SOURCING SODIUM HYDROGEN CARBONATE FROM LAKE SALT FOR THE FORMULATION OF BAKING POWDER

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ABSTRACT

Controlled acid conversion of the carbonate in crystallised fractions of lake salt to the bicarbonate was carried out in solution and solid products obtained from the solutions by recrystallisation. Products containing up to 88.44 ± 1.05% bicarbonate were obtained when hydrochloric acid was used and up to 74.95 ± 1.39% when ethanoic acid was used. A baking powder was formulated using the isolated sodium bicarbonate. The baking powder, when in contact with water, behaved in a similar manner to a commercial baking powder. The formulated baking powder was also used in baking and the baked products were found to be very similar to those obtained with the commercial baking powder.

INTRODUCTION

Lake salt is a substance obtained on evaporation of certain lakes in arid regions.[1] It is taken as medicine for various ailments in Northern Nigeria. It is also used as tenderiser in cooking and in drinking water for cattle.[2]

In Northern Nigeria, the salt is called 'kanwa' in Hausa. However, lake salt is called by various names such as potash, even though some samples may contain little or no potassium, natron and trona implying the presence of $Na_2CO_3.10H_2O$ and $NaHCO_3.2H_2O$ respectively.[3]

Different varieties of lake salt are known and are in use locally in Northern Nigeria. The most common ones include 'jar kanwa' (red 'kanwa'), 'farar kanwa' (white 'kanwa'), 'manda', 'ungurnu' and 'mangul'. Different varieties may have different compositions depending upon the type of lake in which they were formed. The major cation present is that of sodium (Na^+). Potassium is also present in small amounts[4,5]. In addition, some samples may also contain calcium (as $CaCO_3$) and magnesium ions and manganese has also been shown to be present in certain samples[2,4,5]. The major anions present include those of carbonate (CO_3^{2-}) bicarbonate (HCO_3^-), chloride (Cl^-) and sulphate (SO_4^{2-})[4,5,6].

Various chemical substances are obtained from lake salt deposits including sodium carbonate, sodium bicarbonate and sodium sulphate. The chief method used is fractional crystallisation as the salts have different solubilities. However, for the extraction of sodium bicarbonate, carbon dioxide is first bubbled through the solution to react with the sodium carbonate to form sodium bicarbonate which immediately precipitates out as it is less soluble.[7] The reaction can be represented as

$$CO_3^{2-} + CO_2 + H_2O \text{ ------------> } 2HCO_3^-$$

The aim of this work was to optimise a method for concentrating and extracting sodium bicarbonate from lake salt by acid conversion of the carbonate present in it to the bicarbonate and crystallising out. The reaction can be represented as

$$CO_3^{2-} + H^+ \text{ ----------------> } HCO_3^-$$

It was desired to use the sodium bicarbonate so extracted in formulating baking powder. The established methods for manufacturing sodium bicarbonate, such as the Solvay process, require the use of complex equipment for the generation of ammonia and carbon dioxide which are used as raw mateials, and also the tall carbonating towers used. The proposed method for obtaining sodium bicarbonate from lake salt by controlled acid conversion of carbonate eliminates the use of such complex equipment and is cheaper since, also, the lake salt used as raw material is readily available.

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The U.S. Department of Agriculture defines baking powder as the leavening agent produced by mixing of an acid-reacting material and sodium bicarbonate with or without the addition of starch or flour. The permissible acid ingredients are tartaric acid or its acid salts, monocalcium phosphate, alum or a combination of them.[8]

EXPERIMENTAL

Lakesalt samples
The samples of lakesalt chosen were those which looked relatively clean' to the eye and contained minimum amount of earthy impurities. Samples which had high carbonate/bicarbonate content were preferred.

Alum
The alum used as the acid ingredient was obtained from the market. It was purified by crystallisation and dried in air.

Starch
Corn starch was also obtained from the market and washed with water and dried in air.

Dilute HCl
0.20M HCl was obtained by diluting 10.1M "Analar" grade HCl and standardised against sodium carbonate.

Acetic acid
16.67M CH_3COOH was used. It was standardised using standard NaOH solution.

Purification and concentration of the lake salt by crystallisation
100.0g of the sample of lake salt was dissolved in minimum amount of water and filtered. The filtrate was further concentrated by evaporation over a steambath and allowed to cool. Crystallisation was allowed to continue overnight. The crystals were then filtered and washed with ethanol and dried in air.

Determination of carbonate-bicarbonate ratio in the crystallized fraction

0.30g of the crystallized fraction was dissolved in minimum distilled water. The solution was titrated with 0.2M HCl using phenolphthalein and methyl orange indicators successively in a double end point titration. The percentage of bicarbonate and carbonate in the fraction was calculated. Typical average results of triplicate determinations are shown in Table 1 for the first crop of crystals obtained from a selected sample.

Acid conversion of carbonate to bicarbonate in the fractions
5.0g of the crystallized fraction was dissolved in a minimum amount of water. 2.10cm^3 of 10.10M HCl was added very carefully with stirring. The mixture was gently heated to concentrate it and then allowed to cool. Crystals were formed which were filtered out, washed and dried in air before weighing. The results are also shown in Table 1 as averages of three determinations.

Another 5.0g of the crystallized sample fraction was dissolved in minimum water and reacted with 1.3cm^3 of 16.67M CH_3COOH. The mixture was treated as previously done with HCl to obtain crystals which were dried and weighed.

The volume of acid used in both cases contains the equivalent amount of the acid required to convert the sodium carbonate present in 5.0g of the fraction to the bicarbonate according to their stoichiometric equations.

In each case the bicarbonate to carbonate ratio of the product was determined by titrating 0.20g of each product against 0.20M HCl using phenolphthalein and methyl orange successively as indicators. The results are also shown in Table 1 as averages of three determinations.

Table 1: Percentage of $CO_3^{=}$ and HCO_3^- in fractions

	% in sample	
	CO_3^{2-}	HCO_3^-
First crystallized fraction	44.77±0.37	35.10±0.44
HCl treated fraction	5.30±0.80	88.44±1.05
CH_3COOH treated fraction	14.13±1.20	74.94±1.39

Analysis of commercial baking powder
A brand (Royal Active) of baking powder was analysed for the relative amounts of the acid ingredient and starch used. The acid ingredient was determined as aluminium by the gravimetric method[9]. It was then calculated as the amount of alum present. The amount of sodium bicarbonate was found by difference. The results are shown in Table 2 as averages of three determinations.

Formulation of baking powder
Using the sodium bicarbonate obtained from lake

salt as leavening agent, a baking powder was formulated using alum as acid ingredient and starch as filler. The formulation was done to simulate the composition of the commercial brand as shown in Table 2. The constituents were ground together and mixed thoroughly.

Evaluation and properties of the formulated baking powder

A little of the formulated baking powder was put in a beaker and a small amount of water added. The experiment was also performed with the commercial baking powder. The formulated and commercial baking powders were used in baking and the products compared by observing various parameters such as volume gain, physical appearance and taste.

Table 2: Composition of baking powder sample

Constituent	Percentage
Sodium bicarbonate	30.00
Alum	37.60
Starch	32.40

RESULTS AND DISCUSSION

Extraction of bicarbonate

The percentage of carbonate in the fraction was approximated to 45% when calculating the amount of acid required to convert the carbonate present in the fraction to the bicarbonate. Concentrated acid was used in order to minimize the volume of solution applied for crystallisation. Bicarbonate level was enhanced 2.52-fold and 2.14-fold by HCl and CH_3COOH respectively.

Properties of the formulated baking powder

Both the commercial and formulated baking powders gave very similar gentle frothing when in contact with water. The volume gain for the baked product obtained by using the formulated baking powder was about 35% while that using commercial powder was about 36%. Both products had very similar brownish appearance and they all tasted similar. The products also retained their shapes and sizes after storage for three days.

CONCLUSION

The reaction of the carbonate present in lake salt with acid can be carefully controlled to permit the concentration and subsequent isolation of a solid product very rich in bicarbonate. This product could be used for making baking powders and baked product which could be very similar to those obtained with commercial baking powder.

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