7} \pm 1.18 \times 10^{-7}_{b}$	$2.98 \times 10^{-8} \pm 2.65 \times 10^{-10}_{a}$	$3.92 \times 10^{-7} \pm 3.16 \times 10^{-8}_{c}$

Values are average of triplicate measurements. Mean volumetric flow rate ± standard deviation with different subscripts in a row are significantly different at $p < 0.05$.

is not usually desirable for baking applications. Mostly, double acting baking powders have at least one acidic salt with low solubility at room temperature and better hydration at baking temperature. Such acidic salts improve bench tolerance[15]. Contrary to BP-1 and BP-3, BP-2 had a relatively low V_f starting from 2.46×10^{-7} m^3/s. BP-2 could therefore be a good choice for refrigerated canned dough, where slow rate of gas production is required to maintain sufficient internal gas pressure.

The techniques *hitherto* reported for the evaluation of baking powders are complicated, time consuming and require a lot of preparation prior to analysis. Dough reaction rate is the widely reported method for measuring the per cent release of CO_2 gas from the dough under standard conditions. The per cent CO_2 gas liberated is determined manometrically and the whole apparatus is electronically controlled[16]. This manometeric method though effective and quantitative, is a lengthy procedure. Jantzi *et al.*[17] for the first time used pressure meter called Gas Smart apparatus for measuring speed of reactivity of baking powders. The same apparatus was used to measure the chemical kinetics of CO_2 evolution from chemically leavened dough by Bellido *et al.*[18]. Lauck and Tieckelmann[19] used modified Chittick's apparatus in their patent to measure the rate of CO_2 evolution from the dough at specific time intervals. This technique required standard dough formation using Farinograph which makes this technique further complicated and expensive. Oetker[20] measured rate of reaction (ROR) using an apparatus with a gas tight assembly, thermostat and attached kneader. CO_2 gas liberated from the dough was trapped in a burette containing saturated solution of sodium chloride.

All the previously mentioned techniques are difficult, expensive, time consuming and require high tech instruments. The apparatus assembly used in this study has a low fabrication cost and allows rapid evaluation and comparison of baking powders and can therefore be used by industries formulating baking powders so as to have a routine check on the quality of baking powders. This simple laboratory technique is appropriate and less time consuming for comparing the performance of two or more baking powders.

Conclusion

Baking powders formulated with different leavening acid blends can be compared with each other using this simple method to estimate whether the corresponding leavening acid had a fast, retarded or very retarded reaction.

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