CHAPTER VI

Isolation of potassium carbonate from banana plant (*Musa balbisiana*)

VI.1 Introduction

Potassium carbonate (K$_2$CO$_3$) is a white, deliquescent inorganic salt, soluble in water (insoluble in alcohol), which forms a strongly alkaline solution. The hydrated form occurs as small, white, translucent crystals or granules.

Potassium carbonate was first identified in 1742 by Antonio Campanella.$^1$ It is the primary component of potash and the more refined pearl ash or salts of tartar. Historically, pearl ash was created by baking potash in a kiln to remove impurities. The fine, white powder remaining was the pearl ash. The first patent issued by the US Patent Office was awarded to Samuel Hopkins in 1790 for an improved method of making potash and pearl ash. Other terms used for potassium carbonate are

1. Carbonate of potash
2. Dipotassium carbonate
3. Dipotassium salt
4. Pearl ash
5. Potash
6. Salt of tartar
7. Salt of wormwood

The physical properties of potassium carbonate are

- Molar mass : 138.205 g/mol
- Melting point : 891 °C, 1164 K, 1636 °F
- Boiling point : decomposes
- Solubility in water : 112 g/100 mL (20 °C)
  : 156 g/100 mL (100 °C)

VI.1.1 Uses of potassium carbonate

In the late 18th century North America, before the development of baking powder, pearl ash was used as a leavening agent in quick breads.$^2$ Potassium carbonate
is used in the production of soap and glass. The potassium carbonate market is divided between the glass industry and other numerous applications.

1. Potassium carbonate is used to make specialty glasses, such as television screens, cathode ray tubes, and optical lenses. Video and television screens account for 44% of potassium carbonate usage, while specialty glass and ceramics use 10%. The main reason that relatively expensive potassium carbonate is used in place of soda ash in glass applications is that it is more compatible with the required lead, barium and strontium oxides. These specialty glasses possess the improved properties of greater electrical resistivity, higher index of refraction, greater brilliance or luster, lower softening point and a wide temperature working range. In addition, potassium carbonate allows improved behavior of many colorants in glass.  

2. Potassium carbonate is used as fertilizer, provides plants with the potassium they need to stay healthy and grow.

3. Potassium carbonate is used in the chemical industry, where it is used as a raw material to make other chemical compounds, potassium silicate being the most common. It may be used as a mild drying agent where other drying agents, such as calcium chloride and magnesium sulfate, may be incompatible. It is mixed with distilled water to make a safer electrolyte for oxyhydrogen production than potassium hydroxide, the more commonly used electrolyte.

4. Smaller amounts of potassium carbonate are still used for what was once its major application: the manufacture of soap. Potassium soaps (made from potassium carbonate) have some characteristics different from more common sodium soaps (made from sodium carbonate). They tend to be softer or even liquid and better able to create suds in water that contains a high concentration of minerals.

5. Potassium carbonate is used for glazes in the making of pottery.

6. It is used in the manufacture of pigments and printing inks.

7. It is used as an additive in certain food products, chocolate being one example.

8. Potassium carbonate softens hard water. Aqueous potassium carbonate is also used as a toxin-free cleaning agent and is also called electrolyzed or
“engineered” water. The water softening properties of the potassium carbonate add to water's natural ability to remove dirt and sanitize areas.

9. Potassium carbonate is sometimes used as a buffering agent in the production of mead or wine.

10. It may also be used to dry some ketones, alcohols, and amines prior to distillation.5

11. Potassium carbonate was often used to harden rosin in varnish recipes, especially for use on musical instruments. It is also used to emulsify wax to make Punic wax.

12. It is used for the tanning and finishing of leather and the dyeing, washing, and finishing of wool; and

13. It is an ingredient in welding fluxes, and in the flux coating on arc-welding rods.

VI.2 Materials and methods

VI.2.1 Materials

The fibre of the banana plant (Musa balbisiana) pseudo-stem was the material from which potassium carbonate was isolated. The procedure of burning of dry fibre and preparation of water extract from the ash was same as described in section IV.2.1 and IV.2.2.1.

VI.2.2 Methodology

The detection and estimation of the chemical constituents in the aqueous extract of the leaf sheath fibre ash were discussed in the Chapter IV. The two major constituents present are $K^+$ and $CO_3^{2-}$.

VI.2.2.1 Determination of composition of solid obtained from aqueous extract of fibre ash

500 ml of aqueous extract derived from 25 g of banana pseudo-stem fibre ash was taken in a cleaned 1000 ml beaker and evaporated slowly over an electric hot plate. When the volume of the solution became 60 ml, whole the volume was transferred into a pre-weighed 100 ml beaker. Again the solution was evaporated to dryness to yield a white solid. The solid so obtained was kept in a furnace at temperatures of 250 to
350 °C for dehydration and weighed. The composition of the solid was determined from the concentration of the ions in the aqueous extract of fibre ash by simple mathematical back calculation (Table VI.1 & Table VI.2).

**VI.2.2.2 Isolation of high grade potassium carbonate from aqueous extract of fibre ash**

From the study of the solubility product of salts, it is seen that the solubility product of sodium carbonate (K$_2$CO$_3$) is 2130 which is very high with comparison to the solubility product of sodium chloride (37.3), potassium chloride (21.7) and sodium carbonate (1.2) at 25°C. The concentration of major constituents in the water extract derived from fibre ash is as follows (in terms of mol/L).

\[
\begin{align*}
[Na^+] &= 0.0203 \text{ mol/L} & [K^+] &= 0.2048 \text{ mol/L} \\
[Cl^-] &= 0.0137 \text{ mol/L} & [CO_3^{2-}] &= 0.1050 \text{ mol/L} \\
[NO_3^-] &= 0.0041 \text{ mol/L} & [PO_4^{3-}] &= 0.0011 \text{ mol/L}
\end{align*}
\]

From the relationship between solubility product and ionic product of salts, it can be predicted that if the volume of the water solution is reduced to 2.5% of its original volume, the ionic product will exceed the solubility product of sodium carbonate (Na$_2$CO$_3$) only, as a result of which Na$_2$CO$_3$ will precipitate out. But potassium carbonate (K$_2$CO$_3$) has very high solubility product, so the ionic product cannot overcome its solubility product at this concentration. Due to the very low concentration of chloride ion (Cl$^-$), the ionic products cannot cross the solubility products of sodium chloride and potassium chloride. Therefore potassium carbonate will remain in the solution with some Na$^+$ and Cl$^-$ ions. Moreover, at this stage, almost all trace metals will precipitate either as phosphate or as carbonate salt because their solubility products as carbonate or phosphate are very small. Remembering this principle, the separation of potassium carbonate from its solution by fractional crystallization process was performed following the procedure as describe below.

For isolation of K$_2$CO$_3$, 1000 ml kolakhar prepared by dissolving 50 g of ash derived from fibre of leaf sheath of *Musa balbisiana*, as described above (IV.2.2.1) was
taken in a 1000 ml beaker and was evaporated slowly by heating over an electric hot plate. When the volume of the solution reduced to nearly 80 ml, the solution was transferred into a pre-weighed clean 100 ml beaker to create a favorable environment for crystallization. The solution was evaporated slowly again and the volume was reduced to 20 ml (2.0% of its original volume). The solution was allowed to cool to room temperature and after sometimes a white solid appeared. The supernatant liquid was separated carefully with a dropper and the solid residue was dried over a low temperature electric hot plate, cooled to room temperature in a desiccator and weighed. The solid so obtained is termed as 1\textsuperscript{st} crop.

The supernatant liquid was transferred to a pre-weighed 100 ml beaker, and evaporated to dryness over a low temperature electric hot plate. The solid mass along with the beaker was dried in a hot air oven at 200°C for an hour for dehydration, and then allowed to cool down to room temperature in a desiccator and weighed. The solid mass so obtained is termed as 2\textsuperscript{nd} crop.

The solid of the 1\textsuperscript{st} crop (0.9178 g) was dissolved in 100 ml distilled water in a 100 ml volumetric flask and the solid of the 2\textsuperscript{nd} crop (14.9318 g) was dissolved in 1000 ml distilled water in a 1000 ml volumetric flask. The quantity of the constituents in the solution of 1\textsuperscript{st} and 2\textsuperscript{nd} crops were determined by chemical and spectrometric methods as described in the sections II.3.3 and IV.2.2.3.1 and the results are given in the Table VI.3, Table VI.4, Table VI.5 and Table VI.6.

VI.3 Results and discussion

The weight of the anhydrous solid isolated from the aqueous extract of 25 g of fibre ash was 7.9248 g and the compositions of each major constituent are shown in Table VI.1 and the trace metals in Table VI.2.

From the Table VI.1 and Table VI.2, it is observed that 25 g of banana pseudo-stem fibre ash gives 7.9248 g of solid mass (31.70% of ash), i.e., almost one third of the total mass of the ash. The solid, so obtained, contains highest percentage of potassium as cation (50.39%) and highest percentage of carbonate (CO\textsubscript{3}\textsuperscript{2-}) as anion (39.75%). The remaining part consists of Na\textsuperscript{+} (2.95%), Cl\textsuperscript{-} (3.07%), NO\textsubscript{3}\textsuperscript{-} (0.16%), PO\textsubscript{4}\textsuperscript{3-} (0.67%) and trace metals.
Table VI.1: Percentage composition of the constituents in the solid obtained from water extract derived from fibre ash

<table>
<thead>
<tr>
<th>Entry</th>
<th>Chemical constituents</th>
<th>Quantity in gram</th>
<th>Quantity in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Na⁺</td>
<td>0.234</td>
<td>2.95</td>
</tr>
<tr>
<td>2</td>
<td>K⁺</td>
<td>3.993</td>
<td>50.39</td>
</tr>
<tr>
<td>3</td>
<td>Cl⁻</td>
<td>0.243</td>
<td>3.07</td>
</tr>
<tr>
<td>4</td>
<td>CO₃²⁻</td>
<td>3.150</td>
<td>39.75</td>
</tr>
<tr>
<td>5</td>
<td>NO₃⁻</td>
<td>0.013</td>
<td>0.16</td>
</tr>
<tr>
<td>6</td>
<td>PO₄³⁻</td>
<td>0.053</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Table VI.2: Amount of trace metals (mg/100g) in the solid obtained from aqueous extract of fibre ash

<table>
<thead>
<tr>
<th>Entry</th>
<th>Trace metal</th>
<th>Quantity (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al</td>
<td>54.531</td>
</tr>
<tr>
<td>2</td>
<td>Cd</td>
<td>0.222</td>
</tr>
<tr>
<td>3</td>
<td>Co</td>
<td>4.687</td>
</tr>
<tr>
<td>4</td>
<td>Cr</td>
<td>0.580</td>
</tr>
<tr>
<td>5</td>
<td>Cu</td>
<td>0.524</td>
</tr>
<tr>
<td>6</td>
<td>Fe</td>
<td>41.236</td>
</tr>
<tr>
<td>7</td>
<td>Mg</td>
<td>3.672</td>
</tr>
<tr>
<td>8</td>
<td>Mn</td>
<td>0.334</td>
</tr>
<tr>
<td>9</td>
<td>Ni</td>
<td>5.054</td>
</tr>
<tr>
<td>10</td>
<td>Pb</td>
<td>0.296</td>
</tr>
<tr>
<td>11</td>
<td>V</td>
<td>2.202</td>
</tr>
<tr>
<td>12</td>
<td>Zn</td>
<td>3.356</td>
</tr>
</tbody>
</table>

The above experimental findings reveal that 25 g of ash derived from banana (Musa balbisiana) pseudo-stem can give as much as 7.065 g (28%) of potassium.
carbonate (K$_2$CO$_3$). Extending back these data to raw leaf sheath of the banana plant, it can be concluded that 5.65 kg raw leaf sheath can give 187.70 g dry fibre from which 7.065 g potassium carbonate can be isolated. Hence, 3.76% potassium carbonate by weight can be isolated from dry fibre. Results of fractional crystallization to isolate potassium carbonate in more pure form are shown in Table VI.3 and Table VI.4.

Table VI.3: Estimation of Na$^+$, K$^+$, Cl$^-$, CO$_3^{2-}$, NO$_3^-$ and PO$_4^{3-}$ in 1$^{\text{st}}$ and 2$^{\text{nd}}$ crops of fractional crystallization

<table>
<thead>
<tr>
<th>Entry</th>
<th>Sample code</th>
<th>Total weight (g)</th>
<th>Quantity (in g)</th>
<th>Total mass accounted for</th>
<th>g</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Na$^+$</td>
<td>K$^+$</td>
<td>Cl$^-$</td>
<td>CO$_3^{2-}$</td>
</tr>
<tr>
<td>1</td>
<td>1$^{\text{st}}$ crop</td>
<td>0.9178</td>
<td>0.2665</td>
<td>0.1306</td>
<td>0.2190</td>
<td>0.2012</td>
</tr>
<tr>
<td>2</td>
<td>2$^{\text{nd}}$ crop</td>
<td>14.9318</td>
<td>0.2011</td>
<td>7.8550</td>
<td>0.2653</td>
<td>6.1000</td>
</tr>
</tbody>
</table>

Analysis of the results shown in the Table VI.3 shows that out of the total soluble mass of 15.8496 g present in 50 g of ash (1000 ml water extract), 5.79% (0.9178 g) is recovered in the 1$^{\text{st}}$ crop and the rest 94.21% (14.9318 g) in the 2$^{\text{nd}}$ crop. Major parts of K$^+$ (98.36%) and CO$_3^{2-}$ (96.81%) are found in the 2$^{\text{nd}}$ crop whereas major parts of Na$^+$ (56.99%), Cl$^-$ (45.22%) and PO$_4^{3-}$ (67.89%) are found in the 1$^{\text{st}}$ part crop. It is evident that Na$^+$ appears in higher percentage (24.46%) followed by anion K$^+$ (14.23%) in the 1$^{\text{st}}$ crop (Table VI.4) whereas Cl$^-$ and CO$_3^{2-}$ are present almost in equal percentage, 23.86% and 21.92% respectively. On the other hand most of the 2$^{\text{nd}}$ crop is shared by K$^+$ and CO$_3^{2-}$ ions, 52.80% and 40.85% respectively. Data in the table VI.3 also indicate that K$_2$CO$_3$ content in the 1$^{\text{st}}$ crop is 25.18% against 93.07% in the 2$^{\text{nd}}$ crop. Thus the process described in this section for isolation of K$_2$CO$_3$ is a viable process.
Table VI.4: Quantities of Na$^+$, K$^+$, Cl$^-$, CO$_3^{2-}$, NO$_3^-$ and PO$_4^{3-}$ in 1$^{st}$ and 2$^{nd}$ crops of fractional crystallization

<table>
<thead>
<tr>
<th>Entry</th>
<th>Chemical constituents</th>
<th>Quantities in % in the 1$^{st}$ crop</th>
<th>Quantities in % in the 2$^{nd}$ crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Na$^+$</td>
<td>24.46</td>
<td>1.35</td>
</tr>
<tr>
<td>2</td>
<td>K$^+$</td>
<td>14.23</td>
<td>52.80</td>
</tr>
<tr>
<td>3</td>
<td>Cl$^-$</td>
<td>23.86</td>
<td>1.78</td>
</tr>
<tr>
<td>4</td>
<td>CO$_3^{2-}$</td>
<td>21.92</td>
<td>40.85</td>
</tr>
<tr>
<td>5</td>
<td>NO$_3^-$</td>
<td>BDL</td>
<td>0.17</td>
</tr>
<tr>
<td>6</td>
<td>PO$_4^{3-}$</td>
<td>7.65</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Abundance of trace metals in 1$^{st}$ and 2$^{nd}$ crops are shown in Table VI.5. In this table it is seen that major part of the trace metals appear in the 1$^{st}$ crop; as the result the isolation process enhances the purity of K$_2$CO$_3$ in the 2$^{nd}$ crop.

From the study of the Table VI.5 it is seen that among the trace metals, iron has highest quantity (163.434 mg/100g) in the 1$^{st}$ crop followed by Al (108.956 mg/100g). On the other hand, highest quantity of Al (51.166 mg/100 g) is found in the 2$^{nd}$ crop followed by Fe (33.727 mg/100 g). Major parts of all trace metals go into the 1$^{st}$ crop except Al and Fe. About 11.60% of total quantity of Al is retained in the 1$^{st}$ crop and the remaining 88.40% by 2$^{nd}$ crop. On the other hand, 22.95% of total Fe is separated in the 1$^{st}$ crop and 77.05% in the 2$^{nd}$ crop.

It has been observed that, banana pseudo-stem juice has no carbonate content, it has considerable amount of oxalate (described in Chapter II). On the other hand, the water extract of pseudo-stem fibre ash (kolakhar) contains high amount of carbonate, no oxalate. The presence of high amount of carbonate and absence of oxalate in kolakhar implies that oxalate is converted to carbonate in the process of burning of banana pseudo-stem fibre. Hence oxalate content may be the responsible for the concentration of carbonate in kolakhar. Therefore, to know the factors on which concentration of carbonate in kolakhar depends, an attempt was made to study the effect of temperature on the conversion of oxalate to carbonate.
Table VI.5: Amount of trace metals in the 1st and 2nd crops

<table>
<thead>
<tr>
<th>Entry</th>
<th>Metal</th>
<th>1st crop (mg/100 g)</th>
<th>2nd crop (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al</td>
<td>108.956</td>
<td>51.166</td>
</tr>
<tr>
<td>2</td>
<td>Cd</td>
<td>0.115</td>
<td>0.005</td>
</tr>
<tr>
<td>3</td>
<td>Co</td>
<td>3.424</td>
<td>0.788</td>
</tr>
<tr>
<td>4</td>
<td>Cr</td>
<td>1.303</td>
<td>0.067</td>
</tr>
<tr>
<td>5</td>
<td>Cu</td>
<td>6.842</td>
<td>0.134</td>
</tr>
<tr>
<td>6</td>
<td>Fe</td>
<td>163.434</td>
<td>33.727</td>
</tr>
<tr>
<td>7</td>
<td>Mg</td>
<td>32.687</td>
<td>1.888</td>
</tr>
<tr>
<td>8</td>
<td>Mn</td>
<td>3.813</td>
<td>0.121</td>
</tr>
<tr>
<td>9</td>
<td>Ni</td>
<td>49.030</td>
<td>2.351</td>
</tr>
<tr>
<td>10</td>
<td>Pb</td>
<td>0.559</td>
<td>BDL</td>
</tr>
<tr>
<td>11</td>
<td>V</td>
<td>21.791</td>
<td>1.005</td>
</tr>
<tr>
<td>12</td>
<td>Zn</td>
<td>32.689</td>
<td>1.688</td>
</tr>
</tbody>
</table>

VI.4 Origin of carbonate ion in *kolakhar* derived from banana plant pseudostem fibre

Oxalates are common constituents of plants and are found in the majority of plant families, functioning in high capacity calcium regulation and protection against herbivory. They occur in the forms of oxalic acid, soluble salts of potassium, sodium and magnesium, and as the insoluble salt of calcium. The amount of oxalate in plants ranges from a few percent up to 80% of the total weight of the plant. These compounds are usually accumulated within the vacuoles of plant cells, although crystalline calcium oxalate forms within the cells walls of some plants. Since plant cells generally have a large vacuolar compartment, often from 75-90% of the cell volume, there is the massive oxalate accumulation potential.

It is reported that oxalic acid and oxalates was detected in varying quantities in all parts of most plants, leaves, leaf stalks, flowers, tubers and roots. The oxalate content of plants can vary according to their age, the season, the climate and the type of soil. In some plants, such as rhubarb, oxalate content tends to increase as the plants mature, whereas, in other plants, e.g. spinach, sugar beet leaves, and bananas, there is a
large increase in oxalate content during the early stages of development, followed by a decrease as the plants mature.

It is well established that plants are capable of metabolizing oxalate by observing fluctuations in oxalate concentrations under certain conditions, and enzymes degrading oxalic acid have been detected in numerous plants. Several functions have been proposed for the presence of oxalic acid in plants. One of the possible functions is that oxalic acid might be related to ionic balance, since it can combine with various plant ions to form soluble or insoluble compounds. It has been reported that oxalate synthesis occurred to balance the excess of inorganic cations (represented by $K^+$, $Na^+$, $NH_4^+$, $Ca^{2+}$ and $Mg^{2+}$) over anions (represented by $NO_3^-$, $Cl^-$, $H_2PO_4^-$, $SO_4^{2-}$) normally present in the plant, the ability of nitrate ions and chloride ions to inhibit oxalic acid oxidase activity in Beta vulgaris. Previous research supports the idea that oxalate does not originate from the same source in all plants. Many plants accumulate significant soluble salts of oxalate in addition to crystalline calcium oxalate, and soluble and insoluble oxalates could originate from different pathways. In higher plants, calcium oxalate typically develops within intravascular membrane chambers of specialized cells. The complex cellular features associated with calcium oxalate crystallization indicate that it constitutes a biologically controlled process, analogous to calcification processes that shape bones, teeth, and shells in animals.

An understanding of factors involved in increased oxalate biosynthesis in plants is necessary for improving the nutritional value of certain foods. In plants, oxalates occur as metabolic end products of the oxaloacetate, glycolate and glyoxalate pathways. An oxaloacetate hydrolase which cleaves oxaloacetate into acetate and oxalate is found in red beets and spinach. Glycolate oxidase catalyses an oxygen-
dependent oxidation of glycolate to glyoxalate and hydrogen peroxide in plants. Further oxidation of glyoxalate leads to oxalate through either non-enzymatic or in the presence of catalase. A well-known plant antioxidant, ascorbic acid, has also been shown to be an oxalic acid precursor capable of large scale oxalic acid synthesis. Increased ascorbic acid turnover in plants, due to factors such as the environment, may very well lead to raised oxalate content. It has already been shown that factors such as plant nutrition and different season cultivars can influence oxalate content, however environmental stresses, such as the effects of UV-B, have not yet been explored.

VI.4.1 Effect of burning temperatures of banana plant pseudo-stem fibre on carbonate content in ash

This study is carried out to examine whether the concentration of carbonate in kolakhar depends on the temperature at which the fibre is burnt. To study the temperature dependent nature of carbonate content in kolakhar, banana (Musa balbisiana) pseudo-stem fibre (after separation of juice) was burnt at different temperatures viz. 300°C, 400°C, 500°C, 600°C in a muffle furnace (Lab Tech) and in open air.

Procedure:

First of all, a large silica crucible of appropriate size was cleaned and dried in a hot air oven at temperature 150°C to 200°C for an hour and allowed to cool in a desiccator to room temperature and weighed. The process of heating and cooling were repeated until a constant weight of the crucible was recorded. After getting a constant weight of the crucible, well dried 6.000 g fibre of banana (Musa balbisiana) pseudo-stem was taken in it and burnt in a muffle furnace at 300°C. The temperature of the furnace was raised at the rate of 10°C/min and kept at 300°C for an hour. After half an hour, the crucible was taken out from the furnace and cooled in a desiccator to normal temperature and weighed. The ash so obtained was taken in a 250 ml conical flask; added 100 ml distilled water and stirred magnetically for 30 minutes. The mixture was filtered and the filtrate was made up to 100 ml in a volumetric flask. Then carbonate content was estimated by the procedure as described in the Chapter IV, Section IV.2.2.3.1. The same procedure was repeated for the preparation of samples at temperatures 400°C, 500°C and 600°C.
Table VI.6: Carbonate content in kolakhar derived from banana plant pseudo-stem fibre when burned at different temperatures

<table>
<thead>
<tr>
<th>Entry</th>
<th>Wt. of dry fibre (g)</th>
<th>Temperatures (°C)</th>
<th>Wt. of ash obtained (g)</th>
<th>Colour of kolakhar</th>
<th>Total wt. of carbonate (g)</th>
<th>% carbonate in ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.000</td>
<td>300</td>
<td>2.0944</td>
<td>Deep brown</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>6.000</td>
<td>400</td>
<td>0.8703</td>
<td>Brown</td>
<td>0.07247</td>
<td>8.33</td>
</tr>
<tr>
<td>3</td>
<td>6.000</td>
<td>500</td>
<td>0.6545</td>
<td>Colourless</td>
<td>0.0595</td>
<td>9.09</td>
</tr>
<tr>
<td>4</td>
<td>6.000</td>
<td>600</td>
<td>0.6374</td>
<td>Colourless</td>
<td>0.0567</td>
<td>8.89</td>
</tr>
<tr>
<td>5</td>
<td>6.000</td>
<td>Burnt in open air</td>
<td>0.7341</td>
<td>Light brown</td>
<td>0.0925</td>
<td>12.60</td>
</tr>
</tbody>
</table>

Results shown in the Table VI.6 indicates that the quantity of carbonate obtained from 6.000 g dry fibre of banana pseudo-stem decreases with increasing temperature. Highest quantity of carbonate was obtained when the fibre was burnt in open air. In case of burning at temperature 300°C, the colour of the khar was deep brown for which it was very difficult to determine the carbonate content by titrimetric method using methyl orange indicator. The study of the colour of khar and the weight of ash at different temperatures reveal that the fibre might be burnt in open air at a temperature in between 400°C and 500°C. The deep brown colour of khar at 300°C indicates the presence of large excess of carbon in it and high weight of ash at this temperature indicates the incomplete combustion of fibre. Colour of khar changes from brown (at 400°C) to light brown (in open air) indicates the removal of carbon from ash at higher temperatures. The weight loss of ash may be due to the thermal decomposition of sodium oxalate (Na$_2$C$_2$O$_4$) and potassium oxalate (K$_2$C$_2$O$_4$) into their respective carbonate compounds, and as a result of which large increase of carbonate content in khar. The decomposition temperature range of Na$_2$C$_2$O$_4$ is 250°C to 270°C$^{24}$ and K$_2$C$_2$O$_4$ is 346.9°C to 420°C$^{25}$ and K$_2$CO$_3$ remain stable up to 850°C$^{18}$. The weight loss of ash at temperature 500°C due to removal of carbon and thermal decomposition of calcium oxalate (CaC$_2$O$_4$) into calcium carbonate (CaCO$_3$). Decomposition range of CaC$_2$O$_4$ is 450°C to 500°C$^{26}$ and Na$_2$CO$_3$ starts at a temperature above 400°C.$^{27}$ Decomposition of iron carbonate occurs at a temperature below 450°C$^{28}$ and also decomposition of aluminum carbonate is an important factor of weight loss. At temperature 500°C and above weight loss of ash
and decrease in carbonate content is due to decomposition of some carbonates. The insolubility of calcium carbonate in water and decomposition of iron carbonate and aluminum carbonate into respective oxide causes the decrease of carbonate in kharat 500°C. At 600°C, the colour of kharis colorless due to absence of carbon particle, and weight loss arises from the decomposition of unstable carbonates and removal of volatile compounds. Due to the high concentration of carbonate, calcium carbonate was not found in khar as solubility of calcium carbonate is very low (0.00003932 g/100g). Therefore, Ca²⁺ ions were not found in khar derived from fibre.

\[
\begin{align*}
  \text{Na}_2\text{C}_2\text{O}_4 & \xrightarrow{250°C-270°C} \text{Na}_2\text{CO}_3 \xrightarrow{>400°C} \text{Na}_2\text{O} \\
  \text{K}_3\text{C}_2\text{O}_4 & \xrightarrow{346.9°C-420°C} \text{K}_2\text{CO}_3 \xrightarrow{850°C} \text{K}_2\text{O} \\
  \text{CaC}_2\text{O}_4 & \xrightarrow{450°C-500°C} \text{CaCO}_3 \xrightarrow{635°C-865°C} \text{CaO}
\end{align*}
\]

Table VI.6 also shows that the highest carbonate continent was found in 6.000 g of dry fibre burnt in open air. The light yellow colour of khar may be due to the presence of carbon particles, and ferric ions. The decomposition of oxalate compounds are strongly affected by the atmospheric conditions. The supply of oxygen gas or the ease of carrying off the resultant gases plays an important role in the decomposition mechanism. The decomposition of potassium oxalate in a free atmosphere proceeds through two stages.

\[
\begin{align*}
  \text{K}_2\text{C}_2\text{O}_4 & \rightarrow \text{K}_2\text{CO}_3 + \text{CO} \\
  2\text{K}_2\text{C}_2\text{O}_4 & \rightarrow 2\text{K}_2\text{CO}_3 + \text{C} + \text{CO}_2
\end{align*}
\]

This may be the one of the causes of getting high amount of carbonate in fibre burned in open air. Therefore, burning of banana pseudo-stem fibre in open air is the best method to produce optimum amount of carbonate from fibre.

VI.5 Conclusion
Potassium carbonate is an important chemical substance for the use not only in industry but also in pharmaceutical and agricultural sector. There is practically no source of potassium carbonate in nature except very minor source in African lakes and Dead Sea. Generally it is industrially produced from potassium chloride which is expensive and energy consuming process.

Banana plant may be a good source of potassium carbonate. Considerable amount of potassium carbonate can be isolated from banana pseudo-stem fibre ash. Burning of fibre in open air is the most effective process from where maximum quantity of carbonate can be isolated. The source of carbonate might be the oxalate content in plant’s cell. In plants, oxalates occur as metabolic end products of the oxaloacetate, glycolate and glyoxalate pathways.

From the water extract of banana pseudo-stem fibre ash, a white solid can be isolated which is 31.70% of the ash and it contains 89.15% K₂CO₃. Applying fractional crystallization process the percentage of K₂CO₃ can be increased in the product up to 93.07%. Thus, banana plant is a viable and renewable source of potassium carbonate.
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