PART -2
1. INTRODUCTION

The colour of sugar crystal depends on various factors viz. quality of seed crystals and colour of the syrup in which they grow. Inclusion of even a small quantity of colouring matters in the crystal can degrade the quality of sugar. Once the colour-contributing constituents are embedded with the crystals during their growth in boiling stage, they cannot be eliminated. In centrifugation process, only removal of the film of liquor (molasses) adhering on the surface of the crystals takes place. Thus, due to the adverse effect of colorant, on quality as well as quantity of sugar produced it becomes important to remove them up to maximum extent in the process of clarification to get the juice of high purity and better transparency.

Efforts are therefore made for maximum removal of these colouring matters or converting them into their colourless or reduced forms during clarification. The removal may occur either by way of precipitation and coagulation, or by adsorption on the surface of precipitate formed during clarification reaction. By precipitation and coagulation, the removal of colloidal impurities of cane juice occurs, where as colorants are removed during the process of adsorption. The elimination during the process of clarification has been a fascinating subject and many workers have made detailed study. Ramaih et al.\textsuperscript{1,2} studied the elimination of potassium during different clarification reactions and suggested that potassium partially gets
adsorbed on the surface of precipitating solids during clarification and are hence removed. Like wise, a number of studies have been made by various workers to see the extent of removal of total colorants. Knostain Vukov\textsuperscript{3} studied adsorption of colorant of beet juice like melanin's and melanoidin on calcium carbonate and author observed that calcium carbonate showed different adsorption behaviour for both the colorants. Adsorption behaviour of CaCO\textsubscript{3} produced during second carbonation was thoroughly investigated by Dodek\textsuperscript{4,5} and suggested that a number of non-sugars impurities were removed by the process of adsorption. In refinery the phenolic acids and their complexes are removed by adsorption on carbon adsorbents or ion-exchange resin. Removal of polyphenols in defecation, sulphitation and carbonation processes of clarification has been studied by Sharma et al.\textsuperscript{6,7}. They have suggested that these compounds are removed by the way of adsorption on the surface of precipitates of calcium salts formed during clarification. These authors have also studied the removal of amino acids. The colouring matters in juice processing are eliminated to varying extent in different clarification processes, due to the non-availability of suitable method it is difficult to find out the exact amount of removal of any specific colorant in a particular process of clarification. Moreover the removal of colorants also depends on the surface properties of solids precipitated during clarification reaction. At the same time the extent of removal of colorants by adsorption also depends on the nature of other impurities present in cane juice.
2. OBJECTIVE OF WORK

The colouring matters either present originally or formed during the processing and storage of sugar causes various difficulties in the manufacturing process, as well as in the marketing of the final product i.e. sugar. In period of storage for long time sugar develops colour in hot humid atmosphere\(^8^9\). The process of development of colour is indeed slow and is however marked apparent to affect the sugar quality and therefore the prices of sugar.

In the above paragraph it has been realized that there is a great need to know the exact nature and chemistry of the colorants. In the present work, it is therefore, proposed to make an investigation about the colouring matters.
3. EXPERIMENTAL

3.1 Materials and equipments

For Study of adsorption of humic acid and its inhibition, following equipments and materials were used.

1. Flask: Wide mouth glass flask of 1.5 litre capacity.
2. An agitator: For homogeneous mixing supplied by Aldrich
3. Glass tube: Three glass tube (i) to suck in sugar solution (ii) to suck in powdered sugar for seed crystals (iii) to attach vacuum pump.
5. Thermometer: Temperature range (i) 0 to 100°C (ii) 0 to 200°C.
6. Water bath: Perfit India, accuracy 1°C.
7. Oil bath: Perfit India

An apparatus shown in fig.18 is used in order to carry adsorption experiment.

An apparatus illustrated in the figure 18 is used to carry adsorption experiments. ‘A’ is a wide necked glass flask of 1.5 lt. content ‘B’, an agitator, ‘C’, a glass tube to suck in sugar solution, to which non-sugar substrate to be adsorbed is added, ‘D’, a glass tube to a vacuum pump, ‘E’, a
glass tube to suck in powdered sugar for seed crystals; 'F', a thermometer, 'G', a water bath.

Figure 18 Adsorption experiment apparatus

3.2 Adsorption of caramel and humic acid during crystallization

3.2.1 Adsorption of caramel on sugar crystal

Preparation of caramel

Caramel was prepared by direct heating of sucrose in oil bath, 10gm of analar sucrose (Merck) was heated in dry test tube. The temperature of the oil bath was maintained at 210 ±5°C. The heating of sucrose in test tube was
continued for about 4-5 hrs. This time was found satisfactory to convert all the sucrose into caramel in the form of dark brown solid mass.

After complete caramelization the test tube was cooled down to the room temperature and the solid mass was removed by breaking the test tube. The brownish solid mass was dissolved in minimum amount of distilled water. The solution of solid caramel was acidic, which was neutralized by addition of dil. NaOH solution. The solution was dried in vacuum desiccator for further use.

Procedure
1.5g of caramel is added to 1 litre of 60% pure cane sugar solution, 350cc of this solution is sucked in the flask ‘A’ and evaporated in vacuo to about 73% solid. To this concentrated sugar solution, 2 g of powdered cane sugar is added as seed crystals, and after 3 minutes a small amount of 60% sugar solution prepared as above is sucked in, and the sugar crystals begin to grow as evaporation is continued.

Sucking in and evaporation of the solution are repeated until the whole solution is consumed (in about 2 hours) and cane sugar crystals grow to about 0.25 mm in length. The pressure in flask is about 50mm Hg and temperature of the vapour is 50°C. The flask content is poured into a small test centrifuge
and the crystals are separated from the mother liquor. The crystals are taken out and mixed well with 180cc of saturated solution of pure cane sugar, and then separated again from the wash liquor in the centrifuge. This washing procedure is repeated two times. Quantity of caramel adsorbed on crystals is estimated by spectrophotometric method.

3.2.2 Adsorption of humic acid on sugar crystal

3.98-23.8g of humic acid is added to a litre of 60% cane sugar solution. 350 ml of this solution is sucked in to the flask 'A' and evaporated in vacuum to about 73% solid. To this concentrated sugar solution, 2 g of powdered cane sugar is added as seed crystals and after 3 minutes a small amount of 60% sugar solution is sucked in, sugar crystals begin to grow, as evaporation is continued, further procedure of separation of crystals from mother liquor is same as in case of caramel and the quantity of humic acid adsorbed on sugar crystal is estimated by spectrophotometric method.

Adsorption of humic acid isolated from cane molasses

100 gm of molasses was diluted with 1 litre of water. The clarification of the diluted molasses is done by mixing the milk of lime (25 g of quick lime in 100ml of water).

This clarified molasses was heated for 1.5 hours at 70°C, lime was dissolved at once, but Ca-salts of sugar humic acid settled at the bottom. The
settled precipitate was collected by filtration and washed with 2 litres of limewater, thus sugar-humic acid was isolated by suspending the washed precipitate in water and blowing CO₂ gas in it, the filtered sugar-humic acid solution thus made, was added with basic lead acetate and acid was set free again by decomposing lead salts quantitatively, with H₂SO₄, the excess of the later being removed by adding Barium carbonate solution.

After filtration, sugar humic acid solution was concentrated and dried in vacuum desiccator the amount of the dry sugar-humic acid obtained is 4.5 gm.

Procedure
0.18 - 2.8 gm of humic acid is added to litre of 60% cane sugar solution and cane sugar crystals are produced in the same way as in case of caramel. The relation between the adsorbed quantity of humic acid and the quantity remaining in the mother liquor is illustrated in result and discussion.
4. EXPERIMENTAL

4.1.1 Apparatus and equipment

1. Spectrophotometer - Thermo spectronic UV-1
2. Electronic Balance - All the weight were carried out on Metllar

4.1.2 Chemical and materials

AR grade Sodium Sulphite, Sodium Carbonate, Sodium Phosphate, Potassium Sulphite, Potassium Carbonate, Potassium Phosphate, Calcium Sulphite, Calcium Carbonate, Calcium Phosphate supplied by Merck.

Humic acid - AR grade (loba Chemie) was utilized for preparation of Beer's curve.

4.2 Plot of Beer's curve

Stock solutions of humic acid (2000 ppm) were prepared in distilled water. The solutions were diluted with distilled water to known concentrations and their absorbance at 420 nm was observed. The dilution was continued to 10ppm concentration of each colorant and their corresponding absorbance at 420 nm were recorded. Curve between concentration of humic acid and absorbance were plotted to get the Beer's curve. Beer's curve was utilized to
to know the concentration of these colorants in solutions before or after adsorption.

**Adsorption of humic acid, on sodium sulphite, sodium carbonate, sodium phosphate at 25°C**

Varying amount (0-2.5g) of Na$_2$SO$_3$ was taken into different 25 ml measuring flask. 5.0 ml of distilled water was added in to each flask. Each flask was filled up to the mark with humic acid solution (0.01%) prepared in distilled water, solutions in flask were allowed to stand for ten minutes with vigorous shaking. This was done to get the maximum adsorption of humic acid on sodium sulphite.

The solutions were filtered with Whatman No. 1 filter paper to get the clear transparent solution. The absorbance of each filtered solution was observed at 420nm by Shimadzu spectrophotometer. The corresponding concentration of humic acid in each solution was determined with the help of Beer's curve. The concentration of humic acid in other solutions represented the amount of humic acid left in solution after adsorption on Na$_2$SO$_3$.

Similarly the adsorption of humic acid on different amount (0-2.5g), CaCO$_3$, Ca$_3$(PO$_4$)$_2$, CaSO$_3$ and K$_2$SO$_3$, K$_2$CO$_3$, and K$_3$PO$_4$ at 25°C were also studied.
Adsorption of humic acid on (i) Sodium Carbonate, Sodium Sulphite, Sodium Phosphate, (ii) Potassium Carbonate, Potassium Sulphite, Potassium Phosphate (iii) Calcium Carbonate, Calcium Sulphite, Calcium Phosphate, from Sugar Solution at 25°C

To study the effect of sugar, on adsorption of humic acid on varying amount of different salts, the solution of the colorant was prepared in 15% sugar solution, 0.01% solution of humic acid prepared in 15% sugar solution instead of their aqueous solution. The complete experiment was performed identically as given above.

Adsorption of humic acid on (i) Sodium Sulphite, Sodium Carbonate, Sodium Phosphate, (ii) Potassium Carbonate, Potassium Sulphite, Potassium Phosphate (iii) Calcium Carbonate, Calcium Sulphite, Calcium Phosphate, at 55° and 70°C.

To observe the effect of temperature on adsorption of humic acid, on sodium potassium and calcium salts, the adsorption studies were carried out in an ultra thermostat maintained at 55° and 70°C.

Procedure

First of all the temperature of thermostat was maintained at 55°C. 0-2.5g Sodium salt was taken into different 25ml measuring flask and these flasks were kept in thermostat, stock solution of colorant was also kept in thermostat. After maintaining the temperature at 55°C, each flask was made
upto the mark with colorant solution and kept for 10 minutes in thermostat with vigorous shaking. Thereafter the solutions were filtered and cooled separately. The absorbance of each solution was taken at 420 nm and their corresponding concentration was determined with the help of Beer's Curve.

The adsorption of humic acid on the aqueous solution of different sodium, calcium and potassium salt at 55° and 70°C were studied in the identical manner as described above.

**Adsorption of humic acid on constant amount of Sodium, Potassium and Calcium salts at 25°, 55°, 70°C**

To evaluate the adsorbing capacity of sodium, potassium and calcium for adsorption of humic acid, the adsorption of humic acid from their aqueous solutions of different concentration was carried out on constant amount of the salts. For this 1 gm sodium, potassium and calcium salts were used in each case. Aqueous solutions of humic acid (10ppm to 250 ppm) were prepared separately.

**Procedure**

In general 1g of sodium was taken in each ten, 25 ml measuring flaks. Each flask was filled upto the mark with colorant solution, each flask were allowed to stand for 10 minutes with occasional vigorous shaking to get the maximum adsorption of colorant on sodium salts in each. The solutions were
filtered separately by Whatman no. 1 filter paper and their absorbance was observed at 420nm. The concentration of colorant left in the solution was determined by Beer's curve by subtraction of these values from the original concentration of colorant in solution used, the amount of colorant adsorbed on 1g sodium salt in each case was determined.

In similar way the adsorption of humic acid was observed on 1 g potassium sulphite, potassium carbonate, potassium phosphate, calcium carbonate, sulphite and phosphate respectively at 25° , 55° and 70°C by maintaining the temperature in thermostat in the identical manner as described above.

Studies on the formation of colouring matter at different pH, temperature and concentration

Effect of pH on the absorbance (Colour), at 420 nm of known solution of colorant was observed. Experimental procedure were as follows—

To observe the independent effect of $H^+$ and on absorbance of colorant some test were made as given below.

A blank sample was first prepared with 10 ml colorant solution (500 ppm) and 10 ml distilled water. In first test solution 10 ml colorant solution was treated with 1 ml HCl (0.1M) and the volume was made 20 ml with
distilled water. The absorbance of this solution was determined at 420 nm. Such test were made in 10 different samples, and in which amount of colorant solution was kept constant that is 10 ml and absorbance of each test solution was determined accordingly at 420 nm.

Effect of $H^+$ ion on absorbance of colorant solution is studied at 55° and 70°C in identical manner, the temperature of solution were maintained in thermostat. Comparative absorbance of caramel, melanoidin and humic-acid in presence of $H^+$ ion at 25°, 55° and 70°C were determined.

Similarly, to observe the effect of (0.1 M NaOH) on the absorbance of colorant solution, identical experiment was performed as above, but in this case instead of (0.1m HCl), (0.1m NaOH) solution was used to make the solution alkaline.
5. RESULTS AND DISCUSSIONS

5.1 Adsorption of humic acid of different origins, on sugar crystals

1. Adsorption of humic acid prepared from cane molasses

![Adsorption Curve of Humic Acid](image)

Figure 19 Adsorption curve of humic acid isolated by cane molasses.

In fig. 19 the curve illustrates the adsorbed quantity of humic acid isolated from cane molasses, the adsorption on cane sugar crystal reaches quickly to its saturation point, thus in this case isothermal adsorption formula can not be applied. In the above case the adsorbed quantity of humic acid in 100 g of sugar crystal produced is 0.031 g out of 0.6 g/litres of humic acid in mother sugar solution.
2. Adsorption of sugar humic acid prepared from invert sugar solution

Fig. 20 shows the adsorption relation of sugar humic acid prepared by inverted sugar solution.

![Graph showing the adsorption curve of sugar-humic acid by sucrose crystals.](image)

**Figure 20 Adsorption curve of sugar-humic acid by sucrose crystals**

The adsorbed quantity of humic acid is in linear relation to the quantity remaining in mother liquor.

3. Adsorption of caramel by cane sugar crystal

The fig. 21 illustrates the concentration of caramel in mother sugar solution and adsorption by cane sugar crystals.
The maximum quantity of caramel (g) in mother liquor is 11.668 g/ltr and the quantity of caramel adsorbed by 1 mole of sugar crystal (349 g sugar crystals) is 0.342 g.

5.2 Effect of pH on adsorption of colouring matter in cane sugar crystals

The quantity of adsorbed substances in cane sugar crystals is remarkably influenced by pH value of the solution in which adsorption occurs, the pH value of mother liquor, therefore has an important relation to the quality of cane sugar products.
**Adsorption of caramel:** As illustrated in fig. 22 the adsorbed quantity of caramel increases with pH values of the solutions.

![Graph](image)

**Figure 22** Adsorbed quantity of caramel and pH of mother sugar solution

It reaches to its maximum at pH 7, and begins to decrease with further rise of pH. 6.0g of caramel is added to 1 litre of 60% cane-sugar solution and pH of each solution was controlled to the required value, by adding caustic soda solution in one case, and by adding lime water in the other. Cane sugar crystals produced from such solution, and the adsorbed quantity of caramel in them is examined.

**Adsorption of sugar humic acid prepared from invert sugar:** The adsorbed quantity of humic acid in cane sugar crystals, which are produced
from the solution prepared as mentioned, decreases with pH rise of solutions as shown in fig.23. The quantity of humic acid adsorbed on cane sugar crystal decreases with increase in pH of the solution, consequently the colour value used for monitoring the concentration of humic acid on sugar also decreases with increase in pH.

![Figure 23 Adsorption of sugar-humic acid and pH of mother solution](image)

The colour value at 420 nm was recorded. 5.7 g of humic acid is added to 1 litre of 60% cane sugar solution and pH of the solution is controlled to the required value by adding NaOH solution.

**Adsorption of humic acid isolated from cane sugar molasses:** The adsorbed quantity of humic acid in cane sugar crystals produced decreases
rapidly with pH rise of the mother solutions and at pH 10 reaches to almost zero as shown in fig. 24.

![Figure 24 Adsorption of humic acid isolated from molasses and pH of mother solution](image)

0.7gm of humic acid is added to 1 litre of 60% cane sugar solution, and pH of the solution thus prepared is controlled to the desired value, by adding caustic soda solution.

It may be conclude from the above observation, that all the colored substances in juice of cane sugar factory are adsorbed more by sugar crystals, as pH values of mother solution decreased. However, it is worth while to mention here that the appearance of sugar obtained from the carbonation. Syrup of pH
value 5 is always better than sugars from syrup of pH 9, while if the colour content of the two kinds of sugar's is examined in water solution, the color of the sugar from syrup of pH 5 is 12% more than that from syrup of pH 9.

5.3 Adsorption of humic acid on monovalent and bivalent salts

Beer's curve of humic acid are shown in fig. 25 shows the straight line, which suggests that humic acid obeys the Beer's law, at 420nm the absorbance of 40 ppm solution of humic acid is 0.08, which increases linearly with concentration, on raising the concentration up to 200 ppm. At 200 ppm the absorbance was recorded to be 0.39. The variation is linear upto 300ppm i.e.
Beer's. This Beer's plot was used for determination of the concentration of humic acid in the various experiments conducted for finding out the amount of humic acid.

5.3.1 Adsorption of humic acid on $\text{Na}_2\text{SO}_3, \text{Na}_2\text{CO}_3, \text{Na}_3\text{PO}_4$ at 25°C

Percentage of humic acid adsorbed on different amounts of $\text{Na}_2\text{SO}_3$, $\text{Na}_2\text{CO}_3$, $\text{Na}_3\text{PO}_4$ at 25°C is shown in fig 26. It is observed that minimum amount of humic acid is adsorbed on $\text{Na}_2\text{SO}_3$, whereas the adsorbability of $\text{Na}_3\text{PO}_4$ is better among all the three sodium salts, on 2m mole of $\text{Na}_2\text{SO}_3$, $\text{Na}_2\text{CO}_3$, $\text{Na}_3\text{PO}_4$ adsorption of 4, 15, and 20 ppm humic acid is observed. These values increase with increasing amount of sodium salts to a certain limit. Maximum adsorption of 20%, 25% and 30% humic acid is observed on 18, 20 and 8m moles $\text{Na}_2\text{SO}_3$, $\text{Na}_2\text{CO}_3$, $\text{Na}_3\text{PO}_4$ respectively.

Adsorption of humic acid on $\text{Na}_2\text{SO}_3$ at 25°C

Adsorption of humic acid, on varying amount of $\text{Na}_2\text{SO}_3$ at 25°C is shown in fig. 26. On 2m mole of $\text{Na}_2\text{SO}_3$, adsorption of 4% is observed from their solutions. These values increase with increasing amount of $\text{Na}_2\text{SO}_3$. Adsorption of 14.9% of humic acid is observed on 12mmole of $\text{Na}_2\text{SO}_3$. Further increase in weight of $\text{Na}_2\text{SO}_3$ does not seem to increase the adsorption of colorant significantly.
Figure 26 Adsorption of Humic Acid on Na$_2$SO$_3$, Na$_2$CO$_3$, Na$_3$PO$_4$ at 25°C

Adsorption of humic acid on Na$_2$CO$_3$ at 25°C

Adsorption of humic acid on different amount of Na$_2$CO$_3$ at 25°C is shown in fig. 26 by the curve. A sharp increase in adsorption is observed, on increasing the quantity from 2 to 10 m moles. Beyond this, although increase in adsorption is observed with the increase in amount of Na$_2$SO$_3$, but is not as significant as in the beginning. Maximum adsorption of humic acid is recorded to 24.5% on 20 m moles.

Adsorption of humic acid on Na$_3$PO$_4$ at 25°C

Adsorption of humic acid on varying amount of Na$_3$PO$_4$ is shown in fig. 26 by curve. Adsorption of humic acid on 1 m moles Na$_3$PO$_4$ is observed to be 8%,
which increases with increase in the amount of Na₃PO₄. A sharp increase in adsorption on increasing the amount from 1 to 4 m moles, thereafter a constancy is noticed. Maximum adsorption of 30% of humic acid is observed on 8 m moles of Na₃PO₄.

**Adsorption of humic acid on Na₂SO₃ from aqueous and sugar solution 15% at 25°C**

Adsorption of humic acid at 25°C is shown in fig 27 refers to the adsorption of humic acid in aqueous and sugar solution 15%, it is observed from the above figure that adsorption of humic acid increases with amount of Na₂SO₃ in both the cases.

![Graph](image)

**Figure 27 Adsorption of humic acid in aqueous and sugar solution on Na₂SO₃ at 25°C**
In aqueous solution 4% adsorption of humic acid is observed on 2m mole of Na$_2$SO$_3$ is shown in fig 27. A sharp increase in adsorption from 4% to 8% is recorded, on increasing the amount of Na$_2$SO$_3$ from 2 to 8m moles. Further increase in Na$_2$SO$_3$ concentration increases the adsorption but it is not as sharp as in beginning. Maximum adsorption of 19% was recorded on 17m moles of Na$_2$SO$_3$ in aqueous solution.

In sugar solution 15%, it is observed from curve by fig 27 that 3% adsorption of humic acid occurs on 2m moles Na$_2$SO$_3$, which increase to 4% on increasing the amount of Na$_2$SO$_3$ to 12m moles.

**Adsorption of humic acid on Na$_2$SO$_3$ in aqueous and sugar solution at 55°C.**

It is observed in fig 28 by curve of aqueous solution that 2m mole Na$_2$SO$_3$ adsorbs 10% humic acid from its aqueous solution at 55°C. On increasing the amount of Na$_2$SO$_3$ from 2m mole to 8m mole the adsorption increase sharply to 20%. Further increase in amount of Na$_2$SO$_3$ from 8 to 16m mole seems to increase the adsorption only by 2%, after which no more adsorption is observed.
In fig. 28 curve of sugar solution shows the adsorption of humic acid at 55°C. On 2m mole Na₂SO₃, 8.5% adsorption of humic acid is observed, which increases to 15% when amount of Na₂SO₃ is 6.5m mole. After this constancy in adsorption is observed, maximum adsorption in this case is recorded to be about 20%.

Adsorption of humic acid on Na₂SO₃ in aqueous and sugar solution at 70°C

The adsorption of humic acid on Na₂SO₃ at 70°C in aqueous and sugar solution 15% is shown in fig. 29 by two curve. At this temperature maximum
adsorption in both the cases is 96 ppm and 90 ppm is observed. Separate description of individual curve is given as under.

In fig. 29 curve of aqueous solution shows the adsorption of humic acid on Na₂SO₃ in aqueous solution at 70°C. It is observed from the curve, that 2 m mole of Na₂SO₃ adsorbs 11% of humic acid which increases sharply to about 20%, when amount of Na₂SO₃ is 7 m mole. Further increase in amount of Na₂SO₃ increases the adsorption value, but not in identical manner as in beginning. This behaviour of curve shows exponential nature. The maximum adsorption is of about 24% and is observed on 15 m moles Na₂SO₃, beyond which no more adsorption occurs.

![Graph showing adsorption of humic acid](image)

**Figure 29** Adsorption of humic acid in aqueous and sugar solution 15% on Na₂SO₃ at 70°C
In fig. 29 curve shows the adsorption of humic acid on Na$_2$SO$_3$ in sugar solution 15% at 70°C. The behaviour of this curve is somewhat identical to that of aqueous solution, but the adsorption value is less. On 2m mole of Na$_2$SO$_3$ 8% adsorption of humic acid is observed, which is increased to 16% when 8m moles Na$_2$SO$_3$ is used. After this, further addition of Na$_2$SO$_3$ does not show much increase in adsorption. Maximum adsorption is of about 20% and is observed on 15m mole of Na$_2$SO$_3$.

**Adsorption of humic acid from aqueous and sugar solution on Na$_2$CO$_3$ at 25°C**

Adsorption of humic acid on varying quantity of Na$_2$CO$_3$ in aqueous and sugar solution 15% at 25°C is shown in fig 30 by two curves, it is observed from fig 30 that maximum amount of humic acid (92 ppm) is adsorbed on Na$_2$CO$_3$ in aqueous solution, where as in sugar solution minimum amount (90 ppm) of humic acid is adsorbed.

It is observed from fig 30 that the aqueous solution curve, that 2m mole of Na$_2$CO$_3$ adsorbs 6% of humic acid from aqueous solution, as the amount of Na$_2$CO$_3$ increases from 2 to 10m mole adsorption increases to 18%. Though the adsorption of humic acid increases upto 20m moles of Na$_2$CO$_3$, but the adsorption value tends to become constant. Maximum adsorption of 25% is
observed on 20m mole of Na\textsubscript{2}CO\textsubscript{3} which does not seem to increase beyond this limit.

Sugar solution curve of fig 30 shows 3% adsorption of humic acid occurs on 2m moles Na\textsubscript{2}CO\textsubscript{3}, which increases sharply to 10.9% with increasing amount of Na\textsubscript{2}CO\textsubscript{3} to 10m moles. Beyond this no sharp increases in adsorption is found with increasing amount of Na\textsubscript{2}CO\textsubscript{3}. Maximum adsorption of 15.5% is recorded on 18m moles Na\textsubscript{2}CO\textsubscript{3} in sugar solution.
Adsorption of humic acid in aqueous and sugar solution on Na$_2$CO$_3$ at 55°C

Adsorption of humic acid on Na$_2$CO$_3$ in aqueous and sugar solution 15% at 55°C is shown in fig. 31 by the curve.

The above figure shows the adsorption data of humic acid on Na$_2$CO$_3$ at 55°C in aqueous solution. On 2m moles Na$_2$CO$_3$ adsorption of humic acid is observed to be 7.29%, which increases to 25.53% on 10m moles Na$_2$CO$_3$. Further increase in amount of Na$_2$CO$_3$ from 10m moles to 25m moles does not seem to increase the adsorption. Maximum adsorption of 27.38% is observed on 18m moles of Na$_2$CO$_3$.

![Figure 31 Adsorption of humic acid on Na$_2$CO$_3$ in aqueous and sugar solution 15% at 55°C](image-url)
Curve of sugar solution shows the adsorption of humic acid on Na$_2$CO$_3$ at 55°C. On 2m mole of Na$_2$CO$_3$ adsorption of 7% humic acid is observed. Further increase in amount of Na$_2$SO$_3$ to 10m moles the adsorption is raised to 17.5%. Thereafter constancy in adsorption is observed. Maximum adsorption of 22.24% humic acid is observed on 20m moles Na$_2$CO$_3$, after which no more adsorption occurs with increasing amount of Na$_2$CO$_3$.

![Graph showing adsorption of humic acid on Na$_2$CO$_3$ in aqueous and sugar solution](image)

**Figure 32 Adsorption of humic acid on Na$_2$CO$_3$ in aqueous and sugar solution 15% at 70°C**

Adsorption of humic acid on Na$_2$CO$_3$ in aqueous and sugar solution 15% at 70°C

Fig. 32 shows the adsorption data of humic acid on Na$_2$CO$_3$ at 70°C. In fig 32 one curve refers to adsorption in aqueous solution, whereas another curve
shows the adsorption data in sugar solution 15%. The adsorption value in each case is higher than that of 55°C. At 70°C the adsorption value is 108, 105 ppm in aqueous and sugar solution respectively.

From the above figure curve of aqueous solution shows the adsorption value of humic acid on Na₂CO₃ in aqueous solution at 70°C. On 2m moles Na₂CO₃ 10% adsorption of humic acid is recorded. On 10m mole of Na₂CO₃ the adsorption of humic acid is observed to 19%, which does not seem to increase the adsorption as sharp as in beginning. Maximum adsorption of 21% is recorded on 18m moles Na₂CO₃.

The curve of fig 32 shows the adsorption data of humic acid on Na₂CO₃ at 70°C in sugar solution 15%. On 2m moles of Na₂CO₃ adsorption of 6.50% humic acid is observed in this case, as the amount of Na₂CO₃ increases from 2 to 10mmoles adsorption correspondingly increases from 6.50% to 6.63% after which the adsorption is increased by 2%.

**Adsorption of humic acid in aqueous and sugar solution on Na₃PO₄ at 25°C**

Adsorption of humic acid on Na₃PO₄ at 25°C is shown in fig 33. First curve shows the data about the aqueous solution, where as another curve shows the adsorption data in sugar solution 15%. Adsorption curve of humic acid on Na₃PO₄ in aqueous solution shows that the adsorption of humic acid is less.
than that of Ca$_3$(PO$_4$)$_2$. In the beginning the adsorption value of humic acid is recorded to be 7%. On increasing the amount of Na$_3$PO$_4$ from 1 m moles to 3.5 m moles a linear increase corresponding from 7% to 15.5% of adsorption is observed. Further increase in amount of Na$_3$PO$_4$ shows in adsorption per m mole.

![Graph showing adsorption of humic acid on Na$_3$PO$_4$ in aqueous and sugar solution 15% at 25°C](image)

**Figure 33** Adsorption of humic acid on Na$_3$PO$_4$ in aqueous and sugar solution 15% at 25°C

The curve of sugar solution shows the data of humic acid on Na$_3$PO$_4$ in sugar solution 15%. It is observed from the fig. 33 that a linear adsorption region i.e. from 1 m moles to 3 m moles Na$_3$PO$_4$ is apparent. The adsorption value on 1 m moles and 4 m moles of Na$_3$PO$_4$ is observed to be 5.5% and 12%
When the amount of \( \text{Na}_3\text{P}0_4 \) exceeds from 4.5mole, the adsorption of humic acid is minimized. On 9 moles of humic acid 17% of adsorption is observed.

**Adsorption of humic acid on \( \text{Na}_3\text{P}0_4 \) in aqueous and sugar solution 15% at 55°C**

Adsorption of humic acid on \( \text{Na}_3\text{P}0_4 \) at 55°C is shown in fig 34, in both the figure two curve shows the adsorption value of humic acid on \( \text{Na}_3\text{P}0_4 \) in aqueous solution where as the other curve shows the adsorption data in sugar solution 15%.

![Graph showing adsorption of humic acid on Na₃P0₄ in aqueous and sugar solution 15% at 55°C](image)

**Figure 34 Adsorption of humic acid on \( \text{Na}_3\text{P}0_4 \) in aqueous and sugar solution 15% at 55°C**
In fig 34 curve of aqueous and sugar solution shows adsorption value of Na$_3$PO$_4$. 2m moles of Na$_3$PO$_4$ adsorbed 15.2% of humic acid. On increasing the amount of Na$_3$PO$_4$ little increase is observed, which continues upto 4 m moles. Further increase in amount of Na$_3$PO$_4$ from 4 to 9m moles show a increase of 5% only.

![Figure 35 Adsorption of humic acid on Na$_3$PO$_4$ in aqueous and sugar solution 15% at 70°C](image)

**Figure 35 Adsorption of humic acid on Na$_3$PO$_4$ in aqueous and sugar solution 15% at 70°C**

Adsorption of humic acid on Na$_3$PO$_4$ in aqueous and sugar solution 15% at 70°C

In fig 35 the adsorption curve of aqueous and sugar solution shows that 2 m moles of Na$_3$PO$_4$ adsorbed 20% of humic acid, little increase in the adsorption is observed on increasing the amount upto 4 m moles. On
increasing the amount from 4 to 9 m moles only 6% increase in the above value is observed.

**Adsorption of humic acid on constant amount of Na$_2$SO$_3$ at 25°, 55° and 70°C**

Adsorption of humic acid on given amount of Na$_2$SO$_3$ in aqueous and sugar solution at different temperature is described below. Adsorption data are plotted as Ce vs. x/m for each case, where Ce and x/m are the equilibrium concentration (ppm) and amount of humic acid adsorbed on Na$_2$SO$_3$ respectively.

**Adsorption of humic acid on Na$_2$SO$_3$ from aqueous solution**

Fig. 36 shows the adsorption value of humic acid on constant amount of Na$_2$SO$_3$ from aqueous solution at 25°, 55° and 70°C respectively. It is observed that adsorption of humic acid does not increases with temperature as in case of Na$_2$SO$_3$. The values of adsorption are 9, 14 and 20 mg kg$^{-1}$ from the solution of 51ppm at 25°, 55° and 70°C.
Figure 36 Adsorption of humic acid on Na$_2$SO$_3$ from aqueous solution at different temperature

Figure 37 Adsorption of humic acid on Na$_2$SO$_3$ from sugar solution at different temperature
The effect of temperature on adsorption shows a slight increase with the concentration. The adsorption value observed from the solution of 307 ppm concentration is 27, 36 and 50 mg kg\(^{-1}\) at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C respectively.

Adsorption of humic acid in sugar solution 15% is shown in fig 37 by three different curve which correspond to adsorption at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C, respectively. Adsorption of humic acid increases slightly with respect to concentration and temperature. At 25\(^\circ\)C adsorption of 8 ppm of humic acid is observed from the 62 ppm concentrated solution of humic acid. The adsorption at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C is recorded to be 25, 40 and 40 ppm respectively from the solution of 322 ppm concentration.

**Adsorption of humic acid on constant amount of Na\(_2\)CO\(_3\) at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C**

Adsorption of humic acid on 1gm of Na\(_2\)CO\(_3\) from its aqueous and sugar solution at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C are described below:

**Adsorption of humic acid on Na\(_2\)CO\(_3\) in aqueous solution at different temperature**

Adsorption of humic acid form aqueous solution on 1 gm Na\(_2\)CO\(_3\) at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C is shown in fig 38 by three curves. It is observed from the figure that 11, 14 and 17 ppm of adsorption from 1 gm Na\(_2\)CO\(_3\) from solution of 51 ppm humic acid at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C respectively.
Figure 38 Adsorption of humic acid on Na$_2$CO$_3$ in aqueous solution at different temperature

Figure 39 Adsorption of humic acid on Na$_2$CO$_3$ in sugar solution at different temperature
On increasing concentration of solution, the gap in adsorption curve at different temperature is not so widen as in case of CaCO₃. This shows, that in higher concentrated solution the effect of temperature is not so much pronounced in comparison to CaCO₃.

**Adsorption of humic acid on Na₂CO₃ in sugar solution 15%**

In fig 39 three curves refer to adsorption of humic acid on 1 gm of Na₂CO₃, at at 25°, 55° and 70°C respectively. It is observed that adsorption of humic acid in sugar solution is less comparison to aqueous solution. The value of adsorption is observed to be 10, 15 and 18ppm from the solution containing 62 ppm of humic acid at 25°, 55° and 70°C respectively. These values show a sharp increase of 30, 45 and 50 ppm at respective temperature, on increasing the concentration of humic acid to 266ppm in solution, a slight increase in the adsorption is observed with the increase in concentration of humic acid.

**Adsorption of humic acid on constant amount of Na₃PO₄, at 25°, 55° and 70°C.**

Adsorption of humic acid on 1 gm of Na₃PO₄, from its aqueous and sugar solution at 25°, 55° and 70°C.

**Adsorption of humic acid from aqueous solution on Na₃PO₄**

Adsorption of humic acid on 1gm of Na₃PO₄ is shown in fig 40 by three curve which refers to adsorption value at 25°, 55° and 70°C respectively. It is
observed form fig 40 that 19, 21 and 25 ppm is adsorbed on 1 gm of Na$_3$PO$_4$ at 25°, 55° and 70°C respectively from solution containing 51 ppm of humic acid. Adsorption value of humic acid from the solution of 207 ppm at 25°, 55° and 70°C are observed to be 38, 44 and 50 ppm respectively. On increasing the concentration upto 307ppm the adsorption value were recorded to be 40, 96 and 98ppm respectively.

**Adsorption of humic acid in sugar solution 15% on Na$_3$PO$_4$**

Adsorption of on 1gm of humic acid is shown in fig. 41 by three curves. The curves refer the adsorption value at 25°, 55° and 70°C the curve shows the adsorption value of humic acid i.e. 18ppm, 21ppm and 25ppm is recorded at respective temperature. This value increases to 35, 42 and 48ppm on increasing the concentration of the solution to 168 ppm of humic acid.

**5.3.2 Adsorption of humic acid on K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$ at 25°C**

Percentage of humic acid adsorbed on different amounts of K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$ at 25°C is shown by three curves. It is observed from the fig. 42 that minimum amount of humic acid is adsorbed on K$_2$SO$_3$, where as the absorbability of K$_3$PO$_4$ is best amongst all the three Potassium salts. On 2m moles of K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$, adsorption of, 4ppm, 15ppm and 20 ppm. of humic acid is observed. The maximum adsorption of 20%, 24% and 30% of humic acid is observed on 18, 20 and 8m moles of K$_2$SO$_3$, K$_2$CO$_3$, and K$_3$PO$_4$ respectively.
Figure 40 Adsorption of humic acid on Na₃PO₄ from aqueous solution at different temperature

Figure 41 Adsorption of humic acid on Na₃PO₄ from sugar solution at different temperature
Adsorption of humic acid on K$_2$SO$_3$ at 25°

Adsorption of humic acid (250ppm), on varying amount of K$_2$SO$_3$ at 25°C is shown in fig 42 humic acid is adsorbed 20%. On 2m mole of K$_2$SO$_3$ adsorption of 4% of humic acid, is observed. These values increase with the increasing amount of K$_2$SO$_3$. Maximum adsorption of 19.5% of humic acid is observed on 17m mole of K$_2$SO$_3$. Further increase in weight of K$_2$SO$_3$ does not seen to increase the adsorption of any colorant significantly.

![Adsorption of humic acid on K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$ at 25°C](image)

Figure 42 Adsorption of humic acid on K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$ at 25°C

Adsorption of humic acid on K$_2$CO$_3$ at 25°C

Adsorption of humic acid (250ppm) on different amount of K$_2$CO$_3$ at 25°C is shown in fig 42 by the curve. On 2m mole of K$_2$CO$_3$ adsorption of humic acid
is 5%. A sharp increase in adsorption is observed, on increasing the quantity from 2 to 10\text{m moles}. Beyond this, although increase in adsorption of colorant with the increase in amount of $K_2CO_3$ is observed, but is not as significant as in the beginning. Adsorption of humic acid is recorded to 24% on 20\text{m moles}.

**Adsorption of humic acid on $K_3PO_4$ at 25°C**

Adsorption of humic acid (250ppm) on varying amount of $K_3PO_4$ is shown in fig. 42 by curve. It is observed that maximum amount of humic acid was adsorbed 30% from their solutions. Adsorption of humic acid on 1\text{m mole} of $K_3PO_4$ is observed to be 8%, which increases with the increase in the amount of $K_3PO_4$, the adsorption value increases on increasing the amount from 1 to 4\text{m moles}, after which constancy is noticed. Maximum adsorption of 30% of humic acid is observed on 8\text{m moles} of $K_3PO_4$.

**Adsorption of humic acid on $K_2SO_3$ in aqueous and sugar solution 15% at 25°C**

Adsorption of humic acid at 25°C is shown in fig. 43 by the two curves which refer to the adsorption of humic acid on $K_2SO_3$ in aqueous and sugar solution. It is observed that adsorption of humic acid increases with increasing amount of $K_2SO_3$ in both the cases. The maximum adsorption of humic acid is to be 62 ppm on aqueous $K_2SO_3$ (2.5g).
Fig. 43 Adsorption of humic acid in aqueous and sugar solution on K$_2$SO$_3$ at 25°C

Fig. 43 shows that in aqueous solution curve 4% adsorption of humic acid is observed on 2m mole of K$_2$SO$_3$. A sharp increase in adsorption from 4% to 6% is recorded, on increasing the amount of K$_2$SO$_3$ from 2 to 8m moles, after which although adsorption increases, but not as sharp as in beginning. Maximum adsorption of 19% is recorded on 17m moles K$_2$SO$_3$ in aqueous solution.

In sugar solution 15% curve, it is observed that 3% adsorption of humic acid occurs on 2m moles of K$_2$SO$_3$, which increases to 4% on increasing the amount of K$_2$SO$_3$ on 8m moles.
In this case the exponential nature of the curve is not as sharp as in aqueous solution. Adsorption of 12.5% of humic acid is noticed on 16m mole of K$_2$SO$_3$, beyond which, adsorption does not seem to increase with increasing amount of K$_2$SO$_3$.

**Adsorption of humic acid on K$_2$SO$_3$ in aqueous and sugar solution 15% at 55°C**

Adsorption of humic acid on K$_2$SO$_3$ at 55°C is shown in fig 44. Figure refers to adsorption of humic acid on K$_2$SO$_3$ in aqueous solution where as another curve shows the adsorption of the humic acid in sugar solution 15%.

![Figure 44 Adsorption of humic acid in aqueous and sugar solution on K$_2$SO$_3$ at 55°C](image)

Figure 44 Adsorption of humic acid in aqueous and sugar solution on K$_2$SO$_3$ at 55°C
It is observed in fig. 44 by curve that 2m mole K₂SO₃ adsorbs 10% humic acid from its aqueous solution at 55°C, on increasing the amount of K₂SO₃ from 2m moles to 8m moles, the adsorption increase to 20%. Further increase in amount of K₂SO₃ from 8m moles to 16m moles seems to increase the adsorption only by 2%, after which no more adsorption is observed.

In fig. 44 another curve shows the adsorption of humic acid on K₂SO₃ at 55°C in sugar solution 15%. On 2m mole of K₂SO₃ 8.1% of adsorption is observed, which increases to 15%, when amount of K₂SO₃ in 6.5m mole. After this, constancy in adsorption is observed. Maximum adsorption in this case is recorded to be about 21%.

**Adsorption of humic acid on K₂SO₃ in aqueous and sugar solution at 70°C.**

The adsorption of humic acid, on K₂SO₃ at 70°C, in aqueous solution and in presence of sugar solution 15%, is shown in fig. 45 by two curves, respectively. At this temperature, maximum adsorption in both the cases is 96 ppm and 90 ppm is observed. Separate description of individual curve is given as under.

In fig. 45 the aqueous solution curve shows the adsorption of humic acid on K₂SO₃ at 70°C. It is observed from this curve that 2m mole of K₂SO₃ adsorbs 11% of humic acid, which increases sharply to about 20% when amount of
K₂SO₃ is 7m mole. Further increase in amount of K₂SO₃ increases the adsorption, but not in identical manner as in the beginning. This behavior of curve shows exponential nature. The adsorption of 24% is observed on 15m moles of K₂SO₃ beyond which, no more adsorption occurs.

![Figure 45 Adsorption of humic acid on K₂SO₃ in aqueous and sugar solution at 70°C](image)

Adsorption curve of sugar solution shows that the behaviour of this curve is somewhat identical to that of aqueous solution, but the adsorption values are less. On 2m mole of K₂SO₃, 8% adsorption of humic acid is observed, which is raised to 16%, when 8m mole of K₂SO₃ is used. After this, further addition of K₂SO₃ does not show much increase in adsorption. Adsorption of about 20% is observed on 15m moles of K₂SO₃.
Adsorption of humic acid on K₂CO₃ in aqueous and sugar solution at 25°C

Adsorption of humic acid on, varying amount of K₂CO₃ in aqueous solution, and sugar solution 15% at 25°C is shown in fig. 46 by two curves. The maximum amount of humic acid 92 ppm is adsorbed on K₂CO₃ in aqueous solution, whereas in sugar solution 90 ppm of humic acid is adsorbed.

![Figure 46 Adsorption of humic acid on K₂CO₃ in aqueous and sugar solution 15% at 25°C](image)

It is observed from the aqueous solution curve that 2m moles of K₂CO₃ adsorbs 6% of humic acid from aqueous solution as the amount of K₂CO₃ increases from 2 to 10m moles, adsorption increases to 18%, though the adsorption of humic acid increases up to 20m moles of K₂CO₃ and the
adsorption of 25% is observed, which does not seem to increase beyond this limit.

It is observed from sugar solution curve that 3% adsorption of humic acid occurs on 2m moles of K₂CO₃, which increases sharply to 10.9% with increasing amount of K₂CO₃ to 10m moles. Beyond this, no sharp increase in adsorption is found. Adsorption of 15.5% is recorded on 18m moles of K₂CO₃ in sugar solution.

**Adsorption of humic acid on K₂CO₃ in aqueous and sugar solution at 55°C**

Adsorption of humic acid on K₂CO₃ in aqueous and sugar solution 15% at 55°C is shown in fig. 47 by two curves respectively.

In fig 47 the curve shows the adsorption data of humic acid, on K₂CO₃ at 55°C in aqueous solution. On 2m moles of K₂CO₃ adsorption of humic acid is observed to be 7.29%, which increases to 25.53% on 10m moles of K₂CO₃.

Adsorption of 27.38% is observed on 18m moles of K₂CO₃. Another curve shows the adsorption of humic acid, on K₂CO₃ at 55°C in sugar solution 15%. On 2m moles of K₂CO₃, adsorption of 7% humic acid is observed. Further increase in amount of K₂CO₃ to 10m moles, the adsorption is raised to 17.2%.

Adsorption of 22.24% of humic acid is observed on 20m moles of K₂CO₃, after which no more adsorption occurs with increasing amount of K₂CO₃.
Figure 47 Adsorption of humic acid on $\text{K}_2\text{CO}_3$ in aqueous and sugar solution 15% at 55°C

Figure 48 Adsorption of humic acid on $\text{K}_2\text{CO}_3$ in aqueous and sugar solution 15% at 70°C
Adsorption of humic acid in aqueous and sugar solution 15% on K$_2$CO$_3$ at 70°C

In fig 48 shows the adsorption data of humic acid on K$_2$CO$_3$ at 70°C. Two curves refer to adsorption in aqueous solution, whereas another curve shows the adsorption data in sugar solution 15%.

The adsorption in fig. 48 shows, the adsorption value of humic acid on K$_2$CO$_3$ in aqueous solution at 70°C. On 2m moles of K$_2$CO$_3$, 10% adsorption of humic acid is recorded. On 10m moles of K$_2$CO$_3$, the adsorption of humic acid is observed to 25%. Adsorption of 28% is recorded on 18m moles of K$_2$CO$_3$ at 70°C in this case. Adsorption curve of sugar solution shows that on 2m moles of K$_2$CO$_3$, adsorption of 8.20% of humic acid is observed. As the amount of K$_2$CO$_3$ increases from 2 to 10m moles adsorption correspondingly increases by 4.2%. The adsorption of 21% is observed on 18m moles.

Adsorption of humic acid on K$_3$PO$_4$ in aqueous and sugar solution at 25°C

Adsorption of humic acid from aqueous solution, on K$_3$PO$_4$ the value of adsorption is recorded to be 7% on 1m moles, on increasing the amount from 1m moles to 3.5 moles a linear increase from 7% to 21% of adsorption is observed. Little increase in adsorption is observed from 4 to 8m moles of K$_3$PO$_4$. In fig. 49, curve shows the adsorption data of humic acid on K$_3$PO$_4$ in aqueous and sugar solution.
Figure 49 Adsorption of humic acid on $\text{K}_3\text{PO}_4$ in aqueous and sugar solution 15% at 25°C

Figure 50 Adsorption of humic acid on $\text{K}_3\text{PO}_4$ in aqueous and sugar solution 15% at 55°C
The adsorption value on 1m moles and 4m moles of K$_3$PO$_4$ is observed to be 5.5% and 15.5%, respectively. On increasing the amount K$_3$PO$_4$ from 4.5m moles, the adsorption declines and indicates that, presence of sugar solution minimize the adsorption of humic acid on the above salts. On 9m moles of K$_3$PO$_4$, 17% of adsorption is observed.

**Adsorption of humic acid on K$_3$PO$_4$ in aqueous and sugar solution 15% at 55°C**

Adsorption of humic acid on different amount of K$_3$PO$_4$, at 55°C is shown in fig. 50 by the two curves, which shows the adsorption of K$_3$PO$_4$ in aqueous and sugar solution. The value recorded in aqueous solution is 14% on 2m moles at 55°C. On increasing the amount a slight increase in the adsorption is observed.

**Adsorption of humic acid on K$_3$PO$_4$ in aqueous and sugar solution 15% at 70°C**

Adsorption of humic acid on different amount of K$_3$PO$_4$, at 70°C is shown in fig. 51 by the two curves, which shows the adsorption of K$_3$PO$_4$ in aqueous and sugar solution. The value recorded on 2m moles is 16.7% at 70°C. On increasing the amount the adsorption value is of 34% observed at both the temperature which continues upto 4m moles.
Figure 51 Adsorption of humic acid on K₃PO₄ in aqueous and sugar solution 15% at 70°C

Adsorption of humic acid on constant amount of K₂SO₃ at 25°, 55°, and 70°C

Adsorption of humic acid on 1 g of K₂SO₃ in aqueous and sugar solution at various temperatures is described below:

Adsorption data are as Ce vs. x/m for each case, where Ce and x/m are the equilibrium concentration in (ppm) and amount of humic acid adsorbed mg kg⁻¹ respectively.
Adsorption of humic acid on K₂SO₃ in aqueous solution at 25°, 55° and 70°C

Adsorption of humic acid from aqueous solution on K₂SO₃ at 25°, 55° and 70°C is shown in fig. 52 by three curves. The effect of temperature on adsorption value of humic acid shows a slight increase in concentration of humic acid (307 ppm) 26, 35.5 and 38 mg/kg at at 25°, 55° and 70°C respectively.

![Graph showing adsorption of humic acid on K₂SO₃ from aqueous solution at different temperatures](image)

Figure 52 Adsorption of humic acid on K₂SO₃ from aqueous solution at different temperature
Figure 53 Adsorption of humic acid on K₂SO₃ from sugar solution at different temperature

Adsorption of humic acid on K₂SO₃ in sugar solution 15%

Adsorption of humic acid on K₂SO₃ in sugar solutions is shown in fig. 53. Three curves correspond to adsorption of humic acid 62 ppm at, 25°, 55° and 70°C and the adsorption values are 7, 8 and 10 ppm at respective temperatures.

Adsorption of humic acid on constant amount of K₂CO₃ at 25°, 55° and 70°C

Adsorption of humic acid on 1gm of K₂CO₃ from its aqueous and sugar solution at 25°, 55° and 70°C are described below:
Adsorption of humic acid on K$_2$CO$_3$ from aqueous solution at 25°, 55° and 70°C

Adsorption of humic acid from aqueous solution of different concentration on 1 gm of K$_2$CO$_3$ at 25°, 55° and 70°C is shown in fig. 54 by three curves. It is observed from the figure that 10, 13 and 17ppm of adsorption of humic acid occurs on 1gm of K$_2$CO$_3$ from a solution of 51 ppm of concentration of humic acid at 25°, 55° and 70°C respectively, the gap in adsorption curve at different temperature is similar to that of Na$_2$SO$_3$, this shows that the effect of temperature on concentrated solution of humic acid is not so much pronounced.

![Figure 54 Adsorption of humic acid on K$_2$CO$_3$ from aqueous solution at different temperature](image-url)
Adsorption of humic acid on K$_2$CO$_3$ in sugar solution 15%

Three curves of fig. 55 refer to adsorption of humic acid on 1gm of K$_2$CO$_3$ at 25°, 55° and 70°C respectively. It is observed that adsorption values are 9.5, 14.5 and 18 ppm from the humic acid of 62 ppm at 25°, 55° and 70°C respectively. These values show the increase of 29.5 44.5 and 53.4 ppm at the given temperature from 266 ppm concentration of humic acid. Increase in concentration of humic acid does not show any observable increase in adsorption of humic acid.
Adsorption of humic acid on constant amount of K$_3$PO$_4$ in aqueous solution

Adsorption of humic acid on 1 gm of K$_3$PO$_4$ is shown in fig. 56 curve refers to adsorption value at 25°, 55° and 70°C respectively from the solution of 62 ppm of humic acid and the observed values were 18, 22 and 24 ppm, no appreciable change is observed on increasing the concentration. The solution containing 205 ppm of humic acid at 25°, 55° and 70°C are observed to be 37, 44 and 50 ppm respectively.

![Adsorption of humic acid on K$_3$PO$_4$ from aqueous solution at different temperature](image-url)

Figure 56 Adsorption of humic acid on K$_3$PO$_4$ from aqueous solution at different temperature
Adsorption of humic acid on $K_3PO_4$ from sugar solution 15% is shown in fig. 57 by three curves which refer to adsorption value at 25°, 55° and 70°C. The curve shows that minimum adsorption of 17 ppm at 25°C, whereas maximum adsorption of 25 ppm at 70°C is observed, however at 55°C the values is recorded to be 21 ppm. On increasing the concentration of humic acid up to 168 ppm the adsorption value were 33.5, 40 and 46 ppm at 25°, 55° and 70°C no appreciable change is observed at 322 ppm of humic acid.
Adsorption of humic acid on CaSO₃, CaCO₃, Ca₃(PO₄)₂ at 25°C

In fig. 58 it shows the adsorption of three Calcium salts.

![Graph showing adsorption of humic acid on CaSO₃, CaCO₃, Ca₃(PO₄)₂ at 25°C]

Figure 58 Adsorption of humic acid on CaSO₃, CaCO₃, Ca₃(PO₄)₂ at 25°C

It may be observed from the above figure 50 that adsorption of humic acid is maximum on Ca₃(PO₄)₂ whereas minimum in case of CaSO₃.

Adsorption of humic acid on CaSO₃ in aqueous and sugar solution at 25°C

Adsorption of humic acid on CaSO₃ at 25°C is shown in fig. 59 by two curves, which show the adsorption data in sugar and aqueous solution, it is observed from the fig. 59 that in general the adsorption of humic acid increases with amount of CaSO₃.
In aqueous solution 7% adsorption is observed on 2m moles of CaSO_3, as shown in aqueous solution curve. A sharp increase in adsorption from 7% to 13% is recorded, on increasing the amount of CaSO_3 from 2 to 8m moles, the value of adsorption increases, but not as sharp as in the beginning. Adsorption of 29% is recorded on 17m moles CaSO_3 in aqueous solution.

In sugar solution 15% it is observed that 6% adsorption of humic acid occurs on 2m mole CaSO_3, which increases to 20% on increasing the amount of CaSO_3 to 12m mole, maximum adsorption of 21.5% humic acid is noticed on 16m mole CaSO_3 beyond which adsorption does not seem to increase with increasing amount of CaSO_3.
Adsorption of humic acid on CaSO₃ at 55°C

The adsorption of humic acid on CaSO₃ at 55°C is shown in fig. 60 in which the curve refers to adsorption of humic acid in aqueous and sugar solution 15%.

It is observed from the aqueous solution curve that 2 m moles CaSO₃ adsorbs 13% humic acid at 55°C. On increasing the amount of CaSO₃ from 2 to 8 m moles the adsorption increases to 31%. Further increase in amount of CaSO₃ from 8 to 16 m moles seems to increase the adsorption only by 3%, after which no more adsorption is observed.

The sugar solution curve shows the adsorption of humic acid on CaSO₃ at 55°C. On 2 m moles CaSO₃ 10.5% adsorption of humic acid is observed which increases to 21% when amount is 6.5 m moles. After this constancy in adsorption is observed. Maximum adsorption in this case is recorded to be about 26%.
Figure 60 Adsorption of humic acid on CaSO₃ in aqueous and sugar solution at 55°C

Figure 61 Adsorption of humic acid on CaSO₃ in aqueous and sugar solution at 70°C
Adsorption of humic acid on CaSO₃ at 70°C

Fig 61 shows the adsorption of humic acid in aqueous and sugar solution at 70°C. It is observed from the curve that 2m moles of CaSO₃ shows adsorption of 16% humic is observed which increases sharply to 31% when amount of CaSO₃ is 7m moles, further increase in amount of CaSO₃ although increases the adsorption, but not in identical manner as in beginning. Adsorption of about 36% is observed on 15m moles.

The adsorption of humic acid on CaSO₃ in sugar solution 15% at 70°C is shown by another curve in fig 61. On 2m moles of CaSO₃ shows 12% adsorption of humic acid is observed which increases to 26%, when 8m moles of CaSO₃ is used. After this further addition of CaSO₃ does not show much increase in adsorption. Maximum adsorption of about 30% is observed on 15m mole of CaSO₃.

Adsorption of humic acid on CaCO₃ at 25°C

It is observed from fig. 62 that in aqueous and sugar solution 15%. 8.2% and 6.5% adsorption of humic acid occurs on 2m mole CaCO₃, which increases sharply to 31% and 23% respectively with increasing amount of CaCO₃ to 10m moles. Beyond this no sharp increase in adsorption is found. On increasing the amount of CaCO₃ adsorption of 35.5% and 26.5% is recorded on 20m moles and 18m moles of CaCO₃ in aqueous and sugar solution respectively.
Figure 62 Adsorption of humic acid on CaCO$_3$ in aqueous and sugar solution at 25°C

Figure 63 Adsorption of humic acid on CaCO$_3$ in aqueous and sugar solution at 55°C
Adsorption of humic acid on CaCO₃ at 55°C

In fig 63 curves shows the adsorption data of humic acid on CaCO₃ at 55°C in aqueous solution. On 2m moles of CaCO₃ the adsorption of humic acid is observed to be 15.38%, which increases to 36.53% on 10m moles of humic acid. Further increase from 10 to 25m moles does not show any considerable increase. On 18m moles of CaCO₃ adsorption of 40.38% is observed.

Another curve shows the adsorption of humic acid on CaCO₃ at 55°C in sugar solution 15%. On 2m mole of CaCO₃ adsorption of 11.29% humic acid is observed. Further increase in amount of CaCO₃ to 10m moles the adsorption is raised to 27.42%, thereafter constancy in adsorption is observed. Maximum adsorption of 32.24% humic acid is observed on 20m moles CaCO₃, after which no more adsorption occurs with increasing amount of CaCO₃.

Adsorption of humic acid on CaCO₃ at 70°C

Fig. 64 shows the value of humic acid adsorbed on CaCO₃ from aqueous solution at 70°C. On 2m moles CaCO₃ 15% adsorption of humic acid is recorded. On 10m moles of CaCO₃ adsorption of 38% is recorded. Further increase in amount of CaCO₃ does not seem to increase the adsorption as sharp as in the beginning. Adsorption of 41.50% is recorded on 18m moles CaCO₃ at 70°C in this case.
Figure 64 Adsorption of humic acid on CaCO₃ in aqueous and sugar solution at 70°C

In fig 64 another curve shows the adsorption data of humic acid on CaCO₃ at 70°C in sugar solution 15%. On 2m moles CaCO₃ adsorption of 12.50% humic acid is observed in this case. As the amount of CaCO₃ increases from 2m moles to 10m moles adsorption correspondingly increases from 12.50% to 31.25%, after which the adsorption increases only by 3%. Maximum adsorption value 98 ppm i.e. 34.37% adsorption of humic acid is observed on 18m mole of CaCO₃.
Adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in aqueous and sugar solution 15% at 25°C

Fig. 65 shows the adsorption curve of humic acid on Ca$_3$(PO$_4$)$_2$ aqueous solution shows that maximum adsorption of humic acid takes place at Ca$_3$(PO$_4$)$_2$. In the beginning the adsorption of humic acid on 0.15 mg/gm showing 12.50% adsorption. On increasing the amount of Ca$_3$(PO$_4$)$_2$ from 1 to 3.5m moles, a linear increase corresponding from 13 to 33% of adsorption is observed. Further increase in amount of Ca$_3$(PO$_4$)$_2$ shows decline and only 7.4% increase in adsorption are observed from 4 to 8mmole Ca$_3$(PO$_4$)$_2$. Adsorption of 40% is observed to be on 9m moles Ca$_3$(PO$_4$)$_2$.

![Graph](image)

Figure 65 Adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in aqueous and sugar solution at 25°C
In fig 65 another curve shows the adsorption data of humic acid in sugar solution 15%. It is observed that a linear adsorption region i.e. from 1 to 3 m mole $Ca_3(PO_4)_2$ is apparent. The adsorption values on 1 and 4 m mole $Ca_3(PO_4)_2$ is observed to be 8.5% and 23.5% respectively when the amount of $Ca_3(PO_4)_2$ exceeds 4.5 m mole the adsorption declines indicating that in presence of sugar solution adsorption of humic acid on $Ca_3(PO_4)_2$ is minimized. On 9 m moles 28.33% of adsorption is observed, which does not increase further with the amount of $Ca_3(PO_4)_2$.

**Adsorption of humic acid on $Ca_3(PO_4)_2$ in aqueous and sugar solution 15% at 55°C**

Fig. 66 shows the adsorption of humic acid on $Ca_3(PO_4)_2$ in aqueous and sugar solution at 55°C. On 0.2 g of $Ca_3(PO_4)_2$ the adsorption of humic acid in aqueous solution is 40 ppm. On increasing the amount of $Ca_3(PO_4)_2$ a sharp increase in adsorption is observed, which continues upto 4 m moles of $Ca_3(PO_4)_2$. Adsorption value of humic acid on 0.8 g of $Ca_3(PO_4)_2$ is recorded to be 100 ppm. On increasing the amount from 4 to 9 m moles 6% increase in adsorption is observed.

The curve of adsorption of sugar solution at 55°C in fig. 66 is shown. On 1 m moles of $Ca_3(PO_4)_2$ adsorption percentage of humic acid is recorded to be 13.25%. An apparent linear increase in adsorption with the increase in amount of $Ca_3(PO_4)_2$ is observed, this continued upto 6 m moles of $Ca_3(PO_4)_2$, beyond which the value of adsorption declines.
Figure 66 Adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in aqueous and sugar solution at 55°C.

Figure 67 Adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in aqueous and sugar solution at 70°C
Adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in aqueous and sugar solution at 70°C

Fig. 67 shows the two curves which refers to adsorption in aqueous and sugar solution. On 0.2 g of 46 ppm of adsorption of humic acid in aqueous solution is observed, which continues upto 4m moles of Ca$_3$(PO$_4$)$_2$. Adsorption of humic acid on 0.8 g of Ca$_3$(PO$_4$)$_2$ is observed to be 103 ppm at 70°C. On increasing the amount from 4 to 9m moles increased of 7% in adsorption is observed.

In fig 67 shows the another curve of adsorption of humic acid on Ca$_3$(PO$_4$)$_2$ in sugar solution at 70°C. On 1m mole of Ca$_3$(PO$_4$)$_2$ percentage of humic acid is recorded to be 14.25 at 70°C. An apparent linear increase in adsorption with the amount of Ca$_3$(PO$_4$)$_2$ is observed. This continues up to 6m mole Ca$_3$(PO$_4$)$_2$. Beyond this amount of calcium phosphate the value of adsorption declines.

Adsorption of humic acid on constant amount of CaSO$_3$ at 25°, 55° and 70°C

Adsorption of humic acid on a given amount of CaSO$_3$ in presence of aqueous and sugar solution at different temperature is described below. Adsorption data are plotted as Ce Vs X/m for each, where Ce and X/m are the equilibrium concentration (ppm) and amount of humic acid adsorbed (mg/kg) on CaSO$_3$ respectively.
Adsorption of humic acid on CaSO$_3$ in aqueous solution

Adsorption value of humic acid on constant amount of humic acid from aqueous solution at 25°, 55° and 70°C is shown in fig. 68 by three curves it is observed from fig. 68 that adsorption of humic acid increases with temperature. Specific the value of adsorption of humic acid is 15, 21 and 25 mg/kg from the solution of concentration of 51 ppm at 25°, 55° and 70°C. The effect of temperature on adsorption widens as the concentration of humic acid increases.

![Figure 68 Adsorption of humic acid on CaSO$_3$ from aqueous solution at different temperature](image)

Figure 68 Adsorption of humic acid on CaSO$_3$ from aqueous solution at different temperature
Figure 69 Adsorption of humic acid on CaSO₃ from sugar solution at different temperature

Adsorption of humic acid on CaSO₃ in sugar solution 15%

Fig 69 shows three different curves which corresponds to adsorption at 25°, 55° and 70°C. Adsorption increases with increasing humic acid concentration as well as on raising the temperature. At 25°C adsorption of 11 ppm of humic acid is observed from solution of 62 ppm of humic acid. On raising the temperature of same solution to 55° and 70°C the value is recorded to be 16 and 32 ppm respectively.

The concentration of humic acid up to 215 ppm shows a sharp increase in adsorption at each temperature. Adsorption at 25°, 55° and 70°C is recorded to
be 62, 82 and 92 ppm respectively from the solution of 322 ppm concentration occur.

**Adsorption of humic acid on constant amount of CaCO₃ at 25°, 55° and 70°C**

Adsorption of humic acid on 1 gm of CaCO₃ from its aqueous and sugar solution 15% at 25°, 55° and 70°C are described below:

**Adsorption of humic acid on CaCO₃ in aqueous solution**

On 1 gm of CaCO₃ the adsorption of humic acid is shown at 25°, 55° and 70°C in fig. 70 by three curves. It is observed from the fig. 70 that 21, 22 and 25 ppm adsorption of humic acid occurs on 1gm CaCO₃ from aqueous solution of 51 ppm at 25°, 55° and 70° respectively.

This shows that in higher concentrated solution the temperature effect is more prominent. In case of 51 ppm concentrated solution adsorption of 4.7% and 13.3%, increase in adsorption is observed. On raising the temperature from 25° to 55° and 55° to 70°C respectively, where as such values are observed to be 19.8% and 15.45% in solution of 307 ppm concentration.
Figure 70 Adsorption of humic acid on CaCO₃ from aqueous solution at different temperature

Figure 71 Adsorption of humic acid on CaCO₃ from sugar solution at different temperature
Adsorption of humic acid on CaCO₃ in sugar solution 15%

Fig. 71 shows the adsorption of humic acid from sugar solution 15% on 1 gm of CaCO₃ at 25°, 55° and 70°C respectively. It observed that in this case comparatively less adsorption of humic acid occurs than aqueous solution. The value of adsorption are observed to be 16, 22 and 26 ppm from the solution containing 62 ppm of humic acid at 25°, 55° and 70°C respectively. These value increases sharply to 71, 86 and 106 ppm at respective temperature on increasing the concentration of humic acid to 266 ppm in solution, there after bending in curve is observed adsorption of humic acid recorded to be 76, 92 and 122 ppm at 25°, 55° and 70°C respectively from the solution containing 322 ppm humic acid.

Adsorption of humic acid on constant amount of Ca₃(PO₄)₂ at 25°, 55° and 70°C

Adsorption of humic acid on 1g Ca₃(PO₄)₂ from its aqueous and sugar solution 15%, containing different amount of humic acid is given below:

Adsorption of humic acid on 1 gm of Ca₃PO₄ in aqueous solution is shown in fig. 72 by three curves. It is observed from the fig. 72 that 25, 31 and 36 ppm of humic acid on 1gm of Ca₃PO₄ at 25°, 55° and 70°C respectively from a solution containing 51 ppm of humic acid. A sharp increase in adsorption is observed on increasing the concentration of humic acid in solution up to 205
ppm at respective temperature. Amount of humic acid adsorbed on 1gm of Ca$_3$(PO$_4$)$_2$ is observed to be 83, 107 and 117 ppm, respectively. Adsorption of 107 ppm (25°C) and 133 ppm (55°C, 70°C) is observed.

Fig 73 represents adsorption in sugar solution by three curves which refer to adsorption at 25°C, 55°C and 70°C respectively. The curve shows that minimum adsorption 22 ppm occurs at 25°C, whereas maximum amount is adsorbed at 70°C. At 55°C value is recorded to be 26 ppm. These value increases sharply to 70 ppm at 25°C, 86 ppm at 55°C and 91 ppm at 70°C in solution having 168 ppm of humic acid. Adsorption at 25°C, 55°C and 70°C are recorded to be 102, 122 and 127 ppm respectively from the solution containing 322 ppm humic acid.
Figure 72 Adsorption of humic acid on Ca₃(PO₄)₂ from aqueous solution at different temperature

Figure 73 Adsorption of humic acid on Ca₃(PO₄)₂ from sugar solution at different temperature
Effect of pH on absorbance of colorant (humic acid caramel, melanoidin)

The influence of $H^+$ ion on absorbance (420 nm) of above said three colorants at 25°, 55° and 70°C is shown in fig. 74, 75 and 76 the curve shows the variation in absorbance of colorant humic acid solution. On addition of different amount of $H^+$ ions. It is observed from the curve that the original absorbance of colorant solution 250 ppm was 0.50 at 25°C where as, at 55°C and 70°C the absorbance was observed to be 0.60. These values decreased down to 0.28, 0.32 and 0.25 at 25°, 55° and 70°C respectively, on addition of 0.2 m mole $H^+$ ion, further addition of $H^+$ ion did not seem to decrease the absorbance significantly at any temperature, minimum value of absorbance at 25° and 55°C was recorded to be 0.26 where as, at 70°C such value was 0.24.

Caramel curve in fig. 74, 75 and 76 shows the influence of $H^+$ ion on absorbance of caramel solution, at 25°, 55° and 70°C respectively. Absorbance of 2000 ppm of caramel solution at 25° and 55°C was observed 0.22 where as, effect of pH on absorbance was recorded to be 0.23 at 70°C. On addition of 0.2m moles $H^+$ ion these values decreased down to 0.18 at each three temperature, which was observed to be the minimum absorbance of caramel solution, further addition of $H^+$ ion did not showed any change in the absorbance value.
Figure 74 Effect of $H^+$ ion on absorbance 420nm of colorant at 25°C

Figure 75 Effect of $H^+$ ion on absorbance 420nm of colorant at 55°C
Figure 76 Effect of $H^+$ ions on absorbance of colorant at 70°C

$H^+$ ions did not show any influence on absorbance of melanoidin solution at any temperature, which can be observed in fig. 74, 75 and 76 of melanoidin curve at 25°, 55° and 70°C, the absorbance of 250 ppm melanoidin solution was observed to be 0.80, 0.82 and 0.90 respectively. The same constant absorbance of original solution at each temperature was observed up to addition of 1.0 m moles $H^+$ ion.

Effect of $OH^-$ ions on absorbance of colorants
The original absorbance 200 ppm of colorant solution humic acid, caramel and melanoidin 0.28, 0.32 and 0.25 shows a variation in the absorbance.
On addition of OH\(^-\) ions, the absorbance value of humic acid increased up to 0.29, 0.31 and 0.32 at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C respectively, on addition of 0.2m moles OH\(^-\) ions. Further addition of OH\(^-\) ions did not seem to increase the absorbance significantly at any temperature. Maximum value of absorbance at 55\(^\circ\) and 70\(^\circ\)C was recorded to be 0.31 and 0.32 respectively, whereas at 25\(^\circ\)C such value was 0.29.

The influence of OH\(^-\) ions on absorbance of caramel solution at 25\(^\circ\), 55\(^\circ\) and 70\(^\circ\)C show a change in the original absorbance value of caramel solution. On addition of 0.2m mole OH\(^-\) ions, these values increased to 0.32, further addition of OH\(^-\) ions did not showed any change in the absorbance value.

OH\(^-\) ions did not show any influence on the absorbance of melanoidin solution at any temperature. The original absorbance remained constant at each temperature. On additions of 1.0m mole of OH\(^-\) ions no further change was observed.

Quality of cane sugar crystals are closely related to the adsorption of colored substances, when cane sugar crystals are grown in a super saturated sugar solution, containing caramel, the distribution of adsorbed caramel in the sugar crystal is located definitely in the left side of the crystals observed visually and microscopically.
Such an adsorption site of cane sugar crystal is witnessed, if crystallization occurs in sugar solution, containing coloring substances such as caramels which are negatively charged in water solution, where as humic acid behaves as positive charge which are adsorbed uniformly in sugar crystals and the site of adsorption could not be observed due to the colloidal nature of humic acid.

However here is a peculiar fact that the appearance of sugar obtained from the carbonation process on storage looses colour at faster rate as compared to sulphitation sugar.

The present investigation aimed to determine the extent of adsorption of colorant on precipitating solids in either process of sugar manufacture. The work has also been employed to observe the adsorption of humic acid on Na₂SO₃, Na₂CO₃, Na₃PO₄, K₂CO₃, K₂SO₃, K₃PO₄, CaSO₃, CaCO₃, Ca₃(PO₄)₂ in sugar solution 15%.

The adsorption results of humic acid, on the above written salts in different experimental condition could be discussed under two broad headings:
1. Adsorbability of humic acid on the given salts.

2. Adsorbing capacity of salts for humic acid.

Adsorbability of Humic acid on the given Salts Na$_2$SO$_3$, Na$_2$CO$_3$, Na$_3$PO$_4$, K$_2$SO$_3$, K$_2$CO$_3$, K$_3$PO$_4$, CaSO$_3$, CaCO$_3$, Ca$_3$(PO$_4$)$_2$

The adsorbed percentage of humic acid on Na and K Salts in sugar and aqueous solution is less than Ca salts. These results seem to suggest the minimum adsorption of humic acid on these solids, which can be understood as follows.

As soon as the humic acid comes in contact with the surface of these solids, the interaction between the unsaturated valencies (unsaturated forces) is expected to take place.

The possible cause for unsaturated valencies or surface forces responsible for the adsorption results from the chemical bonding of the Na and K salts. The polymeric nature of humic acid (molecular weight range in $10^5$) leaves the tail on the surface of the solids and practically the surface of the solids responsible for adsorption are not able to act freely. Moreover, the tail left over on the surface of the solids tends to polymerize, which further hinders the adsorption process. If humic acid would have been a smaller molecule or ionic compound, it would have been relatively easier to be
adsorbed on the surface of these precipitating solids, this is physically understandable and consistent with the other colorants adsorbed on different solids. Above arguments of adsorption of humic acid is consistent with suggestion made by Baker and MC Bain who observed that compounds having higher molecular weight are relatively less adsorbed than the molecule having lower molecular weight.

The previous literature about the structure of other colorants (Caramel, Melanoidin) is not well established, but certainly its molecular weight is not as high as that of humic acid, further caramel is an anhydride of sucrose, during its formation 1, 2 and 3 molecules of H₂O escape from 1, 2 and 3 molecules of sucrose, respectively to give caramelan(C₁₂H₂₀O₁₀), caramelen(C₂₄H₃₆O₁₈) and caramilin(C₃₆H₅₀O₂₅), which have their mol. Wt. 324, 612 and 882 respectively, this shows the presence of unsaturated valencies in caramel. The presence of ester group¹⁰ in caramel is also reported which decreases the surface tension of solution and increases its extent of adsorption from solution. Therefore on the basis of above reasoning it is natural to expect higher adsorption of caramel than humic acid.

Molecular weight of melanoidin ranges from 10³ to 10⁴ which is also lower than humic acid by 2-1 order of magnitude and this fact is in favour of higher adsorption of melanoidin than humic acid. Melanoidin¹¹ is a
nitrogenous colorant and a lone pair electron of nitrogen possibly experiences some kind of electron overlapping.

**Adsorbing capacity of Na₂SO₃, Na₂CO₃, Na₃PO₄, K₂CO₃, K₂SO₃, K₃PO₄, CaSO₃, CaCO₃, Ca₃(PO₄)₂**

The adsorbing capacity of salts for humic acid at 25°, 55° and 70°C is given in the result. The fact that least amount 51 ppm of humic acid is adsorbed on K₂SO₃.

The data suggests the maximum adsorbing capacity of Ca₃(PO₄)₂ among all the three different types of salts used in this work. This could be understood in terms of surface of these solids. It is of amorphous character, which would be primarily responsible for large surface area leading to the maximum adsorption of colorant.

**Adsorbability of Humic acid on Na₂SO₃, Na₂CO₃, Na₃PO₄, K₂CO₃, K₂SO₃, K₃PO₄, CaSO₃, CaCO₃, Ca₃(PO₄)₂**

The adsorbability of humic acid on the given salts in presence of sucrose at 25°, 55° and 70°C. The adsorption value is decreased by 8%, 13% and 14% on CaSO₃, CaCO₃, Ca₃(PO₄)₂ on sodium salts of sulphite, carbonate and phosphate is decreased by 15% on sulphite and by 3% on carbonates and phosphates respectively. In case of potassium salts the value in case of sulphite is decreased by 17% and decrease in case of carbonates and
phosphates is by 2% and 3% respectively. The influence of sugar solution in general is to decrease the adsorption of humic acid on calcium salts.

The general decrease in adsorption of humic acid in sugar solution could be due to adsorption of these substances on the surface of the given salts along with humic acid for instance the sucrose molecules present along with humic acid would have been also adsorbed on the salts (Ca, Na, K) used this decreases the available surface of sodium and potassium salts due to which the least adsorption in both the salts is observed.

**Influence of pH on absorbance humic acid**

In acidic medium the absorbance of humic acid remains almost constant that is 0.17, where as in alkaline medium it shows abrupt increase to 0.31. This is due to the fact that humic acid contains a large number of phenolic as well as quinonic group. These groups probably undergo structural change, as $H^+$ and $OH^-$ ions concentration in solution vary. In acidic medium, the quinone may change into hydroquinone by accepting $H^+$ ions from the acid, which is a benzenoid structure, due to which the absorbance of humic acid in acidic solution decreases.
In alkaline medium, the hydroquinone of humic acid changes into quinonoid structure, because in general all dihydroxy phenols change into quinone in presence of alkali, due to this the concentration of quinonoid structure in humic acid increases and benzenoid structure decreases, which results in higher absorbance value.

The possible mechanism of structural change in of humic acid in acidic and alkaline medium is illustrated in fig. 77.

In this fig. 77 structure (I) refers to the original structure of humic acid where as in acidic medium structure (I) and (II) both exist in resonating form giving less absorbance value. In alkaline medium humic acid exist in solution as in structure (III) giving higher absorbance.

Figure 77 Structural change of humic acid in acidic and alkaline medium
6. REFERENCES